CHANGES IN WATER-QUALITY CONDITIONS IN LEXINGTON RESERVOIR, SANTA CLARA COUNTY, CALIFORNIA, FOLLOWING A LARGE FIRE IN 1985 AND FLOOD IN 1986

By Marcus J. Taylor, Johnevan M. Shay, *and* Scott N. Hamlin

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Conversion Factors and Vertical Datum

Within this report, both metric (International System or SI) and inch-pound units are used. Depth and water-quality characteristics are reported in metric units, and physical characteristics, velocity, discharge, area, and altitude are reported in inch-pound units.

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
meter (m)	3.281	foot
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
ton per acre-foot	824	milligram per liter

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F=1.8(°C)+32.$$

Vertical Datum

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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Abstract

In July 1985, a wildfire burned 22 square miles of steep, predominantly chaparral-covered terrain in the 37 square miles of the drainage basin upstream from Lexington Reservoir, California. A series of subtropical storms produced 25.5 inches of rain at the reservoir during February 12-19, 1986, with maximum intensities for 1 hour exceeding 0.8 inch. Resulting runoff filled the empty Lexington Reservoir within 36 hours. The changes in water-quality conditions of Lexington Reservoir and its outlet stream Los Gatos Creek that occurred as a result of the combined fire and flood are characterized through analysis of data collected before and after the fire and flood.

After the flood in the spring of 1986, water of low conductivity, low chloride, and high turbidity entering the reservoir slowed the development of phytoplankton and suppressed population numbers by two orders of magnitude. This biological retardation occurred despite increases in the concentrations of nitrogen and phosphorus of one and two orders of magnitude, respectively. During the growing season, water transparency increased as did the phytoplankton population, which rose to three orders of magnitude greater than that recorded during summer and autumn months previous to the fire and flood. Correspondingly, similarity indexes indicate that phytoplankton succession recovered by summer and followed a pattern similar in composition to that of previous years. Trophic State Indexes calculated using values of water transparency, chlorophyll-*a*, and total phosphorus decreased by 2 to 16 points, or about a 10- to 75-percent decrease in biomass production for 1986. The opposite trends in phytoplankton numbers and chlorophyll-*a* concentrations may be attributed partly to the difference in cell volumes associated with individual genera.

INTRODUCTION

Lexington Reservoir in Santa Clara County, California (fig. 1), was formed by the construction of Lexington Dam across Los Gatos Creek and is used primarily for water conservation. Surface-water runoff is impounded in the reservoir during the rainy season and released to downstream recharge areas during the dry summer months. Water released from Lexington Reservoir supplements the natural recharge of the ground-water basin, helping to satisfy increased ground-water pumping demands. Along with water conservation, the reservoir's beneficial uses include recreation and sport fishing.

In 1978, the Santa Clara Valley Water District began a new water-quality monitoring network revised from an earlier program because of changing water- and land-use activities. The increasing complexities of regulations governing the quality of water distributed for various purposes made the existing network outmoded (Pederson and others, 1978). The revised reservoir-monitoring network resulted in the priority ranking of drainage basins with reservoirs and sampling of reservoirs and their major tributaries on a 3-year rotational basis. Lexington Reservoir was the first reservoir sampled under the new water-quality monitoring network designed by the Geological Survey and the Santa Clara Valley Water District.

From 1978 through 1987, the reservoir was sampled on 22 dates, with no data available from 1981 to 1983. Physical and chemical data collected include specific conductance, pH, water temperature, water transparency, dissolved oxygen, major chemical ions,

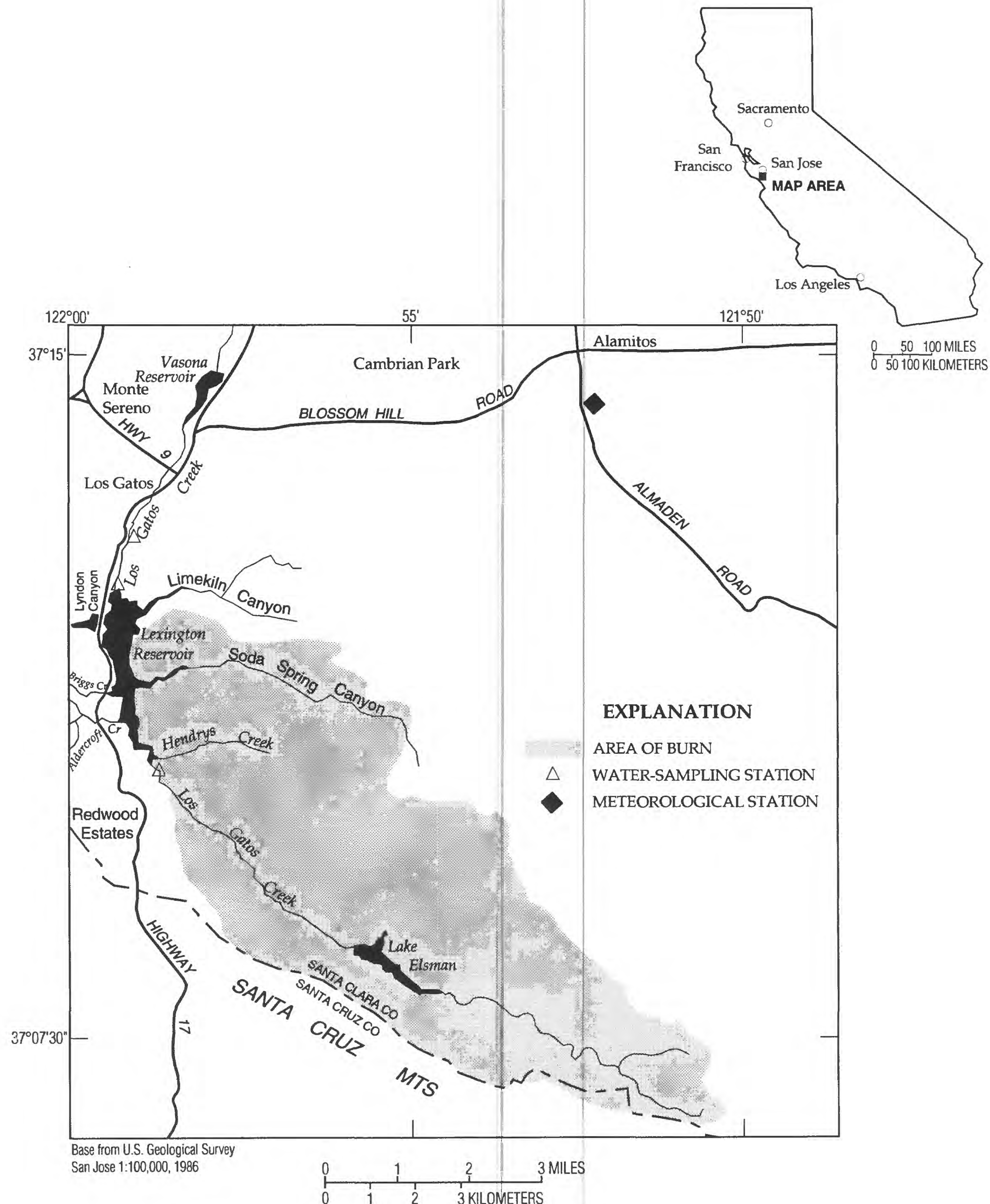

Figure 1. Location of study area.

nutrients, and selected trace constituents. Trophic characteristics data, including phytoplankton numbers and chlorophyll-*a* concentrations, also were collected. The program originally called for quarterly sampling but was restructured in 1985 because the reservoir was frequently empty or was too low to permit launching of a boat for sampling. Starting in 1985, a decision was made not to sample the reservoir unless the volume was significantly different than it was during the same season of the previous year. This decision, in addition to occasional equipment failure and inability to launch, resulted in an incomplete set of monitoring data for the period of record.

In July 1985, a wildfire burned 22 mi^2 or about 80 percent of the steep, predominantly chaparral-covered terrain in the 37 mi^2 of the drainage basin upstream from Lexington Reservoir. During February 12-19, 1986, 25.5 in. of rain fell at the reservoir with maximum intensities for 1-hour intervals exceeding 0.8 in. (Keefer and others, 1986*b*). The resulting runoff filled the empty reservoir with cold turbid water within 36 hours. This report describes results of an analysis of existing data from the ongoing water-quality monitoring in Lexington Reservoir to determine the changes in water-quality conditions and trophic state of Lexington Reservoir resulting from the combined effects of the fire and flood. The study was done by the U.S. Geological Survey in cooperation with the Santa Clara Valley Water District.

STUDY DESIGN

One station was sampled near the Lexington Reservoir Dam in the deepest part of the reservoir, and two stations were sampled on Los Gatos Creek, one immediately upstream from the reservoir and one downstream from the reservoir. The station downstream from the reservoir was monitored only for 1 year after the storm (fig. 1).

The data analyzed in this report were collected by the methods described by Greeson and others (1977), U.S. Geological Survey (1977), Skougstad and others (1979), and Britton and Greeson (1988), and were published by water year by the U.S. Geological Survey (1979, 1981*a*, 1981*b*, 1982), Markham and others (1983), and Anderson and others (1984, 1985, 1987, 1988*a*, 1988*b*). Iwatsubo and others (1988) published an interpretive report describing data collected from 1978 through 1980.

Temperature, pH, specific conductance, and dissolved oxygen were measured using a multiparameter probe at intervals of 1 m. The probe was calibrated in the field just prior to sampling the water column.

Prior to the fire and flood, data useful for this report were so scarce that it was decided to analyze data determined to be representative of the seasonal conditions in the reservoir during wet and dry water years, regardless of the year the data were collected. The 22 sampling dates were divided between before and after the fire and flood and separated by the type of water year, wet or dry, to identify the representative data. The sampling dates were then matched on the basis of the volume of the reservoir (fig. 2) and the date of sampling. On the basis of these criteria, 16 sampling dates were identified and matched to produce the 7 sets of dates presented in table 1. The data from these sets of dates were used to determine

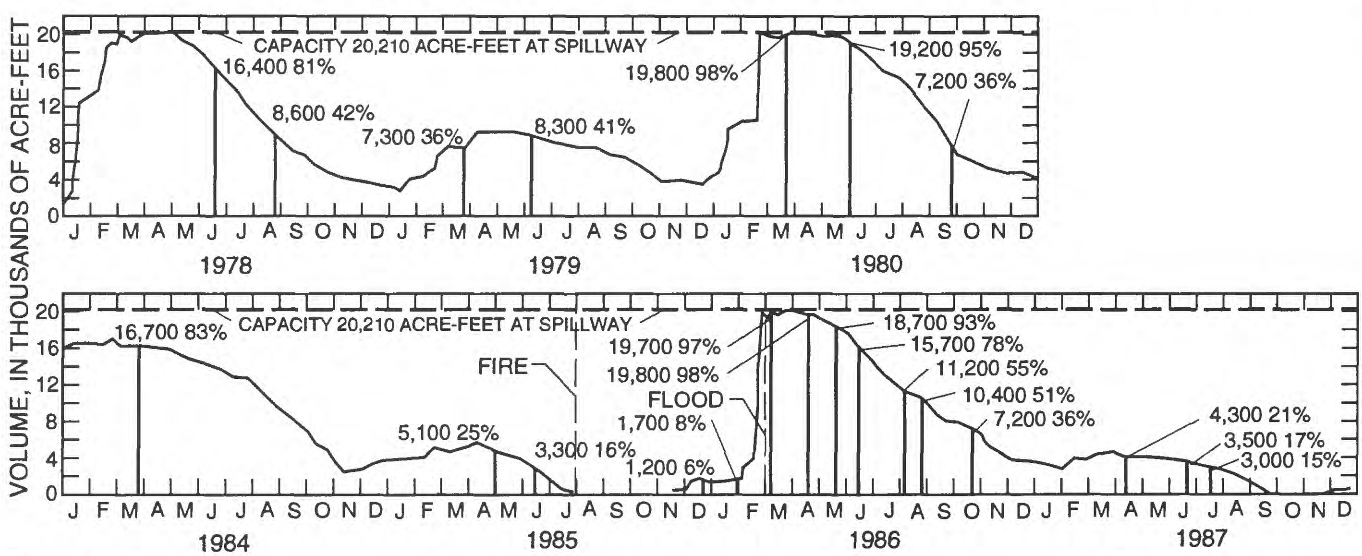

Figure 2. Reservoir volume, sampling dates, and percentage of maximum capacity at time of sampling for Lexington Reservoir. The vertical lines drawn at points on the hydrograph represent the dates on which the reservoir was sampled.

Table 1. Sampling dates selected to represent seasonal conditions in Lexington Reservoir before and after the fire and flood

Before fire and flood		After fire and flood	
Date	Volume (percentage of total capacity)	Date	Volume (percentage of total capacity)
	Wet year		
	Early spring		
3-18-80	98	3-05-86	97
3-22-84	83		
	Late spring		
5-29-80	95	5-15-86	93
	Early summer		
6-15-78	81	6-11-86	78
	Late summer		
8-23-78	42	8-20-86	51
	Early autumn		
9-23-80	36	10-15-86	36
	Dry year		
	Mid-spring		
4-30-85	25	4-09-87	21
	Early summer		
6-11-85	16	6-18-87	17
		7-16-87	15

changes in water-quality conditions that occurred on a seasonal basis in the reservoir as a result of the fire and flood. For statistical analysis and calculation of Trophic State Indexes (TSI), data from these sets of dates were averaged for before and after the fire and flood for comparison.

In spring, one set of three dates was identified to represent the wet early spring; one set of two dates was matched to represent the dry mid-spring; and one set of two dates was selected to represent the wet late spring. In summer, one set of two dates was identified to represent the wet early summer; one set of three dates was matched to represent the dry early summer; one set of two dates was selected to represent the wet late summer. In early autumn, one set of two dates was matched to represent wet early autumn. Matches were not identified for the winter season.

DESCRIPTION OF STUDY AREA

RESERVOIR AND STREAM

Lexington Reservoir, formed by the construction of Lexington Dam across Los Gatos Creek in 1952, is in the Santa Cruz Mountains about 1 mi south of Los Gatos, California (fig. 1). The dam is a rolled, earthfill dam, 195 ft high and 830 ft long at the crest. The reservoir was resurveyed during November 1987 and determined to provide a maximum usable storage capacity of 19,800 acre-ft with a surface area of 474 acres when filled (Santa Clara Valley Water District, written commun., 1989). Lexington Reservoir is classified as a warm monomictic reservoir (Hutchinson, 1957) that stratifies during the summer months and during some years develops an anoxic hypolimnion. The drainage basin upstream from Lexington Reservoir consists of about 37 mi^2 of heavily vegetated, mountainous terrain with a combination of low-level brush and dense forest. Land use in the drainage basin consists predominantly of non-residential uses, including agricultural, recreational, and open-space property. Although most of the drainage basin is sparsely populated, several low-density housing communities are just south of the reservoir and along the southwest boundary of the basin.

The principal stream in the study area is Los Gatos Creek, which originates in the southeastern end of the drainage basin and flows northwesterly for about 9 mi before emptying into Lexington Reservoir. Various additional tributaries feed directly into Lexington Reservoir. Lyndon Canyon, Briggs Creek, and Aldercroft Creek flow into Lexington Reservoir on the west side; Limekiln Canyon, Soda Spring Canyon, and Hendrys Creek flow into the east side of the reservoir (fig. 1). The drainage basins containing Soda Spring Canyon, Hendrys Creek, and Los Gatos Creek were affected by the fire in July 1985. Los Gatos Creek is the only outlet of the reservoir and flows northward downstream from the reservoir about 1 mi to Los Gatos.

CLIMATE

Air temperatures in Lexington Reservoir drainage basin generally are mild throughout the year. In summer, typical maximum daily temperatures average 28°C, and minimum daily temperatures average 8°C.

Table 2. Rainfall recorded at Alamitos

[Data provided by Santa Clara Valley Water District; rainfall in inches; NA, not available]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1977-78	0.07	0.78	2.46	8.47	3.37	4.35	2.88	0.02	0	0	0	0	22.40
1978-79	0	1.21	.53	4.08	2.99	2.20	.42	.09	0	0	0	0	11.52
1979-80	1.39	1.15	3.15	2.65	6.84	1.75	1.23	.09	0	.74	0	0	18.99
1980-81	.02	.10	2.37	4.19	1.26	2.66	.25	.22	0	0	0	.03	11.10
1981-82	1.38	4.24	1.01	5.43	1.41	5.96	3.15	0	.11	0	.02	1.06	23.77
1982-83	.93	3.83	2.51	8.48	3.82	8.21	2.85	0	0	0	.03	.61	31.27
1983-84	.63	5.08	4.08	.12	.89	.79	.47	0	0	0	0	.02	12.08
1984-85	1.10	3.82	1.27	.53	.97	2.52	.23	.07	.01	0	0	.37	10.89
1985-86	.88	1.87	1.80	1.37	8.70	4.66	.59	.29	0	0	0	1.00	21.16
1986-87	.08	.10	.86	1.46	2.37	1.85	.13	0	0	0	NA	NA	*6.85
Mean	0.65	2.22	2.00	3.68	3.26	3.50	1.22	0.08	0.01	0.07	0.01	0.34	17.00
Standard deviation .	.57	1.80	1.12	3.04	2.62	2.28	1.24	.10	.03	.23	.01	44	7.20

* Total compiled from incomplete record

In winter, maximum daily temperatures average 16°C, and minimum daily temperatures average 3°C (Santa Clara Valley Water District, written commun., 1989).

Rainfall for the entire study period was recorded at Alamitos, Santa Clara Valley Water District's meteorological station about 6 mi northeast of Lexington Reservoir (fig. 1) and is summarized by month in table 2. Rainfall data from Alamitos for the month of February (fig. 3) for 1978-87 illustrate the intensity of the storms of February 1986, which were a factor threefold higher than the median value for 1978-87 and considered to be an outside value by the definition of Tukey (1977).

Monthly evaporation rates were recorded at Lexington Reservoir and Alamitos from 1976 to 1980 by using a U.S. Weather Bureau Class A Land Pan and the method described by Veihmeyer (1964). The evaporation rate at Lexington Reservoir was determined using pan factors developed by the California Department of Water Resources for the San Francisco Bay area. The mean annual evaporation rates were 37.7 in. (number of samples, 4; standard deviation, 1.5) recorded at Lexington Reservoir, and 45.4 in. (number of samples, 4; standard deviation, 2.3) recorded at Alamitos. The station at Lexington Reservoir subsequently was discontinued. The mean annual evaporation for the remainder of the study period (1981-87) recorded at Alamitos was 40.5 in. (number of samples, 6; standard deviation, 4.7).

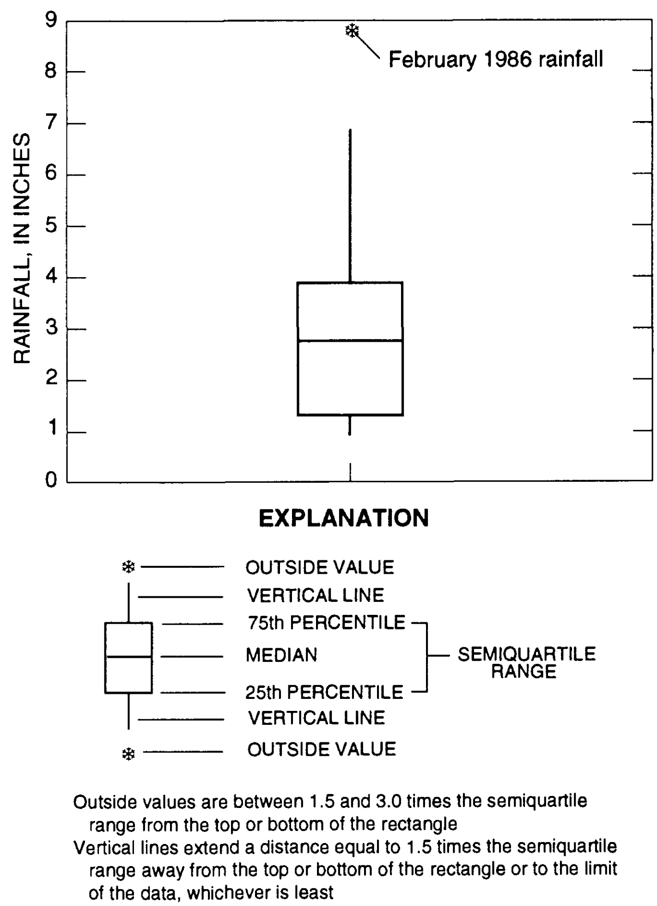

Figure 3. Rainfall at Alamitos in February 1978-87.

FIRE AND FLOOD

During the winter of 1986 after the fire upstream from Lexington Reservoir, an extensive network of rills formed in the part of the burned area underlain by poorly consolidated, highly fractured shales containing thin interbedded sandstone. The rills formed in a 2- to 10-inch deep loam that contained shale and sandstone pebbles and a discontinuous surficial layer of nonwettable material produced by the burning of the chaparral. Keefer and others (1986*a*) observed that most of the rills were formed during the early winter storms between October 21 and December 3, 1985, which produced 11.8 in. of rainfall. Few additional rills formed later in the winter despite an additional 51 in. of rain measured at the reservoir by Keefer and others (1986*a*). These rills, which formed soon after the slopes were burned, controlled the surface drainage and slope erosion as the terrain recovered from the fire.

Studies of the effects of fire on soil erosion rates on California chaparral (DeBano, 1980; Wells, 1984) indicate that fire increases the erosion of sediment by creating a water-repellent layer a few millimeters beneath the soil surface. Unable to infiltrate this hydrophobic layer, water from the post-fire storms mobilizes the soil above it into debris flows at rates that are nearly eight times higher than in nonfire years.

CHANGES IN WATER-QUALITY CONDITIONS FOLLOWING THE FIRE AND FLOOD

PHYSICAL AND CHEMICAL CHARACTERISTICS

WATER-PROFILE DATA

Profiles of the water column consisted of measurements of water transparency, temperature, dissolved oxygen, pH, and specific conductance. Data were collected at 1-m intervals from the surface to the bottom of the reservoir.

Spring.--During the spring, three sets of profile data were measured--one set in March during wet years, one set in April during dry years, and one set in May during wet years. Profile data for the spring are shown in figure 4.

For early spring wet year, measurements were made on March 18, 1980, March 22, 1984, and March 5, 1986 (fig. 4*A*), when the reservoir volume was 98, 83, and 97 percent of total capacity, respectively (fig. 2). The water transparency as measured by Secchi disk depth was 0.4 m in 1980, 0.2 m in 1984, and 0.19 m in 1986. Temperatures were uniform throughout the water column in 1980; however, the onset of stratification is apparent in 1984 and 1986. The epilimnion in 1984 was somewhat better defined than in 1986. Bottom temperatures for 1980, 1984, and 1986 ranged from 11 to 12°C. The differences in degree of stratification can be attributed partly to the daytime air temperatures of the previous month. In 1980, the differences averaged 4°C lower than temperatures recorded during 1984 and 1986.

Dissolved oxygen ranged between 8 and 10 mg/L (milligram per liter) for March 1980 and 1986. The pH averaged 7.7 through the water column for March 1980 and 1986, whereas the pH for 1984 showed a gradual decrease through the metalimnion with values of 8.6 near the surface decreasing to 7.6 near the bottom.

Specific conductance averaged 250 µS/cm (microsiemen per centimeter at 25°C) in 1980, 320 µS/cm in 1984, and 200 µS/cm in 1986. These differences can be attributed partly to the differences shown in the hydrographs (fig. 2) for each of the years. The hydrograph for 1984 is characterized by a smooth curve with the reservoir filling early in the winter and reaching 83 percent of capacity by the beginning of January, whereas the hydrographs for 1980 and 1986 are characterized by a near empty reservoir in the early winter that increased in volume twofold to fourfold during a 1-week period in February. Storm runoff quickly filled the reservoir with water that was lower in specific conductance and dissolved solids. The lowest specific conductance (197 µS/cm) was measured in March 1986. This low value may be attributed partly to the presence of the subsurface hydrophobic layer in the drainage basin formed by the fire, which prevented the water from percolating into the soil, thus minimizing leaching of minerals from the soil.

For the mid-spring dry year, measurements were made on April 30, 1985, and April 9, 1987 (fig. 4*B*). The reservoir volumes were 25 and 21 percent of total capacity, respectively, and both of these years were preceded by wet years. The measured water transparency was 0.9 m in 1985 and 1.2 m in 1987. This increase in transparency may be attributed partly to a 93-percent decrease in the sampled phytoplankton numbers measured between the two dates. Both of the temperature profiles showed stratification. The temperature range for the surface to the bottom of the reservoir was greater in the 1985 measurement than in the 1987 measurement. This higher degree of stratification in 1985 also is reflected in the pH profile. The difference in stratification may be because the 1985

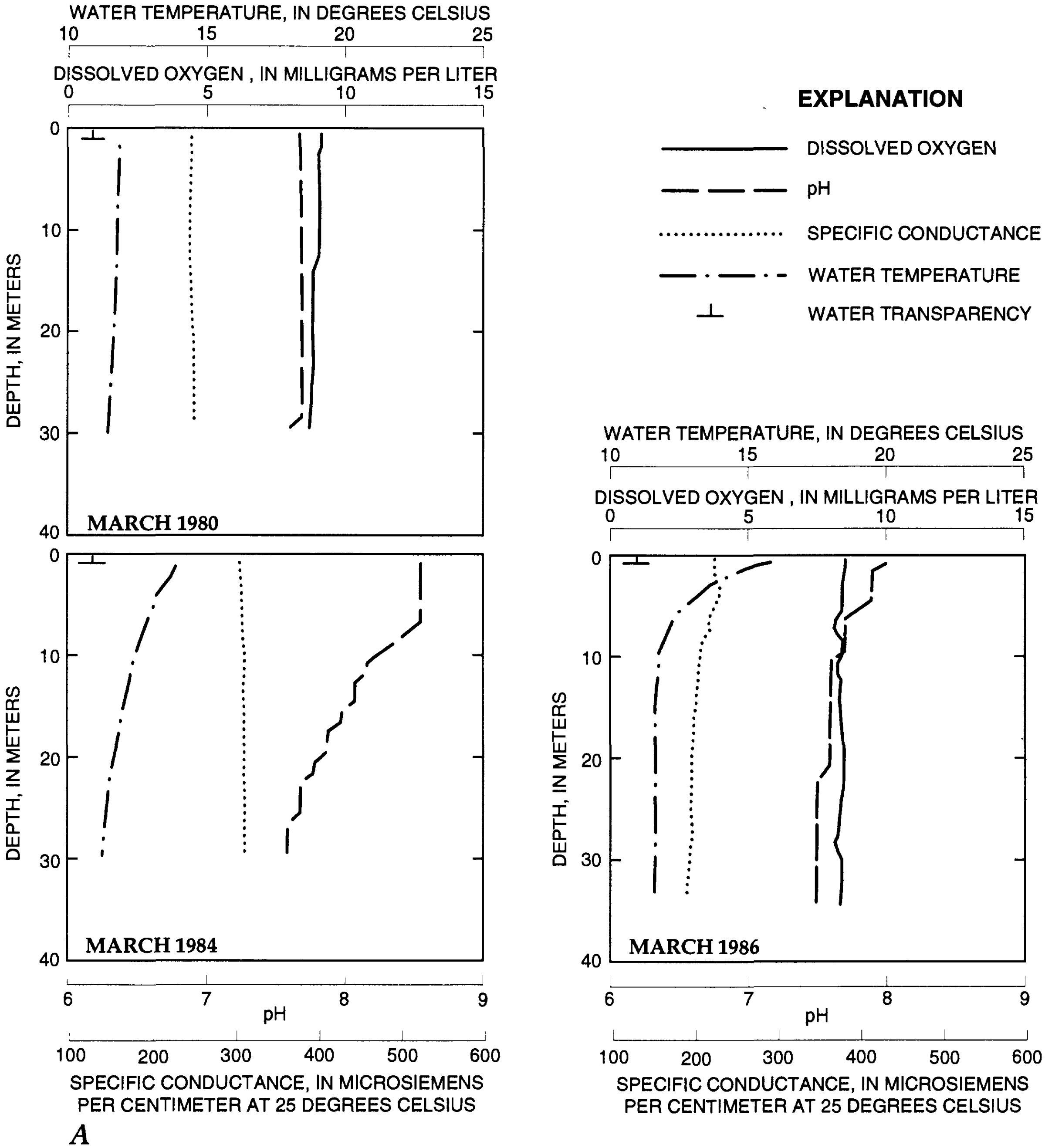

Figure 4. Water transparency, temperature, dissolved oxygen, pH, and specific conductance at Lexington Reservoir for March 1980, 1984, and 1986; April 1985 and 1987; and May 1980 and 1986. ***A.*** Early spring, wet year. ***B.*** Mid-spring, dry year. ***C.*** Late spring, wet year.

measurement was made 3 weeks later than the 1987 sample. The dissolved-oxygen profiles were fairly similar and show a local minimum at a 12-m depth. This minimum also was reflected in the pH profile. Specific conductance profiles were nearly constant; however, the 1985 measurement averaged 70 µS/cm higher than the 1987 measurement. This could result from the high storm flows in 1986 contrasted with the relatively gradual filling of the reservoir that occurred in 1984.

For the late spring wet year, measurements were made on May 29, 1980, and on May 15, 1986 (fig. 4*C*), when the reservoir volume was 95 and 93 percent of total capacity. The measured water transparencies were 1.3 m in 1980 and 2.7 m in 1986. Both temperature profiles were stratified and looked similar, with temperatures ranging from 18°C at the surface to 12°C at the bottom with an epilimnion 4 m in depth. The pH profiles also were similar; however, the 1980 measurement averaged 1 unit greater

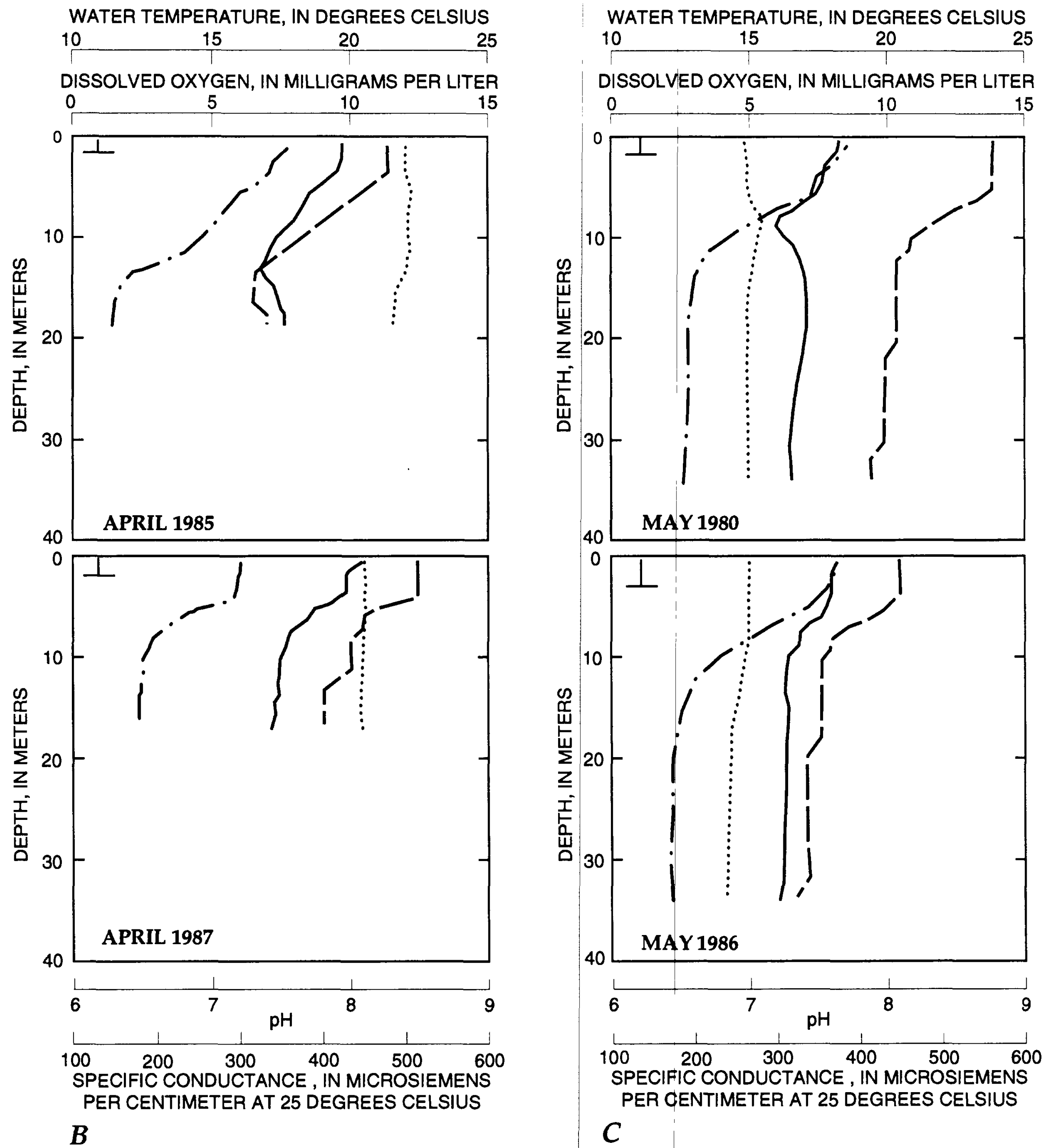

Figure 4. *Continued.*

throughout the epilimnion. This difference was attributable partly to the presence of a bloom of *Aphanizomenon* and to the highest concentration of chlorophyll-*a* sampled during the entire study. Values for pH ranged from 7.3 in the hypolimnion (May 1986) to 8.8 in the epilimnion (May 1980). In 1980, specific conductance had a local maximum in the metalimnion at a depth of 8 m, whereas dissolved oxygen had a sharply defined local minimum at the same depth. The 1986 specific conductance and dissolved oxygen varied within a range similar to that of the 1980 measurements with the exception that the dissolved-oxygen concentrations in the epilimnion were lower.

Summer.--During the summer season, two sets of measurements were made in June, one set during wet years and one set during dry years; a single measurement was made in July during a dry year, and a set of measurements was made in August during wet years.

Profiles for the summer and autumn are shown in figure 5.

For early summer wet year, measurements were made on June 15, 1978, and June 11, 1986 (fig. 5*A*), when the reservoir volume was at 81 and 78 percent of total capacity (fig. 2). The measured water transparencies were virtually the same, 2.1 m in 1978 and 2.2 m in 1986. Temperatures were similar, ranging from 23°C at the surface to 11 to 13°C near the bottom. The epilimnion extended 3 m in depth from the surface. The pH also was similar, ranging from 8.3 to 8.6 at the surface to 7.4 to 7.5 near the bottom. Dissolved oxygen had local minimums in the metalimnion at the 8- and 12-meter depths for 1978 and 1986, indicating the presence of respiring phytoplankton. Specific conductance was greater for 1978 than for 1986 and had a local maximum corresponding to the local minimum in dissolved oxygen, which is indicative of phytoplankton respiration; however, no such relation was evident in 1986.

For the early summer dry year, measurements were made on June 11, 1985, June 18, 1987, and July 16, 1987 (fig. 5*B*), when the reservoir was at 16, 17, and 15 percent of total capacity. The measured water transparencies were 0.53 m in June 1985, 1.45 m in June 1987, and 0.80 m in July 1987. Temperature profiles showed stratification ranging from 24°C near the surface to 15°C near the bottom. The epilimnion extended 3, 6, and 8 m in depth for June 1985, June 1987, and July 1987. The reservoir was shallow, averaging near 12 m in depth. Values for pH ranged from about 8.3 near the surface to 7.0 near the bottom. Measurements of specific conductance were constant with values near 500 µS/cm (maximum of 544 µS/cm), which was typical for dry years. The 1985 measurement of dissolved oxygen had a local minimum at 5 m, indicative of phytoplankton respiration. Dissolved-oxygen samples in June and July of 1987 were anoxic in the hypolimnion. These were the only two anoxic profiles examined for this report.

For the late summer wet year, measurements were made on August 23, 1978, and August 20, 1986 (fig. 5*C*), when the reservoir volume was 42 and 51 percent of total capacity. Water transparencies were measured at 1.4 m in 1978 and 4.6 m in 1986. Both temperature profiles showed stratification, with surface temperatures near 23°C and bottom temperatures between 16 and 18°C. The pH profiles also showed stratification, with values ranging from 8.4 near the surface to about 7.0 near the bottom. Specific conductance was slightly stratified, with values averaging 350 and 300 µS/cm for 1978 and 1986. Dissolved oxygen was similar, with concentrations near 8 mg/L in the epilimnion, decreasing to nearly anoxic in the hypolimnion.

Autumn.--Only wet year measurements were compared for early autumn; one set was measured on September 23, 1980, and one on October 15, 1986 (fig. 5*D*). The reservoir volume was 36 percent of total capacity on both sampling dates (fig. 2). The water transparency was 1.6 m in 1980 and 1.5 m in 1986. In both profiles, autumn overturn had occurred and the water column was unstratified. Temperatures in 1986 were on average 3°C colder than the 1980 measurement, possibly reflecting the 3-week difference between the sampling dates. Temperatures ranged from about 21°C at the surface in 1980 to about 18°C near the bottom in 1986. Values for pH were lower in 1980 than in 1986, with an overall range from about 8.3 at the surface to 7.6 near the bottom. Concentrations of dissolved oxygen also were lower in 1980 than in 1986, with an overall range from about 10 mg/L near the surface to 6.5 mg/L near the bottom. Average values for specific conductance in 1980 (430 µS/cm) were 80 µS/cm higher than in 1986 (350 µS/cm). This difference possibly reflected the rapid filling of Lexington Reservoir by the floods of February 1986 or the impervious zone caused by the fire.

MAJOR IONS

The concentrations of major ions can be used to classify water types and determine changes in water quality. The primary cations are calcium, magnesium, sodium, and potassium; the associated anions are bicarbonate, sulfate, and chloride. The buffering action of bicarbonates influences concentrations of other trace elements (Wetzel, 1983; Hem, 1985).

The changes in concentrations of ions were evaluated in two ways: (1) Overall dominant anions and cations and their relative concentrations were determined; and (2) ionic concentrations were averaged for periods before and after the fire, and nonparametric statistical analyses (Mann-Whitney test) were used to determine significant changes (at the 95-percent level) in the averaged data.

Bicarbonate was the dominant anion and calcium generally was the dominant cation in Lexington Reservoir and in Los Gatos Creek upstream from Lexington Reservoir before and after the fire and flood. Relative concentrations of the major ions are shown in figure 6. Bicarbonate accounted for about 54 to 72 percent of the anion balance, with concentrations ranging from 100 to 215 mg/L with a mean of 162 mg/L. Calcium accounted for 43 to 55 percent of the cation balance with concentrations ranging from 21 to 63 mg/L with a mean of 40 mg/L. Magnesium accounted for 28 to 35 percent of the cation balance with concentrations ranging from 8 to 22 mg/L with a mean of 15 mg/L.

The general character of the reservoir water varied between calcium bicarbonate and calcium magnesium bicarbonate. Calcium accounted for more than 50 percent of all cations present in the calcium bicarbonate water type, whereas in the calcium magnesium bicarbonate water type, neither calcium nor magnesium accounted for more than 50 percent of all cations. Calcium magnesium bicarbonate was associated with periods when the reservoir was filling with runoff from the rainy season. In all months sampled, calcium accounted for a larger proportion of cations than did magnesium.

Changes in the balance of major ions after the fire and flood generally were small; however, the water quality generally improved after the fire and flood. The water classification was not altered for any of the sets of dates listed in table 1; however, comparisons between 1986 and all the other wet years indicate that the chloride concentration decreased 10 to 25 percent after the intense storms of February. This decrease in chloride, which seems to be temporary, can be attributed partly to the sudden influx of freshwater runoff. Comparisons between the dry 1985 and 1987 years do not indicate similar chloride concentrations.

The results of the Mann-Whitney test (table 3) show decreases in concentrations of dissolved sodium, chloride, silica, and dissolved solids ranging from 6 to 20 percent at Los Gatos Creek upstream from the reservoir after the fire. These changes are indicative of the fresher water and the additional sediment present in the creek after the fire and flood. Lexington Reservoir shows a similar trend, with decreases of dissolved sodium, chloride, silica, dissolved solids, and boron ranging from 15 to 40 percent after the fire. No significant changes in ions and trace elements were detected at Los Gatos Creek downstream from the reservoir.

Alkalinity is the acid-neutralizing capacity of water. Commonly occurring anions that increase alkalinity are bicarbonate, carbonate, phosphate, and hydroxide. Alkalinity in municipal water supplies is important because it affects the amounts of chemicals needed for water treatment. Naturally occurring concentrations of alkalinity (as calcium carbonate) in drinking water as much as 400 mg/L are not a health problem (U.S. Environmental Protection Agency,

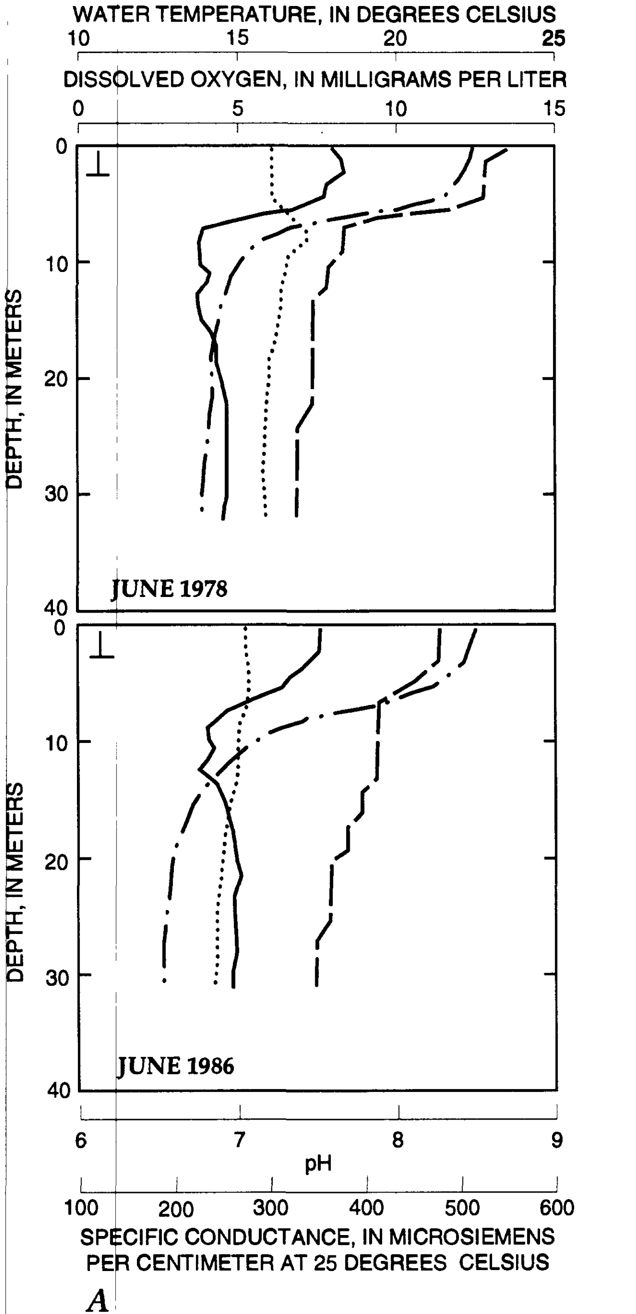

Figure 5. Water transparency, temperature, dissolved oxygen, pH, and specific conductance at Lexington Reservoir for June 1985 and 1987, July 1987, June 1978 and 1986, August 1978 and 1986, September 1980, and October 1986. ***A.*** Early summer, wet year. ***B.*** Early summer, dry year. ***C.*** Late summer, wet year. ***D.*** Early autumn, wet year.

1986). Alkalinity concentrations in Lexington Reservoir ranged from 64 to 172 mg/L with a mean of 132 mg/L, and did not show any significant change before and after the fire and flood (Anderson and others, 1985, 1987).

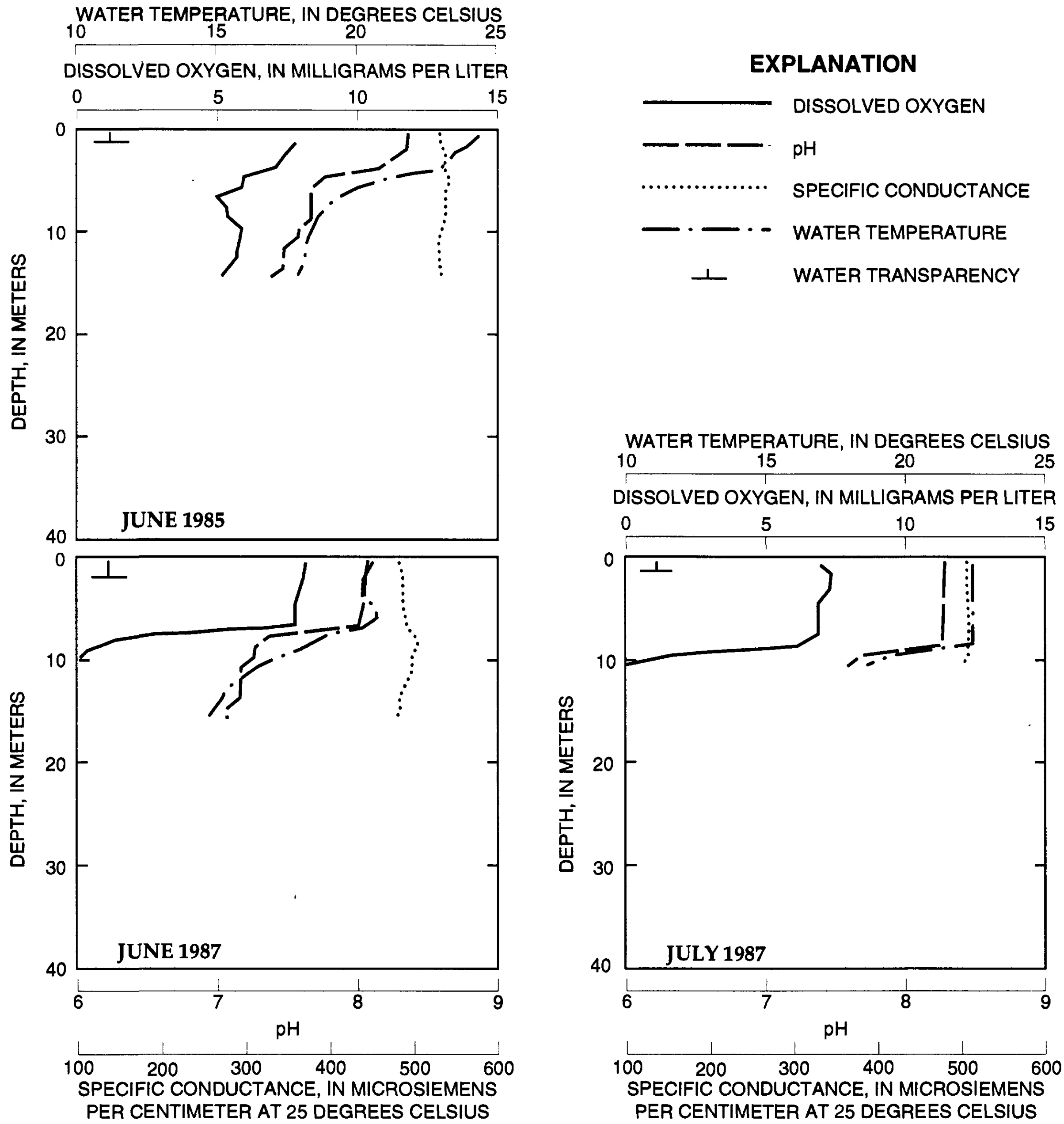

Figure 5. *Continued.*

TRACE ELEMENTS

The trace elements analyzed in this study included aluminum, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc. Concentrations of trace elements in water samples generally were low (less than 1 mg/L). Many trace elements are essential plant nutrients, but some may be toxic even at low concentrations (Wetzel, 1983). Trace elements are transported either in the dissolved state or attached to sediments, which settle to the reservoir bottom. Under anaerobic conditions in the hypolimnion in late summer and early autumn, many trace elements in the sediment desorb and remobilize into the water column. Under such conditions, toxic concentrations may come into contact with biota in the epilimnion during such periods of rapid mixing as autumn overturn.

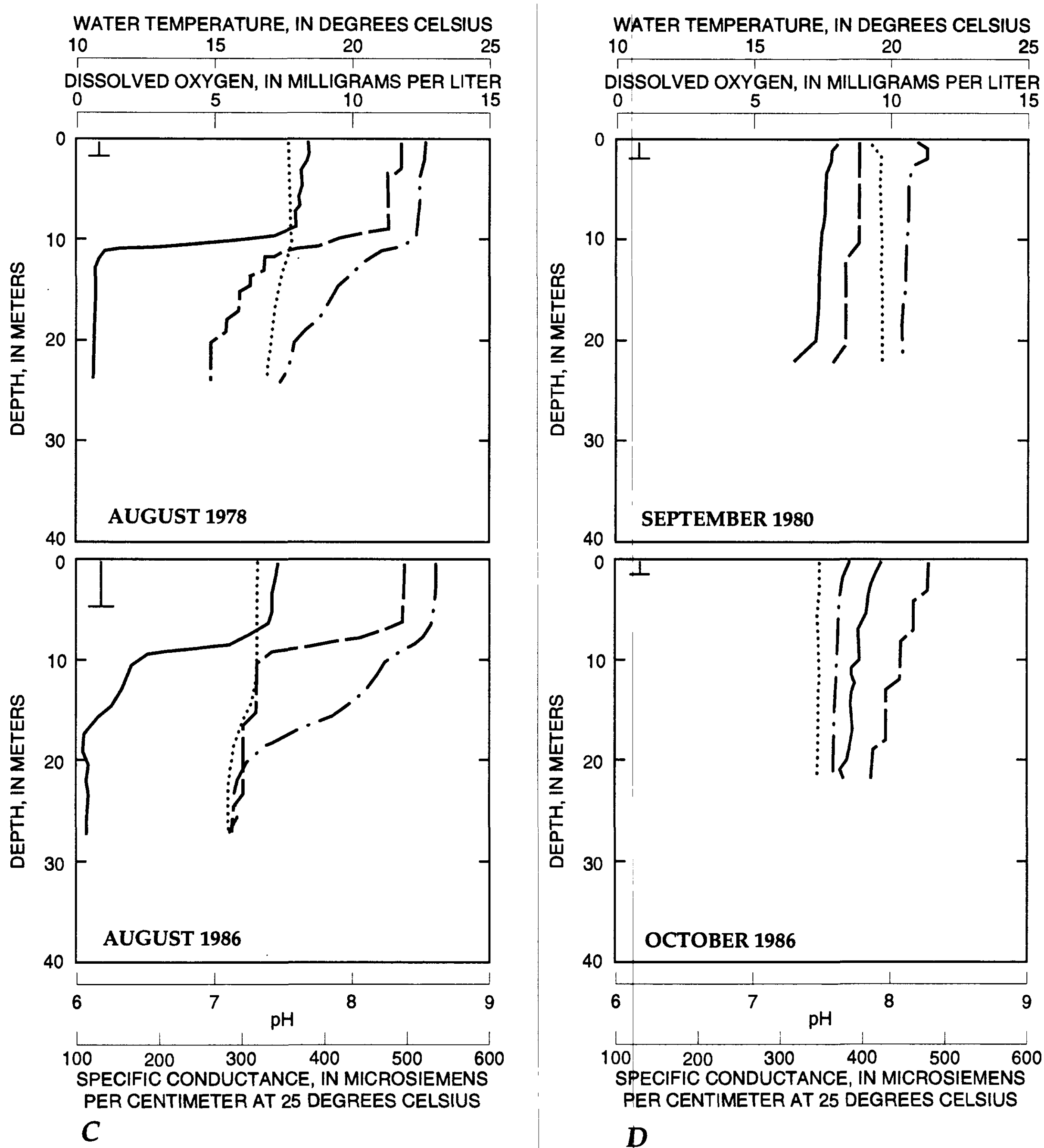

Figure 5. *Continued.*

Changes in the concentrations of trace elements before and after the fire and flood were determined by averaging the data into before-and-after means and then using nonparametric statistics (Mann-Whitney test) to determine any significant differences (at the 95-percent level) between the averaged data groups (table 3). Samples from Los Gatos Creek upstream from Lexington Reservoir show an increase in dissolved iron of 110 percent. Samples from Lexington Reservoir show a decrease in dissolved boron of 29 percent. Of the trace elements sampled in the study, none of the elements that water managers commonly are concerned with (arsenic, boron, iron, and selenium) exceeded U.S. Environmental Protection Agency's (1986) primary or secondary drinking-water standards.

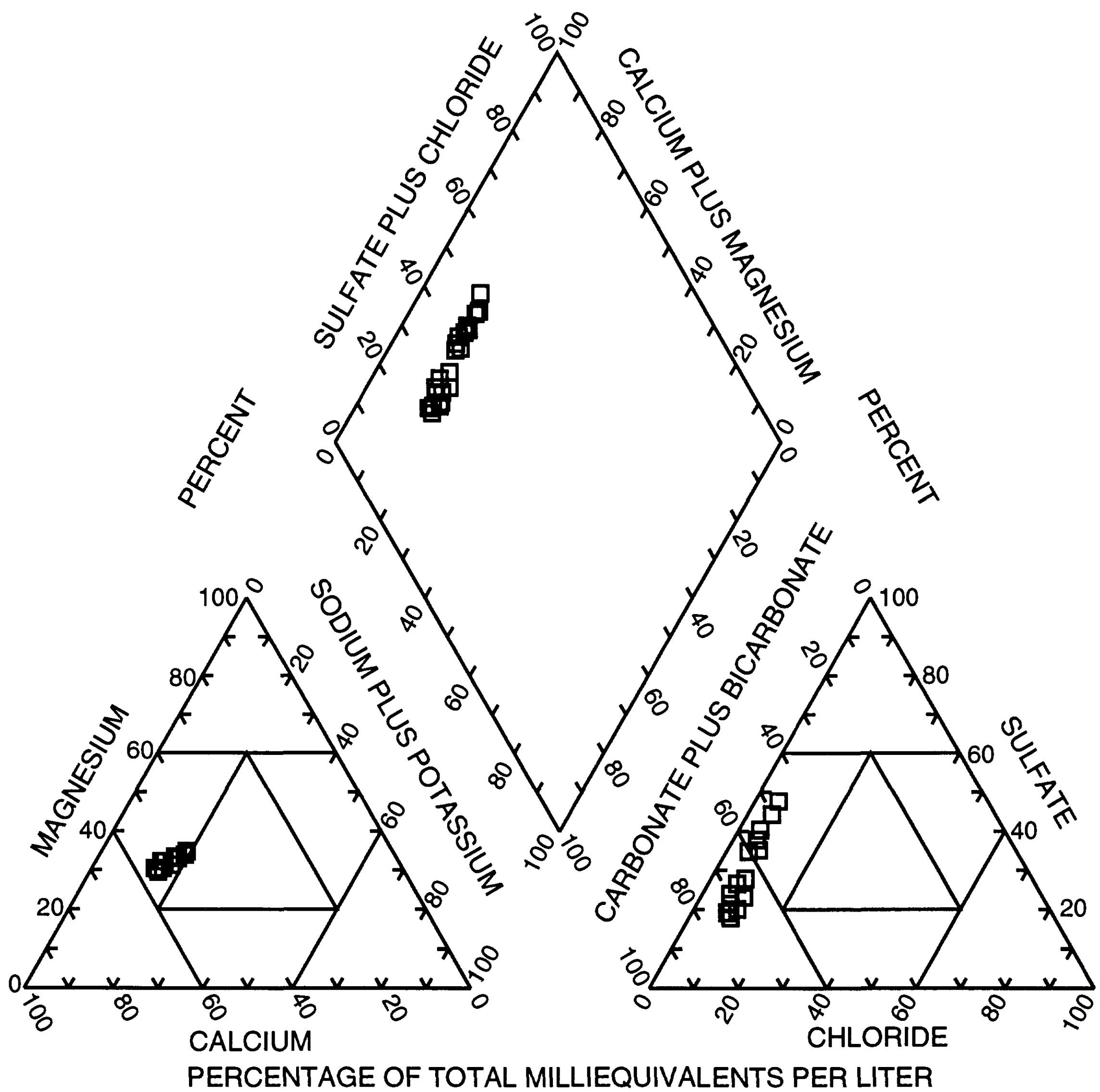

Figure 6. Major-ion composition of water in Lexington Reservoir and Los Gatos Creek upstream from Lexington Reservoir for spring, summer, and autumn months for water years 1978-80 and 1984-86.

PLANT NUTRIENTS

Nitrogen and phosphorus are important plant nutrients. Sources include soils, rocks, and lake sediment; precipitation; and agricultural, industrial, and domestic wastes. In winter and spring, nutrients generally are available to biota throughout the water column. By summer, nutrients generally have been incorporated into biomass, organic waste products, sediment, or are unavailable in the hypolimnion. These nutrients again become available to algae during autumn overturn.

Nitrate is the preferred form of nitrogen used by algae and is produced by the oxidation of nitrite by specialized bacteria or may be produced directly by nitrogen-fixing bacteria and algae. Organic nitrogen may be secreted or released by algae or aquatic plants as they decompose (Wetzel, 1983).

Table 3. Significant changes in mean concentrations of major ions and trace elements in Los Gatos Creek and Lexington Reservoir, before and after the fire and flood

[Los Gatos Creek downstream from Lexington Reservoir was sampled but none of the changes in the levels of constituents were significant. mg/L, milligram per liter; µg/L, microgram per liter; ton/acre-ft, ton per acre-foot. --, no data]

Constituent	Los Gatos Creek upstream from Lexington Reservoir			Lexington Reservoir		
	Before fire and flood	After fire and flood	Change (percent)	Before fire and flood	After fire and flood	Change (percent)
Sodium, dissolved (mg/L)	21.0	18.0	-14	13.0	11.0	-15
Chloride, dissolved (mg/L)	13	11.5	-12	43.0	33.0	-23
Silica, dissolved (mg/L)	18.0	17.0	-6	10.0	7.8	-22
Solids, dissolved (ton/acre-ft)	.49	.39	-20	.4	.24	-40
Boron, dissolved (µg/L)	--	--	--	70.0	50.0	-29
Iron, dissolved (µg/L)	5.0	10.5	+110	--	--	--

More than 90 percent of phosphorus in lake water is bound in living matter, organic phosphates, or adsorbed to particulate organic materials. The only significant form of inorganic phosphorus, soluble orthophosphate, is assimilated rapidly by planktonic algae and bacteria. Inorganic phosphorus commonly is the first limiting nutrient in water bodies (Wetzel, 1983).

Effects of the fire and flood on reservoir water quality were evaluated in two ways: (1) Nutrient data from three depths per site were composited to derive a mean concentration for each set of paired samples (table 1), and constituent concentrations before and after the fire and flood then were compared (table 4); and (2) nutrient data were composited into before and after means, and nonparametric statistics (Mann-Whitney test) then were used to determine any significant differences (at the 95-percent level) between the averaged data groups (table 5).

The results from the comparison of reservoir water-quality data for the paired samples for all nutrient concentration changes greater than 100 percent are shown in table 4. Comparisons of different nitrogen and phosphorus species before and after the fire are remarkably consistent. Concentrations of total and dissolved species of nitrogen and total phosphorus after the fire and flood increased from 100 to 900 percent.

The nitrogen to phosphorus ratio before the fire and flood averaged 77.0 (number of samples, 8; median, 48.5; standard deviation, 69.0), decreasing to 45.9 (number of samples, 15; median, 25; standard deviation, 43.2) after the fire and flood. These ratios indicate an increase in phosphorus relative to nitrogen after the fire and flood, which would be expected with the combustion of organic material during the fire. However, the range of these ratios for both time periods suggests that phosphorus is potentially limiting to the system after the fire (Wetzel, 1983). The increase in the concentrations of phosphorus relative to nitrogen in the reservoir may be attributed partly to the extensive use of the fire retardant (diammonium phosphate) in combating the fire near Lexington Reservoir.

The results from the statistical comparison of the averaged reservoir water-quality data show increases of total nitrogen and orthophosphate and decreases in organic nitrogen (table 5). These opposite trends may be attributed partly to the effects of the fire.

In a review of other studies on the effects of fire on water quality, Hoffman and Ferreira (1976) found that nitrogen concentrations increased in water in drainage basins affected by fire in the central Sierra Nevada of California. Johnson and Needham (1966) found small increases in nitrate concentrations in Sagehen Creek after a fire near Donner Pass, California. Brown and others (1973) found that the maximum concentrations of nitrate tripled following clear-cut logging and slash burning in the coastal forests of Oregon. Tiedmann (1973) found measurable increases in ammonium and organic nitrogen associated with a forest fire in north-central Washington. Lotspeich and others (1970) found no important nitrogen fluctuation that could be attributed to the effects of fire in interior Alaska.

Table 4. Significant changes in mean concentrations of nutrients at Lexington Reservoir for paired samples before and after the fire and flood

[mg/L, milligram per liter]

Constituent	Year	Before fire and flood (mg/L)	After fire and flood (mg/L)	Change (percent)
	Wet year			
	Early spring			
Nitrogen, nitrate, total	1980-86	0.02	0.04	+100
Nitrogen, ammonia, dissolved		.01	.02	+100
Phosphorus, dissolved		.01	.03	+200
Nitrogen, nitrate, total	1984-86	.01	.02	+100
Nitrogen, nitrite plus nitrate, total		.10	.66	+560
Nitrogen, ammonia, dissolved		.01	.02	+100
Phosphorus, total		.01	.10	+900
	Late spring			
Nitrogen, nitrate, total	1980-86	.18	.38	+111
	Early summer			
Nitrogen, ammonia, total	1978-86	.10	.50	+400
Nitrogen, ammonia, dissolved		.10	.30	+200
Phosphorus, total		.10	.30	+200
	Late summer			
Nitrogen, nitrite plus nitrate, total	1978-86	.05	.27	+440
	Dry year			
	Mid-spring			
Nitrogen, nitrate, total	1985-87	0.14	0.57	+307
Nitrogen, nitrite, total		.01	.03	+200
Nitrogen, nitrite plus nitrate, total		.13	.60	+362
Nitrogen, ammonia, dissolved		.07	.27	+286
	Early summer			
Nitrogen, nitrite plus nitrate, total	1985-87	.10	.23	+130
Nitrogen, nitrite plus nitrate, dissolved		.10	.22	+120

BIOLOGICAL CHARACTERISTICS

PHYTOPLANKTON COMPOSITION AND CHLOROPHYLL-A CONCENTRATIONS

Phytoplankton are useful indicators of biological conditions in freshwater systems because they are primary energy producers. The succession of predominant phytoplankton genera, the numbers of phytoplankton, and the rates of biomass production can differ greatly among individual lakes and reservoirs. In order to determine predominant phytoplankton genera, it is best to examine three different parameters for each genus identified: (1) phytoplankton numbers; (2) the cell volume; and (3) chlorophyll-*a* concentration. Consideration of only one or two of these parameters can lead to misleading conclusions regarding the biomass production and trophic status of a water body. Excess nutrients and high temperatures can result in increased phytoplankton populations or

Table 5. Significant changes in mean concentrations of plant nutrients in Lexington Reservoir and Los Gatos Creek averaged before and after the fire and flood

[Los Gatos Creek upstream from Lexington Reservoir was sampled but none of the constituents were detected. mg/L, milligram per liter; --, no data]

Constituent	Lexington Reservoir			Los Gatos Creek downstream from Lexington Reservoir		
	Before fire and flood (mg/L)	After fire and flood (mg/L)	Change (percent)	Before fire and flood (mg/L)	After fire and flood (mg/L)	Change (percent)
Nitrogen, nitrite plus nitrate, total	0.05	0.40	+700	--	--	--
Nitrogen, organic, total	.53	.37	-30	0.55	0.32	-42
Nitrogen, organic, dissolved	.37	.24	-35	--	--	--
Phosphorous, orthophosphate, dissolved	.05	.01	+100	--	--	--

algal blooms, which can cause poor taste and odor, toxicity, and oxygen depletion in reservoirs.

Phytoplankton were identified by two different laboratories during the study. The U.S. Geological Survey Laboratory in Atlanta, Georgia, identified the samples from June 1978 through September 1980. The level of the analysis was to genus. From October 1980 to February 1984, no samples were taken. From March 1984 to July 1987, Chadwick and Associates in Littleton, Colorado, identified the samples to species level. Because two different laboratories and two different levels of analyses were used, the comparison was made only to genus. Cell volumes, which are species specific and vary seasonally, were determined for all samples starting in October 1986.

From June 1978 to September 1980, phytoplankton samples were taken in the epilimnion (1-m depth), metalimnion, and hypolimnion. From March 1984 to July 1987, phytoplankton samples were taken only in the euphotic zone with one sample always taken at the 1-m depth. Comparisons among the sets of sampling dates listed in table 1 were made from data taken at the 1-m depth. Phytoplankton and chlorophyll-*a* samples were collected at the dam site for the entire period; however, phytoplankton were not collected at the 1-m depth on September 23, 1980. Phytoplankton and chlorophyll-*a* data collected at the 1-m depth at a station near the center of the reservoir were substituted for this collection.

The diversity of the taxa was greater during the spring months than during the summer and autumn months before the fire and flood and greater during the summer and autumn months than during the spring months after the fire and flood. A total of 62 different taxa of phytoplankton was identified. Prior to the fire and flood, a total of 43 taxa of phytoplankton was identified. A total of 44 taxa of phytoplankton was identified after the fire and flood.

The dominant algal groups in Lexington Reservoir did not seem to follow the seasonal succession of phytoplankton for lakes outlined by Wetzel (1983), which was based on observations in polar and temperate fresh waters. Lexington Reservoir undergoes drastic changes in storage because of water use, which affects its thermal structure and vertical mixing regime. Observations by Wetzel (1983) indicated that diatoms generally are dominant in lake systems during spring. In the summer months, green algae usually dominate, followed by blue-green algae. During March 1980 and 1984 of the spring periods prior to the fire and flood at Lexington Reservoir, diatoms and blue-green algae were the predominant groups of phytoplankton. Blue-green algae were dominant in May 1980 and April 1985 of the later spring periods prior to the fire and flood (table 6). In March 1986, after the fire and flood, blue-green algae were dominant; diatoms and blue-green algae were the predominant groups of phytoplankton throughout the remainder of the spring. Diatoms, green algae, and blue-green algae were dominant during the wet and dry summer months of June 1978 and June 1985 before the fire and flood; blue-green algae were dominant for the remainder of the summers. Phytoplankton populations were dominated by blue-green algae for the entire summer after the fire and flood. Autumn

Table 6. Co-dominant genera and changes in phytoplankton numbers and chlorophyll-*a* concentration in Lexington Reservoir, before and after the fire and flood

[BG, blue-green algae; G, green algae; D, diatoms. mL, milliliter; µg/L, microgram per liter. --, no data]

Before fire and flood				After fire and flood				Change (percent)	
Date	Dominant genus greater than 15 percent of sample	Numbers (cell/mL)	Chlorophyll-*a* (µg/L)	Date	Dominant genus greater than 15 percent of sample	Numbers (cell/mL)	Chlorophyll-*a* (µg/L)	Numbers (cell/mL)	Chlorophyll-*a* (µg/L)
Wet year									
Early spring									
3-18-80	*Oscillatoria* (BG)	1,400	0.82	3-05-86	*Chroococus lyngbya* (BG)	1,456	0.30	+6	-64
3-22-84	*Aphanocapsa* (BG) *Melosira* (D)	45,000	5.20					-97	-94
Late spring									
5-29-80	*Aphanizomenon* (BG)	170,000	34.50	5-15-86	*Synechococcus* (BG) *Stephanodiscus* (D)	12,269	0.70	-93	-98
Early summer									
6-15-78	*Anabaena* (BG) *Fragilaria* (D) *Oscillatoria* (BG)	2,230	4.00	6-11-86	*Synechococcus* (D)	3,920	5.30	+77	+33
Late summer									
8-23-78	*Anabaena* (BG) *Aphanizomenon* (BG)	25,000	23.20	8-20-86	*Aphanocapsa* (BG)	75,934	1.70	+204	-93
Early autumn									
9-23-80	*Cyclotella* (D)	2,341	3.62	10-15-86	*Aphanocapsa* (BG)	42,967	2.10	+1,700	-42
Dry year									
Mid-spring									
4-30-85	*Aphanocapsa* (BG)	162,164	--	4-09-87	*Cyclotella* (D)	11,235	1.70	-93	--
Early summer									
6-11-85	*Aphanocapsa* (BG) *Micratinium* (G)	40,845	1.20	6-18-87	*Aphanothece* (BG) *Aphanocapsa* (BG)	77,874	2.10	-91	+75

phytoplankton populations were dominated by diatoms before the fire and flood and blue-green algae after the fire and flood.

Changes in the population levels of algal groups before and after the fire and flood indicate a depression of the population during the spring of

1986. Table 6 shows a decrease in population of 93 to 97 percent when compared to the spring of 1984. Changes in population during summer indicate an increase of 77 to 204 percent. The autumn change in population indicates a 1,700-percent increase.

In spring before the fire and flood, the chlorophyll-*a* concentration was greater than after the fire and flood and followed the trends in the phytoplankton population. However, during the summer months before the fire and flood (with the exception of June), the chlorophyll-*a* concentration was greater than after the fire and flood, trending opposite to the changes in the phytoplankton population. Differences in the cell volume partly could explain why these two trends differ. In August before the fire and flood when chlorophyll-*a* decreased, *Anabaena* and *Aphanizomenon* were dominant; after the fire and flood, *Aphanocapsa* was dominant. Cell volumes determined for *Anabaena* and *Aphanizomenon* were 90 and 290 times greater in cell volume, respectively, than *Aphanocapsa*. *Aphanocapsa* also has a smaller amount of chlorophyll-*a* relative to *Anabaena* and *Aphanizomenon* (S.P. Canton, Chadwick & Associates, oral commun., 1989). In September through October after the fire and flood, chlorophyll-*a* decreased relative to before the fire and flood. *Cyclotella* was dominant before the fire and flood, and *Aphanocapsa* was dominant after the fire and flood. *Cyclotella* was 180 times greater in cell volume than *Aphanocapsa*. The cell volume and chlorophyll-*a* concentration per cell could be responsible for the different trends in chlorophyll-*a* concentration and phytoplankton population. Because of sampling errors, the inherent patchiness of phytoplankton also could be responsible for the differing trends in the phytoplankton population and concentrations of chlorophyll-*a*.

Of the dominant algae observed, three of the four genera of diatoms are associated with water-quality problems. Only the dominant green algae identified for Lexington Reservoir are not associated with any water-quality problems. Of the seven dominant blue-green algae, four are associated with water-quality problems.

The characteristics of odor, taste, and filter clogging have been associated with the following diatoms. *Melosira* has been associated with odor and taste problems. When moderate, *Melosira* has a geranium odor; when abundant, the odor is musty (Palmer, 1977). The representative species for filter clogging problems are *M. granulata* and *M. varians* (Taylor, 1980).

Fragilaria has been associated with odor and filter clogging problems. When moderate in population levels, *Fragilaria* has a geranium odor; and when abundant, the odor is musty. *F. construens* is the representative species for odor and filter clogging problems (Palmer, 1977).

Cyclotella has been associated with odor and filter clogging problems. *C. comta*, when moderate, has a geranium odor and, when abundant, a fishy odor (Palmer, 1977). *C. meneghiniana* is associated with filter clogging problems (Taylor, 1980).

Stephanodiscus has been associated with odor and taste problems. *S. niagara* when moderate has a geranium odor and, when abundant, a fishy odor. *S. binderanus* and *S. hantzschii* have caused filter clogging problems (Palmer, 1977).

The characteristics of odor, taste, filter clogging, and toxic problems have been associated with the following dominant blue-green algae. *Oscillatoria* causes odor and filter clogging problems. When the number of cells is moderate, they have a grassy odor. *O. curviceps*, when abundant, has a musty and spicy odor (Palmer, 1977). Seven different species of *Oscillatoria* cause filter clogging problems; one representative species is *O. ornata* (Taylor, 1980).

Lyngbya has been known to be toxic to animals. The representative species is *L. contorta* (Taylor, 1980).

Aphanizomenon causes odor and toxic problems. *A. flos-aquae*, when moderate, has a grassy, nasturtium, and musty odor and, when abundant, has a septic odor and is toxic to animals (Taylor, 1980).

Anabaena has caused odor, filter clogging, and toxic problems. *A. circinalis*, when moderate, has a grassy, nasturtium, and musty odor and, when abundant, a septic odor. Filter clogging problems have been caused by *A. flos-aquae* (Palmer, 1977). Both species can produce toxins that can kill livestock and other animals (Taylor, 1980).

SIMILARITY INDEX

Changes in the phytoplankton composition after the fire and flood were examined using a similarity index (Odum, 1971) calculated for each set of paired phytoplankton samples (table 6). The similarity index, *SI*, is defined as

$$SI = \frac{2\,C}{A+B} \qquad (1)$$

where

A = Number of species in sample A;

B = Number of species in sample B; and

C = Number of species common to both samples.

In this study, A and B could represent phytoplankton compositions before and after the fire and flood, respectively, for different months in wet and dry years. For example, the *SI* for the month of May (about 0.2) was determined by comparing phytoplankton data from May 1980 to May 1986 in wet years (table 6). Similarity index values can range from 0 when two samples have no taxa in common to 1 when two samples have the same taxa. In analyzing the data, a decreasing phytoplankton suppression was noted. To examine this decreasing succession, samples taken after the fire and flood were calculated with lags of 1 and 2 months relative to samples taken earlier.

Results of the similarity index analyses show that in the early spring (March) the 1- and 2-month lagged indexes were greater than the unlagged index; the value for the 2-month lagged index was the highest (fig. 7). Both lagged indexes decreased relative to the unlagged index between April and May. In May, the 2-month lagged index was one-half of the value of the 1-month index, which was the same as the unlagged index. By summer (June), the unlagged index was twice the value of the lagged indexes, indicating that the phytoplankton composition was nearly the same as in past years.

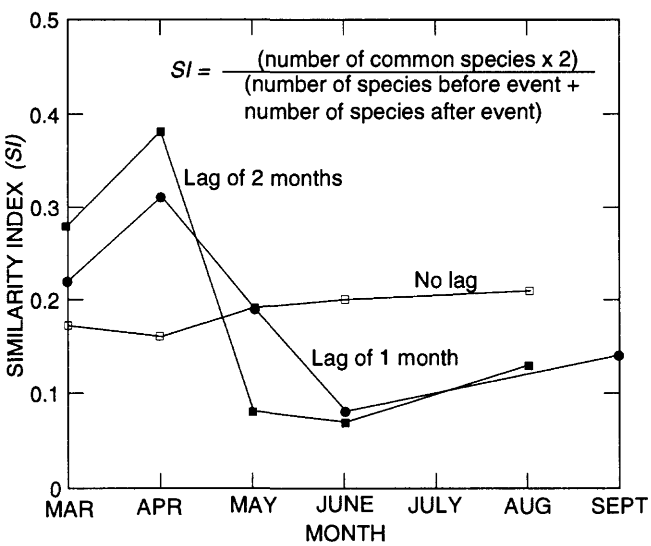

Figure 7. Similarity indexes for phytoplankton composition in Lexington Reservoir before and after the fire and flood, 1978-87. Phytoplankton data are presented in table 6.

These indexes coupled with changes in phytoplankton population, as measured by the number of cells observed, indicate that the intense storms in February 1986 that suddenly filled the reservoir with cold turbid water suppressed the population size by as much as two orders of magnitude throughout the spring. The low water transparency also delayed the usual succession of phytoplankton species composition, as indicated by the higher values of the lagged similarity indexes relative to the unlagged index for March and April. This suppression occurred despite the presence of larger than normal concentrations of nutrients. As the season progressed, the sediment load from the runoff began to settle; the reservoir warmed up; and the water transparency as measured by Secchi disk depth began to increase as did the phytoplankton population, which rose one to two orders of magnitude greater than recorded during the previous summer and autumn months. This increase in water transparency was followed by an increase in phytoplankton population growth in late summer and autumn. Correspondingly, the similarity indexes indicate that by summer the succession of phytoplankton species composition had returned to a pattern that was similar in composition to other years on record.

TROPHIC STATE INDEX

The trophic state of a lake or reservoir indicates the degree of nutrient enrichment. No single criterion for determining trophic state is adequate because many of the constituents measured are seasonal. The Trophic State Index (TSI) developed by Carlson (1977) is based on the relation of water transparency to chlorophyll-*a* and total phosphorus measurements. The technique assumes that highly productive water bodies have low concentrations of non-algal suspended solids, high algal populations and chlorophyll-*a* concentrations, and abundant nutrients, such as total phosphorus, and reduced water transparency. Besides chlorophyll-*a*, turbidity and color may influence the Secchi disk depth reading and should be considered possible sources of error. Generally, TSI values greater than 50 indicate a eutrophic system in which nutrient enrichment results in increased algal productivity and deterioration of water quality. Although TSI formulas were developed for use in regions that are colder than the San Francisco Bay area, use of the indexes to compare trophic levels before and after the fire and flood should be valid. Trophic State Indexes indicate only the general trophic status of a water body and do not define the actual or absolute trophic status (Carlson, 1977).

Table 7. Trophic State Indexes for Lexington Reservoir

[µg/L, microgram per liter; ft, foot]

Before fire and flood				After fire and flood			
Date	Water transparency (ft)	Chlorophyll-*a* (µg/L)	Total phosphorus (µg/L)	Date	Water transparency (ft)	Chlorophyll-*a* (µg/L)	Total phosphorus (µg/L)
Wet year							
Early spring							
3-18-80	0.4	0.8	80	3-05-86	0.2	0.3	80
3-22-80	.2	5.2	80				
Late spring							
5-29-80	1.3	34.5	60	5-15-86	2.7	0.7	10
Early summer							
6-15-78	2.1	4.0	5	6-11-86	2.2	5.3	20
Late summer							
8-23-78	1.4	23.2	30	8-20-86	4.6	1.7	10
Early autumn							
9-23-80	1.6	3.6	20	10-15-86	1.5	2.1	5
Dry year							
Mid-spring							
4-30-85	0.9	0.05	10	4-09-87	1.2	1.7	10
Early summer							
6-11-85	0.53	1.2	40	6-18-87	1.45	2.1	30
				7-16-87	.80	3.8	20

	Before fire and flood		After fire and flood		
	Median	Trophic State Index[1]	Median	Trophic State Index[1]	Change (percent)
Water transparency	1.3	56	1.5	54	-4
Chlorophyll-*a*	3.6	43	1.7	38	-12
Total phosphorus	.03	56	.01	40	-29

[1]Trophic State Index calculated from:
Water transparency = 60 - 33.2 log Secchi disk depth
Chlorophyll-*a* = 33.6 + 17.64 log chlorophyll-*a*
Total phosphorus = 60 - 332 log (40.5/total phosphorus) in micrograms per liter

Pre- to post-fire and flood Trophic State Indexes were calculated for Lexington Reservoir on the basis of water transparency (STSI), chlorophyll-*a* (CTSI), and total phosphorus (PTSI) (table 7). The differences between indexes before and after the fire and flood were generally less than 30 percent. The STSI was 56 before the fire and flood and decreased 2 points to 54 after the fire and flood. The CTSI was 43 before the fire and flood, decreasing 5 points to 38 after the fire and flood. The PTSI was 56 before the fire and flood, dropping 16 points to 40 after the fire and flood. Most TSI values ranged between 40 and 65, indicating a mesotrophic state. STSI values varied more than the other indexes and were highest during early spring because of sediment-laden runoff (R.T. Iwatsubo, U.S. Geological Survey, oral commun., 1989) and lowest during summer. Because of the high turbidity observed in the late spring, STSI should be considered suspect. CTSI values were highest in late summer during algal blooms and low reservoir volume and lowest during early spring. PTSI values varied the least of the indexes; they were highest in spring and lowest during the summer stratification period.

Trophic State Indexes averaged for the period before and after the fire and flood show a consistent decrease of 2 to 16 points, or 4 to 29 percent. This decrease represents roughly a 10- to 75-percent reduction in the biomass production of the lake. The largest decrease after the fire and flood (12 percent), which occurred in the CTSI, reflected the suppression of the phytoplankton population in the early spring of 1986 because of high turbidity from the storm runoff (STSI reached a maximum of 80 on March 5). The PTSI and STSI decreased 29 percent and 4 percent, respectively, after the fire and flood.

SUMMARY

In July 1985, a wildfire burned over half of the chaparral-covered terrain in the drainage basin upstream from Lexington Reservoir. Subsequent storms in February 1986 produced 25.5 inches of rain at the reservoir and resulted in flooding throughout the area. Physical, chemical, and biological conditions in the reservoir were altered as a consequence of the fire and flood.

From 1978 to 1987, the reservoir volume varied from empty to full capacity. Water transparency ranged from a minimum of 0.2 m (meters) immediately after the flood of February 1986 to a maximum of 4.6 m during August 1986. Temperatures ranged from 11°C during early spring to 24°C in the epilimnion during the summer. Dissolved oxygen ranged from 0 mg/L (micrograms per liter) in the hypolimnion during summer to 12 mg/L in the epilimnion during late spring. Of the 22 measurements made, the hypolimnion was anoxic twice during summer. Values of pH were between 7.0 in the hypolimnion during summer to 8.8 in the epilimnion during late spring. Specific conductance ranged from 197 µS/cm (microsiemens per centimeter at 25°C) just after the major storm in February 1986 to 544 µS/cm during the dry summer of 1985.

The chemical composition of the reservoir water varied between calcium bicarbonate and calcium magnesium bicarbonate. The calcium magnesium bicarbonate water usually was associated with periods when the reservoir was filling with runoff from the rainy season. Changes in the balance of major ions after the fire and flood, indicated by a decrease of 10 to 25 percent in the concentration of chloride, was attributed to dilution by freshwater runoff generated by the storms of February 1986. This decrease in chloride seems to be a temporary effect as chloride concentrations in 1987 were similar to 1985 samples. The results from nonparametric statistical tests after the fire and flood showed significant decreases in dissolved sodium, chloride, silica, and dissolved solids of 15 to 40 percent for samples from Lexington Reservoir.

Of the trace elements sampled in the study, none that water managers commonly are concerned with (arsenic, iron, boron, and selenium) exceeded national primary or secondary drinking-water standards. The results from the nonparametric statistics show an increase of 110 percent in dissolved iron in samples from Los Gatos Creek upstream from Lexington Reservoir. Samples from Lexington Reservoir show a decrease in dissolved boron of 29 percent.

The results from the nonparametric tests on nutrient samples from Lexington Reservoir before and after the fire and flood indicate an increase of total nitrogen and dissolved orthophosphorus of 700 and 100 percent, respectively, and decreases in total and dissolved organic nitrogen of 30 and 35 percent. Samples from Los Gatos Creek downstream from Lexington Reservoir showed a decrease in total organic nitrogen of 42 percent.

Changes in phytoplankton population levels and composition indicate that the cold turbid runoff from the flood of February 1986 filled the reservoir suddenly, resulting in the lowest measured water transparency, and suppressed the development of the phytoplankton during the spring of 1986 relative to

the past years. This suppression was manifested by the decrease in the population size by two orders of magnitude throughout the spring and a retardation of the succession of the phytoplankton species composition in the early spring despite the presence of high concentrations of nutrients. However, as the season progressed, the water transparency as measured by Secchi disk depth began to increase followed by the phytoplankton population, which rose one to three orders of magnitude greater than recorded during previous summer and autumn months. Correspondingly, the similarity indexes indicate that by summer the phytoplankton succession had caught up and followed a pattern similar in composition to those of previous years.

Trophic State Indexes averaged before and after the fire and flood show a consistent decrease of 2 to 16 points, or 4 to 29 percent. This decrease represents about a 10- to 75-percent decrease in the biomass production of the lake.

References Cited

Anderson, S.W., Markham, K.L., Piro, Vincent, Shelton, W.F., and Grillo, D.A., 1984, Water resources data--California, water year 1983. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-83-2, 421 p.

_____1985, Water resources data--California, water year 1984. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-84-2, 315 p.

Anderson, S.W., Markham, K.L., Shelton, W.F., Trujillo, L.F., and Grillo, D.A., 1987, Water resources data--California, water year 1985. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-85-2, 341 p.

_____1988*a*, Water resources data--California, water year 1986. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-86-2, 371 p.

Anderson, S.W., Markham, K.L., Shelton, W.F., and Trujillo, L.F., 1988*b*, Water resources data--California, water year 1987. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-87-2, 315 p.

Britton, L.J., and Greeson, P.E., eds., 1988, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Open-File Report 88-190, 685 p.

Brown, B.W., Gahler, A.R., and Warston, R.B., 1973, Nutrient losses after clear-cut logging and slash burning in the Oregon Coast Range: Water Resources Research, v. 9, no. 5, p. 1450-1453.

Carlson, R.E., 1977, A trophic state index for lakes: American Society of Limnology and Oceanography, v. 22, no. 2, p. 361-369.

DeBano, L.F., 1980, Water repellent soils: A state-of-the-art: U.S. Department of Agriculture, Forest Service, General Technical Report PSW-46.

Greeson, P.E., Ehlke, T.A., Irwin, G.A., Lium, B.W., and Slack, K.V., 1977, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey, Book 5, chap. A4, 332 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hoffman, R.J., and Ferreira, R.F., 1976, A reconnaissance of the effects of a forest fire on water quality in Kings Canyon National Park, California: U.S. Geological Survey Open-File Report 76-497, 17 p.

Hutchinson, G.E., 1957, A treatise on limnology, volume 1: New York, John Wiley, 1015 p.

Iwatsubo, R.T., Sylvester, M.A., and Gloege, I.S., 1988, Water quality of the Lexington Reservoir, Santa Clara County, California, 1978-80: U.S. Geological Survey Water-Resources Investigations Report 87-4253, 64 p.

Johnson, C.M., and Needham, P.R., 1966, Ionic composition of Sagehen Creek, California, following an adjacent fire: Ecology, v. 47, p. 636-639.

Keefer, D.K., Harp, E.L., and Zatkin, R.S., 1986*a*, Formation of rills by debris flows on burned chaparral-covered slopes in the San Francisco Bay region, California: Geological Society of America, Abstracts with Programs, v. 18, no. 6, p. 652.

Keefer, D.K., Vassil, B.V., and Zatkin, R.S., 1986*b*, Effects of the February 1986 storms on burned slopes near the Lexington Reservoir, Santa Clara County, California: Association of Engineering Geologists, Abstracts and Programs, 29th, Proceedings, p. 53-54.

Lotspeich, F.B., Mueller, E.W., and Frey, P.J., 1970, Effects of large scale fires on water quality in Interior Alaska: U.S. Federal Water Pollution Control Administration, 115 p.

Markham, K.L., Piro, Vincent, Shelton, W.F., and Weston, M.W., Jr., 1983, Water resources data--California, water year 1982. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-82-2, 407 p.

Odum, E.P., 1971, Fundamentals of ecology [3d ed.]: Philadelphia, W.B. Saunders Co., 574 p.

Palmer, C.M., 1977, Algae and water pollution: Cincinnati, Ohio, U.S. Environmental Protection Agency EPA-600/9-77-036, 123 p.

Pederson, G.L., Sylvester, M.A., and Higgins, H.H., 1978, Design of an integrated water quality monitoring program for Santa Clara County, California, *in* Everett, L.G., and Schmidt, K.D., eds., Establishment of water quality monitoring programs: American Water Resources Association Symposium, San Francisco, California, June 12-14, 1978, Proceedings, p. 74-84.

Skougstad, M.W., Fishman, M.J., Friedmann, L.C., Erdmann, D.E., and Duncan, S.S., eds., 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chap. A1, 626 p.

Taylor, W.D., 1980, Phytoplankton water-quality relationships in U.S. lakes Part VIII: Algae associated with or responsible for water-quality problems: Las Vegas, Nevada, U.S. Environmental Protection Agency EPA-600/3-80-100, 317 p.

Tiedmann, A.R., 1973, Stream chemistry following a forest fire and area fertilization in north-central Washington: U.S. Department of Agriculture, Forest Service Research Note PNW-203, 20 p.

Tukey, J.W., 1977, Exploratory data analysis: Reading, Massachusetts, Addison-Wesley Co., v. 1, chap. 5.

U.S. Environmental Protection Agency, 1986, Quality criteria for water: U.S. Environmental Protection Agency, EPA 4405-86-001, 452 p.

U.S. Geological Survey, 1977 [1981], Sediment, chap. 3, *in* National handbook of recommended methods for water-data acquisition: U.S. Geological Survey Office of Water Data Coordination, p. 3-1 to 3-100.

U.S. Geological Survey, 1979, Water resources data--California, water year 1978. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-78-2, 566 p.

_____1981*a*, Water resources data--California, water year 1979. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-79-2, 509 p.

_____1981*b*, Water resources data--California, water year 1980. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-80-2, 521 p.

_____1982, Water resources data--California, water year 1981. Volume 2. Pacific slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-81-2, 513 p.

Veihmeyer, F.J., 1964, Evapotranspiration, *in* Chow, V.T., ed., Handbook of applied hydrology: A compendium of water-resources technology, Sec. 11: New York, McGraw-Hill, p. 1-38.

Wells, W.G., II, 1984, Fire dominates sediment production in California chaparral, *in* Medecos Symposium on Mediterranean Ecosystems: Perth, Western Australia, August 1984, p. 163-164.

Wetzel, R.G., 1983, Limnology (2d ed.): New York, Saunders College Publishing, 767 p.