WATER QUALITY IN THE BLUE CREEK ARM OF LAKE EUFAULA AND BLUE CREEK, OKLAHOMA, MARCH-OCTOBER 1978

By J. K. Kurklin

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CONTENTS

Page
Abstract........ 1
Introduction........ 1
    Purpose and scope........ 1
    Geographic setting........ 3
    Climate........ 3
Hydrologic system........ 3
Sampling sites and data collected........ 4
Water quality........ 5
    Physical properties........ 5
        Light penetration........ 5
        Dissolved oxygen........ 10
        pH........ 10
        Water temperature........ 34
        Specific conductance........ 34
    Chemical constituents........ 34
        Major cations........ 34
        Alkalinity, major anions, and silica........ 44
        Major plant nutrients........ 46
        Trace elements........ 53
            Arsenic........ 53
            Cadmium........ 53
            Chromium........ 61
            Copper........ 61
            Iron........ 61
            Lead........ 62
            Manganese........ 62
            Mercury........ 62
            Selenium........ 62
            Zinc........ 63
    Biota........ 63
        Phytoplankton........ 63
        Benthic invertebrates........ 69
        Bacteria........ 83
Summary and conclusions........ 83
References cited........ 90

ILLUSTRATIONS

Figure 1. Map showing location of Blue Creek arm of Lake Eufaula, Blue Creek, and associated water sampling and measurement sites........ 2
2-6. Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along:
    2. Transect A-A'........ 11
    3. Transect B-B'........ 16
    4. Transect C-C'........ 21
    5. Transect D-D'........ 24
    6. Transect E-E'........ 29

ILLUSTRATIONS--Continued

Page

Figure 7A. Graphs showing changes in concentrations of major cations, sampling sites A-E........................ 35

7B. Graphs showing changes in concentrations of alkalinity, major anions, and silica, sampling sites A-E.......... 45

8-12. Graphs showing numbers of phytoplankton cells comprising the major classes of algae at:

8. Sampling site A.................................. 64

9. Sampling site B.................................. 65

10. Sampling site C.................................. 66

11. Sampling site D.................................. 67

12. Sampling site E.................................. 68

13. Diagrams showing implied indicative associations of phytoplankton.. 82

14-17. Graphs showing bacterial data for:

14. Sampling site A.................................. 85

15. Sampling site B.................................. 86

16. Sampling site D.................................. 87

17. Sampling site E.................................. 88

TABLES

Table 1. Lake elevations at end of month............................ 5

2. National primary drinking-water standards.................. 6

3. National secondary drinking-water standards................ 7

4. State drinking-water standards.............................. 7

5. Water-quality criteria...................................... 8

6. Secchi-disc transparencies at sampling sites A-E............ 9

7. Physical properties and concentrations of major chemical constituents in water from sampling sites A-G............ 37

8. Concentrations of nitrogen and phosphorus in water from sampling sites A-G.. 47

9. Concentrations of trace elements in water from sampling sites A-G... 54

10. Phytoplankton counts, number of genera, and diversity index at sampling sites A-E................................. 70

11. Significance of phytoplankton genera present at sampling sites A-E... 76

12. Phytoplankton and bacteria concentrations at sampling sites A-F... 79

13. Benthic invertebrates identified in the study area in March 1978.. 84

CONVERSION FACTORS

Many numbers in this report are given in inch-pound units. These may be onverted to the International System (SI) of Units by using the conversion actors listed below:

Inch-pound unit	Multiply by	To obtain SI units
acre	0.4047	square hectometer
acre-foot (acre-ft)	1,223	cubic meter
cubic foot per second (ft^3/s)	.02832	cubic meter per second
foot (ft)	.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Chemical concentrations and water temperatures in this report are given in metric units. Water temperatures are given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8\ (°C) + 32$$

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ABSTRACT

Based on samples collected bimonthly for major inorganic and trace elements and monthly for biota and bacteria, water from the Blue Creek arm of Lake Eufaula and Blue Creek is suitable for most uses when compared to water-quality standards or criteria. Concentrations of most chemical constituents gradually increased from spring to fall. The concentrations generally were within established drinking-water standards, with the exception of iron and manganese.

Using water-quality determinations and biologic indicators, the water from Blue Creek arm of Lake Eufaula and Blue Creek is: (1) Soft and acidic with little mineral content and conductivity; (2) calm or very slowly moving; and (3) warm and enriched with organic matter.

INTRODUCTION

The drainage basin of Blue Creek in northeastern Pittsburg County, Oklahoma, is a potential area for surface mining of coal. Blue Creek flows directly into Lake Eufaula. Consequently, surface mining of coal in the Blue Creek drainage basin and the interruption of the hydrologic regime may have direct effect on the quality of Lake Eufaula, one of the largest recreational lakes in Oklahoma. Blue Creek begins near Blocker in Pittsburg County and flows about 4 mi before entering Lake Eufaula (fig.1). Blue Creek has a drainage area of 12.1 mi^2, most of which has not been previously mined. Forty acres were mined in the 1930's but the mining has had no effect on the water quality of the area.

Purpose and Scope

The purpose of this report is to describe the water quality of the Blue Creek arm of Lake Eufaula and Blue Creek based on data collected from March to October 1978. The water-quality data are evaluated in terms of drinking-water standards and water-quality criteria. The data in this report are intended as background information that can be used in the future to compare with data collected during and following surface mining and reclamation and to assess the effect of mining activities on the water quality in Lake Eufaula. For a more detailed appraisal of the hydrology of the Blue Creek area, the reader is referred to the report by Marcher and others (1981). The following section describing the Blue Creek study area is based on that report.

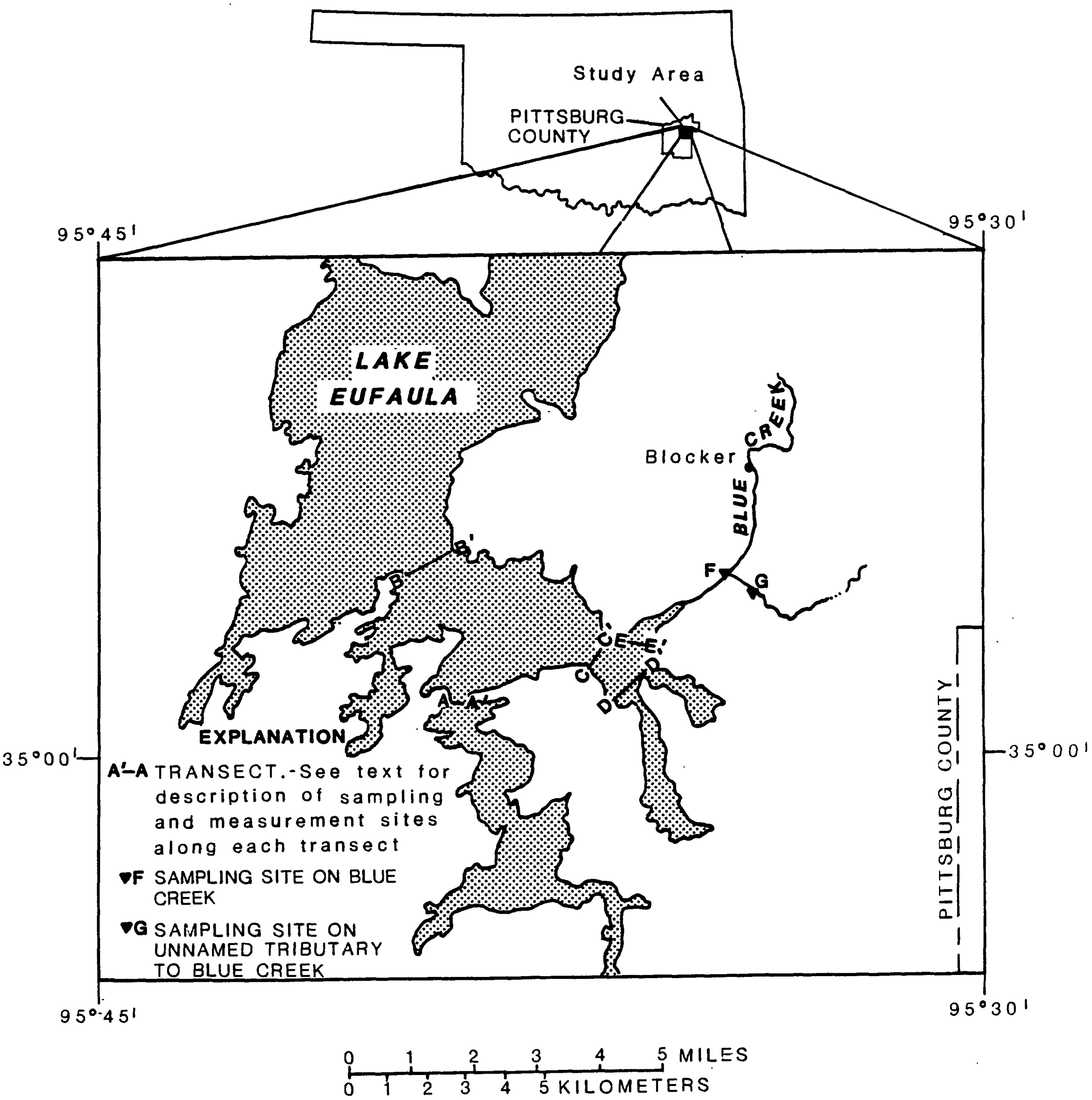

Figure 1.--Location of Blue Creek arm of Lake Eufaula, Blue Creek, and associated water sampling and measurement sites.

Geographic Setting

The Blue Creek area is in the McAlester marginal hills geomorphic province (Johnson and others, 1972) and is in the Arkoma geologic basin. In this area, the rocks have been moderately folded to form east-trending anticlines and synclines. The landscape is characterized by irregular hills and ridges generally capped by erosion-resistant sandstone and covered with scrubby trees and brush. The intervening broad valleys have been formed by weathering and erosion of thick, weakly-resistant shales and are vegetated with native grasses, shrubs, wild flowers, and weeds.

Climate

The area has a warm, temperate, continental climate (Holbrook, 1974). Winters are varied, springs and falls usually are mild and the summers are long and hot. Based on records at McAlester and Eufaula, the nearest weather stations, 15 and 25 mi from Blocker, respectively, annual precipitation is estimated to be 42 in. Most precipitation falls as rain during short, intense thunderstorms. About 32 percent of the precipitation falls in the spring, 27 percent in the summer, 22 percent in the fall, and 19 percent in the winter (Holbrook, 1974). Based on records for 1931-60, the long-term average, 1 year in 10 will have less than 29 in. of precipitation and 1 year in 10 will have more than 53 in. Average annual lake evaporation is about 53 in. (Marcher and others, 1981).

HYDROLOGIC SYSTEM

Of the precipitation falling on a given area, some runs off quickly as streamflow and some percolates into the soil. The relative proportion of water that runs off to that which infiltrates the soil depends on the form, intensity, and duration of precipitation, slope of the land surface, permeability of the soil, character and density of vegetation, antecedent soil moisture, and climatic conditions. Precipitation entering the soil first replaces previously depleted soil moisture. Water in excess of that needed to replace soil moisture percolates downward into the zone of saturation to become ground-water recharge. Water retained in the soil is eventually evaporated or transpired by plants.

Because the predominantly shale rocks underlying most of the Blue Creek drainage basin lack the capacity to store water, Blue Creek is ephemeral and most of its flow is the result of storm runoff. The available discharge records for Blue Creek show that it had no flow for extended periods during 1976-79 (Marcher and others, 1981). However, streamflow during this interval may have been less than average because long-term streamflow records for a nearby gaging station on James Fork near Hackett, Arkansas, show that the average annual flow for 1976-79 was about 50 percent of the 20-year average (Marcher and others, 1981).

During 1976-79, Blue Creek had virtually no daily discharge (equal to or less than 0.01 ft^3/s) 46 percent of the time. Marcher and others (1981) also reported that periods of more than 60 consecutive days of virtually no flow occurred from mid-June to mid-September each year. Flow was less than 0.1 ft^3/s for at least 90 consecutive days during these 3 months. Sustained flows for Blue Creek were recorded for November-May except for a few isolated days. Sustained flows of 1 ft^3/s or more had a duration of less than 2 weeks and sustained flows of 10 ft^3/s or more had a duration of less than 1 week. The mean annual daily flows ranged from about 5 to 8 ft^3/s for the 4 years.

All natural waters contain mineral constituents dissolved from the rock and soil with which the water has been in contact. Concentrations of the dissolved constituents largely depend on the type of soil or rock, the length of contact time, pressure, and temperature. In addition to these natural conditions, man's activities such as disposal of sewage and industrial wastes, diversion and use of water, agricultural practices, and activities associated with mineral or fuel production, can have a significant effect on the chemical quality of water.

The study area is rural with no industrial development and no municipal waste-disposal systems. The unwooded lands are used for cattle grazing and, other than home gardens and limited cutting of hay, there are no agricultural activities in the area. Timber in the area is not used for lumber. A few natural gas wells have been drilled but, as far as is known, none of them produce saltwater. In sum, there are no man-induced activities in the area that would significantly affect the chemical quality of water.

SAMPLING SITES AND DATA COLLECTED

Five sampling transects, horizontal distances between points on opposite lake shores identified as A-A', B-B', C-C', D-D', and E-E' in figure 1, were established along the Blue Creek arm of Lake Eufaula. Five measurement sites were located equidistant along sampling transects A-A' through D-D'. Sampling sites were located at the midpoint of each transect; these sites are identified as sampling sites A through D. Measurement sites to the left of the midpoint (facing downstream) are identified as A_1 and A_2 through D_1 and D_2; those to the right of the midpoint are identified as A_3 and A_4 through D_3 and D_4. Three measurement sites were located equidistant along transect E-E'. Sampling site E was located at the midpoint of the transect. Measurement site E_1 was to the left of sampling site E (facing upstream) and measurement site E_2 was to the right of sampling site E. Two additional sampling sites were located on the streams. Sampling site F was an existing site on Blue Creek near Blocker (fig. 1). Sampling site G was established on an unnamed tributary to Blue Creek (fig. 1). For this study, only those data collected for the streams from March 1978 through October 1978, the duration of the project, were considered.

Each lake transect was sampled bimonthly for major inorganic constituents, major nutrients, and trace elements and monthly for biota and bacteria. The samples were collected 3 ft from the surface, and 1 ft from the bottom at the center point of a transect. Mid-depth samples only were collected when lake depths were shallow at a transect. Sampling depths varied throughout the study due to the fluctuation in lake elevations as shown in table 1. In addition, vertical profiles of light penetration, dissolved oxygen, pH, water temperature, and specific conductance were made at a minimum of three measurement sites on each lake transect. Stream samples were collected monthly for major inorganic constituents and major nutrients, and bimonthly for trace elements. For each sample, dissolved

Table 1.--Lake elevations at end of month

Month	Elevation (feet above National Geodetic Vertical Datum of 1929)
March 1978	585.23
April 1978	585.46
May 1978	587.46
June 1978	585.81
July 1978	583.45
August 1978	581.34
September 1978	580.22

oxygen, pH, water temperature, specific conductance, and fecal coliform and fecal streptococcal bacteria were determined at the site.

All water-quality samples were collected and analyzed by methods outlined in Brown and others (1970); Goerlitz and Brown (1972); and Greeson and others (1977). Biological analyses were made at the U.S. Geological Survey's laboratory in Doraville, Georgia. The remainder of the laboratory analyses were made at the Survey's laboratory in Arvada, Colorado. Microbiological analyses were performed by Oklahoma District personnel.

WATER QUALITY

Determinations of physical properties, chemical constituents, and biota and bacteria are compared to established drinking-water standards and water-quality criteria to determine the suitability of water for various uses. Water that is suitable for one use may be completely unsuitable for another use. Included in each section is a brief definition of the water-quality characteristic and, if possible, a reference to drinking-water standards or water-quality criteria, which are summarized in tables 2-5.

Physical Properties

Light penetration

Three factors with respect to light are important to a lake study: (1) How much solar radiation strikes the lake surface with time; (2) how far solar radiation penetrates, and (3) how solar radiation can be used or how it affects aquatic organisms. Almost all energy that controls the metabolic processes within a lake is derived from solar energy. This solar energy is transformed by synthesis into some form of organic matter either within the lake or the catchment basin. The absorption of solar energy and its dissipation as heat greatly affect thermal stratification and circulation patterns which in turn, affect nutrient cycling, distribution of dissolved gases and biota, and behavioral adaptation of organisms.

Table 2.--National primary drinking-water standards[1]

Maximum contaminant levels for dissolved inorganic chemicals

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1
Cadmium	.010
Chromium	.05
Lead	.05
Mercury	.002
Nitrate (as N)	10.
Selenium	.01
Silver	.05

Maximum contaminant level for dissolved fluoride based on annual average of maximum daily air temperature

Temperature (degrees Fahrenheit)	Level (milligrams per liter)
50 - 54	1.4
55 - 58	1.6
59 - 64	1.8
65 - 71	2.0
72 - 79	2.2
80 - 91	2.4

[1] U.S. Environmental Protection Agency, 1976.

Table 3.--National secondary drinking-water standards[1]

Contaminant	Level (milligrams per liter unless indicated otherwise)
Chloride, dissolved	250
Color	15 platinum-cobalt units
Copper, dissolved	1
Dissolved solids	500
Iron, dissolved	.03
Manganese, dissolved	.05
pH	6.5 - 8.5 pH units
Sulfate, dissolved	250
Zinc, dissolved	5

[1] U.S. Environmental Protection Agency, 1979.

Table 4.--State drinking-water standards[1]

Parameter (dissolved phase)	Numerical limit (milligrams per liter)
Arsenic	.05
Barium	1.0
Cadmium	.01
Chromium	.05
Copper	1.0
Fluoride (at 90° F)	1.6
Lead	.05
Mercury	.002
Nitrate (as N)	10.0
Selenium	.01
Silver	.05
Zinc	5.0

[1] Oklahoma Water Resources Board, 1979

Table 5.--Water-quality criteria

[µg/L, micrograms per liter; mg/L, milligrams per liter]

Constituent	Domestic water supplies	Irrigation of crops	Freshwater aquatic life	Wildlife	Livestock (upper limits)
Alkalinity	--	--	20 mg/L or more as $CaCO_3$	require 30-130 mg/L	--
Ammonia	--	--	20 µg/L (as un-ionized ammonia	--	--
Arsenic	50 µg/L	100 µg/L	--	--	200 µg/L
Cadmium	10 µg/L	10 µg/L	Soft water 0.4 µg/L Hard water 1.2 µg/L [1] Soft water 4.0 µg/L Hard water 12.0 [2]	--	50 µg/L
Chromium	50 µg/L	100 µg/L	1,000 µg/L	5,000 µg/L	5,000 µg/L
Copper	1,000 µg/L	200 µg/L	20 µg/L	--	500 µg/L
Iron	300 µg/L	5,000 µg/L	1,000 µg/L	--	--
Lead	50 µg/L	5,000 µg/L	30 µg/L	--	100
Manganese	50 µg/L	500 µg/L	--	--	--
Mercury	2.0 µg/L	--	50 µg/L	50 µg/L	10
Nitrate, N	10 mg/L	--	--	--	--
Nitrite, N	1 mg/L	--	--	--	--
Dissolved oxygen	--	--	minimum 5 mg/L	--	--
pH (units)	5-9	--	6.5-9.0	--	--
Selenium	10 µg/L	20 µg/L	(3)	--	50 µg/L
Chloride	250 mg/L	--	--	--	--
Sulfate	250 mg/L	--	(4)	--	--
Zinc	5,000 µg/L	2,000 µg/L	--	--	25,000 µg/L

---

[1] For cladocerans and salmonid fish.

[2] For other less sensitive aquatic life.

[3] One-hundredth times a 96-hour LC_{50} as determined through nonaerated bioassy using a sensitive aquatic-resident species.

[4] One-tenth times a 96-hour LC_{50} as determined through nonaerated bioassy using a sensitive aquatic-resident species.

The depth of light penetration in a lake can be used to estimate the depth to which photosynthesis can occur. Secchi-disc transparencies give an estimation of light penetration. The Secchi-disc transparency is the mean depth of the points where the disc disappears from view as it is lowered, and where it reappears as it is being raised. The minimum intensity of subsurface light that permits photosynthesis has been estimated to be about 1 percent of incident surface light. The region from the surface to the depth at which 99 percent of the surface light has disappeared is called the euphotic zone. Multiplying the Secchi-disc transparency by a factor, ranging from 2.7 to 5, depending on the reference, gives an approximation of the depth at which the 1-percent level of the euphotic zone is reached. For this study a factor of 3.0, favored by most limnologists (Cole, 1975) was used.

Light penetration was estimated each month with a Secchi disc (table 6). The maximum depth or Secchi-disc transparency measured during the study was 1.2 ft; the minimum was 0.4 ft. Using the factor of 3.0, the maximum depth of the euphotic zone was about 4 ft and the minimum depth was about 1 ft. Even though the Secchi disc rapidly disappeared from sight, diffuse light, scattered by particulate matter probably penetrated much deeper. Therefore, the value of 4 ft estimated from the Secchi-disc transparency can only approximate the euphotic zone. Photosynthetic activity could take place at greater depths.

Table 6.--Secchi-disc transparencies at sampling sites A-E

	Secchi-disc transparency (feet)				
Site	May	June	July	August	September
A	0.7	0.6	0.6	0.9	0.6
B	.6	.5	.6	1.2	.5
C	.7	.5	.6	.7	.5
D	.6	.5	.6	.6	.5
E	.6	.4	.6	--	.5

Dissolved Oxygen

Dissolved oxygen in lake water has an essential biological role; for most organisms, oxygen is a requisite for life. Concentrations of dissolved oxygen are dependent on a number of factors including water temperature, agitation, and the degree of photosynthesis. In most lakes, the phytoplankton contribute the majority of the oxygen supply. Additional oxygen is added by exchanges with the atmosphere at the lake surface. Decreases in oxygen are due mostly to the respiration of plants, animals, and the aerobic bacteria involved in decay of organic matter. On a purely physical basis, the warming of the summer epilimnion could account for oxygen decrease. The solubility of oxygen decreases as temperature increases. A deep stratum of the lake may be lacking in oxygen if light does not penetrate the lake. As a result, respiration and decomposition prevail in the deep strata and oxygen is depleted faster than it is produced.

Dissolved-oxygen profiles for each of the five lake transects are shown in figures 2-6. Generally, dissolved-oxygen concentrations were greatest near the water surface and least near the lake bottom. Maximum fluctuations occurred in the early summer and early fall. Values in late August were less variable with respect to depth.

There are very few dissolved-oxygen criteria for water use. The most commonly published criteria are based on requirements for aquatic life. Recommended minimum concentrations of dissolved oxygen are dependent on species and age of fish, acclimatization, water temperature, concentrations of some trace elements, and concentrations of other gases. It is recommended that dissolved-oxygen concentration not be less than 5 mg/L (milligrams per liter) during extended periods of the day (National Academy of Sciences, National Academy of Engineering, 1972). Although concentrations less than this recommended concentration were measured, there were not sufficient data to determine if the deficient concentrations occurred for extended periods.

pH

The pH was originally defined as the negative logarithm (base 10) of the hydrogen-ion concentration (moles per liter) (Hawley, 1971), but for most purposes pH can be equated to the negative logarithm of the hydrogen-ion activity (Weast, 1972). Hydrogen-ion activity is approximately equal to hydrogen-ion concentration in moles per liter. The intervals on the pH scale are exponential; therefore, a unit change in pH represents a 10-fold change in activity.

The normal range of pH in most lakes is 6.5 to 8.5 (Welch, 1952). During this study, pH of water in the Blue Creek arm of Lake Eufaula and Blue Creek ranged from 6.0 to 9.6 (figs. 2-6). The pH values greater than the normal range probably were due to the effects of photosynthesis; that is, dissolved carbon dioxide was being utilized by organisms. The smaller pH values were measured in the lower depths. These values probably were due to an accumulation of acid-forming substances associated with decomposition activities.

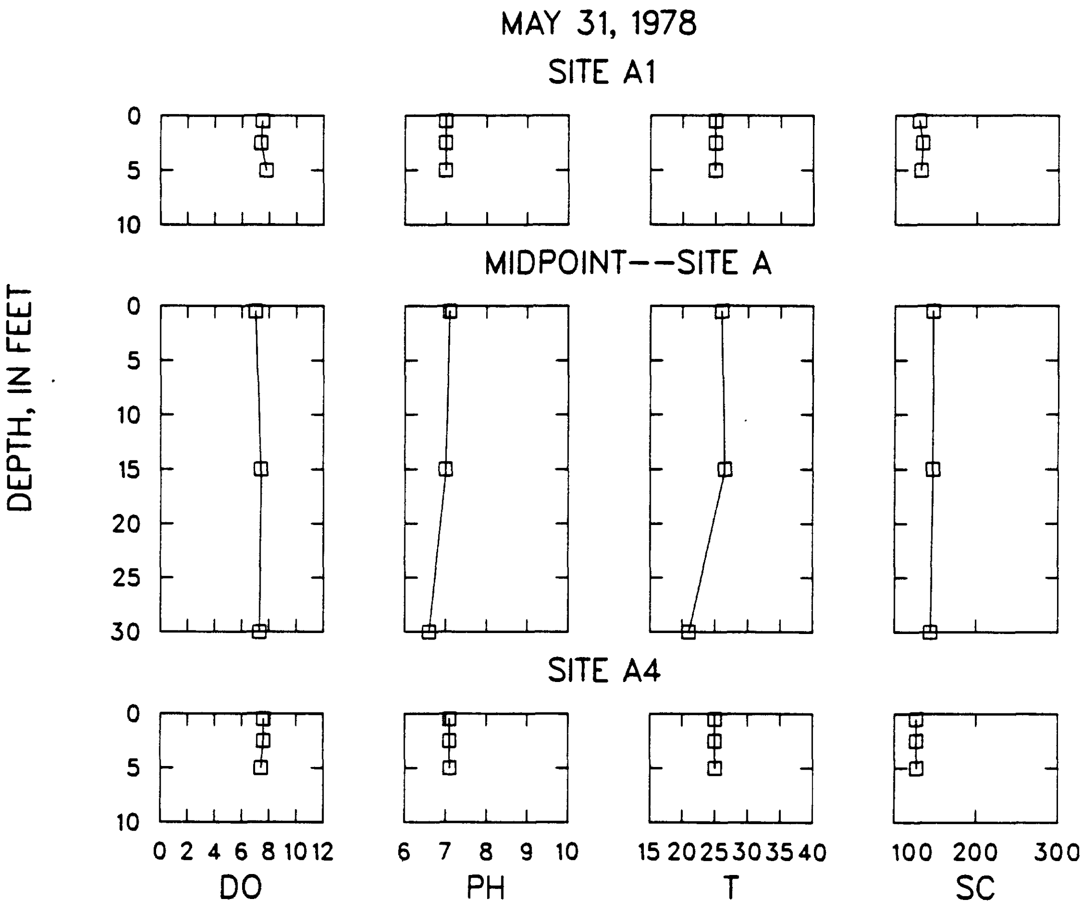

Figure 2A.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect A-A', May 31, 1978.

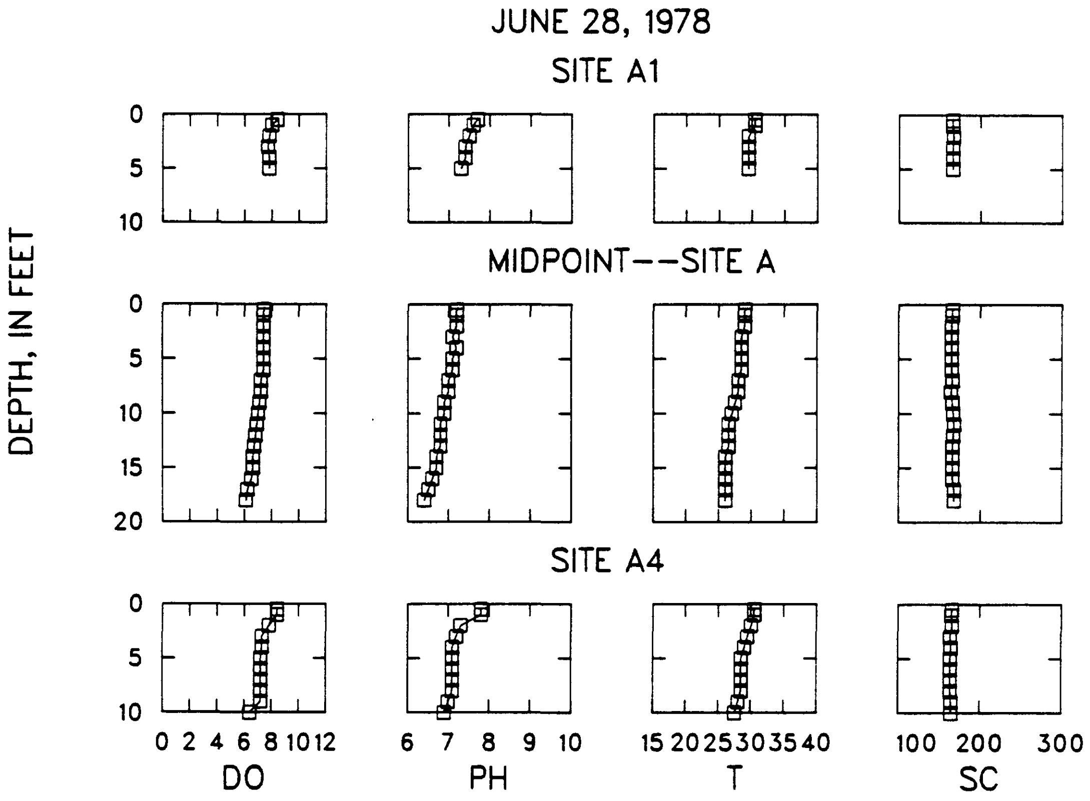

Figure 2B.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect A-A', June 28, 1978.

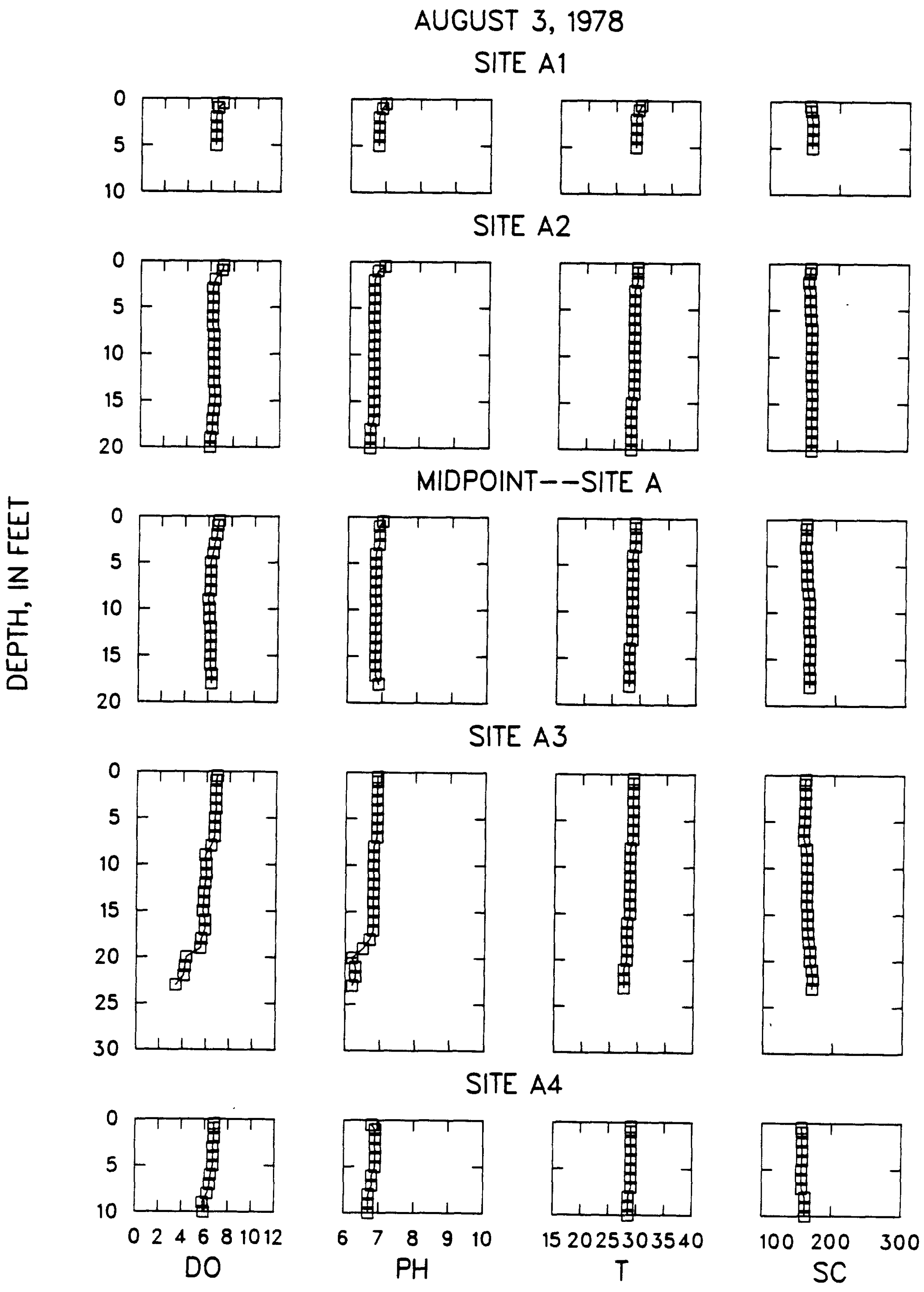

Figure 2C.-- Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect A-A', August 3, 1978.

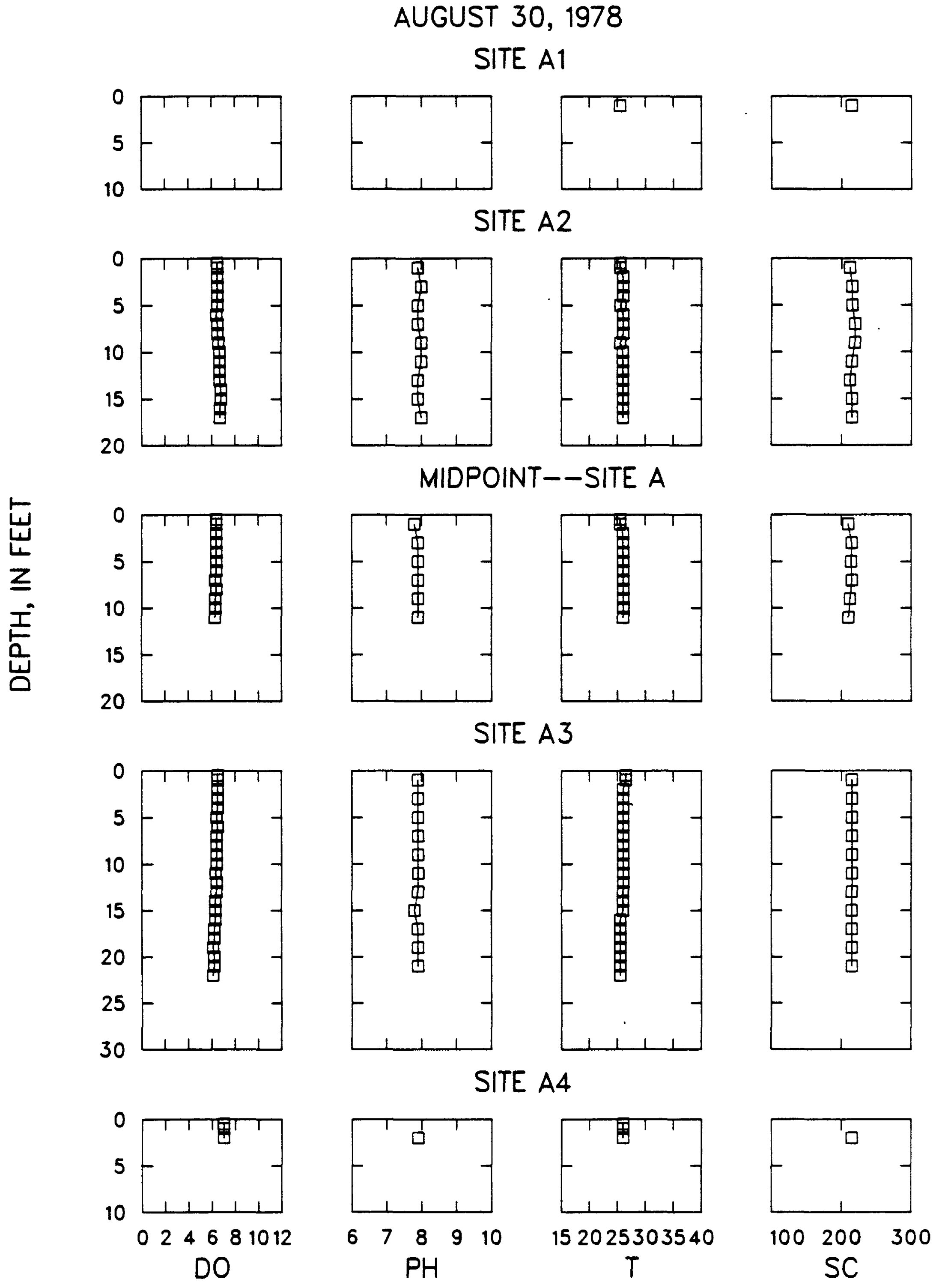

Figure 2D.-- Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect A-A', August 30, 1978.

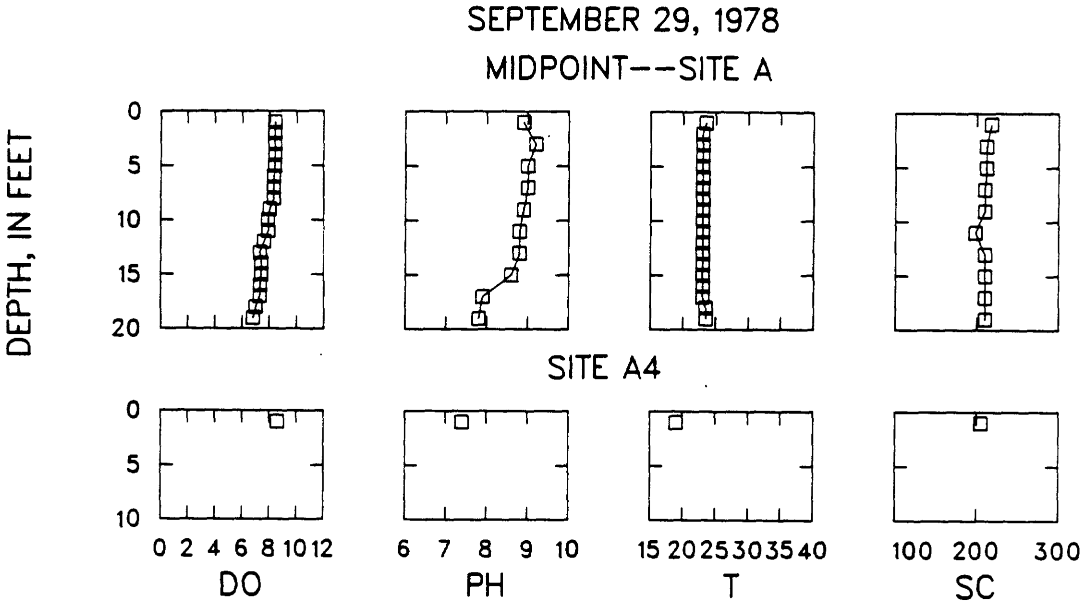

Figure 2E.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect A-A', September 29, 1978.

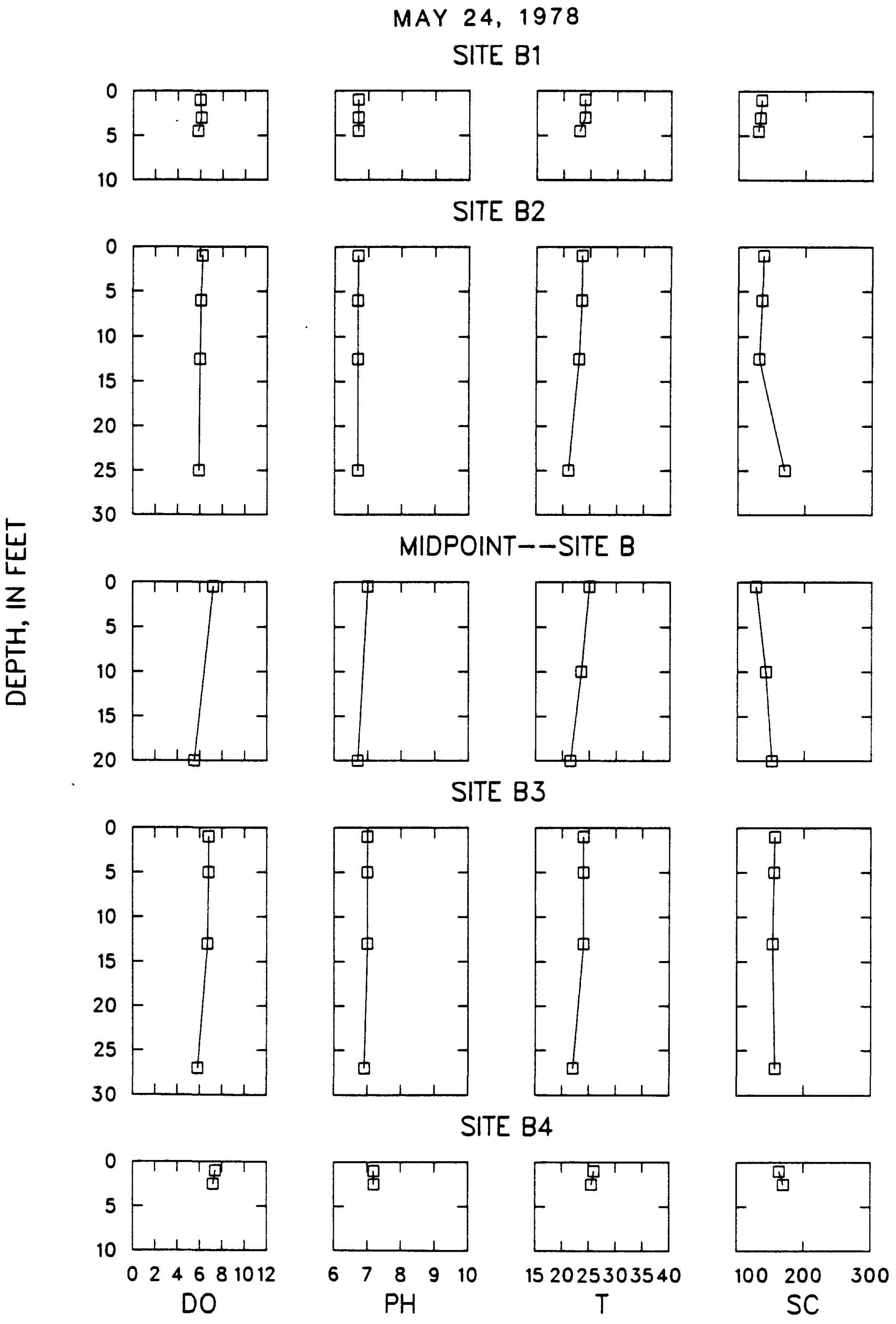

Figure 3A.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect B-B', May 24, 1978.

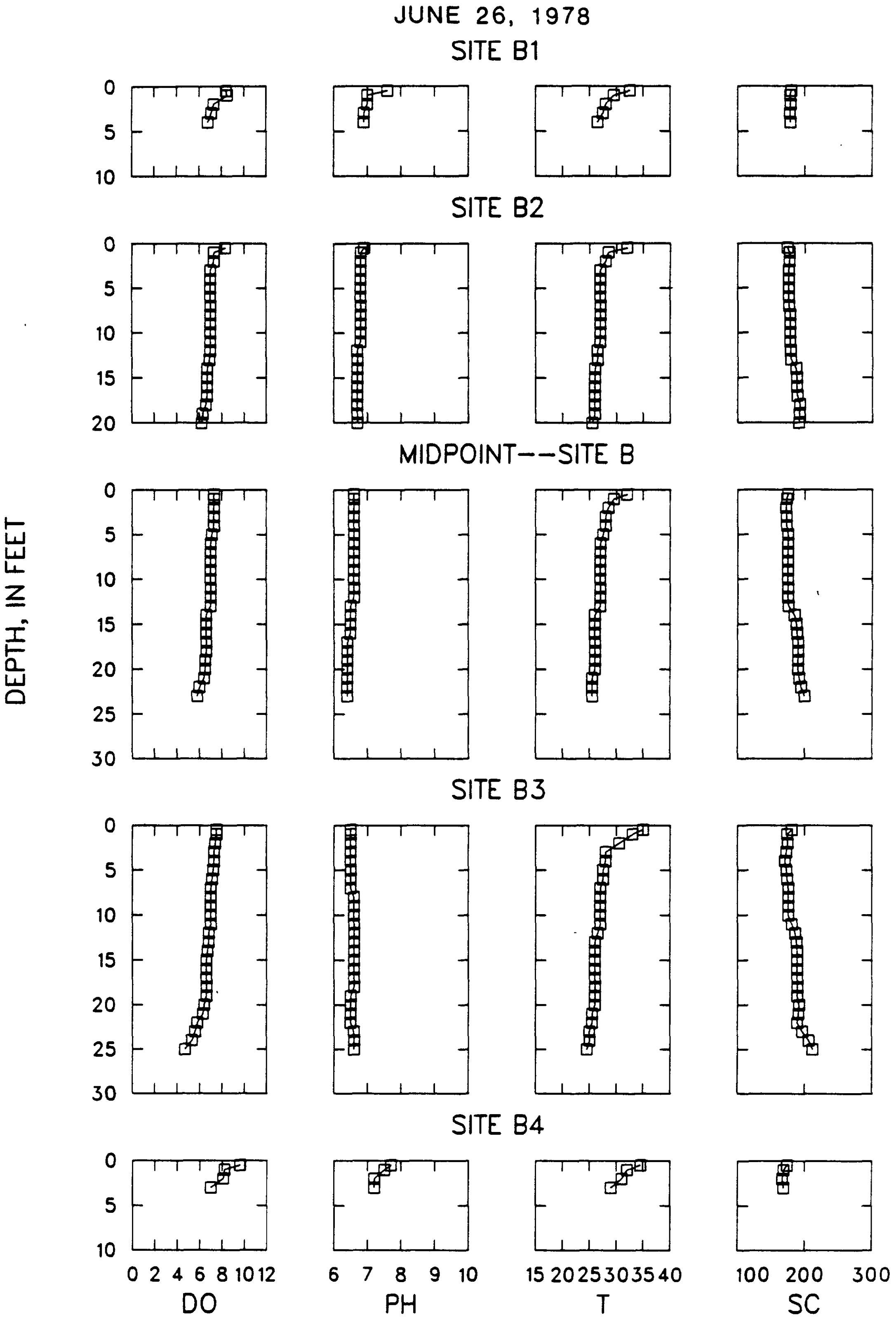

Figure 3B.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect B-B', June 26, 1978.

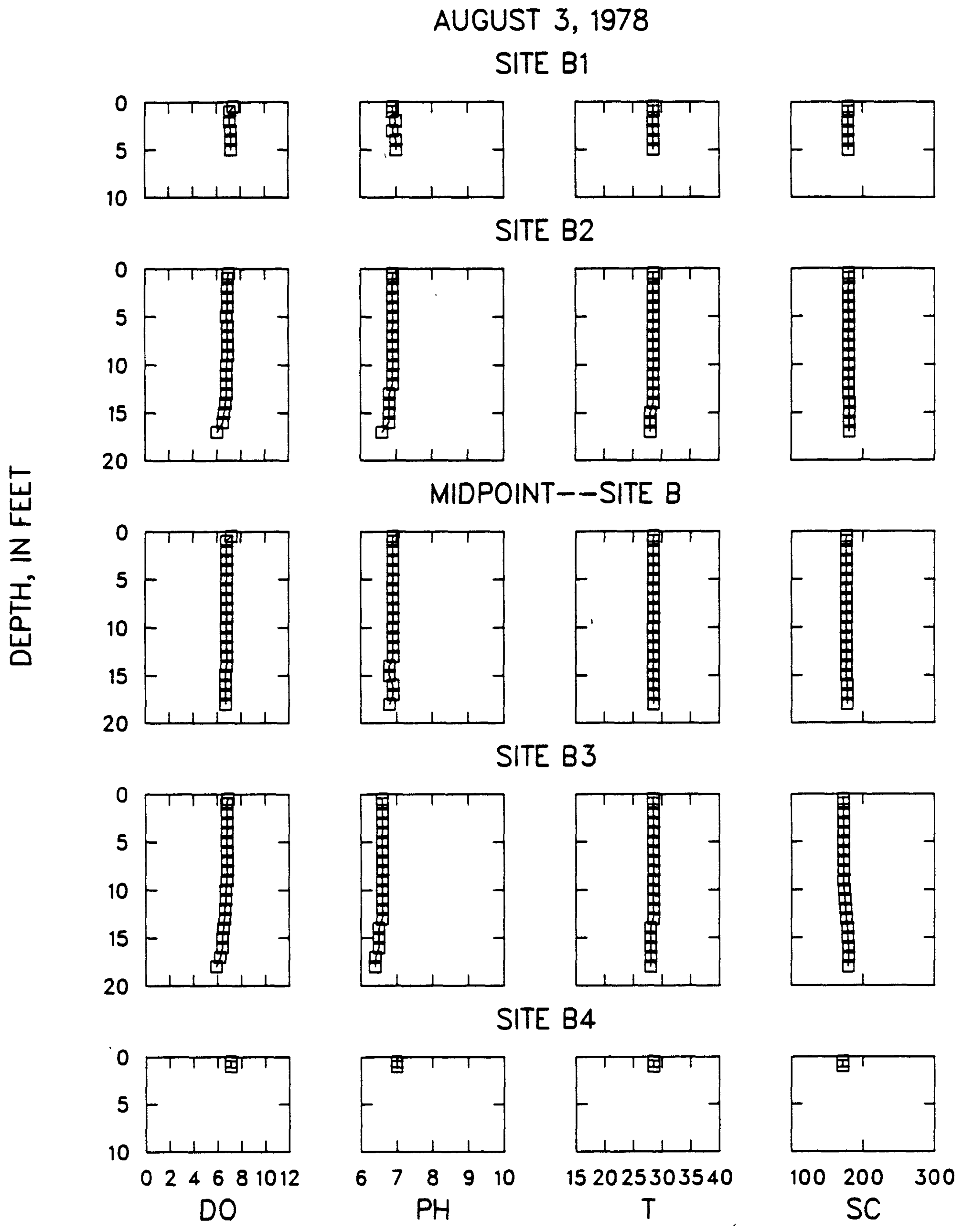

Figure 3C.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect B-B', August 3, 1978.

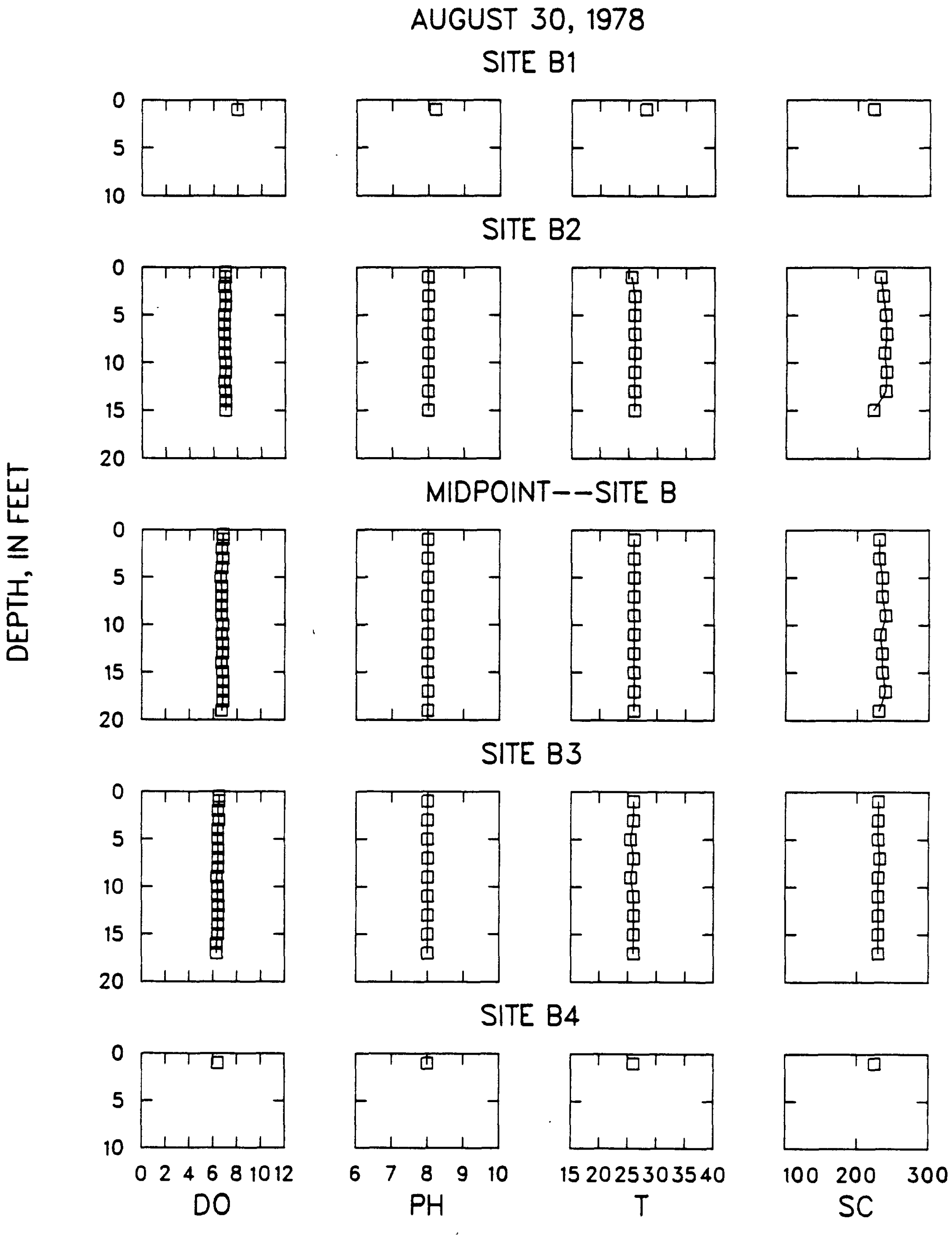

Figure 3D.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect B-B', August 30, 1978.

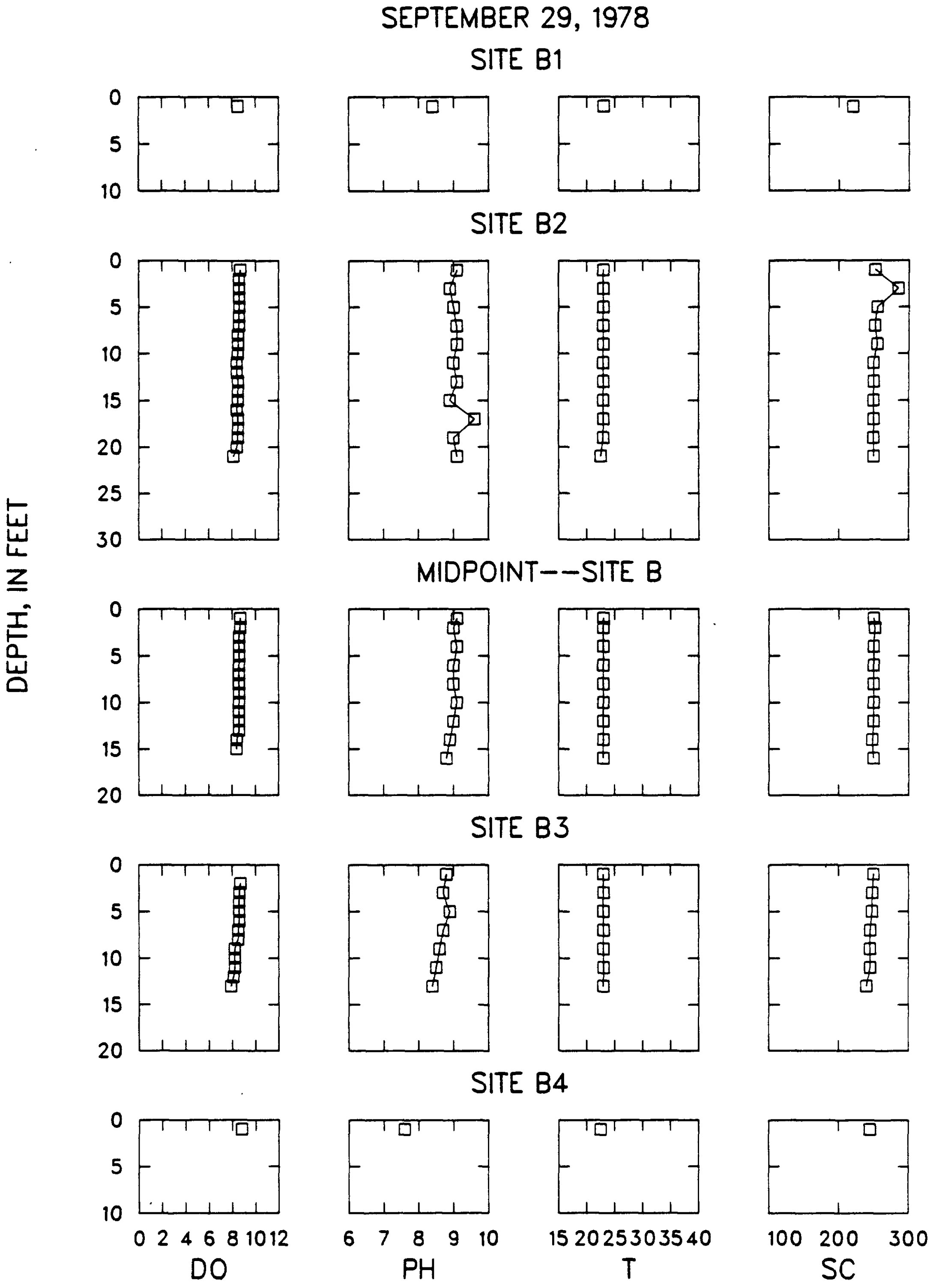

Figure 3E.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect B-B', September 29, 1978.

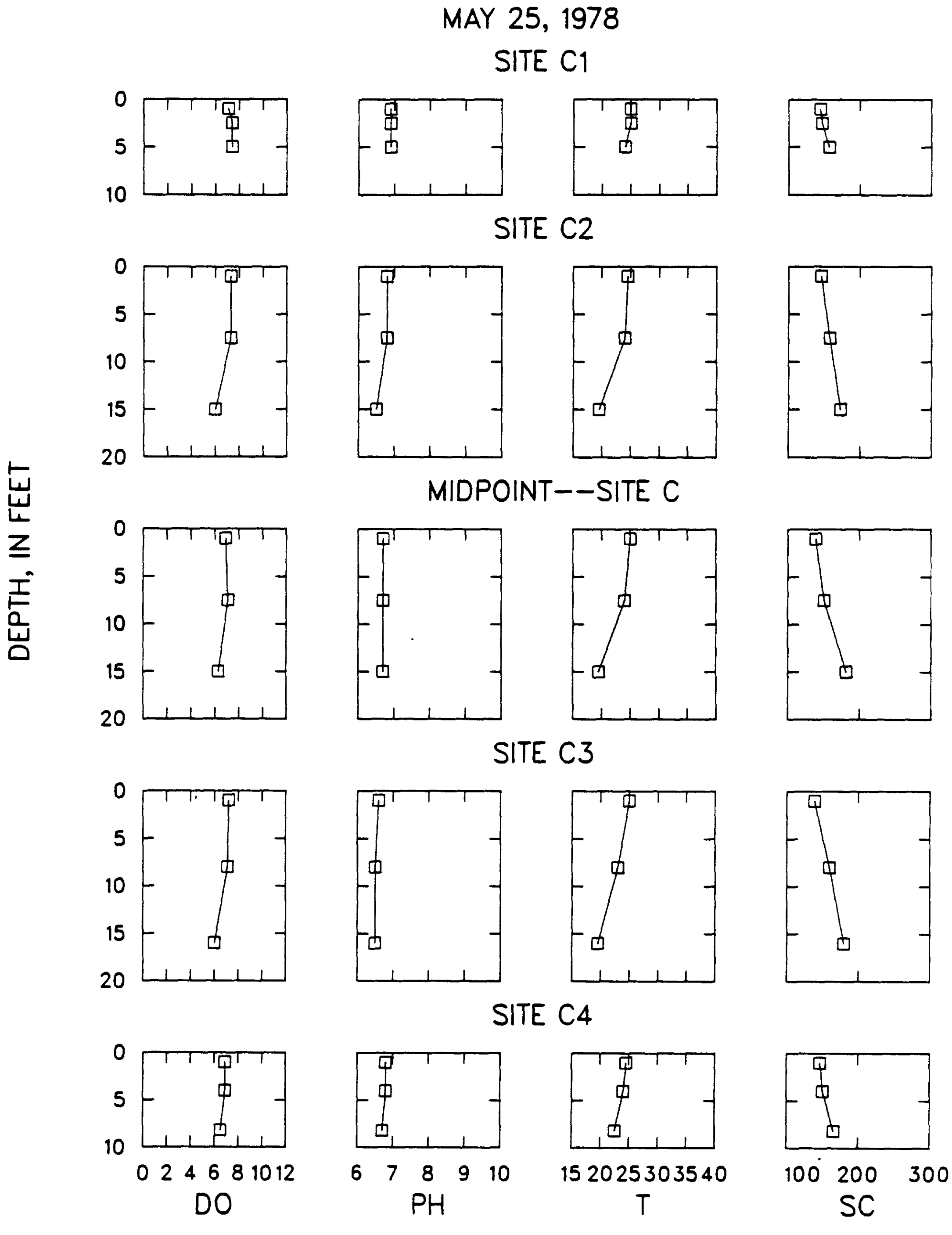

Figure 4A.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect C-C', May 25, 1978.

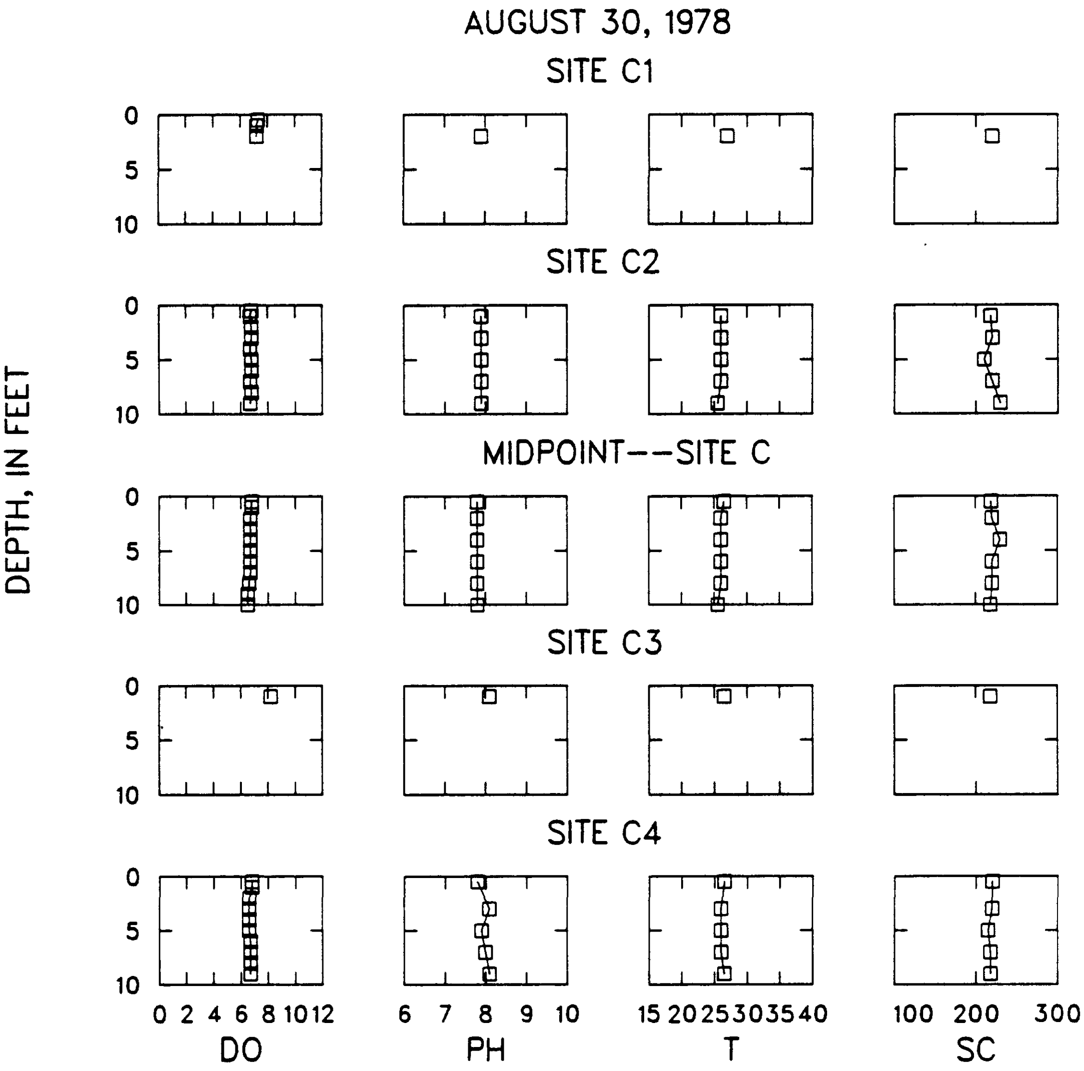

Figure 4B.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect C-C', August 30, 1978.

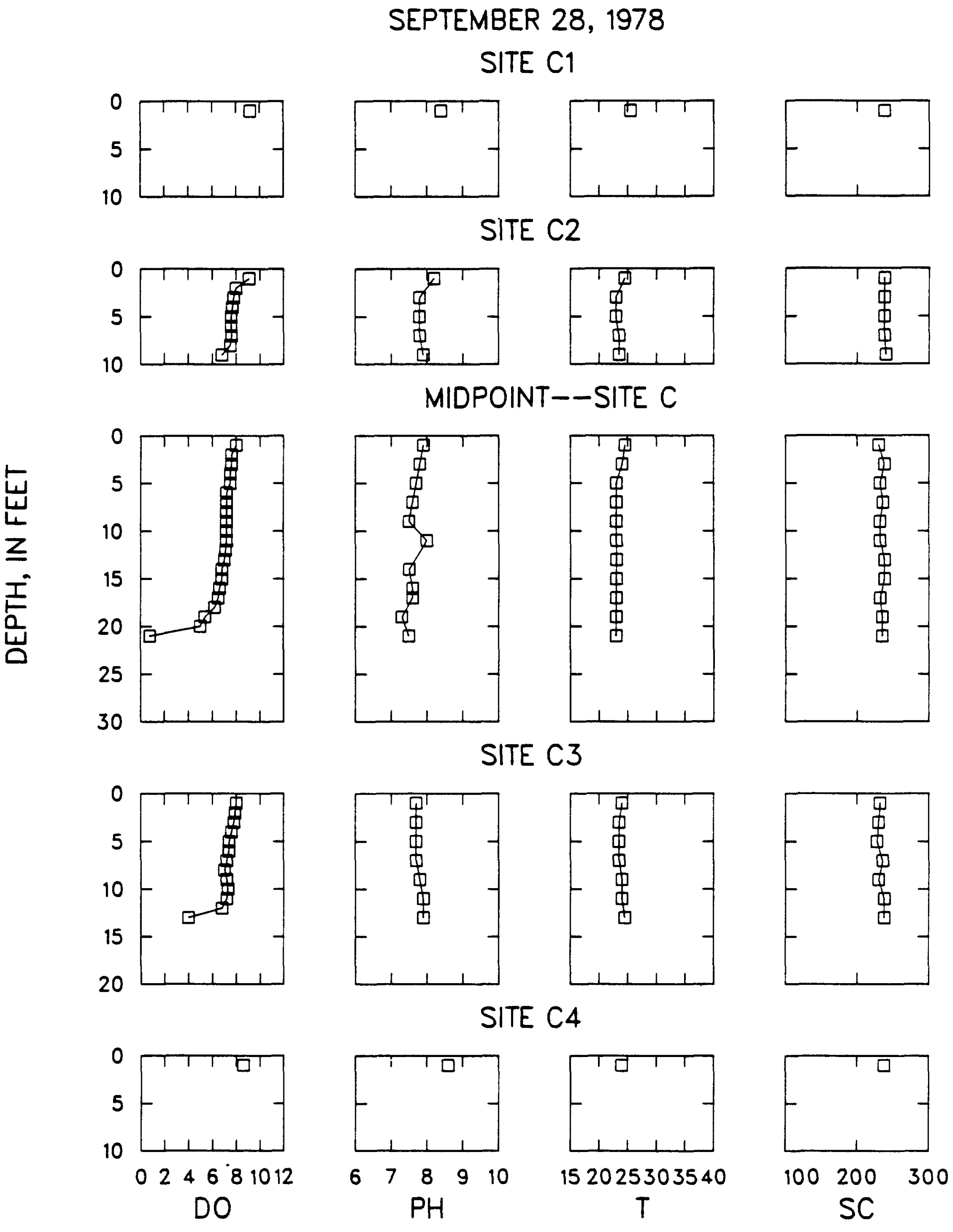

Figure 4C.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect C-C', September 28, 1978.

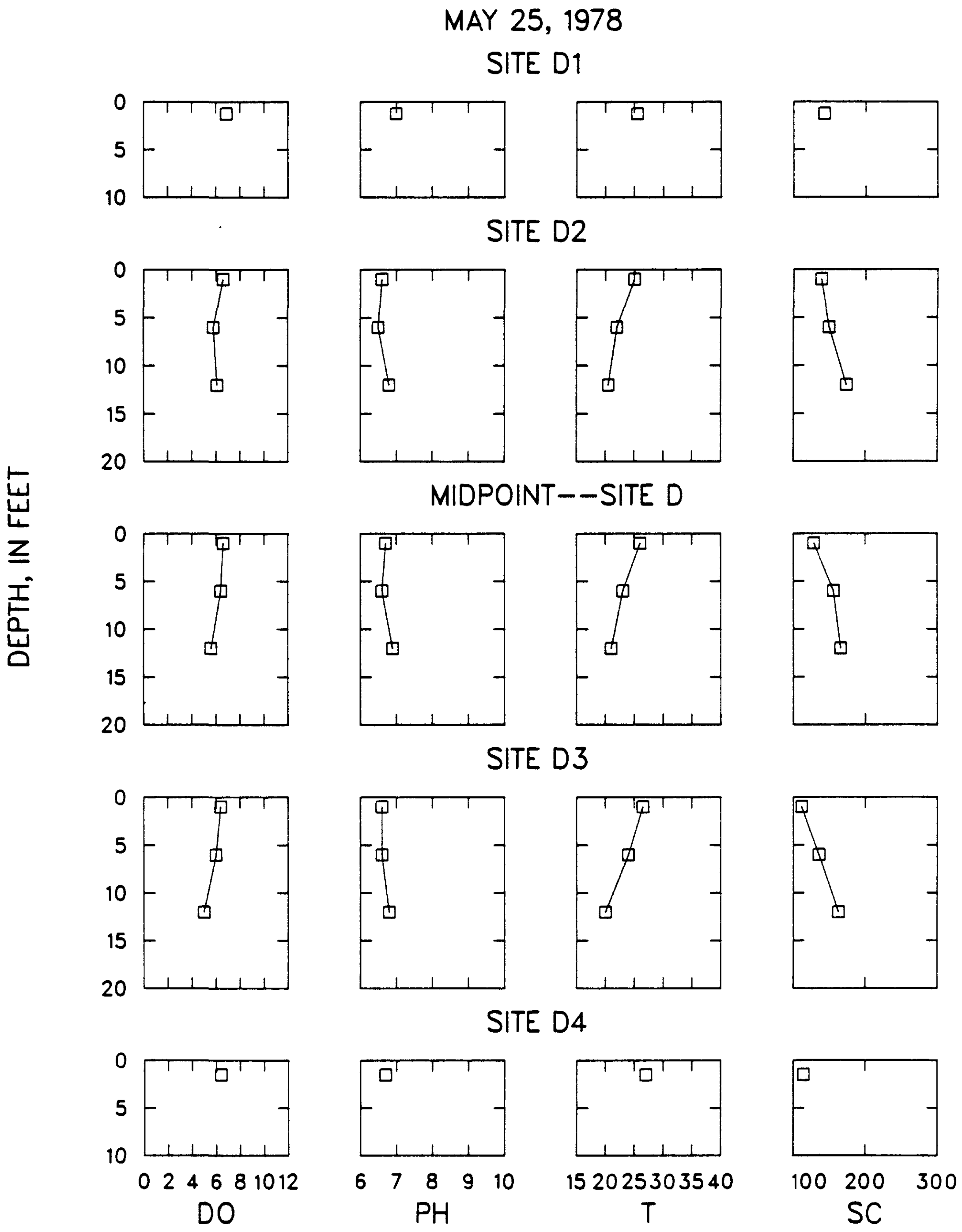

Figure 5A.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect D-D', May 25, 1978.

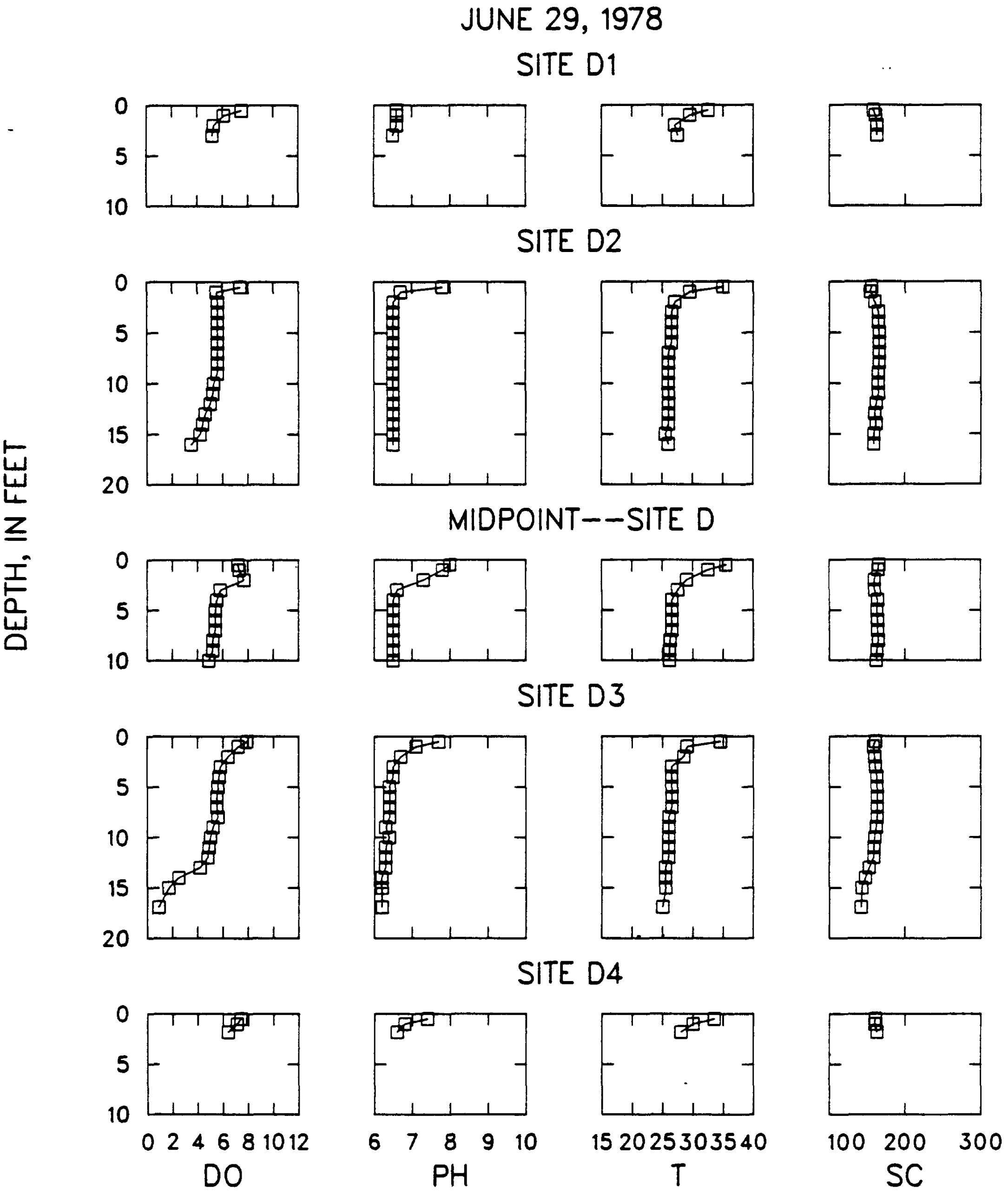

Figure 5B.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect D-D', June 29, 1978.

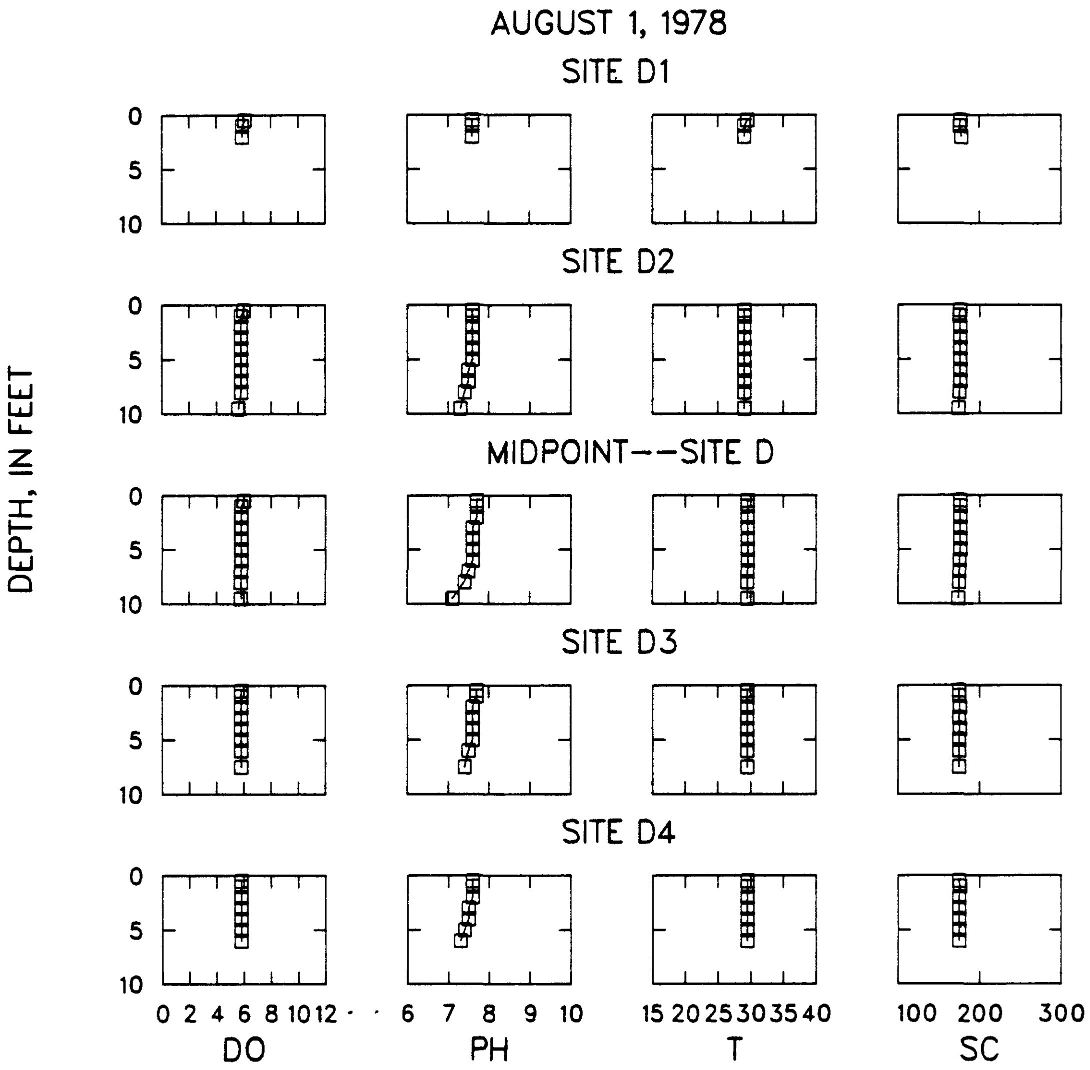

Figure 5C.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect D-D', August 1, 1978.

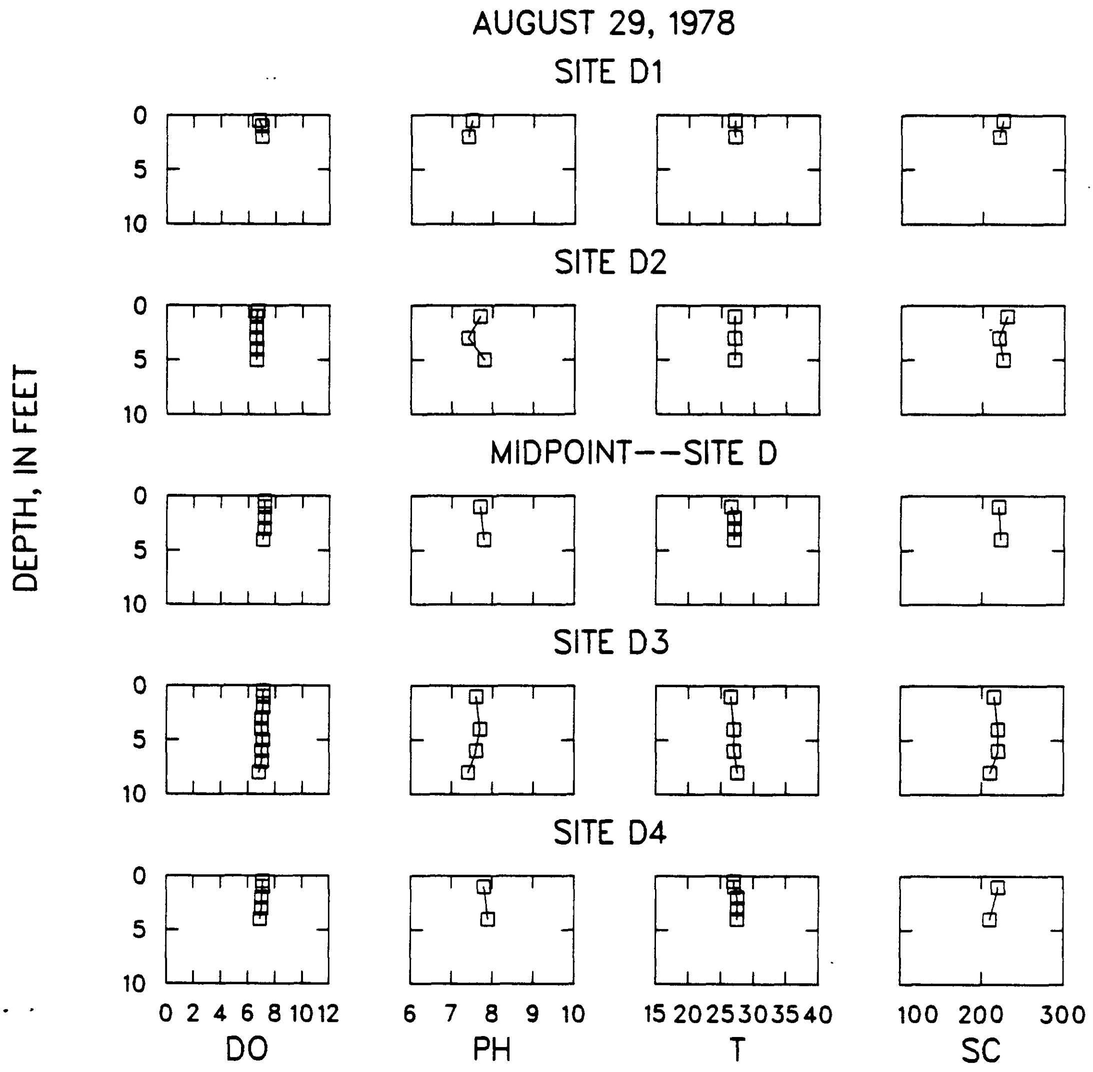

Figure 5D.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect D-D', August 29, 1978.

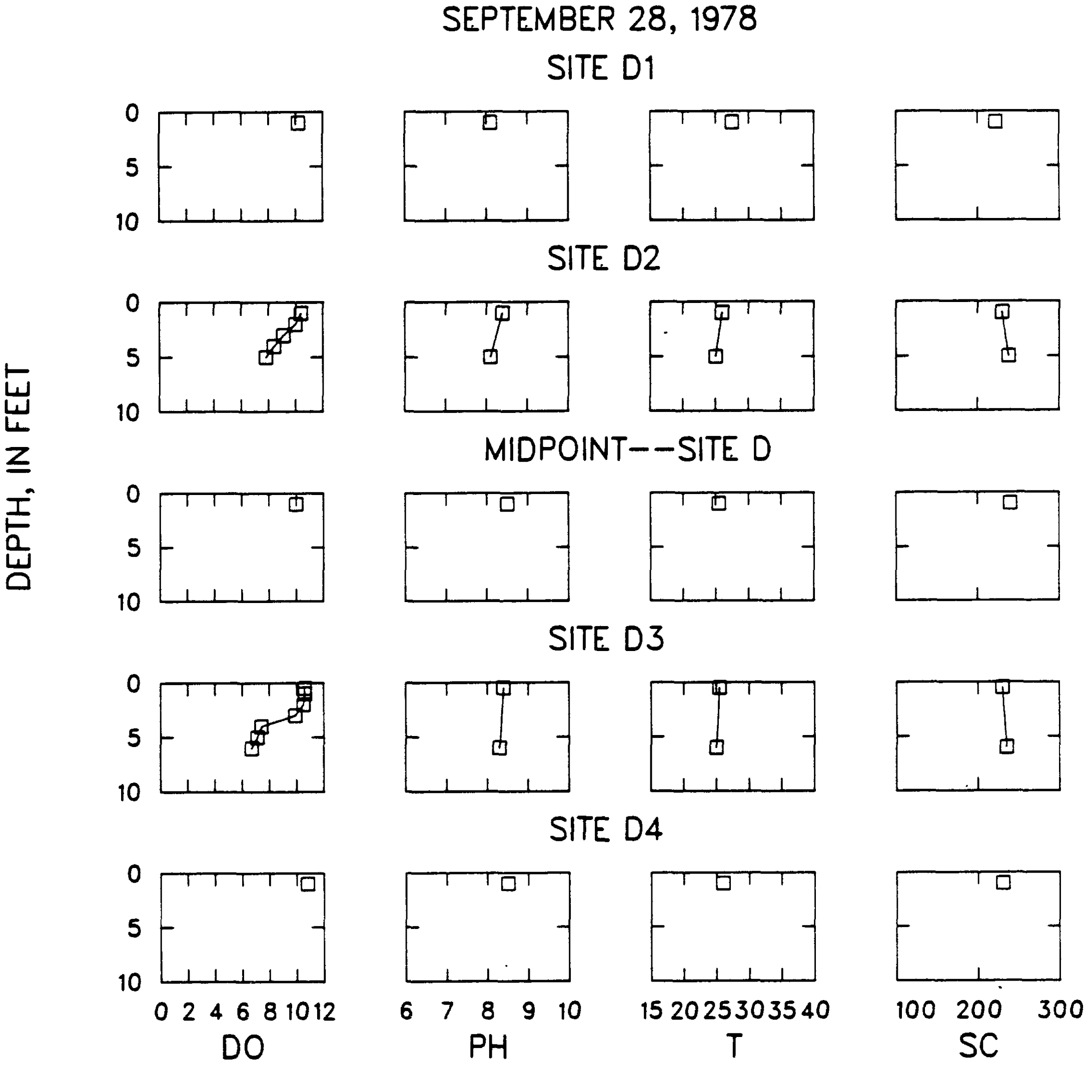

Figure 5E.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect D-D', September 28, 1978.

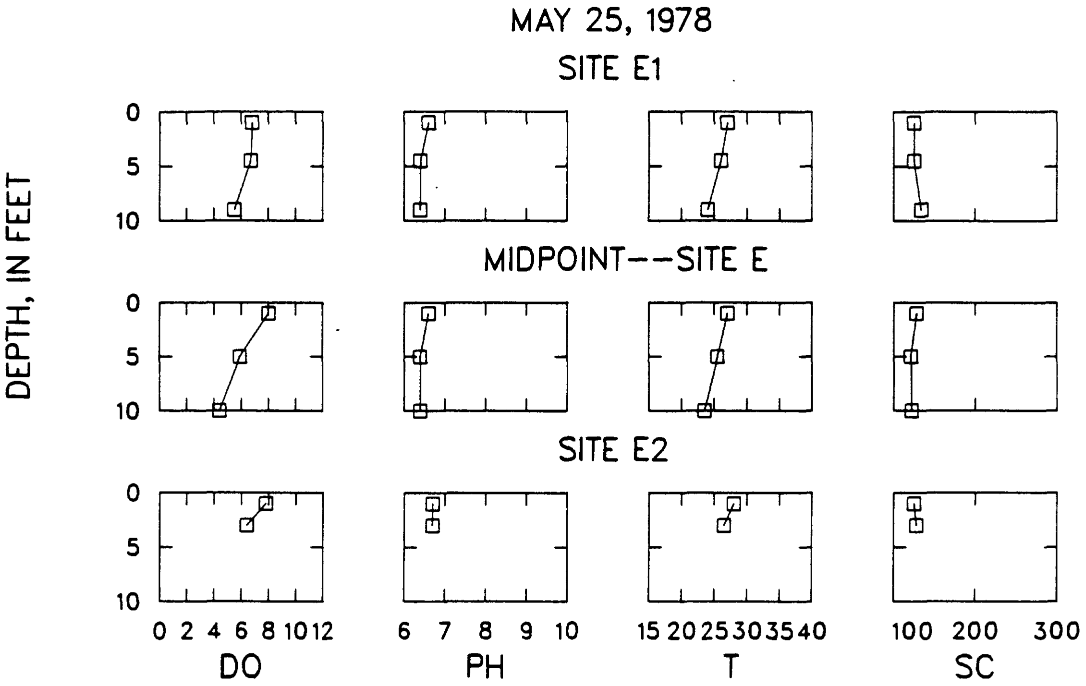

Figure 6A.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect E-E', May 25, 1978.

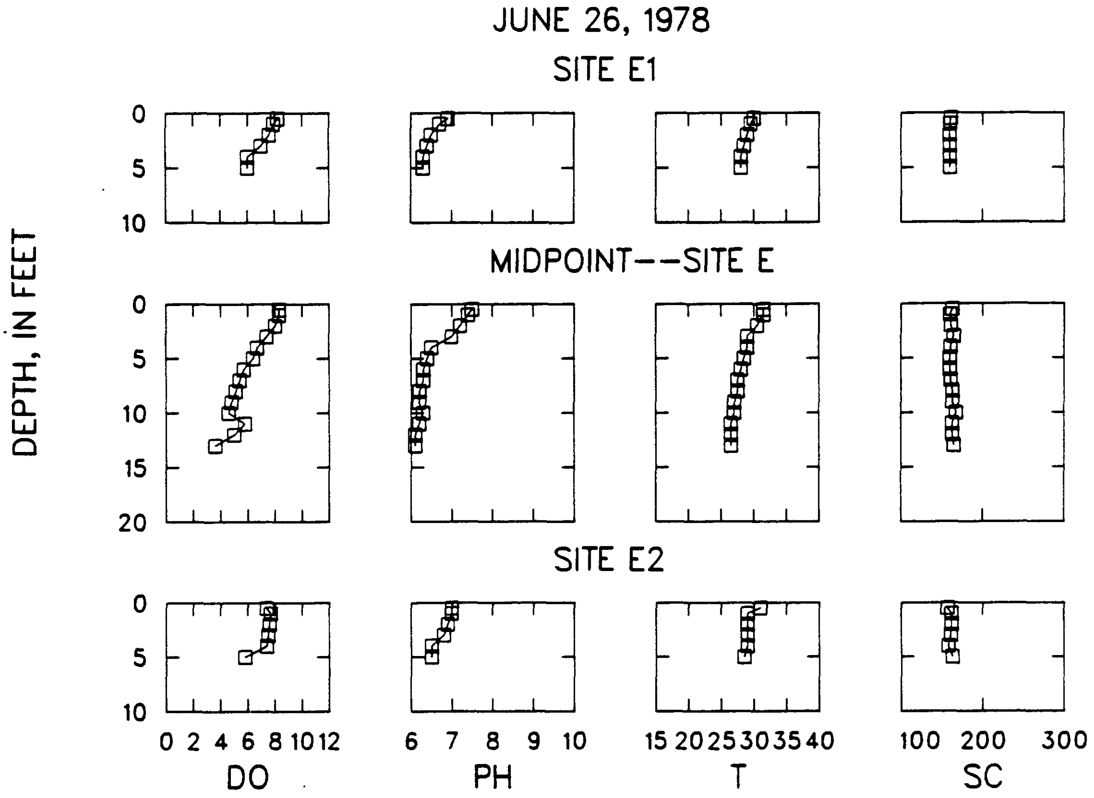

Figure 6B.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect E-E', June 26, 1978.

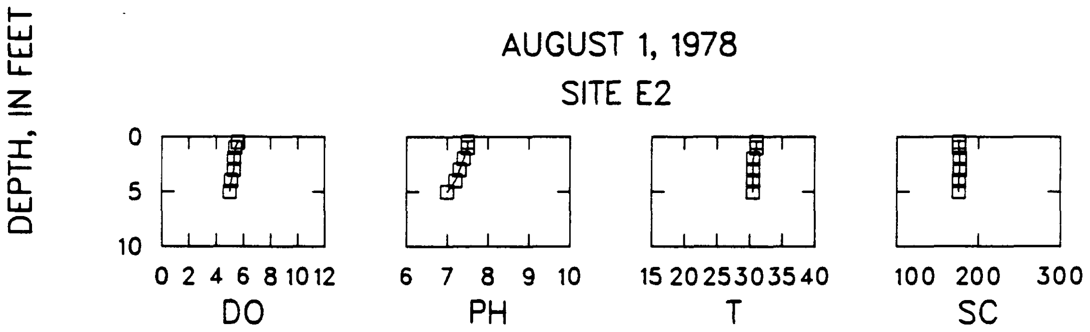

Figure 6C.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect E-E', August 1, 1978.

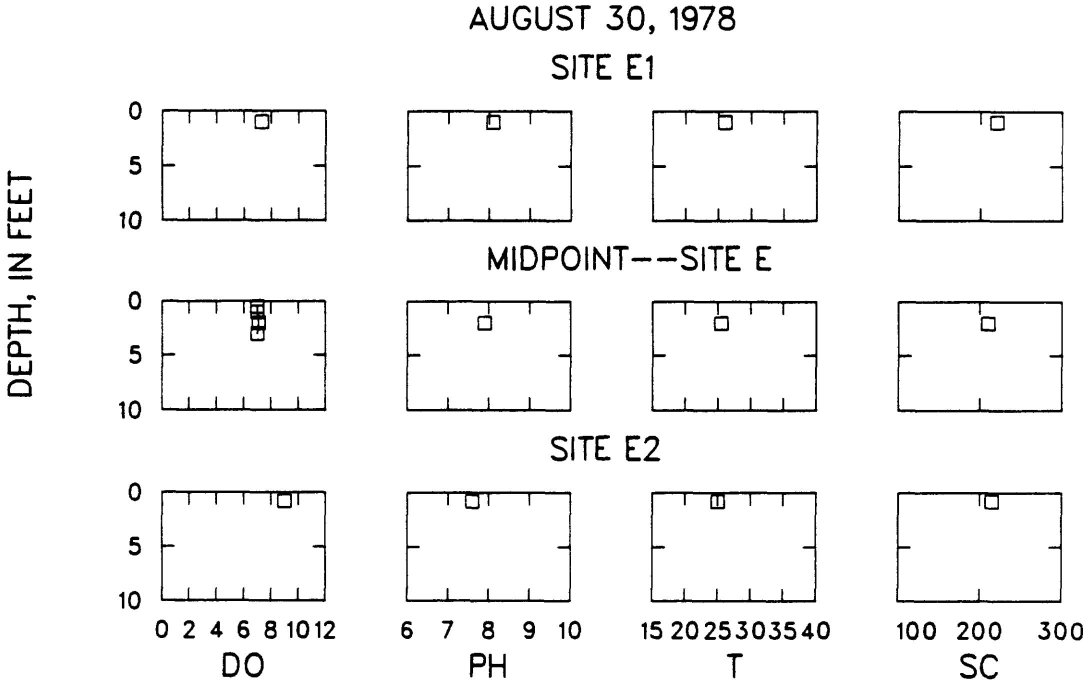

Figure 6D.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect E-E', August 30, 1978.

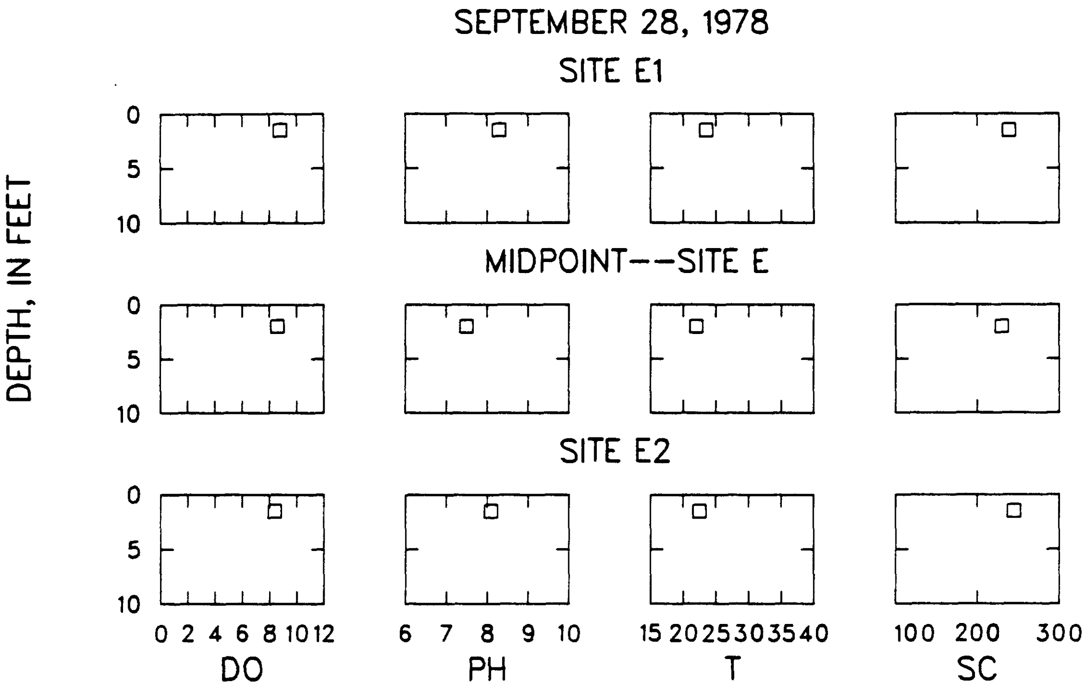

Figure 6E.--Profiles of dissolved oxygen, pH, water temperature, and specific conductance at sampling and measurement sites along Transect E-E', September 28, 1978.

Standards for pH of recreational waters may be more restrictive than those established for public supplies. To minimize eye irritation and enhance recreational enjoyment, pH needs to be within the range of 6.5 and 8.3 except for those waters with little buffering capacity where a range of pH between 5.0 and 9.0 may be tolerated (National Academy of Sciences, National Academy of Engineering, 1972). Oklahoma's water-quality standards (Oklahoma Water Resources Board, 1979) state, "The pH values shall be between 6.5 and 9.0 for Oklahoma's water; unless pH values outside that range are due to natural conditions."

Water Temperature

Ecologically, the thermal properties of water are the most important factors in determining the suitability of water as a natural environment and in regulating activities of aquatic organisms (Wetzel, 1975). Many physical and chemical processes that occur in a lake are affected by water temperatures.

Although water temperature varies both seasonally and areally, the extent of seasonal variation was not determined in this project due to the study's limited duration. Temperature profiles made at a minimum of three measurement sites along a transect (figs. 2-6) were compared by transect for each month. Profiles for all transects for May and June showed the greatest temperature variation with respect to depth. Warmer water was found near the surface and cooler water near the bottom. As summer progressed, water temperatures were less variable with depth. Some of the September profiles indicated the beginning of a temperature reversal with bottom temperatures slightly higher than surface temperatures. The water temperature ranged from 16.0 °C in October to 30.5 °C in August.

Specific Conductance

Specific conductance is a measure of the ability of ions in solution to conduct an electrical current. Specific conductance is related to the type and concentration of ions in solution. Specific conductance increases with water temperature; however, all specific-conductance values reported in this study were temperature corrected to 25 °C. Profiles for specific conductance are shown in figures 2-6. Specific-conductance values showed little variation with depth. The greatest variation occurred temporally with lesser values in May increasing to larger values in September.

Chemical Constituents

Major Cations

The changes in concentration of the major cations with respect to time at the midpoint sampling site along each transect are shown in figure 7A. The predominant compound in most inland waters is calcium carbonate ($CaCO_3$); it is also one of the least soluble (Cole, 1975). Magnesium usually is the second most abundant cation in inland waters of temperate regions (Cole, 1975). Calcium and magnesium are the two constituents most commonly associated with hardness. Values for hardness are reported in table 7. There are

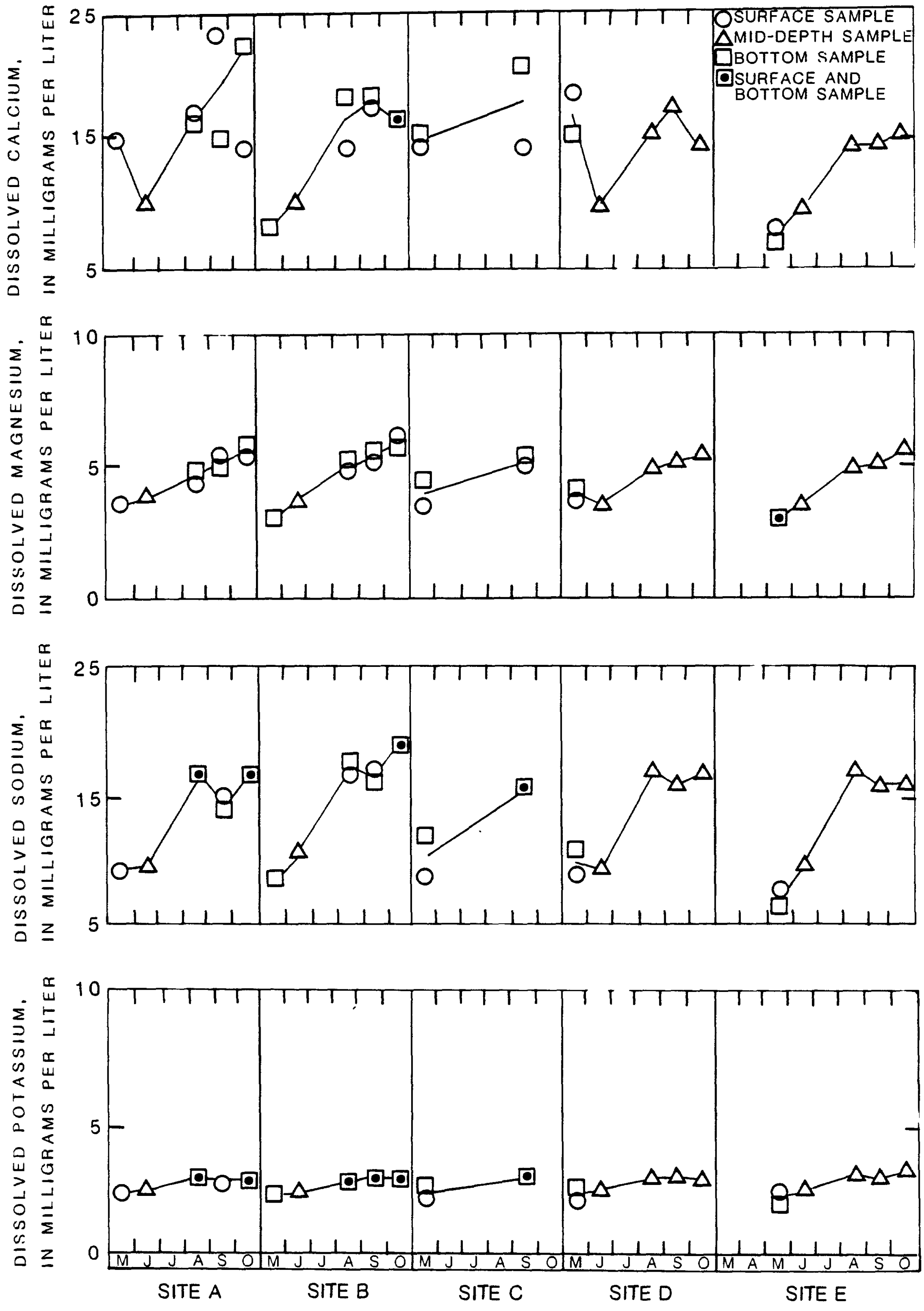

Figure 7A.--Changes in concentrations of major cations, sampling sites A-E.

no quantitative standards for hardness; acceptable concentrations are based on user preference. According to the hardness classification (Hem, 1970) given below, the lake water may be considered to be soft:

	Hardness as calcium carbonate (milligrams per liter)
Soft	0-60
Moderately hard	61-120
Hard	121-180
Very hard	More than 180

Soft-water lakes usually contain lesser living matter per unit area than hard-water lakes (Reid and Wood, 1976). Calcium is an essential element for most green plants although not for many algae. Magnesium also is considered a necessary element for most green plants. It has been observed that the more calcium and magnesium in the water, the greater the biological productivity. Additionally, calcium ions are said to make physiologically available other important nutrient ions (Welch, 1952). Magnesium is an essential component of chlorophyll; therefore, its concentration is important in photosynthesis. Waters with calcium concentrations greater than 25 mg/L are considered enriched in calcium (Reid and Wood, 1976).

Sodium salts are readily soluble in water; they are added to water from natural sources as well as from sewage, industrial effluents, and deicing salts. Of the 100 largest public water supplies in the U.S., most of which are surface supplies, the median sodium concentration was 12 mg/L with a range of 1.1 to 177 mg/L (Dufor and Becker, 1964). Potassium has some similar properties to sodium and usually is the fourth ranking cation in lake water. Because potassium does not remain in solution as well as sodium, it is not as prevalent as sodium in natural waters (Cole, 1975).

Both sodium and potassium are essential elements for biological processes. Potassium is a catalyst in photosynthesis; sodium sometimes may be a substitute when potassium is not present in sufficient quantities. The ranges for the major cations determined during the study are listed below:

Constituent	Maximum	Minimum
Calcium	22	1.1
Magnesium	5.6	1.8
Sodium	19	3.0
Potassium	3.0	.6

In general, concentrations for the major cations gradually increased from spring to fall.

Table 7.--Physical properties and concentrations of major chemical constituents in water

[US/CM, microsiemens per centimeter at 25° Celsius; DEG C, degrees Celsius; NTU, nephelometric turbidity units; MG/L, milligrams per liter; AC-FT, acre-feet]

SAMPLING SITE A

DATE	TIME	SAMPLING DEPTH (FEET)	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
MAY												
31...	1030	29.0	145	6.6	21.0	140	800	7.3	90	--	--	--
31...	1115	3.00	147	7.0	26.5	120	90	7.0	88	53	15	3.7
JUNE												
28...	1110	13.0	166	6.8	26.5	--	--	6.7	84	41	10	3.8
AUG												
24...	1330	31.0	153	7.6	27.0	320	140	6.3	78	59	16	4.7
24...	1340	3.00	193	7.2	29.0	100	78	6.4	79	61	17	4.6
SEPT												
28...	1215	42.0	230	7.6	23.5	100	100	7.5	88	59	15	5.2
28...	1230	3.00	226	8.4	26.0	56	24	8.4	98	79	23	5.3
OCT												
26...	0950	17.0	220	7.7	16.0	120	--	6.5	66	78	22	5.6
26...	1040	3.00	212	7.2	15.5	60	--	8.0	82	58	14	5.5

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
MAY											
31...	--	--	--	--	--	20	13	0.2	7.0	91	0.12
31...	9.7	27	0.6	2.4	--	16	9.8	.1	5.4	85	.12
JUNE											
28...	9.9	33	.7	2.5	27	12	13	.1	5.5	81	.11
AUG											
24...	17	37	1.0	3.0	22	41	18	.1	4.4	125	.17
24...	17	36	1.0	3.0	34	22	21	.1	3.8	111	.15
SEPT											
28...	14	33	.8	3.0	43	21	18	.2	4.9	116	.16
28...	15	28	.8	2.9	43	35	29	.2	4.6	122	.17
OCT											
26...	17	31	.9	2.9	41	23	31	.1	5.6	122	.17
26...	17	38	1.0	2.9	44	18	22	.1	5.3	125	.17

Table 7.--Physical properties and concentrations of major chemical constituents--Continued

SAMPLING SITE B

DATE	TIME	SAMPLING DEPTH (FEET)	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
MAY												
24...	1730	19.0	150	6.7	21.5	140	130	5.5	64	34	8.2	3.3
24...	1830	3.00	130	7.0	24.5	140	110	7.2	89	--	--	--
JUNE												
28...	1355	11.0	190	6.4	25.8	--	--	6.5	81	41	10	3.8
AUG												
24...	1300	3.00	235	8.0	26.5	90	54	6.8	86	55	14	4.9
24...	1315	18.0	231	8.0	26.5	84	66	6.8	86	66	18	5.1
SEPT												
28...	1245	16.0	240	7.8	25.0	100	72	6.4	78	67	18	5.4
28...	1300	3.00	238	8.3	28.0	60	44	10.3	132	64	17	5.3
OCT												
26...	1300	24.0	240	7.4	--	80	--	--	--	64	16	5.8
26...	1330	3.00	220	7.9	--	50	--	--	--	64	16	5.9

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
MAY											
24...	8.9	34	0.7	2.4	--	14	10	0.1	4.5	77	0.10
24...	--	--	--	--	--	15	11	.1	5.0	80	.11
JUNE											
28...	--	--	--	--	--	--	--	--	--	--	--
28...	11	35	.8	2.5	25	12	15	.1	5.6	84	.11
AUG											
24...	17	39	1.0	2.9	36	20	20	.1	4.0	118	.16
24...	18	36	1.0	2.9	26	20	20	.1	4.2	132	.18
SEPT											
28...	16	33	.9	3.0	44	23	22	.2	4.6	124	.17
28...	17	35	1.0	3.0	43	23	23	.2	4.6	128	.17
OCT											
26...	19	38	1.1	3.0	47	21	28	.2	5.2	136	.19
26...	19	38	1.1	3.0	48	19	30	.2	5.2	140	.19

Table 7.--Physical properties and concentrations of major chemical constituents in water--Continued

SAMPLING SITE C

DATE	TIME	SAMPLING DEPTH (FEET)	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
MAY												
25...	1100	14.0	180	6.7	19.5	140	100	6.3	70	55	15	4.3
25...	1130	3.00	190	6.7	24.5	150	95	6.9	85	49	14	3.5
SEPT												
28...	1100	20.0	235	7.5	23.0	80	68	5.0	59	71	20	5.2
28...	1135	3.00	238	7.8	24.0	80	50	7.6	90	56	14	5.1

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
MAY											
25...	12	31	0.7	2.5	--	19	13	0.1	5.7	98	0.13
25...	8.9	27	.6	2.3	--	16	10	.1	5.5	77	.10
SEPT											
28...	16	32	.9	3.0	42	24	27	.1	5.1	123	.17
28...	16	37	1.0	3.0	43	21	21	.1	4.6	118	.16

Table.7.--Physical properties and concentrations of major chemical constituents--Continued

SAMPLING SITE D

DATE	TIME	SAMPLING DEPTH (FEET)	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
MAY												
25...	1745	11.0	166	6.9	21.0	140	170	5.6	64	54	15	4.0
25...	1750	3.00	140	6.7	25.5	120	110	6.5	79	60	18	3.7
JUNE												
29...	1700	5.00	166	6.5	26.5	110	80	5.4	68	39	9.5	3.6
AUG												
24...	--	4.00	220	7.8	27.0	70	81	7.1	91	57	15	4.7
SEPT												
28...	0930	1.00	210	7.5	25.5	80	64	10.0	125	63	17	5.1
OCT												
26...	1415	1.00	254	7.3	--	--	--	--	57	--	14	5.4

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
MAY											
25...	11	30	0.7	2.4	--	17	11	0.1	5.6	82	0.11
25...	9.0	24	.5	2.3	--	15	9.5	.1	5.4	75	.10
JUNE											
29...	9.5	33	.7	2.5	25	12	15	.1	5.5	89	.12
AUG											
24...	17	38	1.0	3.0	34	23	24	.1	3.5	110	.15
SEPT											
28...	16	34	.9	3.0	43	22	21	.1	4.6	124	.17
OCT											
26...	17	38	1.0	2.9	44	25	24	.2	5.8	155	.21

Table 7.--Physical properties and concentrations of major chemical constituents in water--Continued

SAMPLING SITE E

DATE	TIME	SAMPLING DEPTH (FEET)	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
MAR												
30...	1000	3.00	90	7.1	--	53	40	--	--	--	--	--
MAY												
25...	1310	9.00	122	6.4	23.5	110	85	4.4	52	30	7.0	3.0
25...	1325	3.00	125	6.5	27.0	120	85	8.0	102	32	7.9	3.0
JUNE												
27...	1430	6.00	162	6.3	27.5	100	80	5.7	74	37	9.1	3.5
AUG												
24...	1430	3.00	180	7.5	30.5	60	64	6.7	--	55	14	4.9
SEPT												
28...	1005	2.00	230	7.5	22.0	60	22	8.6	99	56	14	5.1
OCT												
26...	1445	1.00	220	6.9	--	40	38	--	--	61	15	5.6

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
MAR											
30...	--	--	--	--	--	16	5.7	0.1	8.9	52	0.07
MAY											
25...	6.9	32	0.6	2.2	--	13	7.6	.1	6.0	77	.10
25...	7.6	32	.6	2.3	--	13	7.9	.1	5.4	70	.10
JUNE											
27...	9.5	34	.7	2.5	27	12	14	.1	5.1	80	.11
AUG											
24...	17	39	1.0	3.1	39	19	15	.1	3.4	127	.17
SEPT											
28...	16	37	1.0	3.0	17	26	27	.1	4.6	140	.19
OCT											
26...	16	35	.9	3.2	46	23	16	.1	5.6	174	.24

Table 7.--Physical properties and concentrations of major chemical constituents in water--Continued

SAMPLING SITE F

DATE	TIME	SPECIFIC CONDUCTANCE (US/CM)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	COLOR (PLATINUM-COBALT UNITS)	TURBIDITY (NTU)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
JAN 26...	1520	110	7.3	3.0	90	45	13.1	98	35	7.4	3.9
FEB 07...	1330	120	6.6	1.0	90	45	13.0	92	35	7.4	4.0
MAR 07...	1530	70	7.0	7.5	220	300	11.2	95	21	4.6	2.2
APR 04...	1550	112	6.9	22.0	25	18	10.0	115	31	6.9	3.4
MAY 03...	1630	90	7.1	14.0	--	55	9.2	91	21	4.8	2.2
JUNE 20...	1700	130	6.7	29.0	--	6.5	7.3	96	31	7.3	3.1

DATE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER AC-FT)
JAN 26...	7.8	31	0.6	1.9	21	26	5.1	0.1	6.5	86	0.12
FEB 07...	9.9	37	.7	1.8	19	21	9.7	.1	6.8	92	.13
MAR 07...	5.5	34	.5	2.3	15	12	5.2	.1	5.6	65	.09
APR 04...	7.8	34	.6	1.6	16	23	7.4	.1	7.7	62	.08
MAY 03...	5.6	35	.5	1.3	15	13	6.0	<.1	7.2	52	.07
JUNE 20...	3.0	15	.2	4.8	21	13	7.0	.1	8.4	78	.11

Table 7.--Physical properties and concentrations of major chemical constituents in water--Continued

SAMPLING SITE G

DATE	TIME	SPE-CIFIC CON-DUCT-ANCE (US/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
JAN 26...	1535	128	7.2	3.5	90	65	12.0	90	39	8.5	4.3
FEB 07...	1200	121	6.6	2.0	30	16	12.2	88	40	7.9	5.0
MAR 07...	1445	68	6.1	6.0	65	24	11.6	94	16	3.0	2.0
APR 05...	0920	64	7.3	18.0	33	19	8.3	89	17	3.6	1.9
MAY 03...	1400	56	6.3	14.0	--	21	8.9	88	10	1.1	1.8
JUNE 21...	0830	100	5.6	23.0	--	2.6	5.7	67	30	5.7	3.8

DATE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER AC-FT)
JAN 26...	8.9	31	0.6	2.7	33	15	6.9	0.1	6.4	78	0.11
FEB 07...	8.8	31	.6	1.6	7.0	31	9.9	.1	6.7	92	.13
MAR 07...	4.7	38	.5	.6	4.0	13	4.3	<.1	6.7	51	.07
APR 05...	4.9	37	.5	1.2	8.0	13	4.9	.1	8.7	44	.06
MAY 03...	4.3	46	.6	.6	7.0	14	3.9	<.1	8.7	47	.06
JUNE 21...	7.3	34	.6	1.1	18	22	5.9	<.1	11	63	.09

Alkalinity, Major anions, and Silica

Alkalinity; the major anions, sulfate, chloride, and fluoride; and silica; (table 7) were present in water from the Blue Creek arm of Lake Eufaula, Blue Creek, and Blue Creek tributary in concentrations that were much less than the water-quality criteria for public water supplies (table 3). Changes in concentration of alkalinity, sulfate, chloride, and silica with respect to time in water from the five Blue Creek arm sites are shown in figure 7B.

Alkalinity is important for fish and other aquatic life because it buffers pH changes that occur naturally as a result of photosynthetic activity of chlorophyll-bearing vegetation (U.S. Environmental Protection Agency, 1976). Generally, waters with greater bicarbonate alkalinity are more productive of food plants for waterfowl than are waters with less bicarbonate alkalinity (National Technical Advisory Committee to the Secretary of the Interior, 1968).

Sulfate concentrations ranging from 3 to 30 mg/L may be considered normal (Hutchinson, 1957). Sulfate is important in the formation of chlorophyll and is necessary for plant growth. A limited supply of sulfate can inhibit the development of phytoplankton populations (Reid and Wood, 1976).

Chloride is present in all natural waters, but mostly in small concentration (Hem, 1970). Based on studies done for public water supplies of the 100 largest cities in the United States, the median chloride concentration was 13 mg/L with a range of 0 to 540 mg/L (Durfor and Becker, 1964).

Silicon is the second most abundant element in the Earth's surface; therefore, it is readily available for weathering and input into the water system. In rivers and lakes, silicon commonly ranges from 2 to 25 mg/L, and usually is expressed as silica in water analyses (Cole, 1975). Silica is an essential nutrient for diatoms; it also may be essential for some plankton and sponges.

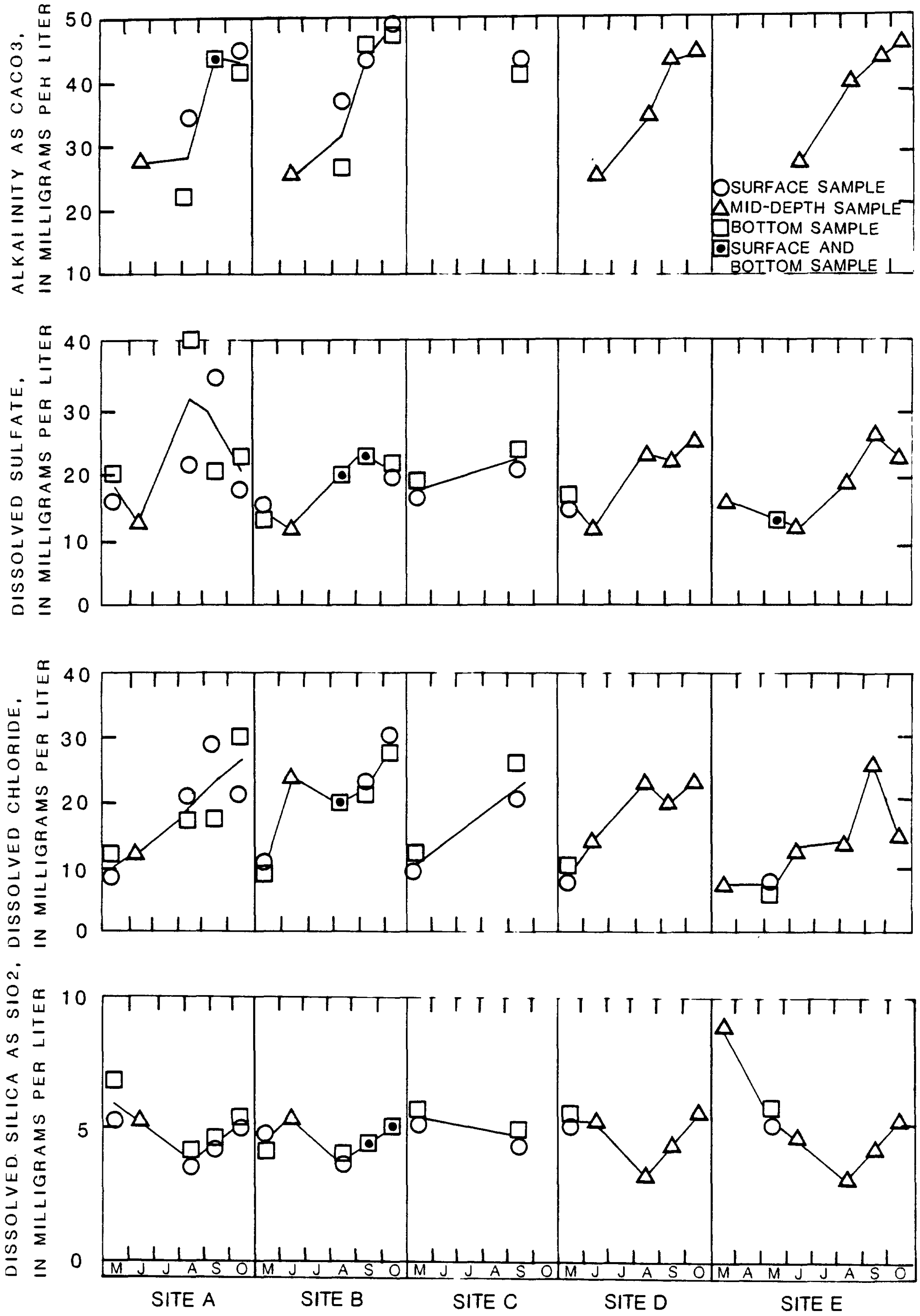

Figure 7B.--Changes in concentrations of alkalinity, major anions, and silica, sampling sites A-E.

Fluoride has potential beneficial effects, but excessive fluoride in drinking water supplies produces dental fluorosis (an abnormal condition characterized chiefly by mottling of the teeth) that increases with increasing fluoride concentration greater than the recommended control limits (National Academy of Sciences, National Academy of Engineering, 1972). Recommended concentrations of fluoride in drinking water are temperature dependent (table 2).

The ranges for alkalinity, the major anions, and silica determined during the study are listed below:

	Milligrams per liter	
Constituent	Maximum	Minimum
Alkalinity	48	4.0
Sulfate	41	5.7
Chloride	31	3.9
Fluoride	.2	<.1
Silica	11	3.4

Major Plant Nutrients

Nitrogen and phosphorus are considered the two major plant nutrients and commonly are identified as the limiting factors for aquatic-plant growth. The primary source of nitrogen is the atmosphere. Nitrogen also occurs in organic, ammonia, nitrite, and nitrate forms. Each form can be utilized by different organisms. Phosphorus sources usually are igneous rocks, sedimentary rocks, and soils. Phosphorus is not available from the atmosphere. Concentrations of phosphorus in natural waters usually are small, commonly much less than nitrogen concentrations. Phosphorus usually is the limiting nutrient because it is easily used by algae and aquatic plants.

Nutrient enrichment is a natural process in lakes and reservoirs. Man has become a significant contributor of large concentrations of nitrogen and phosphorus to the aquatic systems by activities such as agriculture and urbanization. As more nutrients are made available, plant productivity may increase, and the natural eutrophication or enrichment process accelerates.

The recommended maximum nitrate-nitrogen concentration in public water supplies is 10 mg/L. For nitrite-nitrogen concentrations, the water-quality criteria limit for aquatic life is 1 mg/L. Maximum contaminant levels have not been established for phosphorus. All the nitrate and nitrite concentrations determined in water from the Blue Creek arm of Lake Eufaula and Blue Creek, sampling sites A-G (table 8), are within drinking-water standards and water-quality criteria.

Table 8.--Concentrations of nitrogen and phosphorus in water from sampling sites A-G

[MG/L, milligrams per liter]

SAMPLING SITE A

DATE	TIME	SAMPLING DEPTH (FEET)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)
MAY											
31...	1030	29.0	0.52	0.52	2.3	0.020	0.010	0.03	0.54	0.53	0.080
31...	1115	3.00	.35	.26	1.2	.030	.021	.07	.38	.28	.090
JUNE											
28...	1110	13.0	.26	.30	1.3	.020	.010	.03	.28	.31	.060
AUG											
24...	1330	31.0	1.4	.98	4.3	.030	.010	.03	1.4	.99	.040
24...	1340	3.00	.13	--	--	.020	.010	.03	.15	1.8	.060
SEPT											
28...	1215	42.0	.29	.35	1.5	.010	<.010	.00	.30	.35	.030
28...	1230	3.00	.07	.14	.62	.010	<.010	.00	.08	.14	.280
OCT											
26...	0950	17.0	.24	.28	1.2	.010	<.010	.00	.25	.28	.030
26...	1040	3.00	.23	.32	1.4	.010	<.010	.00	.24	.32	.020

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS NO3)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)
MAY										
31...	<0.010	0.00	2.2	0.22	2.30	0.22	2.8	13	0.620	<0.010
31...	<.010	.00	.50	.34	.59	.34	.97	4.3	.100	.010
JUNE										
28...	<.010	.00	.50	.35	.56	.35	.84	3.7	.080	--
AUG										
24...	.010	.01	1.3	.32	1.30	.33	2.7	12	.110	--
24...	.050	.06	1.5	1.3	1.60	1.3	1.8	7.7	.100	--
SEPT										
28...	<.010	.00	.87	1.1	.90	1.1	1.2	5.3	.060	.010
28...	.010	.01	.82	.40	1.10	.41	1.2	5.2	.070	.010
OCT										
26...	.010	.01	.59	.90	.62	.91	.87	3.9	.100	.040
26...	.010	.01	.48	.80	.50	.81	.74	3.3	.090	.020

Table 8.--Concentrations of nitrogen and phosphorus in water from sampling sites A-G--Continued

SAMPLING SITE B

DATE	TIME	SAMPLING DEPTH (FEET)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)
MAY											
24...	1730	19.0	0.38	0.37	1.6	0.030	0.030	0.10	0.41	0.40	0.090
24...	1830	3.00	.39	.41	1.8	.030	.010	.03	.42	.42	.090
JUNE											
28...	1355	11.0	.33	.36	1.6	.030	.010	.03	.36	.37	.070
AUG											
24...	1300	3.00	.18	--	--	.020	.010	.03	.20	1.6	.040
24...	1315	18.0	1.9	--	--	.020	.009	.03	1.9	8.5	.030
SEP											
28...	1245	16.0	.21	.26	1.2	.010	<.010	.00	.22	.26	.060
28...	1300	3.00	.17	.17	.75	.010	<.010	.00	.18	.17	.060
OCT											
26...	1300	24.0	.24	.30	1.3	.010	<.010	.00	.25	.30	.030
26...	1330	3.00	.24	.27	1.2	.010	<.010	.00	.25	.27	.020

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS NO3)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)
MAY										
24...	<0.010	0.00	0.44	0.34	0.53	0.34	0.94	4.2	0.120	0.020
24...	<.010	.00	.44	.35	.53	.35	.95	4.2	.180	.010
JUNE										
28...	<.010	.00	.48	.38	.55	.38	.91	4.0	.070	--
AUG										
24...	.060	.08	.54	1.0	.58	1.1	.78	3.5	.070	--
24...	.040	.05	.60	.96	.63	1.0	2.5	11	.080	--
30...	--	--	--	--	--	--	--	--	--	--
SEP										
28...	<.010	.00	.40	.44	.46	.44	.68	3.0	.050	.010
28...	<.010	.00	.73	.42	.79	.42	.97	4.3	.040	.020
OCT										
26...	.010	.01	.67	.39	.70	.40	.95	4.2	.190	.020
26...	<.010	.00	.44	.30	.46	.30	.71	3.1	.070	.010

Table 8.--Concentrations of nitrogen and phosphorus in water from sampling sites A-G--Continued

SAMPLING SITE C

DATE	TIME	SAMPLING DEPTH (FEET)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)
MAY											
25...	1100	14.0	0.47	0.47	2.1	0.030	0.010	0.03	0.50	0.48	0.110
25...	1130	3.00	.34	.37	1.6	.030	.010	.03	.37	.38	.110
AUG											
SEPT											
28...	1100	20.0	.33	.28	1.2	.010	<.010	.00	.34	.28	.100
28...	1135	3.00	.22	.23	1.0	.010	<.010	.00	.23	.23	.120

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N)	NITROGEN,AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS NO3)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)
MAY										
25...	<0.010	0.00	0.36	0.33	0.47	0.33	0.97	4.3	0.110	0.010
25...	<.010	.00	.37	.31	.48	.31	.85	3.8	.100	.010
SEPT										
28...	.030	.04	1.1	.43	1.20	.46	1.5	6.8	.060	.010
28...	.010	.01	.76	.40	.88	.41	1.1	4.9	.040	.010

Table 8.--Nitrogen and phosphorous constituents in water from sampling sites A-G--Continued

SAMPLING SITE D

DATE	TIME	SAMPLING DEPTH (FEET)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)
MAY											
25...	1745	11.0	0.46	0.46	2.0	0.040	0.020	0.07	0.50	0.48	0.110
25...	1750	3.00	.35	.37	1.6	.030	.020	.07	.38	.39	.100
JUNE											
29...	1700	5.00	.30	.30	1.3	.030	.020	.07	.33	.32	.070
AUG											
24...	--	4.00	.14	--	--	.020	.010	.03	.16	.30	.050
SEPT											
28...	0930	1.00	.21	.24	1.1	.010	<.010	.00	.22	.24	.080
OCT											
26...	1415	1.00	.16	.20	.89	.010	<.010	.00	.17	.20	.030

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS NO3)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)
MAY										
25...	<0.010	0.00	0.58	0.29	0.69	0.29	1.2	5.3	0.160	0.010
25...	<.010	.00	.42	.23	.52	.23	.90	4.0	.100	.010
JUNE										
29...	<.010	.00	.47	.28	.54	.28	.87	3.9	.070	--
AUG										
24...	.030	.04	.34	.38	.39	.41	.55	2.4	.100	--
SEPT										
28...	.010	.01	.85	.42	.93	.43	1.2	5.1	.050	.010
OCT										
26...	<.010	.00	.66	.46	.69	.46	.86	3.8	.090	.010

Table 8.--Concentrations of nitrogen and phosphorus in water from sampling sites A-G--Continued

SAMPLING SITE E

DATE	TIME	SAMPLING DEPTH (FEET)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)
MAR											
30...	1000	3.00	--	--	--	--	--	--	--	0.05	--
MAY											
25...	1310	9.00	0.29	0.22	0.97	0.040	0.030	0.10	0.33	.25	0.090
25...	1325	3.00	.56	.23	1.0	.030	.021	.07	.59	.25	.120
JUNE											
27...	1430	6.00	.23	.22	.97	.050	.010	.03	.28	.23	.060
AUG											
24...	1430	3.00	.30	--	--	.010	.021	.07	.31	4.2	.060
SEP											
28...	1005	2.00	.05	--	--	.010	<.010	.00	.06	8.3	.240
OCT											
26...	1445	1.00	.24	.27	1.2	.010	<.010	.00	.25	.27	.020

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS NO3)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)
MAR										
30...	--	--	--	--	--	--	--	--	--	0.020
MAY										
25...	<0.010	0.00	0.39	0.47	0.48	0.47	0.81	3.6	0.100	.010
25...	<.010	.00	.51	.32	.63	.32	1.2	5.4	.100	.010
JUNE										
27...	<.010	.00	.63	.51	.69	.51	.97	4.3	.110	--
AUG										
24...	.010	.01	.69	.57	.75	.58	1.1	4.7	.090	--
SEP										
28...	.040	.05	2.2	.71	2.40	.75	2.5	11	.080	<.010
OCT										
26...	<.010	.00	.74	.37	.76	.37	1.0	4.5	.110	.010

Table 8.--Concentrations of nitrogen and phosphorus in water from sampling sites A-G --Continued

SAMPLING SITE F

DATE	TIME	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)
MAR						
07...	1530	4.60	20	0.030	0.10	4.6
APR						
04...	1550	.01	.04	.010	.03	.02
MAY						
03...	1630	.13	.58	.010	.03	.14
JUNE						
20...	1700	.57	2.5	.050	.16	.62

SAMPLING SITE G

DATE	TIME	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)
MAR						
07...	1445	--	--	.010	.03	--
APR						
05...	0920	.00	.00	.010	.03	<.10
MAY						
03...	1400	.08	.35	<.010	.00	.08
JUNE						
21...	0830	.01	.04	.010	.03	.02

Trace Elements

Generally, trace elements occur in most natural waters at concentrations that are not toxic to humans, animals, and plants; they are, in many instances, essential to plant growth as micronutrients. Many trace elements are toxic to humans, animals, and plants when they occur in large concentrations. Large concentrations commonly occur as a result of mining or industrial activities. The presence of trace elements in water supplies has a variety of implications concerning the potability and ultimate other uses of drinking water (Rubin, 1976). Concentrations of trace elements in water from the Blue Creek arm of Lake Eufaula and Blue Creek (sampling sites A-E and G) are shown in table 9. Each trace element will be discussed separately in the following paragraphs. The concentrations generally were much less than the drinking-water standards, with the exception of iron and manganese.

Analyses were made for both dissolved and total recoverable trace elements. As defined in the Water Resources Data for Oklahoma, Water Year 1983, "Dissolved is that material in a representative water sample which passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of 'dissolved' constituents are made on subsamples of the filtrate." Total recoverable is defined as "...the amount of a given constituent that is in solution after a representative water-suspended sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all particulate matter is not achieved by the digestion treatment, and thus the determination represents something less than the 'total' amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample."

Arsenic.--Arsenic occurs ubiquitously in nature and is insoluble in water. Most forms of arsenic are toxic to humans, mammals, and aquatic species. Although no form of arsenic is known to be essential, arsenic has been added in small amounts to animal food as a growth stimulant (National Academy of Sciences, National Academy of Engineering, 1972). Water samples collected from 130 sampling points in the United States have shown arsenic concentrations of 5 to 336 µg/L (micrograms per liter) with a mean concentration of 64 µg/L (Kopp, 1969).

The national primary drinking-water standard for arsenic is 50 µg/L (table 2 and table 5). Dissolved-arsenic concentrations were less than the drinking-water standard in all samples from the study area. Concentrations ranged from 0 to 3 µg/L in water from most sites (table 9).

Cadmium.--Cadmium is biologically a nonessential, nonbeneficial element. Concentrations of cadmium generally are very small in natural water. Cadmium can be added to the water system from electroplating plants and zinc-galvanized iron in which cadmium is a contaminant (National Academy of Sciences, National Academy of Engineering, 1972). Large concentrations of cadmium in drinking water are toxic to humans and animals. Water samples collected from 130 sampling points in the United States have shown detectable concentrations of 1 to 20 µg/L of cadmium with a mean concentration of 9.5 µg/L (Kopp, 1969).

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

[UG/L, micrograms per liter; ND, not determined]

SAMPLING SITE A

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC SUSPENDED TOTAL (UG/L AS AS)	ARSENIC DISSOLVED (UG/L AS AS)	CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	CADMIUM DISSOLVED (UG/L AS CD)	MIUM, TOTAL RECOVERABLE (UG/L AS CR)	MIUM, SUSPENDED RECOV. (UG/L AS CR)	CHROMIUM, DISSOLVED (UG/L AS CR)	COPPER, TOTAL RECOVERABLE (UG/L AS CU)
MAY										
31...	1030	3	3	<1	ND	ND	<20	10	ND	15
31...	1115	1	1	<1	ND	ND	5	0	5	7
JUNE										
28...	1110	2	1	1	ND	ND	ND	0	ND	11
AUG										
24...	1330	3	1	2	ND	ND	<20	0	<20	31
24...	1340	2	1	1	ND	ND	<20	10	ND	6
SEPT										
28...	1215	2	1	1	ND	ND	ND	0	ND	6
28...	1230	2	1	1	ND	ND	ND	0	ND	4
OCT										
26...	0950	2	1	1	ND	ND	ND	0	ND	7

DATE	COPPER, DISSOLVED (UG/L AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	IRON, SUSPENDED RECOVERABLE (UG/L AS FE)	IRON, DISSOLVED (UG/L AS FE)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	LEAD, DISSOLVED (UG/L AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MANGANESE, SUSPENDED RECOV. (UG/L AS MN)	MANGANESE,. DISSOLVED (UG/L AS MN)
MAY									
31...	ND	9400	9400	20	ND	ND	630	590	40
31...	ND	3500	3400	110	ND	ND	70	60	<10
JUNE									
28...	ND	3600	3600	40	<200	ND	110	110	2
AUG									
24...	40	6500	6100	440	ND	ND	370	280	90
24...	ND	3600	3500	130	ND	ND	160	140	20
SEPT									
28...	ND	4700	4600	70	6	ND	300	300	<10
28...	ND	2900	2800	20	3	ND	120	120	<10
OCT									
26...	ND	4700	4600	70	5	ND	400	400	<10
26...	<20	3300	3200	90	6	<10	190	150	40

DATE	MERCURY TOTAL RECOVERABLE (UG/L AS HG)	MERCURY SUSPENDED RECOVERABLE (UG/L AS HG)	MERCURY DISSOLVED (UG/L AS HG)	SELENIUM, TOTAL (UG/L AS SE)	SELENIUM, SUSPENDED TOTAL (UG/L AS SE)	SELENIUM, DISSOLVED (UG/L AS SE)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	ZINC, SUSPENDED RECOVERABLE (UG/L AS ZN)	ZINC, DISSOLVED (UG/L AS ZN)
MAY									
31...	<0.1	0.1	<0.1	<1	0	<1	30	20	<20
31...	<.1	.0	<.1	<1	0	<1	20	20	ND
JUNE									
28...	.6	.6	<.1	<1	0	<1	20	20	<3
AUG									
24...	<.1	.0	<.1	<1	0	<1	30	10	20
24...	<.1	.0	<.1	<1	0	<1	<20	0	<20
SEPT									
28...	.2	.2	<.1	<1	0	<1	20	20	ND
28...	<.1	.0	<.1	<1	0	<1	<20	10	ND
OCT									
26...	.3	.3	<.1	<1	0	<1	20	20	ND
26...	.3	.3	<.1	<1	0	1	<20	7	<3

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

SAMPLING SITE B

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC SUS-PENDED TOTAL (UG/L AS AS)	ARSENIC DIS-SOLVED (UG/L AS AS)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, SUS-PENDED RECOV. (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)
MAY										
24...	1730	2	1	1	ND	ND	<20	10	ND	11
24...	1830	--	--	<1	ND	ND	<20	0	<20	7
JUNE										
28...	1355	3	2	1	ND	ND	<20	10	ND	13
AUG										
24...	1300	3	2	1	ND	ND	ND	0	ND	6
24...	1315	2	1	1	ND	ND	ND	0	ND	7
SEPT										
28...	1245	2	1	1	ND	ND	<20	10	ND	6
28...	1300	2	1	1	<2	ND	<20	10	ND	4
OCT										
26...	1300	4	3	1	ND	<2	ND	0	ND	8
26...	1330	2	1	1	ND	<2	ND	0	ND	3

DATE	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
MAY									
24...	ND	6300	6100	180	ND	ND	140	100	40
24...	ND	5000	4500	480	ND	ND	110	90	20
JUNE									
28...	ND	3400	3300	70	<200	ND	70	70	1
AUG									
24...	ND	2800	2600	170	ND	ND	90	80	<10
24...	ND	3100	3000	140	ND	ND	100	60	40
SEPT									
28...	ND	3700	3600	50	6	ND	200	180	20
28...	ND	2600	2600	50	6	ND	80	80	<10
OCT									
26...	<20	9500	9300	190	9	<10	1000	950	50
26...	<20	2400	2300	140	4	<10	140	120	20

DATE	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG)	MERCURY SUS-PENDED RECOV-ERABLE (UG/L AS HG)	MERCURY DIS-SOLVED (UG/L AS HG)	SELE-NIUM, TOTAL (UG/L AS SE)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)
MAY									
24...	0.7	0.5	0.2	<1	0	<1	30	20	<20
24...	--	--	<.1	--	--	<1	30	30	ND
JUNE									
28...	1.1	1.0	<.1	<1	0	<1	20	20	5
AUG									
24...	<.1	.0	<.1	<1	0	<1	<20	10	ND
24...	.4	.4	<.1	<1	0	<1	<20	0	<20
SEPT									
28...	.2	.2	<.1	<1	0	<1	40	40	ND
28...	<.1	.0	<.1	<1	0	<1	50	50	ND
OCT									
26...	.8	.8	<.1	<1	0	<1	30	27	<3
26...	<.1	.0	<.1	<1	0	<1	<20	7	<3

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

SAMPLING SITE C

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC SUS-PENDED TOTAL (UG/L AS AS)	ARSENIC DIS-SOLVED (UG/L AS AS)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, SUS-PENDED RECOV. (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)
MAY										
25...	1100	1	1	<1	<2	ND	5	5	ND	7
25...	1130	1	1	<1	ND	ND	<20	10	ND	6
SEPT										
28...	1100	8	8	<1	<2	ND	30	30	ND	23
28...	1135	2	1	1	<2	ND	ND	0	ND	4

DATE	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
MAY									
25...	ND	3900	3800	110	ND	ND	120	110	<10
25...	ND	3600	3500	80	ND	ND	100	100	5
SEPT									
28...	ND	34000	34000	60	30	ND	4300	3700	600
28...	ND	2800	2600	170	5	ND	120	120	<10

DATE	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG)	MERCURY SUS-PENDED RECOV-ERABLE (UG/L AS HG)	MERCURY DIS-SOLVED (UG/L AS HG)	SELE-NIUM, TOTAL (UG/L AS SE)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)
MAY									
25...	<0.1	0.1	<0.1	<1	0	<1	20	0	20
25...	.2	.2	<.1	<1	0	<1	20	20	5
SEPT									
28...	1.1	1.1	<.1	<1	0	<1	100	100	ND
28...	<.1	.0	<.1	<1	0	<1	20	20	ND

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

SAMPLING SITE D

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC SUS-PENDED TOTAL (UG/L AS AS)	ARSENIC DIS-SOLVED (UG/L AS AS)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, SUS-PENDED RECOV. (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)
MAY										
25...	1745	1	<1	1	<2	ND	<20	10	ND	7
25...	1750	1	<1	1	ND	ND	ND	0	ND	9
JUNE										
29...	1700	2	1	1	<2	ND	<20	0	<20	<20
AUG										
24...	--	2	1	1	<2	<20	ND	0	ND	8
SEPT										
28...	0930	2	2	<1	3	<20	<20	10	ND	4
OCT										
26...	1415	2	<1	9	ND	ND	ND	0	ND	5

DATE	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
MAY									
25...	ND	4200	4000	160	ND	ND	130	110	20
25...	ND	3500	3400	100	ND	ND	100	90	<10
JUNE									
29...	ND	2900	2900	50	<200	ND	100	100	3
AUG									
24...	ND	4600	4500	140	ND	ND	230	210	20
SEPT									
28...	ND	2800	2800	20	46	<200	140	130	<10
OCT									
26...	ND	4700	4600	110	4	ND	360	120	240

DATE	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG)	MERCURY SUS-PENDED RECOV-ERABLE (UG/L AS HG)	MERCURY DIS-SOLVED (UG/L AS HG)	SELE-NIUM, TOTAL (UG/L AS SE)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)
MAY									
25...	0.5	0.5	<0.1	<1	0	<1	20	10	<20
25...	<.1	.1	<.1	<1	0	<1	20	20	5
JUNE									
29...	1.5	1.5	<.1	<1	0	<1	<20	7	<3
AUG									
24...	<.1	.1	<.1	<1	0	<1	20	10	<20
SEPT									
28...	<.1	.0	<.1	<1	0	<1	20	20	ND
OCT									
26...	<.1	.0	<.1	<1	0	<1	20	10	<20

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

SAMPLING SITE E

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC SUS- PENDED TOTAL (UG/L AS AS)	ARSENIC DIS- SOLVED (UG/L AS AS)	CADMIUM TOTAL RECOV- ERABLE (UG/L AS CD)	CADMIUM DIS- SOLVED (UG/L AS CD)	CHRO- MIUM, TOTAL RECOV- ERABLE (UG/L AS CR)	CHRO- MIUM, SUS- PENDED RECOV. (UG/L AS CR)	CHRO- MIUM, DIS- SOLVED (UG/L AS CR)	COPPER, TOTAL RECOV- ERABLE (UG/L AS CU)
MAR										
30...	1000	2	2	<1	ND	ND	ND	0	ND	15
MAY										
25...	1310	1	1	<1	<2	ND	ND	0	ND	11
25...	1325	1	1	<1	3	ND	<20	10	ND	7
JUNE										
27...	1430	2	1	1	ND	ND	<20	10	ND	8
AUG										
24...	1430	2	<1	3	ND	<20	ND	0	ND	6
SEPT										
28...	1005	2	2	<1	<2	ND	<20	10	ND	7
OCT										
26...	1445	2	1	1	ND	ND	<20	10	ND	<20

DATE	COPPER, DIS- SOLVED (UG/L AS CU)	IRON, TOTAL RECOV- ERABLE (UG/L AS FE)	IRON, SUS- PENDED RECOV- ERABLE (UG/L AS FE)	IRON, DIS- SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV- ERABLE (UG/L AS PB)	LEAD, DIS- SOLVED (UG/L AS PB)	MANGA- NESE, TOTAL RECOV- ERABLE (UG/L AS MN)	MANGA- NESE, SUS- PENDED RECOV. (UG/L AS MN)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)
MAR									
30...	ND	1400	1200	170	ND	ND	150	50	100
MAY									
25...	ND	3300	3200	90	ND	ND	210	140	70
25...	ND	3100	3000	60	ND	ND	100	90	<10
JUNE									
27...	ND	3700	3700	30	<200	ND	140	120	20
AUG									
24...	60	4400	4000	410	ND	ND	250	140	110
SEPT									
28...	ND	3800	3700	130	16	ND	210	170	40
OCT									
26...	5	4100	3900	230	3	4	270	180	90

DATE	MERCURY TOTAL RECOV- ERABLE (UG/L AS HG)	MERCURY SUS- PENDED RECOV- ERABLE (UG/L AS HG)	MERCURY DIS- SOLVED (UG/L AS HG)	SELE- NIUM, TOTAL (UG/L AS SE)	SELE- NIUM, SUS- PENDED TOTAL (UG/L AS SE)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	ZINC, TOTAL RECOV- ERABLE (UG/L AS ZN)	ZINC, SUS- PENDED RECOV- ERABLE (UG/L AS ZN)	ZINC, DIS- SOLVED (UG/L AS ZN)
MAR									
30...	0.6	0.6	<0.1	<1	0	<1	20	0	20
MAY									
25...	.5	.5	<.1	<1	0	<1	20	20	ND
25...	<.1	.1	<.1	<1	0	<1	20	20	ND
JUNE									
27...	1.2	1.2	<.1	<1	0	<1	<20	7	<3
AUG									
24...	.3	.3	<.1	<1	0	<1	20	10	<20
SEPT									
28...	<.1	.0	<.1	<1	0	<1	20	20	ND
OCT									
26...	<.1	.0	<.1	<1	0	<1	20	20	ND

Table 9.--Concentrations of trace elements in water from sampling sites, A-G--Continued

SAMPLING SITE F

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DIS-SOLVED (UG/L AS AS)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)
MAR										
07...	1530	--	<1	--	<2	--	ND	--	7	--
APR										
04...	1550	2	2	<2	<2	ND	ND	2	ND	950
MAY										
03...	1630	<1	<1	2	ND	<20	<20	7	ND	1500
JUNE										
20...	1700	1	2	2	2	ND	ND	8	3	700

DATE	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG)	MERCURY DIS-SOLVED (UG/L AS HG)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)
MAR									
07...	240	--	<2	--	20	--	<0.1	--	40
APR									
04...	20	9	19	100	80	<0.1	<.1	<20	ND
MAY									
03...	80	25	10	80	20	<.1	<.1	150	ND
JUNE									
20...	250	14	4	70	40	<.1	<.1	20	<20

Table 9.--Concentrations of trace elements in water from sampling sites A-G--Continued

SAMPLING SITE G

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DISSOLVED (UG/L AS AS)	CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR)	CHROMIUM, DISSOLVED (UG/L AS CR)	COPPER, TOTAL RECOVERABLE (UG/L AS CU)	COPPER, DISSOLVED (UG/L AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)
MAR 07...	1445	--	<1	--	<2	--	ND	--	2	--
APR 05...	0920	2	2	<2	ND	ND	ND	<2	ND	680
MAY 03...	1400	<1	<1	ND	ND	100	ND	6	ND	650
JUNE 21...	0830	<1	<1	3	2	ND	ND	6	4	460

DATE	IRON, DISSOLVED (UG/L AS FE)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	LEAD, DISSOLVED (UG/L AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MANGANESE, DISSOLVED (UG/L AS MN)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)	MERCURY DISSOLVED (UG/L AS HG)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	ZINC, DISSOLVED (UG/L AS ZN)
MAR 07...	90	--	<2	--	20	--	<0.1	--	<20
APR 05...	40	4	2	20	<10	<0.1	<.1	<20	<20
MAY 03...	100	12	6	20	20	<.1	<.1	20	ND
JUNE 21...	90	11	3	80	80	<.1	<.1	ND	<20

The national primary drinking-water standard for cadmium is 10 µg/L (table 2). Criteria for aquatic life range from 0.4 to 12.0 µg/L (table 5). Concentrations of dissolved cadmium equaled the national primary drinking-water standards at least once in water from sampling site E (table 9).

Chromium.--Chromium commonly is associated with industrial wastes; it also is a common element in the environment. Large concentrations of chromium are toxic to humans and animals. Although chromium can be detected in most biological systems, it has not been shown to be essential. Water samples collected from 130 sampling points in the United States have shown concentrations of 1 to 112 µg/L with a mean concentration of 9.7 µg/L for chromium (Kopp, 1969).

The national primary drinking-water standard for chromium is 50 µg/L (table 2). Criteria for fish, and stock and wildlife watering have been set at 1,000 and 5,000 µg/L, respectively (McKee and Wolf, 1963) (table 5). All dissolved-chromium concentrations were less than the national primary drinking-water standard (table 9).

Copper.--Copper, although widely distributed in the environment, occurs only in trace concentrations in natural waters because of solubility controls. Copper is essential in the nutrition of plants and animals but is toxic to some algae. Mining and industrial activities sometimes contaminate water with copper. Copper is esthetically significant in public water supplies because it can cause taste and discoloration problems (Rubin, 1976). Water samples collected from 130 sampling points in the United States have shown concentrations of 1 to 280 µg/L with a mean concentration of 15 µg/L (Kopp, 1969).

The national secondary drinking-water standard for dissolved copper is 1,000 µg/L (table 3). Dissolved-copper concentrations were much less than the secondary drinking-water standard. The recommended criteria for fresh-water aquatic life is 20 µg/L (McKee and Wolf, 1963) (table 5). Many of the dissolved copper concentrations exceeded the criteria for fresh-water aquatic life. Water from Site E had the greatest dissolved-copper concentation with a maximum of 60 µg/L (table 9).

Iron.--Iron is an abundant and important element unsurpassed by any other heavy metal in the Earth's crust (Cole, 1975). It is essential to photosynthesizing plants; it is the metal part of some plant cytochromes that function in the transfer of electrons during photosynthesis. It also is a vital element in the respiratory pigments of many animal species and affects many chemical reactions in water. Excessive concentrations may be toxic. Large concentrations of dissolved iron will not be present in natural waters with near-neutral pH. Large concentrations, if they occur, will be found in the suspended phase. Iron is esthetically significant in public water supplies because it can cause taste and discoloration problems (Rubin, 1976).

The national secondary drinking-water standard for dissolved iron is 300 µg/L (table 3). This limit of 300 µg/L for iron was exceeded in numerous samples collected during the study. Large concentrations of total recoverable and dissolved iron were found in samples from all sites (table 9). The largest concentrations were for samples collected near the reservoir bottom.

Lead.--Lead is found in small concentrations in streams due to its minimal solubility. Large concentrations of lead are toxic to humans. Water samples collected from 130 sampling points in the United States have showed detectable concentrations of 0.002 to 0.140 mg/L with a mean concentration of 0.023 mg/L (Kopp, 1969).

The national primary drinking-water standard for dissolved lead is 50 µg/L (table 2). Fish can be affected adversely by water with a lead concentration of 30 µg/L or more (McKee and Wolf, 1963). The dissolved-lead concentrations in water from the study area were much less than the drinking-water standard (table 9). Total recoverable-lead concentrations commonly were equal to but never exceeded 100 µg/L.

Manganese.--Manganese concentrations in natural water generally are large in comparison to most trace elements other than iron. Manganese is a necessary nutrient for both plants and animals; manganese stimulates plankton growth. Excessive concentrations may be toxic to humans (Rubin, 1976).

The national secondary drinking-water standard of 50 µg/L for dissolved manganese (table 3) was established to prevent brownish staining of laundry and objectionable taste to certain beverages. Dissolved-manganese concentrations in water from the study area commonly exceeded the secondary drinking-water standard. However, only one of four water samples from Blue Creek had dissolved-manganese concentrations that exceeded the secondary drinking-water standard (table 9). Total recoverable-manganese concentrations exceeded the 500-µg/L criteria reported to be toxic to certain plants (McKee and Wolf, 1963) (table 5). Samples that had the largest concentrations of total recoverable manganese were collected near the reservoir bottom.

Mercury.--The natural concentration of mercury in most surface waters is thought to be less than 0.5 µg/L (Wershaw, 1970). Larger concentrations of mercury in natural water can result from mining, metallurgical, or other industrial wastes. In addition to the more commonly known sources of man's mercury contributions, the burning of fossil fuels has been reported as a source of mercury pollution (Bertine and Goldberg, 1971, Joensuu, 1971). Mercury and mercuric salts are toxic to human, fish, and plant life (table 5).

Because of dissolved-mercury's toxicity, a national primary drinking-water standard of 2 µg/L was established (table 2). All dissolved-mercury concentrations were less than the drinking-water standard (table 9). The largest total recoverable-mercury concentration was detected in a sample from Site E.

Selenium.--Selenium in the elemental form is almost insoluble, but in an oxidized form, it can occur in appreciable concentrations in water. Selenium is toxic to humans, animals, and plants (table 5).

The national primary drinking-water standard for dissolved selenium is 10 µg/L (table 2). Criteria for livestock and irrigation waters are 50 and 20 µg/L, respectively, (National Academy of Sciences and National Academy of Engineering, 1972). None of the selenium concentrations determined exceeded either the established standard or criteria. The largest measured concentration for either dissolved or total recoverable selenium was 1 µg/L (table 9).

Zinc.--Zinc has many industrial uses and is common in ores. Zinc has no known adverse physiological effects on humans except in very large concentrations (McKee and Wolf, 1963). Water samples collected from 130 sampling points in the United States have shown concentrations of 2 to 1,183 µg/L and a mean concentration of 64 µg/L (Kopp, 1969).

For considerations of taste, national secondary drinking-water regulations set an upper limit of 5,000 µg/L for dissolved zinc (table 3). The criterion for livestock water is 25,000 µg/L (McKee and Wolf, 1963). Dissolved zinc concentrations were considerably less than either the drinking-water standard or the livestock criterion. The largest zinc concentration was a total recoverable-zinc concentration of 100 µg/L determined in water from site C (table 9).

Biota

Phytoplankton

Phytoplankton are primary producers in the aquatic food chain. Planktonic variability in lakes is determined by the physical, chemical, and biological characteristics of the individual lake. Some information about the degree of lake enrichment can be determined by the phytoplankton members present.

In a study done by W. D. Williams (Cole, 1975) some generalities were cited. The phytoplankton of oligotrophic waters (those that contain few nutrients) includes the desmid *Staurastrum*, the chrysophyte *Dinobryon*, noted for its tolerance of only small phosphate concentrations, and the diatoms *Tabellaria* and *Cyclotella*. The eutrophic lake (enriched in nutrients) has a different group of diatoms and a mixed group of blue-green algae that may eventually replace the diatoms. As the lake becomes eutrophic, the filamentous diatoms *Melosira* and *Stephanodiscus* appear first. If there is agricultural runoff or erosion from clear cutting, *Asterionella* may appear. Later, if sewage enters the lake, *Fragillaria* may appear.

Hern and others (1979) in a study of some Oklahoma lakes found that whereas desmids and many pennate diatoms are found in oligotrophic waters because they generally cannot tolerate large nutrient concentrations, *Cyanophyta*, *Euglenophyta*, centric diatoms, and members of the *Chlorococcales* generally are associated with eutrophic waters.

Generally, during the study, the greatest number of phytoplankton cells were found in the surface samples (table 10) where the light penetration was the greatest. The diatoms and blue-green algae were the dominate organisms. The temporal distribution of the major classes of algae to the total phytoplankton counts at sampling sites A-E are shown in figures 8-12.

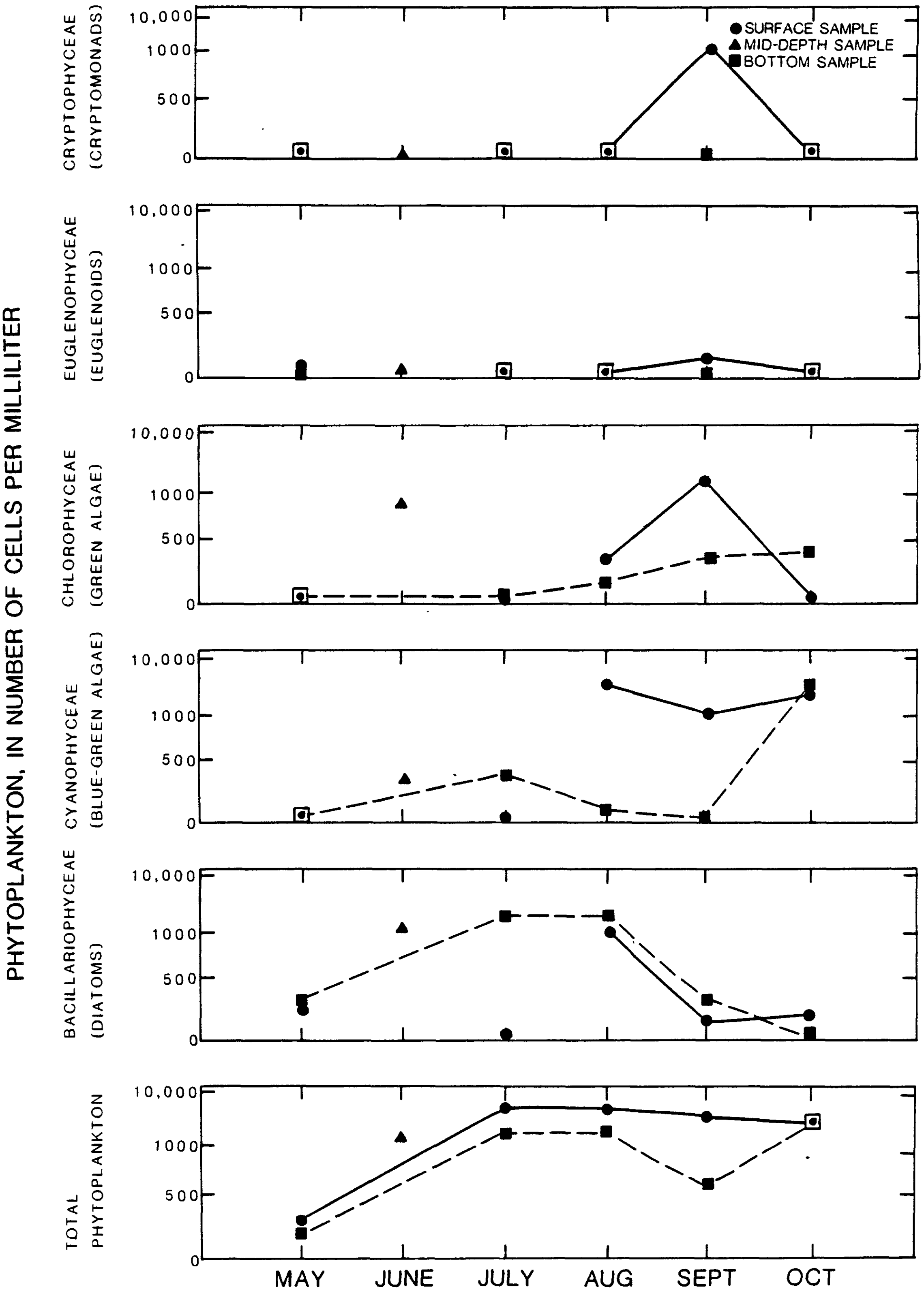

Figure 8.--Numbers of phytoplankton cells comprising the major classes of algae at sampling Site A.

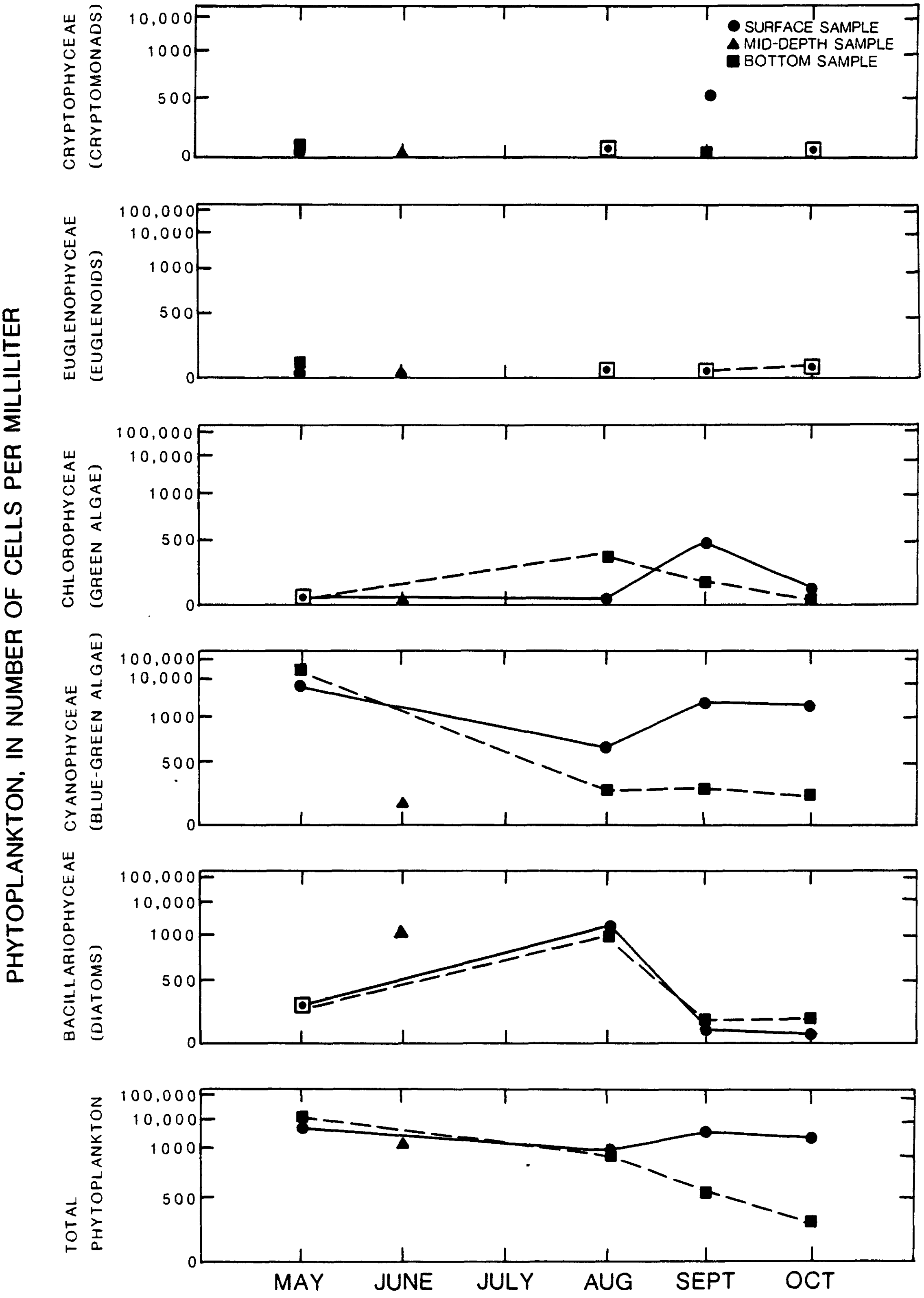

Figure 9.--Numbers of phytoplankton cells comprising the major classes of algae at sampling Site B.

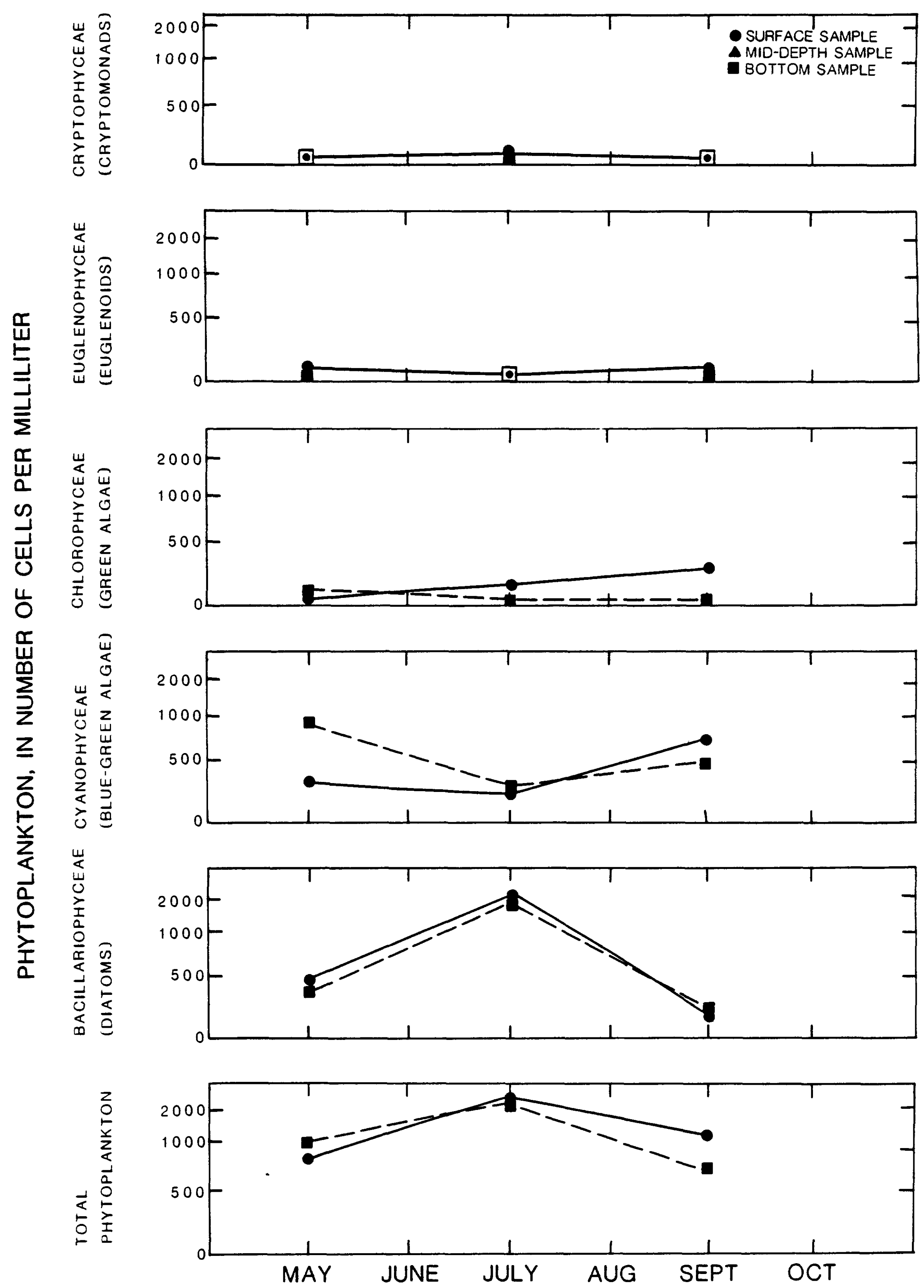

Figure 10.--Numbers of phytoplankton cells comprising the major classes of algae at sampling Site C.

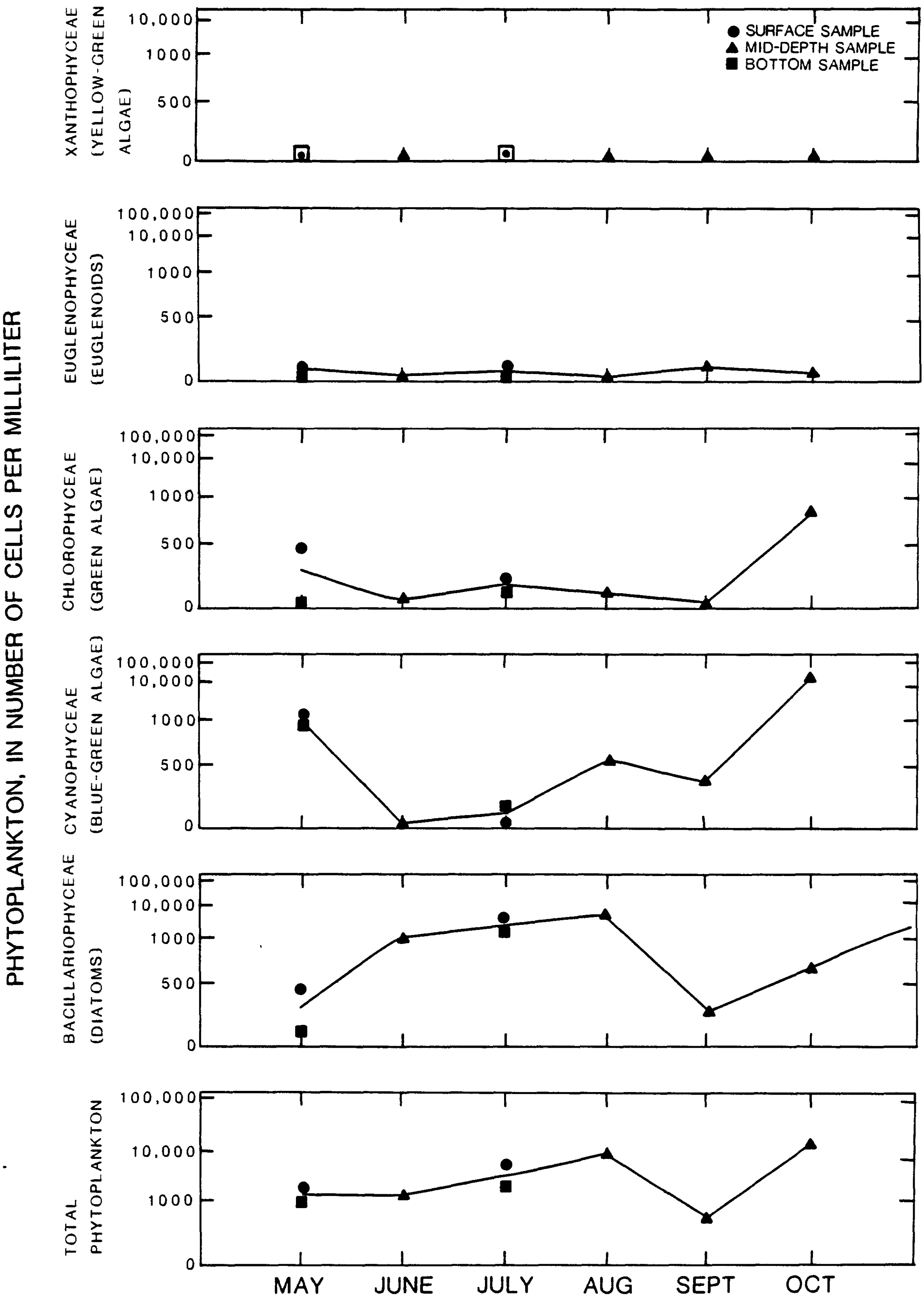

Figure 11.--Numbers of phytoplankton cells comprising the major classes of algae at sampling Site D.

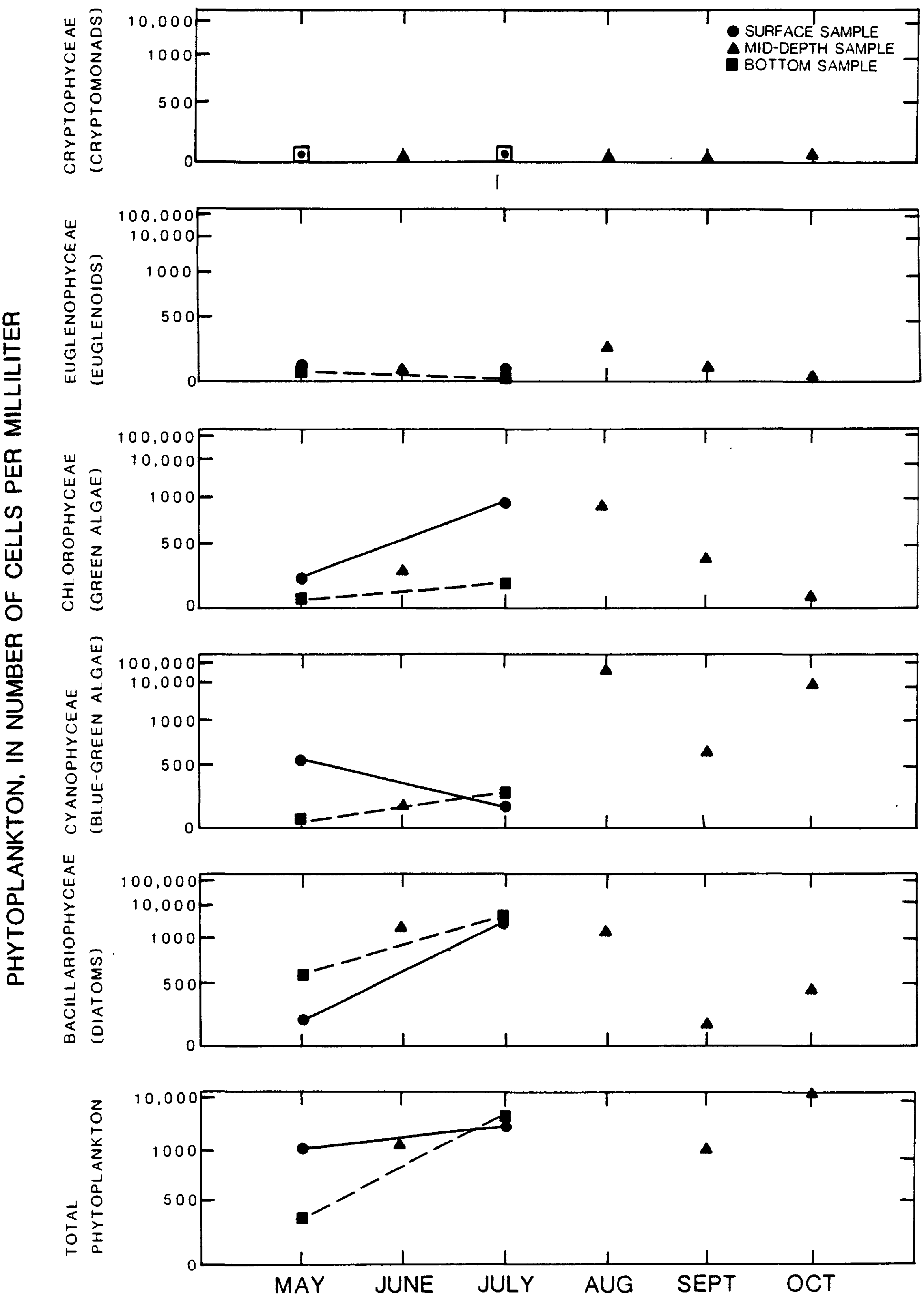

Figure 12.--Numbers of phytoplankton cells comprising the major classes of algae at sampling Site E.

Diversity of phytoplankton has been determined in a number of ways because of the observed species changes as a lake becomes enriched. Among the best indices of species are those that are largely independent of sample size (Wetzel, 1975). As defined in the Water Resources Data for Oklahoma Water Year 1983, "...diversity index is the numerical expression of evenness of distribution of aquatic organisms. The formula for diversity index is:

$$\bar{d} = - \sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

There n_i is the number of individuals per taxon, n is the total number of individuals, and s is the total number of taxa in the sample of the community. Diversity index values range from zero, when all the organisms in the sample are the same, to some positive number, when some or all of the organisms in the samples are different" (table 10). Predominance of one or two species results in small diversity values, large values occur when there are populations of several species. There is a general tendency for species diversity to decrease with increasing enrichment of the water. Presumably, the slower growth rates attainable in oligotrophic lakes permit a greater number of species with reasonably similar requirements to coexist within the temporal variations of regulating parameters than would be found in more enriched waters (Wetzel, 1975).

The significance of phytoplankton genera present at sampling sites A-E during this investigation are listed in table 11. Although several of the genera are widely distributed, many are indicative of specific conditions. Generally, the genera indicate that the water at sites A-E may be classified as: (1) Soft and acidic with little mineral content and conductivity; (2) calm or very slowly moving; and (3) warm and enriched with organic matter.

Another means of categorizing lakes on the basis of phytoplankton has been suggested by P.E. Greeson (U.S. Geological Survey, written commun., 1978) on the basis of phytoplankton data collected by the U.S. Geological Survey during the 1974 to 1976 water years (fig. 13). Phytoplankton present in Lake Eufaula indicate that lake tends to be acidic, has significant organic and nutrient contents, and has little conductivity and dissolved solids. Phytoplankton indicative of both soft and hard water were present; both mesotrophic- and eutrophic-indicating plankton were present (tables 11 and 12).

Benthic Invertebrates

Aquatic bottom-dwelling organisms, the benthos, include sessile or attached animals and algae, and creeping and burrowing forms. Benthic invertebrates, a component of the benthos, can be found on natural substrates such as rocks and plants or on the bottom sediments of a lake. The number and type of organisms is dependent on the physical and chemical conditions in the lake environment. Data in this report are presented with no attempt to quantify them. Sampling was random and designed only to give an indication of organisms present.

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E

[S, sampled at 3 feet below surface; M, sampled at mid-point of depth interval; B, sampled 1.5 feet above bottom]

MAY 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	290	--	230	8900	--	1800	860	--	1400	3500	--	1100	1300	--	310
Diatoms	250	--	220	390	--	250	480	--	370	440	--	120	540	--	190
Green algae	51	--	15	0	--	230	44	--	93	440	--	23	210	--	44
Blue-green algae	0	--	0	8500	--	1700	290	--	900	2300	--	970	510	--	29
Euglenoids	29	--	0	0	--	93	44	--	0	93	--	510	88	--	29
Crytomonads	0	--	0	0	--	0	0	--	0	0	--	0	0	--	0
Fire algae	0	--	0	0	--	0	0	--	0	0	--	0	0	--	0
Yellow-green or brown algae	0	--	0	23	--	23	0	--	0	230	--	0	0	--	15
Number of genera	5	--	3	6	--	12	7	--	7	16	--	6	11	--	11
Diversity index	1.1	--	0.7	0.4	--	0.5	1.6	--	1.7	2.8	--	0.8	2.7	--	3.0

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E--Continued

JUNE 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	--	3000	--	--	1300	--	--	--	--	--	1800	--	--	2200	--
Diatoms	--	1700	--	--	1200	--	--	--	--	--	1600	--	--	1700	--
Green algae	--	910	--	--	0	--	--	--	--	--	150	--	--	270	--
Blue-green algae	--	310	--	--	110	--	--	--	--	--	54	--	--	130	--
Euglenoids	--	54	--	--	7	--	--	--	--	--	22	--	--	4	--
Crytomonads	--	0	--	--	0	--	--	--	--	--	0	--	--	4	--
Fire algae	--	0	--	--	0	--	--	--	--	--	0	--	--	0	--
Number of genera	--	15	--	--	4	--	--	--	--	--	11	--	--	13	--
Diversity index	--	2.4	--	--	0.5	--	--	--	--	--	0.9	--	--	1.5	--

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E--Continued

JULY 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	7500	--	3600	--	--	--	2400	--	2200	8000	--	4200	5100	--	5500
Diatoms	--	--	3200	--	--	--	2000	--	1900	7700	--	3400	4000	--	5000
Green algae	--	--	41	--	--	--	140	--	9	170	--	350	950	--	190
Blue-green algae	--	--	390	--	--	--	210	--	210	0	--	450	170	--	250
Euglenoids	--	--	0	--	--	--	0	--	0	70	--	0	17	--	0
Crytomonads	--	--	0	--	--	--	8	--	0	0	--	0	0	--	0
Fire algae	--	--	0	--	--	--	0	--	0	0	--	0	0	--	0
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Number of genera	--	--	7	--	--	--	9	--	6	5	--	5	11	--	5
Diversity index	--	--	0.8	--	--	--	1.0	--	0.6	0.5	--	1.1	1.3	--	0.6

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E--Continued

AUGUST 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	7100	--	3700	2400	--	1900	--	--	--	--	10000	--	--	36000	--
Diatoms	1400	--	3400	1700	--	1300	--	--	--	--	9300	--	--	1500	--
Green algae	330	--	140	26	--	380	--	--	--	--	93	--	--	910	--
Blue-green algae	5400	--	90	670	--	260	--	--	--	--	560	--	--	33000	--
Euglenoids	14	--	0	0	--	0	--	--	--	--	0	--	--	240	--
Crytomonads	0	--	0	0	--	0	--	--	--	--	0	--	--	0	--
Fire algae	0	--	0	5	--	0	--	--	--	--	0	--	--	0	--
Number of genera	12	--	6	7	--	0	--	--	--	--	6	--	--	16	--
Diversity index	2.0	--	0.7	1.2	--	1.7	--	--	--	--	0.6	--	--	1.0	--

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E--Continued

SEPTEMBER 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	6300	--	670	5200	--	540	1200	--	720	--	710	--	--	1200	--
Diatoms	130	--	310	79	--	130	190	--	200	--	260	--	--	140	--
Green algae	1300	--	360	460	--	140	250	--	27	--	28	--	--	350	--
Blue-green algae	3000	--	0	3500	--	270	690	--	490	--	330	--	--	610	--
Euglenoids	160	--	0	0	--	0	30	--	0	--	92	--	--	98	--
Crytomonads	1600	--	0	580	--	0	0	--	0	--	0	--	--	0	--
Fire algae	0	--	0	0	--	0	0	--	0	--	0	--	--	0	--
Number of genera	12	--	6	9	--	4	13	--	7	--	8	--	--	8	--
Diversity index	2.5	--	1.9	1.8	--	2.0	2.5	--	2.2	--	2.1	--	--	1.9	--

Table 10.--Phytoplankton counts, number of genera, and diversity index at sampling sites A-E--Continued

OCTOBER 1978

Phytoplankton	Cells per milliliter of water														
	Sampling site A			Sampling site B			Sampling site C			Sampling site D			Sampling site E		
	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
Total	4500	--	4500	3200	--	290	--	--	--	--	28000	--	--	11000	--
Diatoms	210	--	220	170	--	29	--	--	--	--	710	--	--	420	--
Green algae	0	--	420	86	--	14	--	--	--	--	820	--	--	69	--
Blue-green algae	4300	--	3800	3000	--	230	--	--	--	--	27000	--	--	10000	--
Euglenoids	0	--	0	14	--	14	--	--	--	--	67	--	--	14	--
Crytomonads	0	--	0	0	--	0	--	--	--	--	0	--	--	28	--
Fire algae	0	--	0	0	--	0	--	--	--	--	0	--	--	0	--
Number of genera	6	--	9	6	--	4	--	--	--	--	11	--	--	12	--
Diversity index	1.5	--	1.4	0.8	--	1.0	--	--	--	--	0.9	--	--	1.4	--

Table 11.--Significance of phytoplankton genera present at sampling sites A-E

Genus	Group	Significance
Actinastrum	Green	Widely distributed
Ankistrodesmus	Green	Widely distributed; commonly occurring *A. falcatus* generally found in acid waters of high temperature where there is a dense conglomeration of other algae
Chlamydomonas	Green	Widespread distribution; generally found in calm or very slowly moving waters
Coelastrum	Green	Widely distributed in slowly moving waters; an insignificant component indicating eutrophic conditions
Crucigenia	Green	Widely distributed
Dictyosphaerium	Green	Widely distributed; generally indicative of soft to moderately hard water
Eudorina	Green	Generally indicative of soft water
Kirchneriella	Green	Somewhat uncommon in occurrence; generally indicative of acidic conditions
Oocystis	Green	Generally indicative of soft water or oligotrophic waters; some species can be indicative of the presence of organic acids.
Pandorina	Green	Rarely found in abundance; generally indicative of hard water
Pediastrum	Green	Widely distributed; found in all types of water; some species indicative of particular environmental conditions
Scenedesmus	Green	Widely distributed; found in all types of water; commonly occurring *S. quadricauda* is one of the most nearly ubiquitous algal species
Tetraedon	Green	Widely distributed

Table 11.--Significance of phytoplankton genera present at sampling sites A-E--Continued

Genus	Group	Significance
Tetrastrum	Green	Somewhat uncommon in occurrence
Cyclotella	Centric diatom	Widely distributed
Melosira	Centric diatom	Widely distributed; most commonly found centric diatom; one of the most ubiquitous of the algal genera; some species indicative of particular environmental conditions
Stephanodiscus	Centric diatom	Widely distributed; an insignificant component of algae indicating eutrophic conditions
Achnanthes	Pennate diatom	Widely distributed; freshwater species generally are epiphytic
Cymbella	Pennate diatom	Widely distributed; a distinctly freshwater genus
Gomphonema	Pennate diatom	Widely distributed; freshwater species generally are epiphytic
Navicula	Pennate diatom	Widespread distribution; found in all types of water; some species indicative of particular environmental conditions
Nitzchia	Pennate diatom	Widespread distribution; found in all types of water; some species indicative of particular environmental conditions
Pinnularia	Pennate diatom	Widely distributed; generally indicative of calm or slowly moving, slightly acidic water having little mineral content
Rhoicosphenia	Pennate diatom	Widespread distribution; the single species, R. curvata, commonly found in flowing alkaline waters with little conductivity; generally intolerant of saline conditions

Table 11.--Significance of phytoplankton genera present at sampling sites A-E--Continued

Genus	Group	Significance
Synedra	Pennate diatom	Widely distributed; found in all types of water; common species generally prefer circumneutral water of moderate to large conductivity including brackish water; generally indicative of mesotrophic to eutrophic conditions
Dinobryon	Golden-brown	Widely distributed; generally indicative of hard water
Agmenellum	Blue-green	Widely distributed; generally indicative of soft water and acidic conditions
Anacystis (Microcystis)	Blue-green	Very common in hard water or eutrophic waters during high temperature conditions; a common component of algae blooms; notorious as a spoiler of water for domestic uses, swimming and recreation; usually causes death of fish when present in large masses; indicative of hard water with large nutrient content when occurring in large numbers with Anabaena or Aphanizomenon
Oscillatoria	Blue-green	Widely distributed; found in all types of water; one of the most ubiquitous of the algae genera
Euglena	Euglenoid	Very indicative of waters enriched in organic matter (for example downstream from domestic sewage outfalls); can occur in such abundance as to color the water a deep green
Trachelomonas	Euglenoid	Very indicative of warm waters having a large content of organic matter; can occur in such abundance as to color the water brown

Table 12.--Phytoplankton and bacteria concentrations at sampling sites A-F

[CELLS PER ML, cells per milliliter; COLS/PER 100 ML, colonies per 100 milliliters of water; K, nonideal-colony count]

SAMPLING SITE A

DATE	TIME	SAMPLING DEPTH (FEET)	PHYTOPLANKTON, TOTAL (CELLS PER ML)	COLIFORM, FECAL, (COLS./ 100 ML)	STREPTOCOCCI, FECAL (COLS. PER 100 ML)
MAY					
31...	1030	29.0	230	K60	K168
31...	1115	3.00	290	K34	K27
JUNE					
28...	1110	13.0	3000	--	--
30...	0625	22.5	--	K200	K22
AUG					
02...	1930	24.0	3600	<1	K74
02...	1935	1.50	7500	K8	160
24...	1330	31.0	3700	K1200	K48
24...	1340	3.00	7100	K3	K4
SEPT					
28...	1215	42.0	670	K4	K35
28...	1230	3.00	6300	K3	K28
OCT					
26...	0950	17.0	4500	K5	K4
26...	1040	3.00	4500	K3	K8

SAMPLING SITE B

DATE	TIME	SAMPLING DEPTH (FEET)	PHYTOPLANKTON, TOTAL (CELLS PER ML)	COLIFORM FECAL (COLS./ 100 ML)	STREPTOCOCCI, FECAL (COLS. (PER 100 ML)
MAY					
24...	1730	19.0	18000	840	707
24...	1830	3.00	8900	412	2150
JUNE					
28...	1355	11.0	1300	--	--
30...	0640	11.0	--	12	27
AUG					
02...	1015	14.0	--	K16	253
02...	1020	1.50	--	<1	96
24...	1300	3.00	2400	>1200	125
24...	1315	18.0	1900	>1200	58
SEPT					
28...	1245	16.0	540	K2	K24
28...	1300	3.00	5200	K12	K40
OCT					
05...	1540	--	--	<1	<1
05...	1545	--	--	K2	<1
26...	1300	24.0	1400	K2	K20
26...	1330	3.00	3200	K20	K32

Table 12.--Phytoplankton and bacteria concentrations at sampling sites A-F--Continued

SAMPLING SITE C

DATE	TIME	SAMPLING DEPTH (FEET)	PHYTOPLANKTON, TOTAL (CELLS PER ML)	COLIFORM FECAL, (COLS./ 100 ML)	STREPTOCOCCI, FECAL, (COLS. PER 100 ML)
MAY					
25...	1100	14.0	1400	114	306
25...	1130	3.00	860	116	98
AUG					
02...	2200	--	2200	--	--
02...	2205	--	2400	--	--
SEPT					
28...	1100	20.0	720	--	K20
28...	1135	3.00	1200	--	K55
OCT					
05...	1530	--	--	K4	K21

SAMPLING SITE D

DATE	TIME	SAMPLING DEPTH (FEET)	PHYTOPLANKTON, TOTAL (CELLS PER ML)	COLIFORM FECAL, (COLS./ 100 ML)	STREPTOCOCCI, FECAL, (COLS. PER 100 ML)
MAY					
25...	1745	11.0	1100	700	255
25...	1750	3.00	3500	89	109
JUNE					
29...	1700	5.00	1800	--	--
30...	0600	5.00	--	178	25
AUG					
02...	2005	7.00	4200	K20	K68
02...	2010	--	8000	K30	K10
24...	--	4.00	10000	K7	K4
SEPT					
28...	0930	1.00	710	K14	K8
OCT					
04...	1430	--	--	K19	K13
26...	1415	1.00	28000	--	--

Table 12.--Phytoplankton and bacteria concentrations at sampling sites A-F--Continued

SAMPLING SITE E

DATE	TIME	SAM- PLING DEPTH (FEET)	PHYTO- PLANK- TON, TOTAL (CELLS PER ML)	COLI- FORM FECAL, (COLS./ 100 ML)	STREP- TOCOCCI, FECAL, (COLS. PER 100 ML)
MAR					
30...	1000	3.00	320	--	--
MAY					
25...	--	--	1300	--	--
25...	1310	9.00	310	164	210
25...	1325	3.00	1300	140	113
JUNE					
27...	1430	6.00	2200	--	--
30...	0605	4.00	--	K12	92
AUG					
02...	2035	6.00	5500	ND	545
02...	2040	1.50	5100	K4	377
24...	1430	3.00	36000	93	186
SEPT					
28...	1005	2.00	1200	K8	K18
OCT					
04...	1530	--	--	--	K19
26...	1445	1.00	11000	--	--

SAMPLING SITE F

DATE	TIME	PHYTO- PLANK- TON, TOTAL (CELLS PER ML)
MAY		
25...	2030	1100
JUNE		
30...	0001	1400

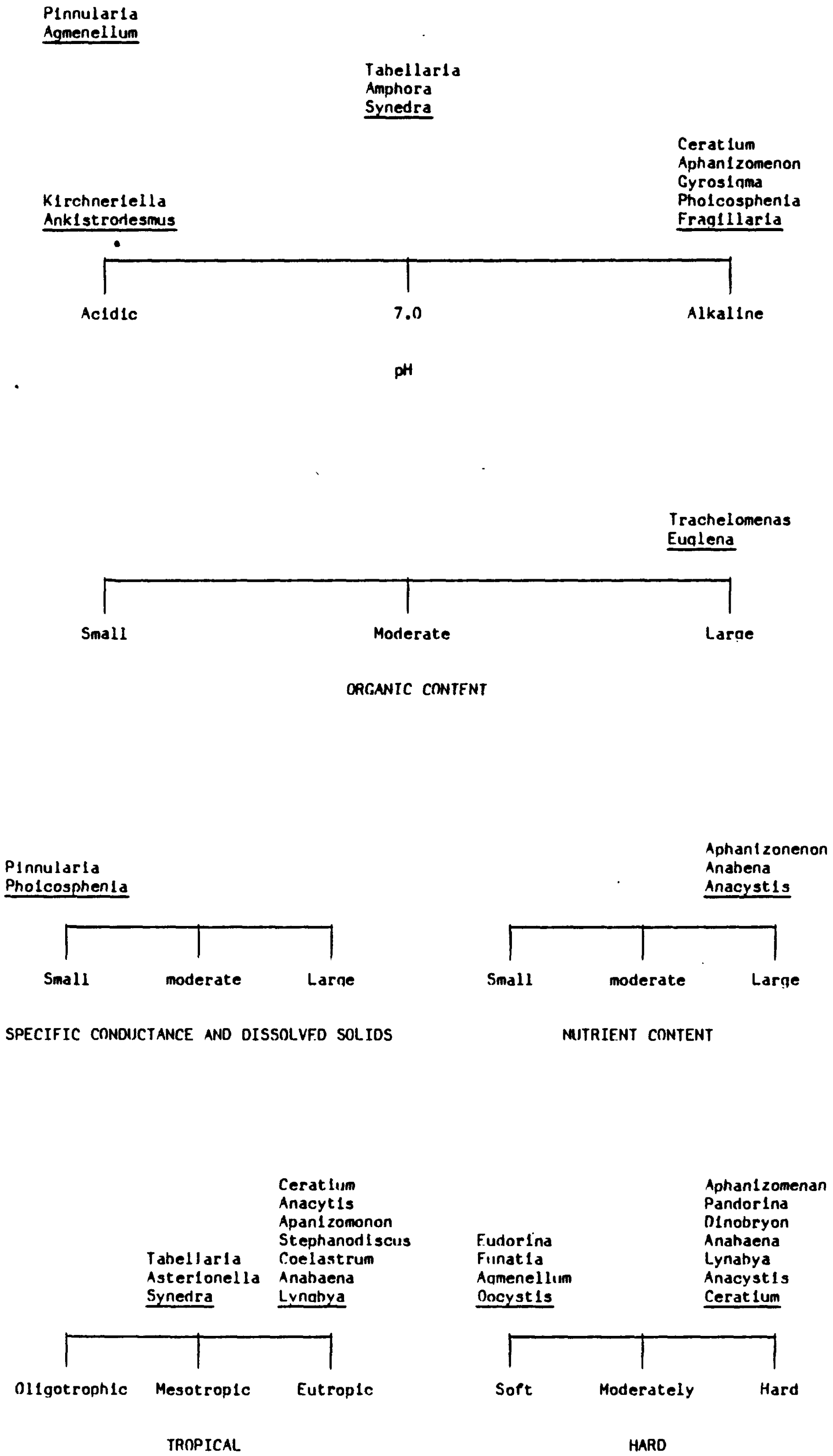


Figure 13.--Implied indicative associations of phytoplankton (modified from P. E. Greeson, U.S. Geological Survey, written commun., 1978).

Only one benthic-invertebrate sample was successfully analyzed. Those benthic invertebrates identified included representatives that are typically considered clean-water dwellers as well as representatives that are typically polluted-water dwellers (table 13). The largest count was for midges (Chironomidae), which usually are considered as polluted-water inhabitants.

Bacteria

All recreational waters and drinking-water supply sources need to be free of pathogenic bacteria so as not to pose hazards to health. Procedures for detecting these bacteria are complex and time-consuming; therefore, the coliform bacteria test is used as an indirect measure of this hazard.

Fecal coliform bacteria are bacteria that are present in the intestine or feces of warm-blooded animals. For this reason fecal coliform bacteria usually are used as indicators of the sanitary quality of water. These bacteria are defined as all organisms that produce blue colonies within 22 hours when incubated at 44.5 °C+0.2 °C on M-FC medium (nutrient medium for bacterial growth).

Other bacteria found in intestines of warm-blooded animals include fecal streptococcal bacteria. Their presence in water is considered to verify bacterial pollution. These bacteria are defined as all organisms that produce red or pink colonies within 48 hours at 35 °C+1.0 °C on M-enterroccus or KF streptococcus medium.

It is recommended (National Academy of Science, National Academy of Engineering, 1972) that the geometric mean of fecal coliform bacteria not exceed 2,000 colonies per 100 milliliters of water. No recommendation is cited for fecal streptococcal bacteria. Oklahoma's water-quality standards (Oklahoma Water Resources Board, 1979) recommend that "...the bacteria of the fecal coliform group shall not exceed a monthly geometric mean of 200/100 ml, at a point of intake for a public or private water supply." This standard also applies to waters designated for primary body-contact recreation. The relationships of bacteria concentrations with time are shown in figures 14-17. All concentrations reported during the study (table 12) were within recommended limits.

SUMMARY AND CONCLUSIONS

Water from the Blue Creek arm of Lake Eufaula and Blue Creek is suitable for most uses when compared to water-quality standards or criteria. Profiles for all transects for May and June 1978 had the greatest temperature variation with respect to depth because the lake was stratified. Warmer water was found near the surface and cooler water near the bottom. Temperatures were least in May 1978, and greatest in September 1978.

Dissolved-oxygen concentrations had a similar pattern to that of water temperature. Dissolved oxygen was greatest near the water surface and least near the lake bottom. Greatest fluctuations occurred in the early summer and early fall when the most significant biological activity took place. Concentrations in late August were less variable with respect to depth.

Table 13--Benthic invertebrates identified in study area in March 1978

Organism Name	Common name	Count
Annelida		
. Oligochaeta	Aquatic earthworms	
..Unknown order		4
Arthopoda	Arthopods	
. Insecta		
..Coleoptera		
...Elmidae	Riffle beetles	1
..Diptera		
...Chironomidae	Midges	96
..Ephemeroptera	May flies	54
..Trichoptera	Caddis flies	4
	Total	159

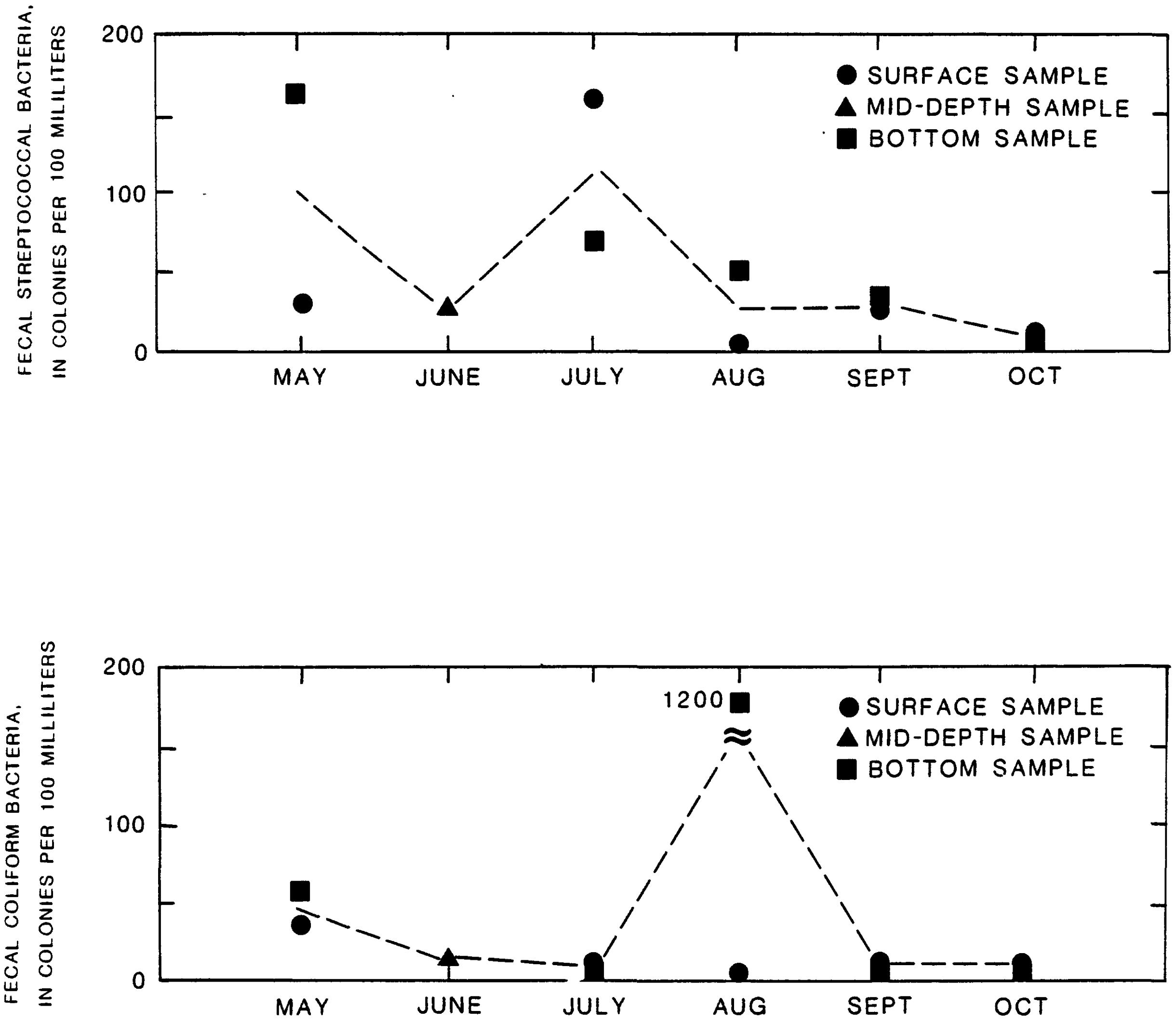
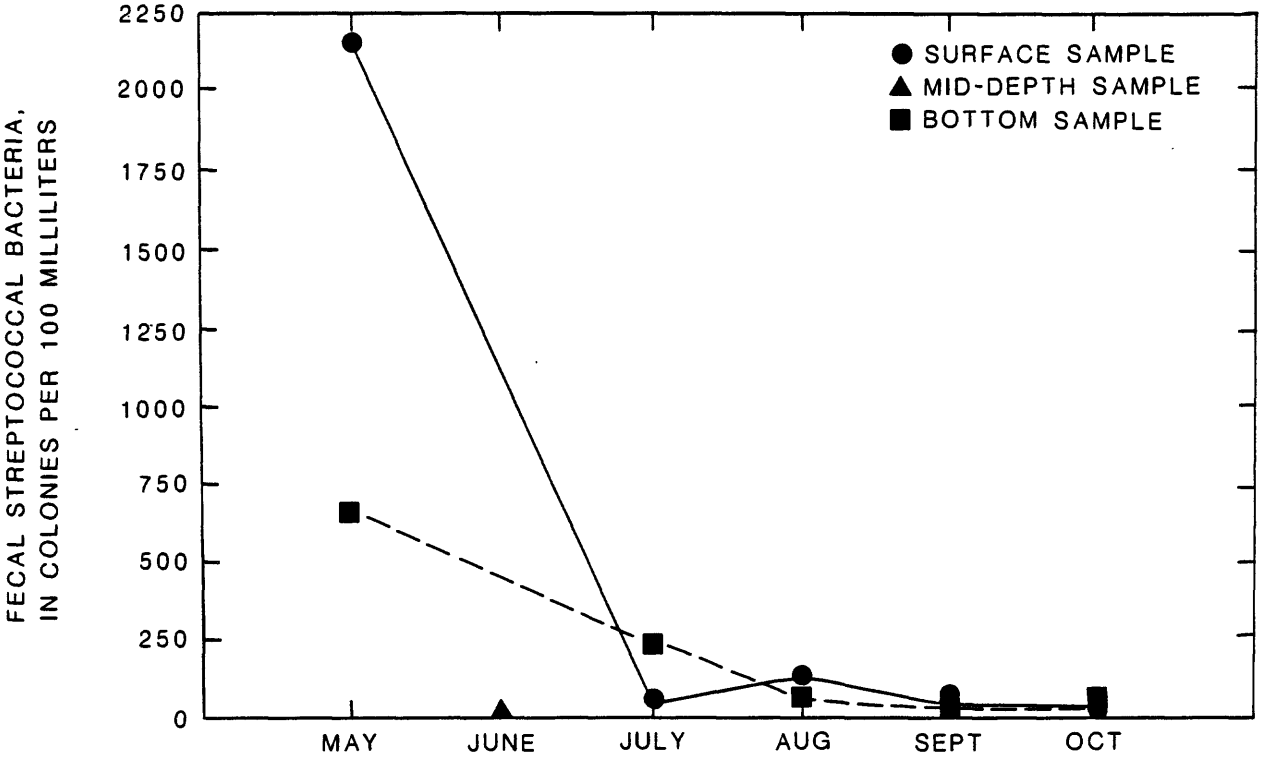


Figure 14.--Bacterial data for sampling Site A.



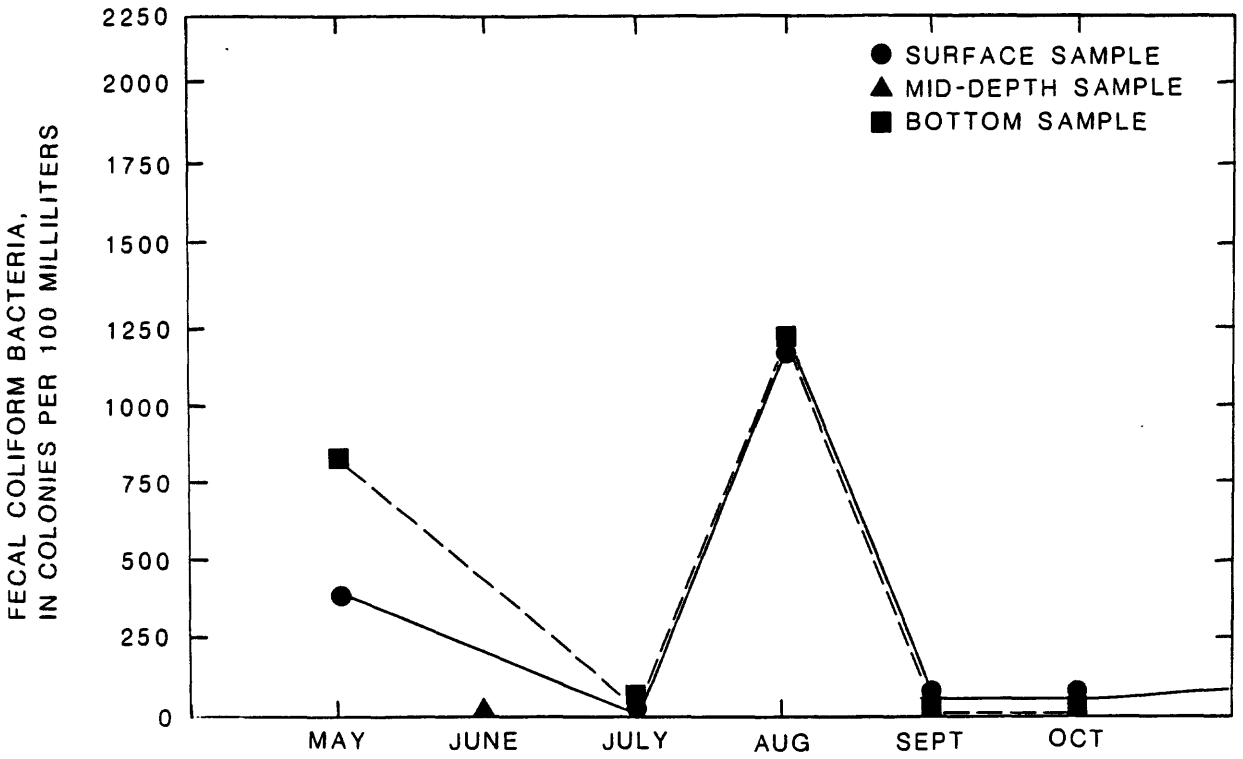
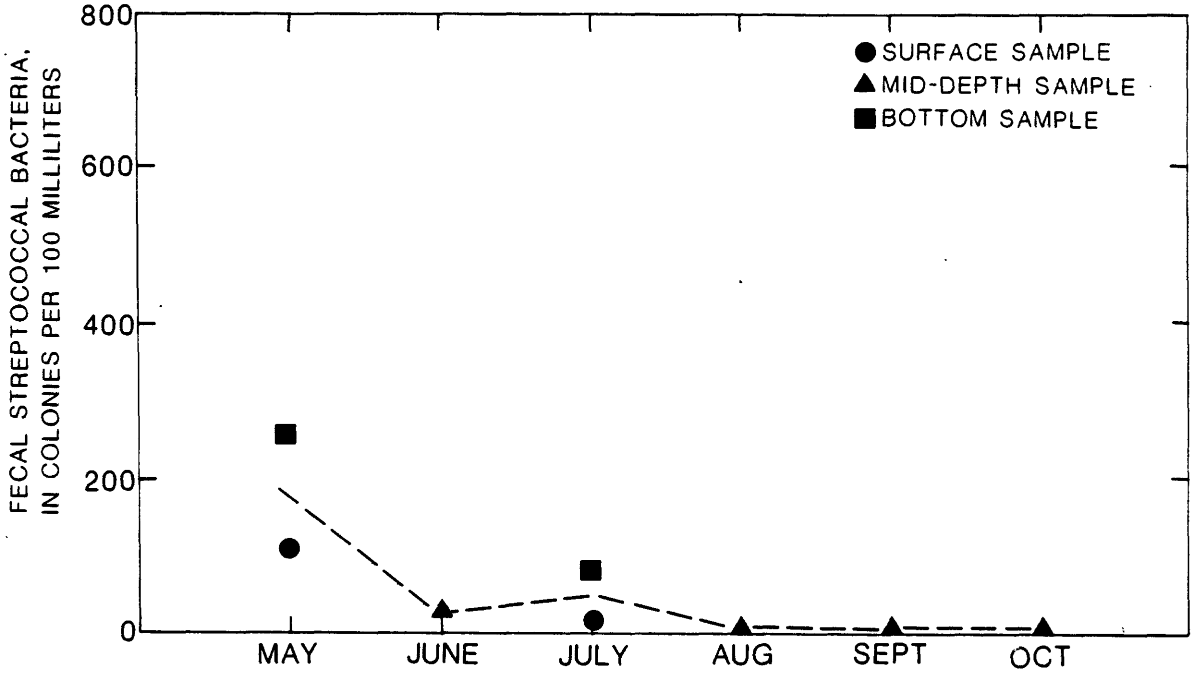


Figure 15.--Bacterial data for sampling Site B.



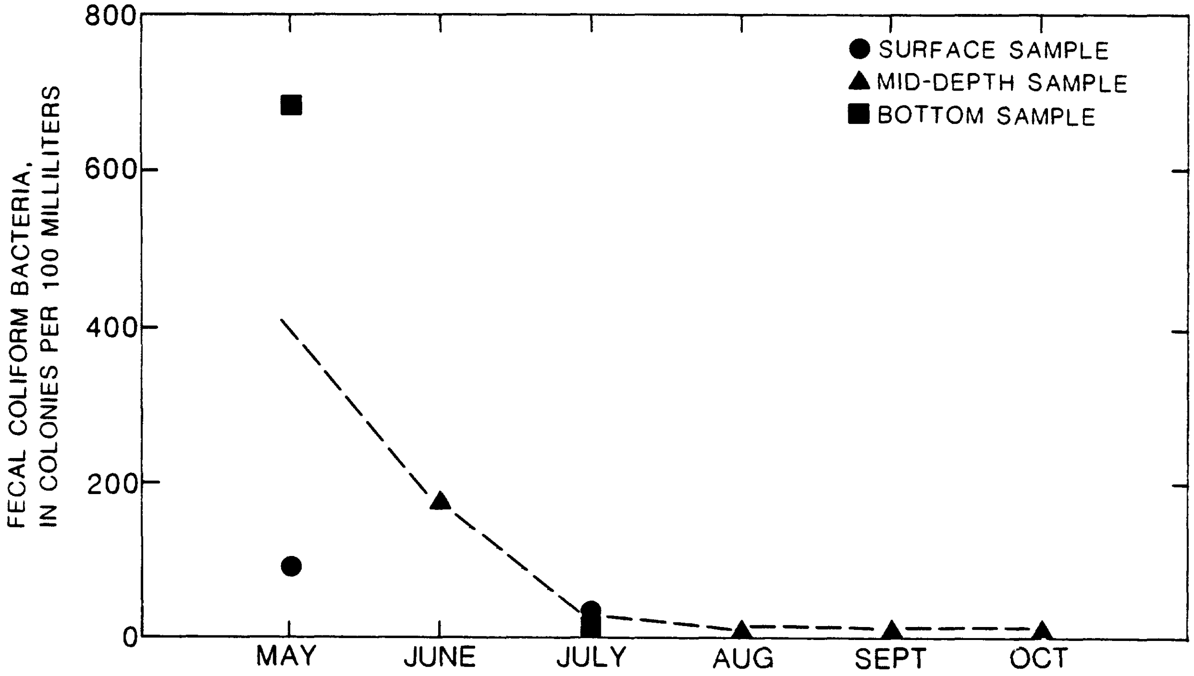


Figure 16.--Bacterial data for sampling Site D.

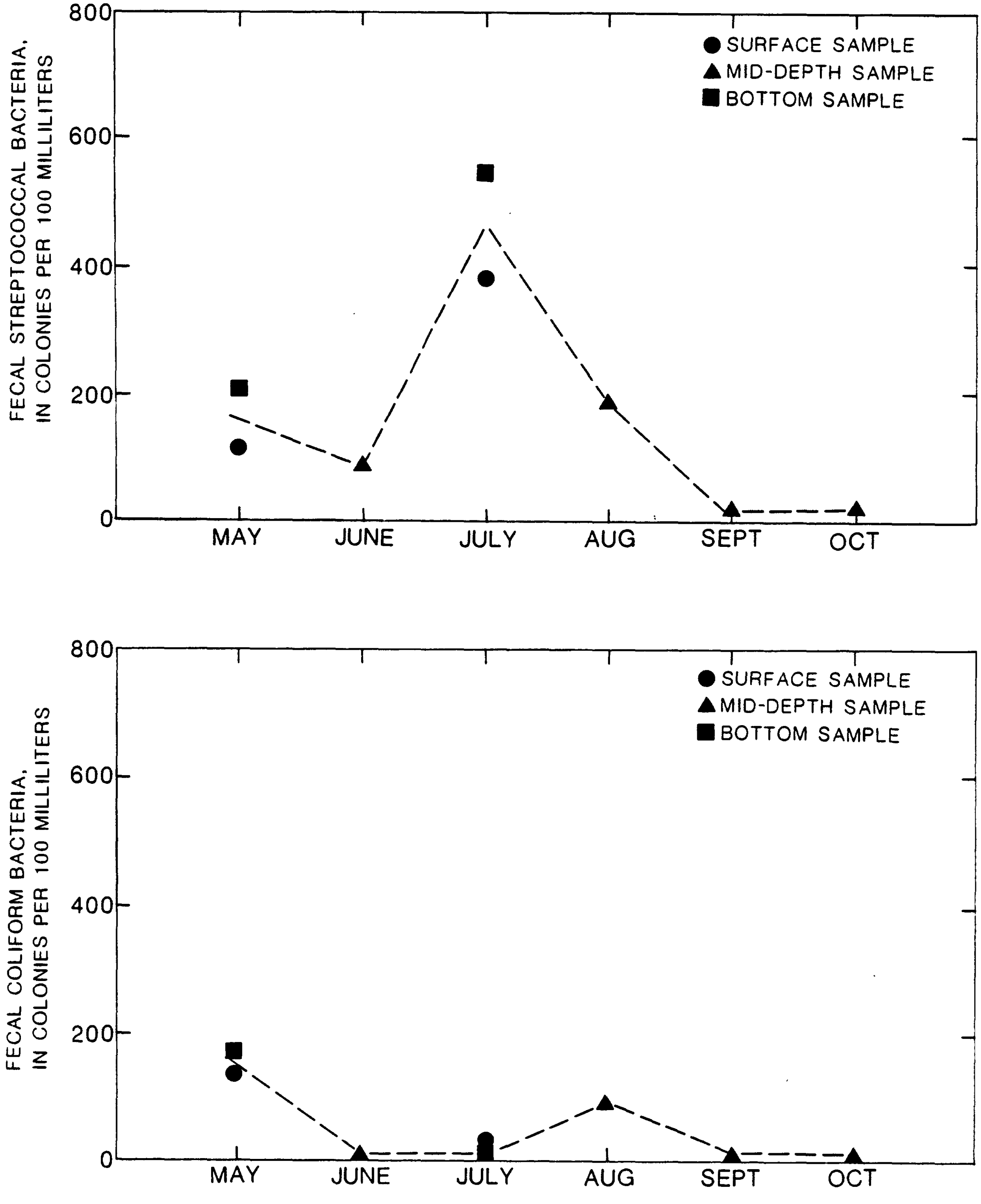


Figure 17.--Bacterial data for sampling Site E.

Specific conductance values showed little variation with depth. The greatest variation occurred with time.

Values for pH ranged from 6.0 to 9.6. Values greater than the normal range probably are due to the effects of photosynthesis, during which dissolved carbon dioxide (bicarbonate) was being utilized. The smaller pH values were measured at the lower depths. This probably was due to an accumulation of bicarbonate associated with the decomposition activities of organic material by bacteria.

Chemical analyses of the water indicated the water to be soft with little mineral content and conductivity. Cation and anion concentrations were small to normal. Nutrient and trace element concentrations generally were much less than the established drinking-water standards. The exceptions to this were iron and manganese concentrations.

In general, concentrations for various chemical constituents gradually increased from spring to fall. No seasonal variation could be determined due to the limited duration of the project.

Biological analyses of the water indicated similar results to those of the chemical analyses. Using biologic indicators, genera of phytoplankton, and chemical data, the water in the Blue Creek arm of Lake Eufaula and Blue Creek is: (1) Soft and acidic with little mineral content and conductivity; (2) calm or very slowly moving; and (3) warm and enriched with organic matter.

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