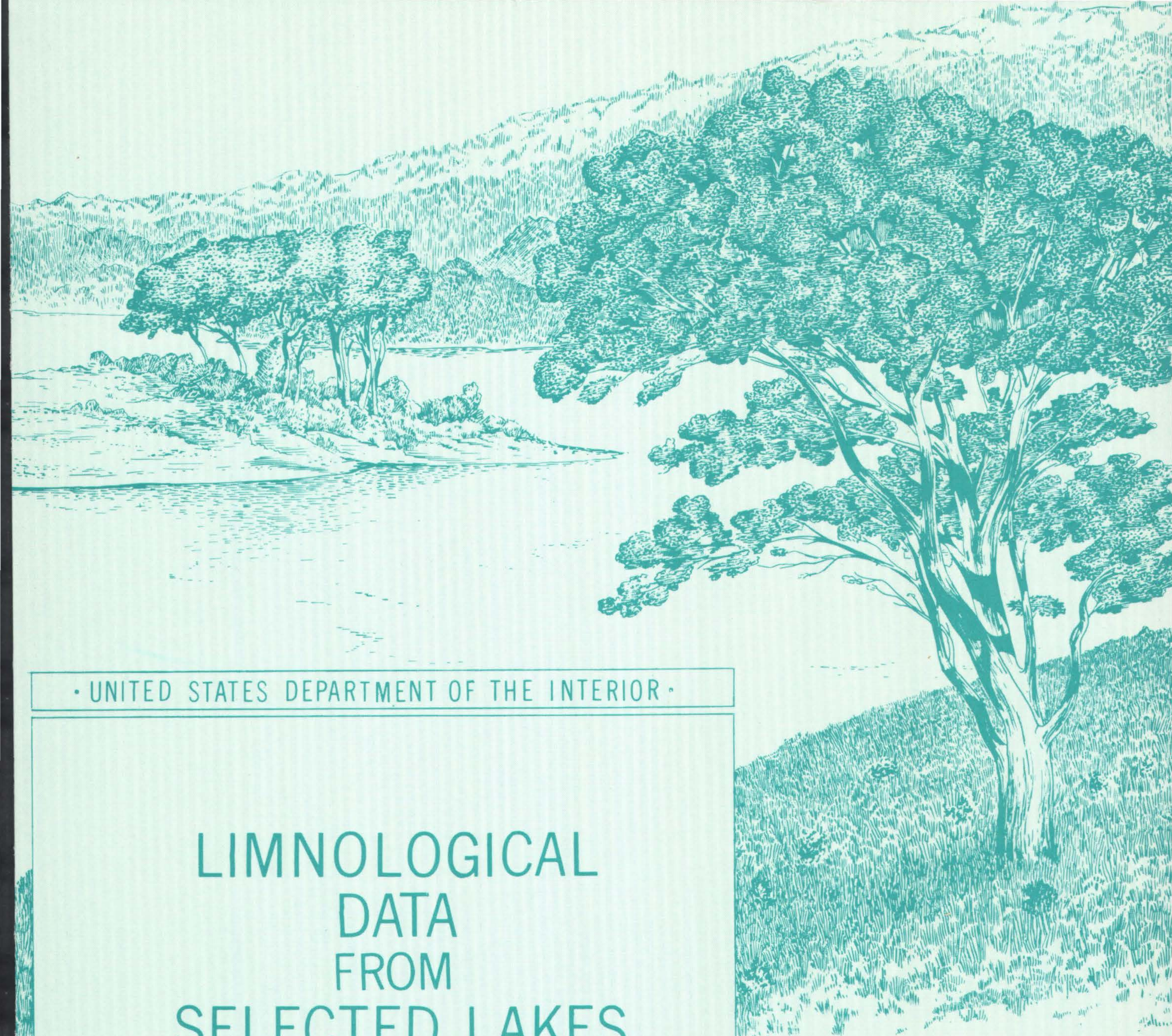

· UNITED STATES DEPARTMENT OF THE INTERIOR ·

LIMNOLOGICAL DATA FROM SELECTED LAKES IN THE SAN FRANCISCO BAY REGION CALIFORNIA

OPEN-FILE REPORT

JOINTLY SUPPORTED BY THE U. S. GEOLOGICAL SURVEY AND THE DEPARTMENT OF HOUSING & URBAN DEVELOPMENT AS PART OF A PROGRAM TO DEVELOP EARTH-SCIENCE INFORMATION IN A FORM APPLICABLE TO LAND-USE PLANNING AND DECISION MAKING

· GEOLOGICAL SURVEY · WATER RESOURCES DIVISION ·

Menlo Park, California
1974

UNITED STATES
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By Linda J. Britton, Rodger F. Ferreira, and Robert C. Averett

Jointly supported by the U.S. Geological Survey and the Department of Housing and Urban Development as part of a program to develop earth-science information in a form applicable to land-use planning and decision making.

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June 25, 1974

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CONVERSION FACTORS

Factors for converting English units to the International System of Units (SI) are given below to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by:*	*Metric (SI)*
acre-ft (acre-foot)	1.234×10^{-3}	hm^3 (cubic hectometre)
ft (foot)	3.048×10^{-1}	m (metre)
in (inch)	2.540	cm (centimetre)
mi (mile, statute)	1.609	km (kilometre)
mi^2 (square mile)	2.590	km^2 (square kilometre)

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ABSTRACT

Limnological data were compiled on 21 lakes in the San Francisco Bay area. The data were obtained from regulating agencies and from recent surveys made by the U.S. Geological Survey. The history of each lake and of its respective regulating agency is presented, along with methods used for data collection and analyses.

The largest reservoir, Lake Berryessa, has a volume of 1,600,000 acre-ft (1,975 hm^3), with a drainage area of 576 mi^2 (1,490 km^2). Pilarcitos Lake is one of the smallest reservoirs, with a volume of 3,100 acre-ft (3.8 hm^3) and a drainage area of 3.80 mi^2 (9.84 km^2). Eleven of the 21 reservoirs are open to the public for recreation. The most intensive shoreline development and use is at Lake Berryessa and Lake Merced. All but three of the 21 reservoirs (not including Upper Crystal Springs Reservoir) were thermally stratified during the summer. Eight of the reservoirs showed evidence of dissolved-oxygen depletion during the summer. Lafayette Reservoir and Loch Lomond are mechanically aerated in order to increase the dissolved-oxygen concentration and lower the surface water temperature. The lake waters ranged from the hard (320 mg/l $CaCO_3$) of Calero Reservoir, to the soft (27 mg/l $CaCO_3$) of Upper Crystal Springs Reservoir. Drainage from abandoned mercury mines in Santa Clara County has resulted in mercury concentrations in Calero and Lexington Reservoir fish which exceed U.S. Food and Drug limitations (0.5 μg/g) for acceptability of mercury in fish used for human food. In Loch Lomond, four major production periods of the blue-green algae, *Anabaena sp*., occurred from May to October, 1967-69. Blue-green algae were the most numerous algae in Lake Del Valle from March through July 1971, with 5,400 blue-green algal organisms per millilitre collected in April.

INTRODUCTION

Early settlers in the San Francisco Bay area probably noticed the paucity of fresh-water lakes. Originally, there were but a few small perennial lakes in the area. These few lakes were, however, supplemented by scattered ephemeral lakes that filled during winter rains, only to become dry by early summer.

As development in the bay area increased, the need for supplemental supplies of water for irrigation and domestic uses became evident. The first major water storage and distribution development was the Hetch Hetchy system. The system was later expanded, and Hetch Hetchy, a Sierra-Nevada reservoir, was enlarged. As the population spread down the peninsula and into the East Bay, local water districts were formed. These districts developed water supplies by impounding small streams and thus forming storage reservoirs. While some of these dams were constructed before the turn of the century (Pilarcitos and San Andreas, for example), most were built later. The dam forming Calaveras Reservoir in Alameda and Santa Clara Counties was built in 1925, while Calero and Coyote Reservoirs, as well as several others, were built in 1935 as part of a multiple reservoir project in the Santa Clara Valley. Recent reservoirs in the bay area include Loch Lomond, formed in 1960, and Lake Del Valle, formed in 1969.

These reservoirs, as well as the resulting water distribution systems, have provided the bay area with numerous sources of relatively high-quality water. Nonetheless, the formation of a reservoir is not without its attendant problems. Reservoirs and lakes act as sinks and depositories for man's wastes and materials from the land. Not only are they continuously filling, but in the process of filling they become enriched with nutrients and organic material and may produce large groups of undesirable primitive organisms, such as the blue-green algae. An abundance of these organisms causes an unsightly appearance to the water, clogs water filters, produces odors, and upon decomposition, may remove much or all of the dissolved oxygen from the deeper waters of lakes and reservoirs. This aging and subsequent enrichment process is collectively called eutrophication.

Accelerated eutrophication, enrichment and filling of lakes that is hastened by man, is just now emerging as a world-wide malady of lakes and reservoirs. The result has been an increased emphasis on measuring the quality of water. In this regard, agencies responsible for the distribution of water and management of lakes and reservoirs, have engaged in extensive and costly water-quality assessment programs. The success of these programs is dependent upon collecting the correct types of data at sufficient frequencies throughout the year.

This report brings together some of the physical, chemical, and biological data collected from 21 San Francisco Bay area lakes and reservoirs. Most of the data were collected and supplied by the agencies responsible for the management of the lakes and reservoirs. In a number of instances, however, data collections were made by personnel of the U.S. Geological Survey.

A circular entitled "An Introduction to the Processes, Problems, and Management of Urban Lakes," (Britton, Averett, and Ferreira, 1974) has been written in conjunction with the present report. It presents basic lake management guidelines and emphasizes the need for consistency and accuracy of sampling techniques. A limnological text is provided to inform urban planners of the properties and processes of lakes and how they affect the water quality. A literature review is also included on equipment and lake survey techniques, and references are cited on how a particular measurement should be made. The reader may wish to refer to this report, in order to obtain a better understanding of the data on the selected lakes in the San Francisco Bay region.

Real-estate lakes, lakes created for particular housing or commercial developments, have been covered in a U.S. Geological Survey circular entitled "Real-Estate Lakes," by Rickert and Spieker (1971). This document should also be consulted by planners and managers engaged in decision-making concerned with real-estate lakes.

PURPOSE AND SCOPE

In 1969, the Geological Survey, together with the U.S. Department of Housing and Urban Development, began an environmental study of the San Francisco Bay area. A part of this study was to assess the water resources of the San Francisco Bay area. This report is concerned with the water quality of selected lakes and reservoirs in the general San Francisco Bay area.

The report is limited to 21 lakes and reservoirs, and includes selected physical (drainage area, volume, surface area, temperature), chemical (dissolved oxygen, major and minor chemical constituents), and biological (phytoplankton and zooplankton) results. The bulk of the findings are from recent surveys. However, when data were available, information from earlier surveys is given.

U.S. GEOLOGICAL SURVEY METHODS

At various depths, temperature, pH, and dissolved-oxygen measurements were made by the Geological Survey approximately 200 ft (60 m) upstream from the dam in each reservoir. In Lake Merced, a natural lake, these measurements were made near the lake center. These sites generally correspond to the deepest part of each body of water. Temperature was measured with a thermister and pH with a meter. Water samples for dissolved-oxygen analyses were collected with a messenger-tripped polyethylene water-sampling bottle, hereafter called a water-sampling bottle. The Alsterberg azide modification of the Winkler method was used for dissolved-oxygen determinations.

Water samples for chemical analyses were collected with a water-sampling bottle near the shore of each lake, at about the 2-ft (0.6-m) depth. The samples were pretreated in the field and analyzed at the Geological Survey Central Chemical laboratory using the methods in Brown, Skougstad, and Fishman (1970).

Surveys were also made at each lake by the respective lake regulating agencies. The methods used in these sample collections are in a "Methods" section following the description of each regulating agency.

RESULTS OF SURVEY

All but one of the lakes included in this report are in the 9-county San Francisco Bay area (fig. 1). Loch Lomond, in Santa Cruz County, is included because of its proximity to San Francisco, and thus heavy recreational use by bay area residents. Lake Merced, the only natural lake in this study, is an emergency water supply which is heavily used for recreation. Nearly all the lakes surveyed are used as domestic water supplies, and many are used for recreation and flood control.

The location, ownership, selected physical features, and various water-quality summations are given in table 1. Individual lake descriptions are given to supplement the table. Since the lakes are presented on an ownership or regulating agency basis, a short discussion of these agencies is included. This includes a methods section, which discusses the collection and analytical techniques employed for those samples and measurements obtained by the respective regulating agencies. The results of all the data collections follow each lake presentation.

An analysis of chemical constituents is included for every lake discussed in this report. The chemical analyses include the following dissolved constituents, with their appropriate units of measurement: mg/l (milligrams per litre) and μg/l (micrograms per litre, which is a thousand times less than mg/l).

B - Boron (μg/l)
HCO_3 - Bicarbonate (mg/l)
Ca - Calcium (mg/l)
CO_3 - Carbonate (mg/l)
Cl - Chloride (mg/l)
F - Fluoride (mg/l)
Fe - Iron (μg/l)
Mg - Magnesium (mg/l)
NO_3 - Nitrate (mg/l)
K - Potassium (mg/l)
SiO_2 - Silica (mg/l)
Na - Sodium (mg/l)
SO_4 - Sulfate (mg/l)

In addition, the following measurements are also included in the report:

Alk. - Alkalinity as $CaCO_3$ (mg/l)

Calc. Solids - Calculated dissolved solids: sum of major constituents plus one-half (actually 0.4917) of the bicarbonate concentration (mg/l)

Hrd. - Hardness as $CaCO_3$; sum of calcium and magnesium concentrations, expressed in terms of $CaCO_3$ (mg/l)

pH - Hydrogen ion concentration (standard units)

Spec. Cond. - Specific conductance (micromhos per centimetre, at 25°C).

An explantation of these measurements is given in Hem (1970); American Public Health Association and others (1971); Iwatsubo, Britton, and Averett (1972); and Feth (1973). The analytical techniques are given in Brown, Skougstad, and Fishman (1970).

Standard limnological symbols from Hutchinson (1957) are used to show the temperature and dissolved-oxygen profiles and to designate the Secchi disk transparency depth. These symbols are:

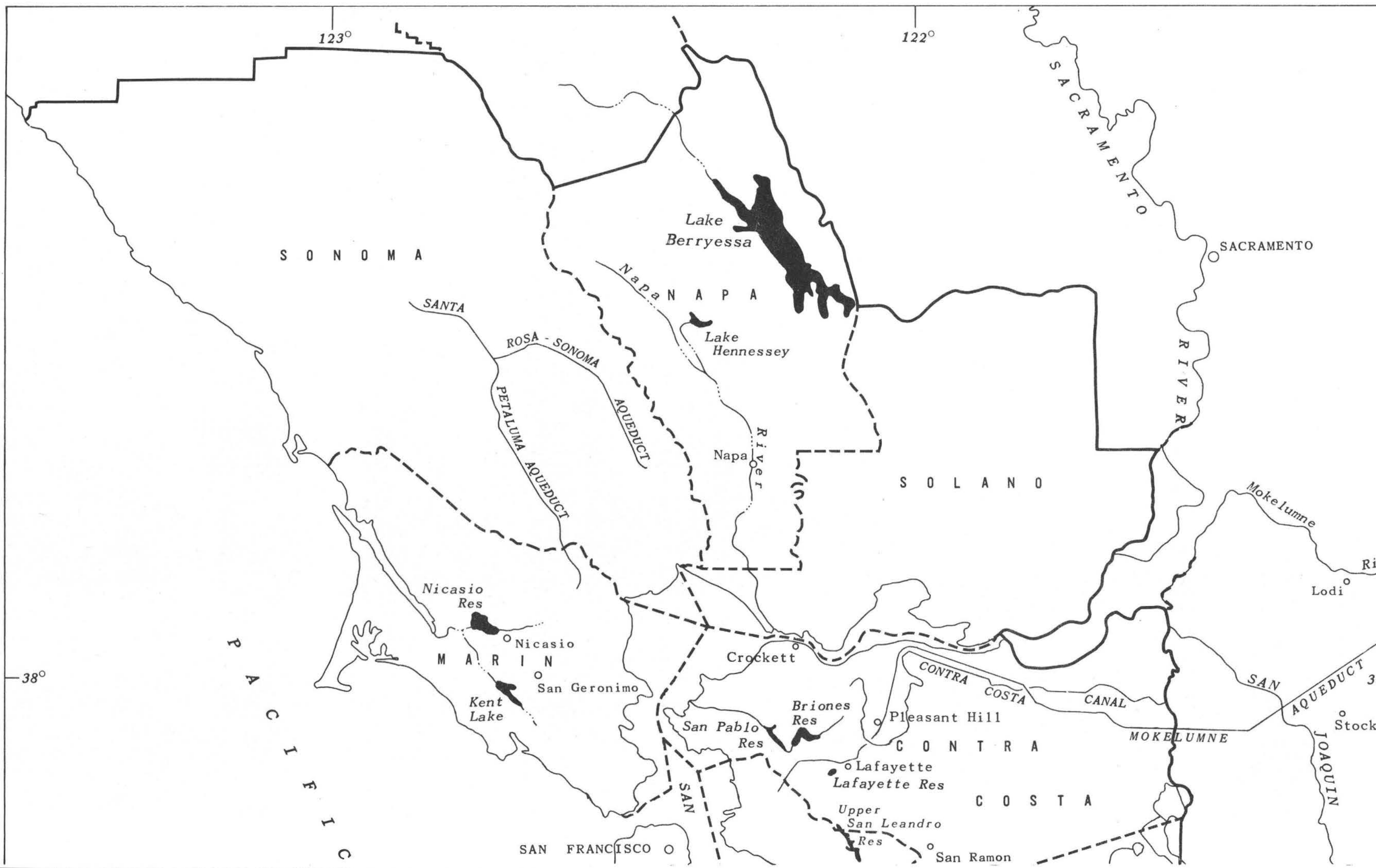
θ = Water temperature, in degrees Celsius (°C)

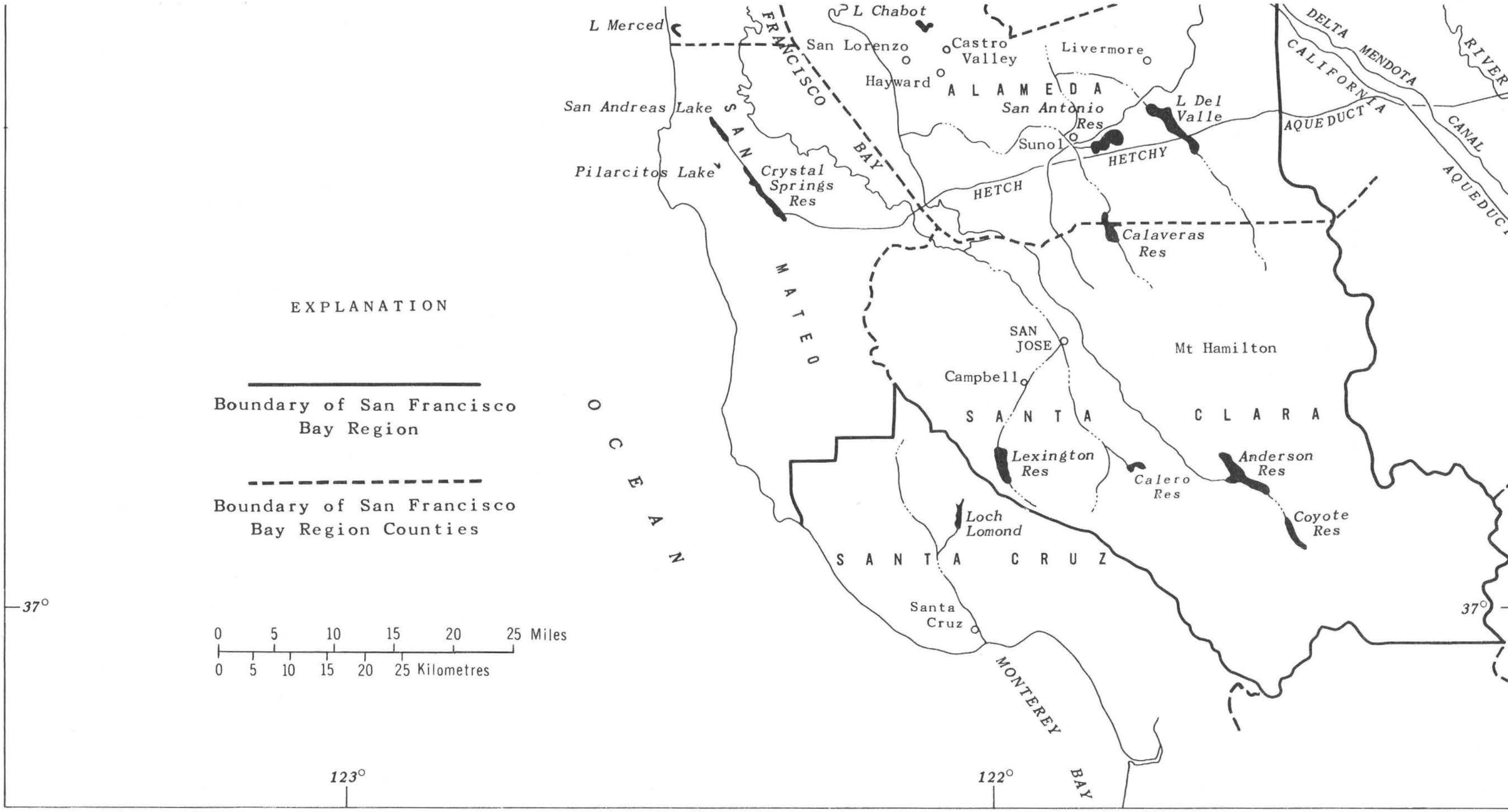
$[O_2]$ = Actual measured dissolved-oxygen concentration in the lake, in milligrams per litre (mg/l)

$[O_2]_S$ = The equilibrium oxygen-solubility concentration, in milligrams per litre, for the given temperature and salinity of the lake water, and adjusted for the atmospheric pressure at the altitude of the lake surface

pH = Hydrogen ion concentration, in standard units

$\underline{Tr}$ = Secchi disk transparency. The underscore refers to the depth of the Secchi disk transparency at the time of the survey.


123°
122°
38°
38°
SONOMA
NAPA
SOLANO
MARIN
CONTRA COSTA
PACIFIC
SACRAMENTO RIVER
SACRAMENTO
Lake Berryessa
Napa
Lake Hennessey
Napa River
Napa
SANTA ROSA - SONOMA AQUEDUCT
PETALUMA AQUEDUCT
Nicasio Res
Nicasio
San Geronimo
Kent Lake
Crockett
CONTRA COSTA CANAL
MOKELUMNE
SAN JOAQUIN AQUEDUCT
SAN JOAQUIN
Mokelumne River
Lodi
Stockton
Briones Res
San Pablo Res
Pleasant Hill
Lafayette
Lafayette Res
Upper San Leandro Res
San Ramon
SAN FRANCISCO
SAN



Base from U.S.Geological Survey
STATE OF CALIFORNIA,1970, 1;500,000

FIGURE 1.--San Francisco Bay area showing general location of lakes.

Table 1.--*Selected physical features of the lakes*

Explanation

Lake name - The lakes are presented in alphabetical order. The lake name may differ from the name of the controlling dam. The official names (from U.S. Geological Survey topographic maps) are cited in the table. Alternate names which have been used for the lake are identified in parentheses.

County - This refers to the name of the county in which the lake lies. Lakes which lie in more than one county are listed in the county in which the greater part of the lake lies.

Owner or regulating agency - The owner or regulating agency of each lake is given using the following abbreviations:

DWR - Department of Water Resources (State of California)
EBMUD - East Bay Municipal Utility District
MMWD - Marin Municipal Water District
NCWD - Napa City Water Department
SFWD - San Francisco Water Department
SCVWD - Santa Clara Valley Water District
SCWD - Santa Cruz Water Department
USBR - United States Bureau of Reclamation

Principal uses - Many lakes are multipurpose systems; that is, their waters are regulated for various uses. The principal uses of the lakes are classified using the following abbreviations:
A - agricultural; D - domestic; FC - flood control; In - industrial; M - municipal; R - recreation (open to public).

Crest height of dam - This is the vertical distance in feet from top of dam to original streambed at downstream position (California Department of Water Resources (1971).

Altitude of water surface - This is the altitude corresponding to the height of the water surface, in feet above mean sea level. However, these are approximations, as the surface altitude of many lakes varies with fluctuations in water volume (Crippen, 1969; Wallace, 1970; and California Department of Water Resources, 1971).

Area of water surface - This refers to the lake surface area at the spillway crest elevation or at maximum operating level (Crippen, 1969; Wallace, 1970; California Department of Water Resources, 1971; or directly from U.S. Geological Survey topographic maps).

Storage capacity - This is the total capacity of the lake at the maximum water-storage elevation (Crippen, 1969; Wallace, 1970; and California Department of Water Resources, 1971--except as indicated on table).

Drainage area - Drainage area includes both the land area that can contribute inflow to the lake and the area of the lake itself (Crippen, 1969; Wallace, 1970; and California Department of Water Resources, 1971).

Principal inflow - This is the stream or diversion facility that normally provides the largest single surface inflow to the lake (Crippen, 1969; California Department of Water Resources, 1971; or from U.S. Geological Survey topographic maps).

Summer thermal stratification - Refers to the presence of a temperature distribution which separates the water into distinct layers (see glossary), characteristic of many lakes during the summer (from data presented in this report, at most recent date).

Surface dissolved-oxygen supersaturation - This refers to the surface dissolved-oxygen concentration of the lake in excess of the equilibrium concentration that the lake water would normally hold at the existing temperature, pressure, and salinity (from data presented in this report, at most recent date). See glossary.

Dissolved-oxgyen depletion - This refers to those lakes having dissolved-oxygen concentrations below 1 mg/l, generally at the bottom (from data presented in this report, at most recent date). See *anaerobic* in glossary.

Description of hardness - This refers to the amount of calcium and magnesium, expressed as calcium carbonate, present in the lake water (from data presented in this report, at most recent date). Water hardness is classified into the following categories in milligrams per litre of $CaCO_3$: Soft (0-60), Moderately hard (61-120), Hard (121-180), and Very hard (>180). The terms "hard" and "soft" originated to describe water types from a domestic use standpoint. Hard water generally requires considerable quantities of soap to produce a foam or lather. Classification is according to Durfor and Becker (1964).

Table 1.--*Selected physical*

Lake name	County	Owner or regulating agency	Principal uses	Crest height of dam (ft)	Altitude of water surface (ft above mean sea level)	Area of water surface (mi^2)
Anderson Reservoir	Santa Clara	SCVWD	D,FC,M,R	235	625	1.53
Berryessa, Lake	Napa	USBR	A,In,M,R	271	440	32.4
Briones Reservoir	Contra Costa	EBMUD	D,M	273	575	1.14
Calaveras Reservoir	Santa Clara	SFWD	D,M	210	750	2.26
Calero Reservoir	Santa Clara	SCVWD	FC	90	480	.52
Chabot, Lake	Alameda	EBMUD	D,M,R	135	235	.49
Coyote Reservoir	Santa Clara	SCVWD	D,FC,M,R	140	775	1.08
Crystal Springs Reservoir	San Mateo	SFWD	D,M	140	280	1.84
Del Valle, Lake	Alameda	DWR	FC,R	222	750	1.12
Hennessey, Lake	Napa	NCWD	D,M,R	125	315	1.36
Kent Lake	Marin	MMWD	D,M	188	355	.41
Lafayette Reservoir	Contra Costa	EBMUD	D,M,R	132	450	.78
Lexington Reservoir	Santa Clara	SCVWD	D,FC,M,R	205	645	.70
Loch Lomond[1] (Newell Reservoir)	Santa Cruz	SCWD	D,M,R	182	590	.27
Merced, Lake	San Francisco	SFWD	R		21	.57
Nicasio Reservoir	Marin	MMWD	D,M	115	165	1.32
Pilarcitos Lake	San Mateo	SFWD	D,M	103	700	.17
San Andreas Lake	San Mateo	SFWD	D,M	107	450	.86
San Antonio Reservoir	Alameda	SFWD	D,M	193	470	1.29
San Pablo Reservoir	Contra Costa	EBMUD	D,M,R	170	840	1.34
Upper San Leandro Reservoir	Alameda	EBMUD	D,M	190	460	1.23

[1]Not within 9-county San Francisco Bay area.

[2]From City and County of San Francisco (1967).

Storage capacity (acre-ft)	Drainage area (mi^2)	Principal inflow	Summer thermal stratification	Surface dissolved oxygen supersaturation	Dissolved oxygen depletion	Description of hardness
91,300	193	Coyote Creek	Yes	No	No	Hard
1,600,000	576	Putah Creek	Yes	No	No	Hard
67,500	8.60	Bear Creek	Yes	No	Yes	Mod. hard
100,000	98.6	Calaveras Creek	Yes	No	No	Mod. hard
9,300	7.10	Calero Creek	Yes	No	Yes	Very hard
12,600	43.0	San Leandro Creek	Yes	Yes	Yes	Hard
24,500	116	Coyote Creek	Yes	Yes	No	Very hard
[2]69,500	29.8	Hetch Hetchy Aqueduct	Yes-lower No-upper	No	No	Soft
77,100	149	Arroyo Valle	Yes	No	No	Hard
30,000	52.3	Conn, Chiles, Sage Creeks	Yes	No	Yes	Mod. hard
16,500	22.0	Lagunitas Creek	Yes	No	No	Mod. hard
3,500	1.40	Lafayette Creek				Hard
21,430	38.0	Los Gatos Creek	Yes	Yes	No	Very hard
8,400	8.30	Newell Creek	Yes	Yes	Yes	Very hard
[2]7,870	8.0	None	No	No-north Yes-south	No	Very hard-north Hard-south
22,500	36.0	Nicasio Creek	No	No	No	Mod. hard
3,100	3.80	Runoff from coastal mountains	Yes	No	Yes	Mod. hard
18,500	4.40	Several small creeks	No	Yes	No	Soft
50,500	40.0	San Antonio Creek	Yes	Yes	No	Hard
43,193	32.0	San Pablo Creek	Yes	No	Yes	Soft
41,436	31.0	San Leandro Creek	Yes	No	Yes	Mod. hard

LAKE OWNED BY CALIFORNIA DEPARTMENT OF WATER RESOURCES

The California Department of Water Resources has as its primary goal the protection and conservation of the water resources of California and the development of plans and projects for meeting California's water needs. In an effort to meet these needs, the Department also supports studies in wastewater reclamation, desalting, and weather modification. An additional responsibility is to provide for public safety, in relation to suitability of water from a public health standpoint, and for flood control. The Department thus acts as the State's water-quality data collection agency. Lake Del Valle in Alameda County is a facility of the State Water Project, and is the single Department of Water Resources reservoir included in this report.

Methods

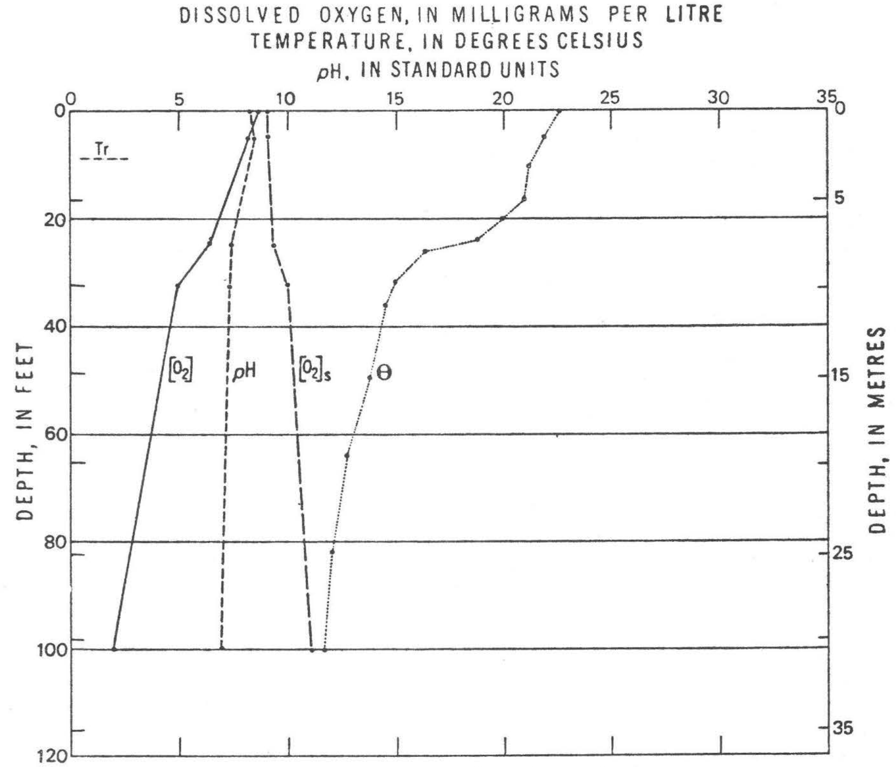
All physical and chemical measurements in Lake Del Valle were made by personnel of the Geological Survey. Temperature, pH, and dissolved-oxygen measurements were made approximately 200 ft (60 m) upstream from the dam. A water sample for chemical analysis was collected with a water-sampling bottle near the northeast shore, at the 2-ft (0.6-m) depth.

Water samples for phytoplankton analyses were collected and analyzed by personnel of the California Department of Water Resources. The samples were collected with a water-sampling bottle at selected depths near the dam. The samples from each depth were treated with a preservative in the field. In the laboratory, a well-mixed aliquot was removed from each sample and placed in a counting chamber having a capacity of 3.3 millilitres. The sample was allowed to settle and identification and counts of phytoplankton were made using an inverted microscope. The counts were expressed as phytoplankton organisms per millilitre.

Lake Del Valle

Lake Del Valle was formed in 1969 when a dam was built on Arroyo Valle, below Livermore, Calif. The primary use of Lake Del Valle water is regulation of aqueduct flows. Other uses include storage for flood control and the conservation of upstream runoff. Whereas the reservoir is owned by the California Department of Water Resources, it is managed by the East Bay Regional Parks Department for recreational use. The reservoir is occasionally planted with rainbow trout (*Salmo gairdneri*) by the California Department of Fish and Game. Waste discharges to surface waters in the watershed are prohibited.

On July 1, 1970, Lake Del Valle was thermally stratified (fig. 2). The dissolved-oxygen concentration steadily decreased with depth throughout the water column, and at the 100-ft (30-m) depth was only 2 mg/l. The under-saturation (below equilibrium concentration) of dissolved oxygen at all depths, as well as a decreasing pH with depth, indicated intense respiratory activity by bacteria and algae, at low light levels.



(See page 5 for explanation of symbols.)

FIGURE 2.--Temperature, dissolved-oxygen, and pH profiles of Lake Del Valle, July 1, 1970.

The results of a chemical analysis from a sample collected on September 9, 1972, showed a relatively high specific conductance value of 423 micromhos, and a calculated dissolved-solids concentration of 240 mg/l (table 2).

Figure 3 compares the numbers of blue-green algae, green algae, and diatoms in Lake Del Valle from March 1971 to February 1972. Blue-green algae were dominant in March through July. The increase of blue-green numbers in April resulted from a bloom of *Aphanizomenon sp.* Diatoms were dominant in the November and February samples when the blue-green algae were absent. Green algae were found in each sampling period, but not at all depths. They were found in greatest numbers in August, when the diatoms and blue-green algae were absent. The green alga, *Scenedesmus sp.* was common in late July, when blue-green algae were decreasing. Other commonly occurring green algae were *Schroederia sp.* and *Selenastrum sp.*

Table 2.--*Chemical analysis of a water sample from California Department of Water Resources lake*

LAKE DEL VALLE

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972 19...	7.2	30	35	17	26	2.3	162	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept. 19...	133	48	27	0.2	0.00	210	240	160	423	8.2

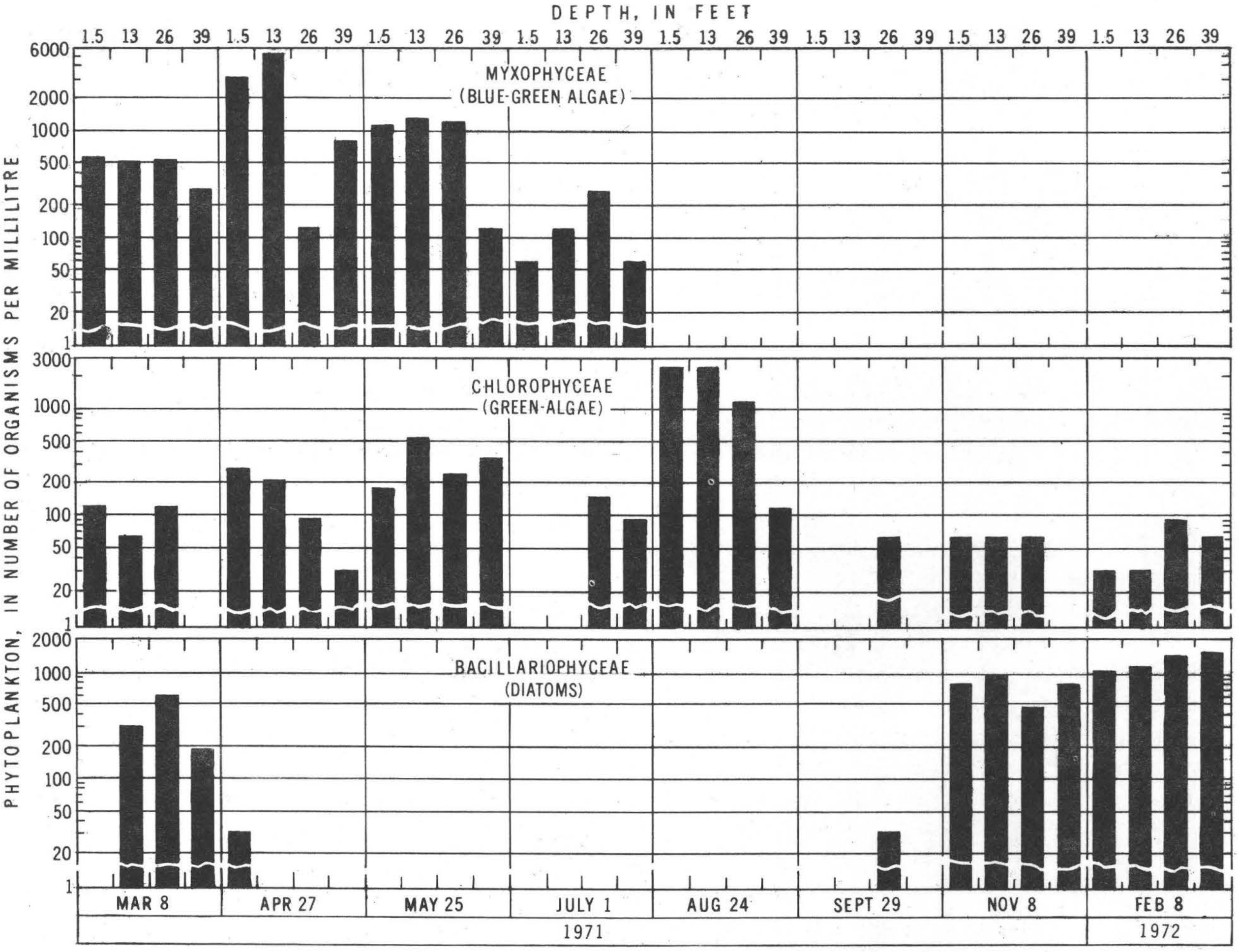


FIGURE 3.--A comparison of the concentrations of the major groups of phytoplankton in Lake Del Valle.

LAKES OWNED BY EAST BAY MUNICIPAL UTILITY DISTRICT

The East Bay Municipal Utility District was formed in 1923. The greatest source of water for this District comes from the Pardee and Camanche Reservoirs (not included in report) in the Sierra Nevada. The water from these reservoirs is piped to the five local reservoirs of Briones, Chabot, Lafayette, San Pablo, and Upper San Leandro in the San Francisco Bay area. The combined watershed area of all East Bay Municipal Utility District reservoirs is 85.2 mi^2 (220.7 km^2), with a total combined storage capacity of 798,000 acre-ft (985 hm^3).

Approximately 85 percent of the water obtained by the East Bay Municipal Utility District has its source in the watershed of the Mokelumne River, which is fed by snowmelt from the Sierra Nevada in Alpine, Amador, and Calaveras Counties. The water is first collected in Pardee Reservoir, which is 38 mi (61 km) northeast of Stockton. Camanche Reservoir, 10 mi (16 km) downriver from Pardee Reservoir, provides storage to meet the needs of other holders of Mokelumne River rights in the Lodi area. This reservoir enables the full allotment of water (about 100 acre-ft [0.12 hm^3] per day) from Pardee Reservoir to be transported through three aqueducts to the East Bay. This water is then either immediately filtered and distributed to District customers, or placed in the local terminal reservoirs (listed above) for storage. The remaining water is obtained from local runoff of East Bay watershed lands.

The East Bay Municipal Utility District serves 1.1 million people in 15 cities and surrounding areas. This service area encompasses 280 mi^2 (725 km^2) and extends from Crockett and Richmond, southward to San Lorenzo, Hayward, and San Ramon Valley. Eastward the area extends from San Francisco Bay to Pleasant Hill. All watershed lands owned by the utility district are open to the public for limited use. Chabot, Lafayette, and San Pablo Reservoirs have developed recreation areas and are open for fishing and boating, but body contact recreation is prohibited. Developed recreational areas are proposed for Briones and Upper San Leandro Reservoirs.

Methods

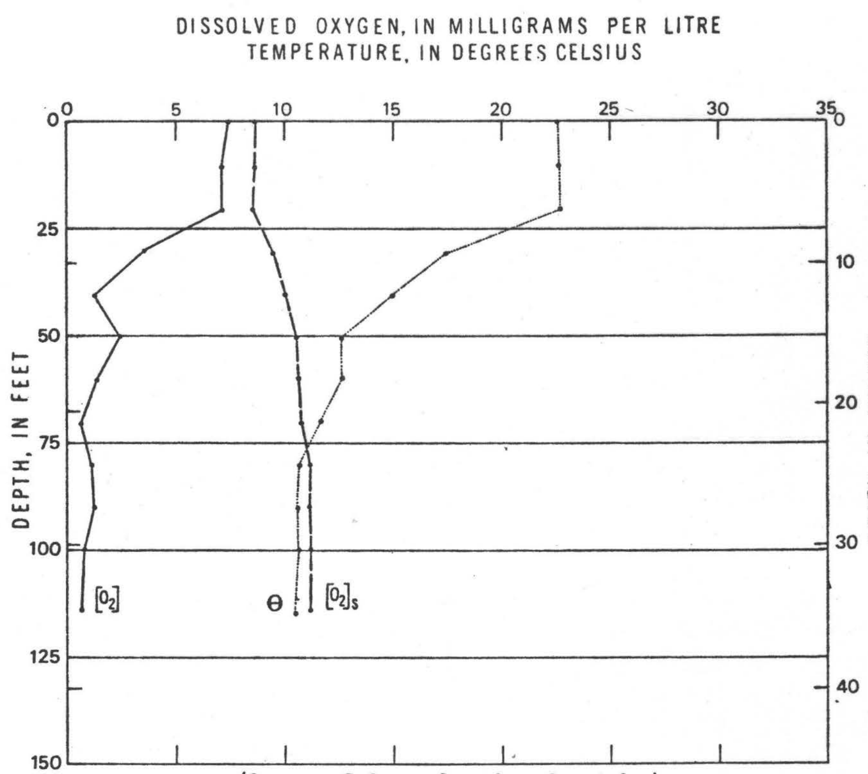
Temperature and dissolved-oxygen measurements were made by personnel of the East Bay Municipal Utility District. These measurements were frequently made at the surface and bottom, near the outlet tower in each reservoir. Thermal and dissolved-oxygen measurements were made at several depth intervals during the summer to determine the extent of stratification. Temperature measurements were made with a thermister, and water samples for dissolved-oxygen analyses were collected with a water-sampling bottle. The Alsterberg azide modification of the Winkler method was used for dissolved-oxygen determinations.

All water samples for chemical analyses obtained from the reservoirs were collected by personnel of the Geological Survey. These samples were collected near shore, by each dam, at the 2-ft (0.6-m) depth.

Briones Reservoir

Briones Reservoir was formed in 1964 by the completion of an earthfill dam across Bear Creek. Briones is the newest and largest of the East Bay Municipal Utility District reservoirs, having a storage capacity of 67,500 acre-ft (83.3 hm^3), and draining a watershed area of 8.60 mi^2 (22 km^2). The reservoir and its watershed are scheduled to be developed for recreation by the late 1970's (East Bay Municipal Utility District, Board of Directors, 1970). Recreational uses of the reservoir will be primarily boating and fishing.

Briones Reservoir was thermally stratified on July 22, 1968, with a metalimnion between the 20- and 80-ft (6- and 24-m) depths (fig. 4). The dissolved-oxygen concentration was undersaturated at all depths, with the water being virtually devoid of oxygen below the 70-ft (21-m) depth. Mean monthly surface- and bottom-temperature differences and dissolved-oxygen values for Briones Reservoir are in figure 5. The reservoir was thermally stratified from April through October. During the spring, summer, and autumn months, thermal density differences in the water prevented the replenishment of dissolved oxygen, and it became depleted in the bottom waters from July through November. As the water became homothermous in December and January 1969, the dissolved oxygen increased from 2 mg/l to 8 mg/l in the bottom water.



(See page 5 for explanation of symbols.)

FIGURE 4.--Temperature and dissolved-oxygen profiles of Briones Reservoir, July 22, 1968.

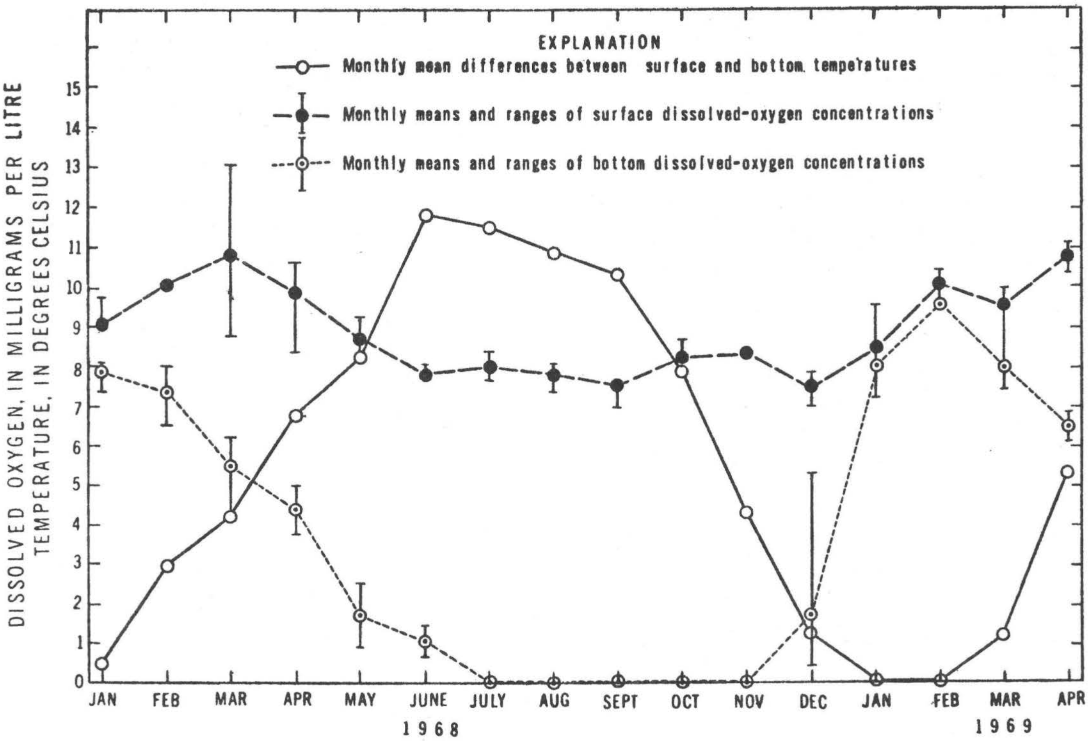


FIGURE 5.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of Briones Reservoir, 1968-69.

The results of a chemical analysis of water collected from Briones Reservoir are shown in table 3. The calculated dissolved-solids content was 150 mg/l and the specific conductance was 265 micromhos.

Lake Chabot

In 1875, an earthfill dam was constructed across San Leandro Creek to form Lake Chabot. The reservoir drains a watershed area of 43.0 mi^2 (111 km^2) and has a storage capacity of 12,600 acre-ft (15.5 hm^3). Whereas Lake Chabot is owned by the East Bay Municipal Utility District, its surrounding watershed lands are managed by the East Bay Regional Park District for boating, fishing, picnicking, and hiking. The lake contains several species of game fish.

Lake Chabot was thermally stratified on July 2, 1969, with a metalimnion between the 15- and 30-ft (4.6- and 9-m) depths (fig. 6). Above the 10-ft (3-m) depth, the dissolved oxygen was slightly supersaturated (above equilibrium concentration). However, below the 10-ft (3-m) depth, undersaturation of dissolved oxygen was apparent, and the concentration dropped to zero at the 30-ft (9-m) depth. Mean monthly surface and bottom temperature differences and dissolved-oxygen values for Lake Chabot are in figure 7. Homothermous conditions existed in January and February. Thermal stratification began in about April and continued through October, with the bottom water in the reservoir being devoid of oxygen from June through November. As the mean temperature differences between the surface and the bottom waters decreased in the autumn, the waters began to mix again, thus replenishing the oxygen supply in the hypolimnion.

The results of a chemical analysis for Lake Chabot water are shown in table 3. The dissolved-solids concentration of 230 mg/l was the highest among the East Bay Municipal lakes. The lake water would be considered hard due to the hardness concentration of 160 mg/l.

Table 3.--*Chemical analyses of water samples from East Bay Municipal Utility District reservoirs*

BRIONES RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
05...	0.7	30	26	7.1	15	2.2	91	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept., 1972										
05...	75	48	7.6	0.3	0.00	90	150	94	265	7.9

LAKE CHABOT

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
06...	1.3	10	37	17	23	2.0	176	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept.										
06...	144	48	20	0.3	0.00	130	230	160	416	8.3

Table 3.--*Chemical analyses of water samples from East Bay Municipal Utility District reservoirs*--Continued

LAFAYETTE RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
06...	3.0	10	30	13	16	2.0	166	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept.										
06...	136	12	10	0.4	0.00	100	170	130	306	8.3

SAN PABLO RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
05...	6.9	40	14	3.0	5.9	0.8	49	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept.										
05...	40	7.8	5.6	0.2	0.00	30	68	47	111	7.8

UPPER SAN LEANDRO RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
05...	1.7	30	24	7.3	11	1.3	97	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept.										
05...	80	17	8.4	0.4	0.00	80	120	90	212	7.9

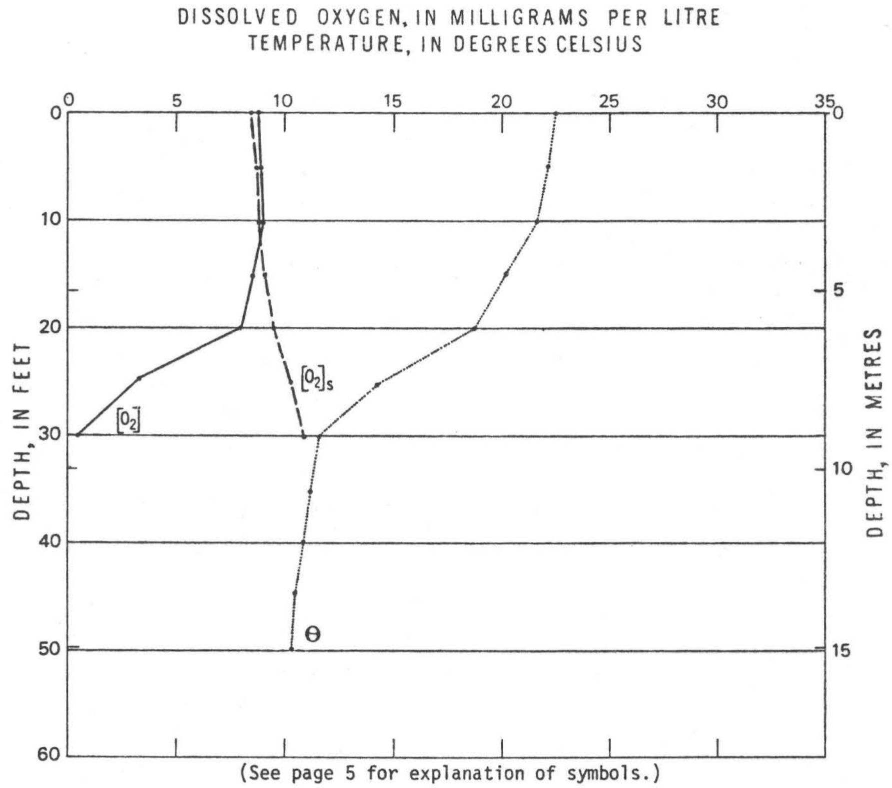


FIGURE 6.--Temperature and dissolved-oxygen profiles of Lake Chabot, July 2, 1969.

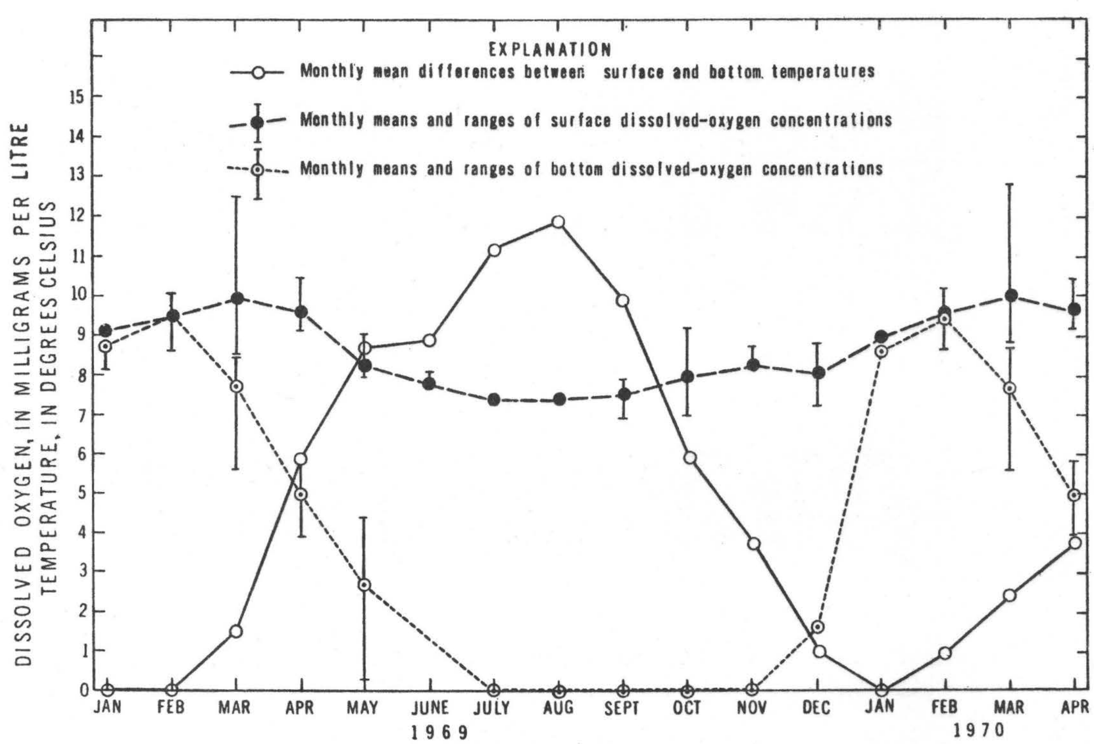


FIGURE 7.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of Lake Chabot, 1969-70.

Lafayette Reservoir

Lafayette Reservoir is within the city of Lafayette. The reservoir, formed in 1928, is the smallest in the East Bay Municipal Utility District, with a capacity of 3,500 acre-ft (4.3 hm^3) and a surface area of 0.78 mi^2 (2.0 km^2). Its drainage area is only 1.40 mi^2 (3.6 km^2). While the main purpose of Lafayette Reservoir is for storage and distribution of water for domestic and municipal use, it was opened to the public in 1966 for row-boating, bank fishing, picnicking, and hiking.

The 1967 monthly mean temperature differences between the surface and the bottom waters indicated that Lafayette Reservoir was thermally stratified from May through October (fig. 8). The mean dissolved-oxygen concentration at the surface decreased slightly during the summer. In the bottom water, the mean dissolved-oxygen concentration was zero from June through November. Surface water cooling during the autumn months caused mixing of the surface and bottom water, resulting in increased oxygen levels near the lake bottom. In 1969, an aeration program began at Lafayette Reservoir to eliminate anaerobic conditions in the hypolimnetic waters during the summer and fall months. The effects of aeration greatly reduced the differences between the surface and bottom temperatures and dissolved-oxygen concentrations (fig. 9).

The concentrations of chemical constituents in Lafayette Reservoir are shown in table 3.

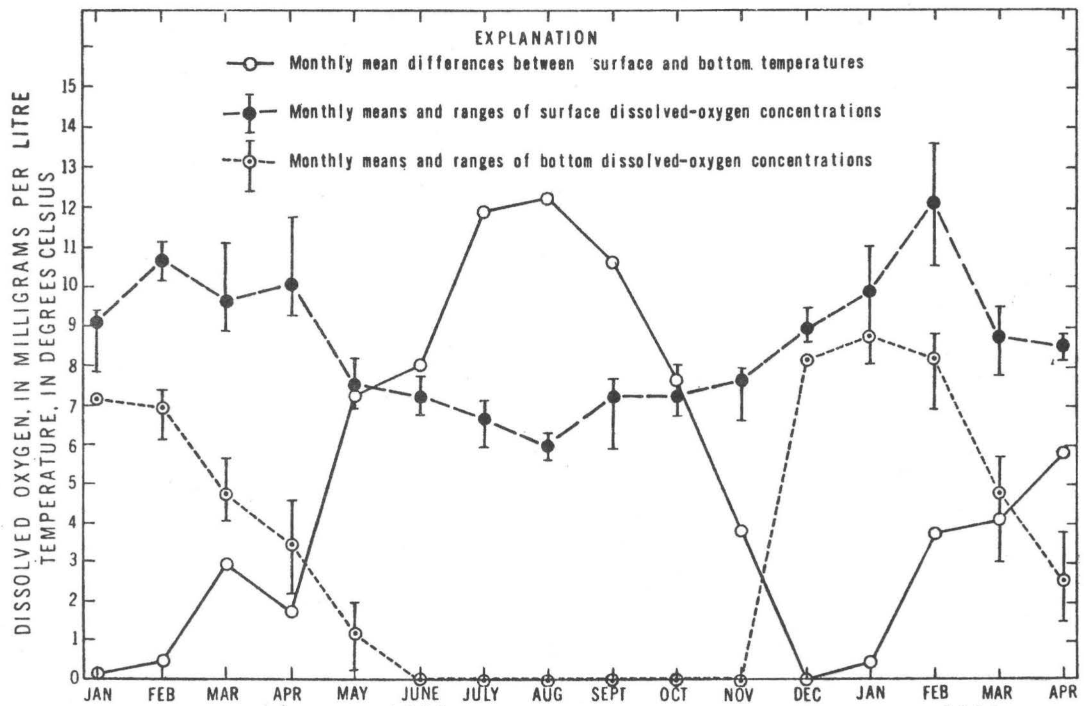


FIGURE 8.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of Lafayette Reservoir, 1967-68.

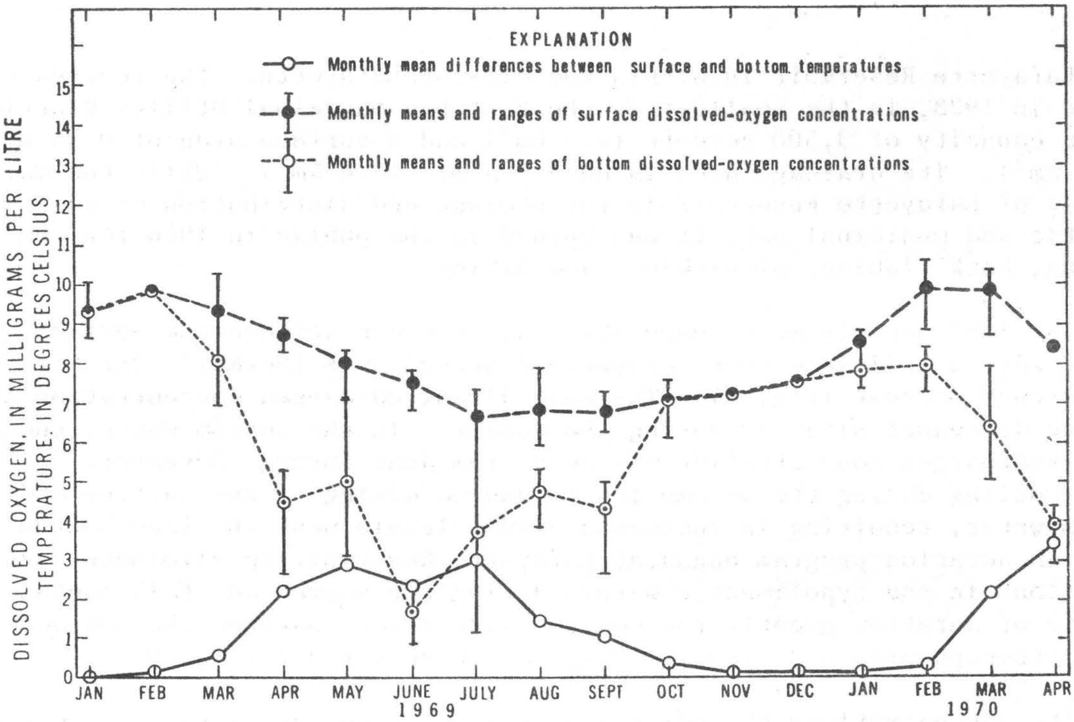


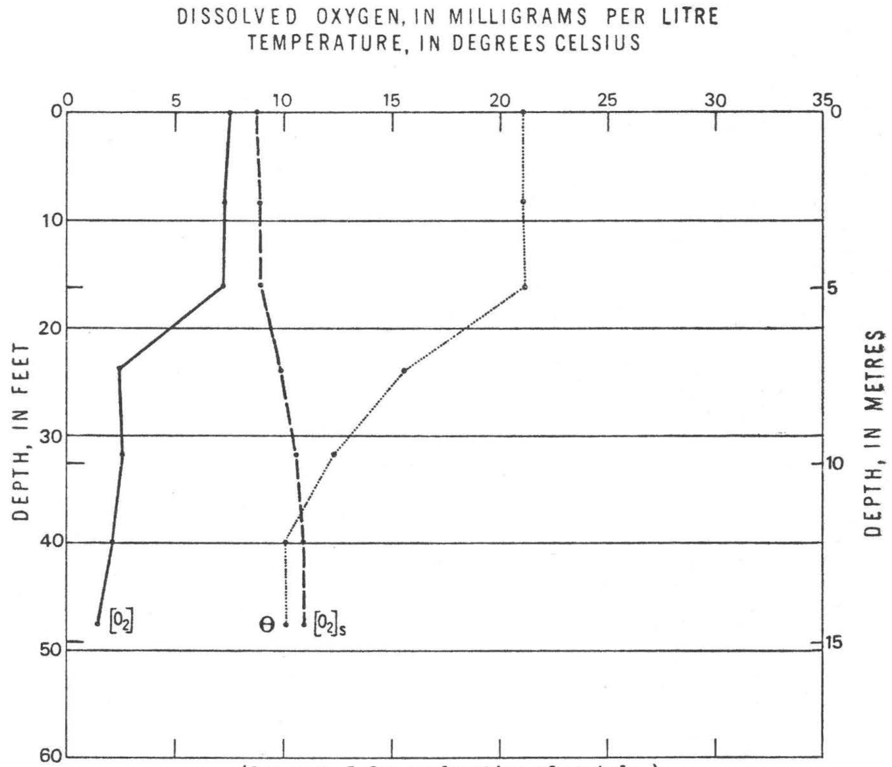
FIGURE 9.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of Lafayette Reservoir, 1969-70.

San Pablo Reservoir

San Pablo Reservoir was formed in 1919 by the completion of an earthfill dam across San Pablo Creek. The reservoir drains a watershed area of 32.0 mi^2 (83 km^2), has a capacity of 43,193 acre-ft (53.3 hm^3), and a surface area of 1.34 mi^2 (3.5 km^2). The reservoir and the surrounding lands are open to the public for fishing, boating, picnicking, and hiking.

On August 27, 1969, San Pablo Reservoir was thermally stratified with a metalimnion between the 20- and 40-ft (6- and 12-m) depths (fig. 10). The dissolved oxygen was undersaturated at all depths. The monthly mean differences between surface and bottom water temperatures in 1969 (fig. 11) showed that maximum stratification occurred during August. The mean dissolved-oxygen concentration in the bottom waters steadily dropped from a high of 10.2 mg/l in January 1969 to zero in September, October, and November.

The results of a chemical analyses for San Pablo Reservoir showed that the water had a hardness value of 47 mg/l $CaCO_3$ (table 3). Such waters are considered to be soft (Hem, 1970, p. 225).



(See page 5 for explanation of symbols.)

FIGURE 10.--Temperature and dissolved-oxygen profiles of San Pablo Reservoir, August 27, 1969.

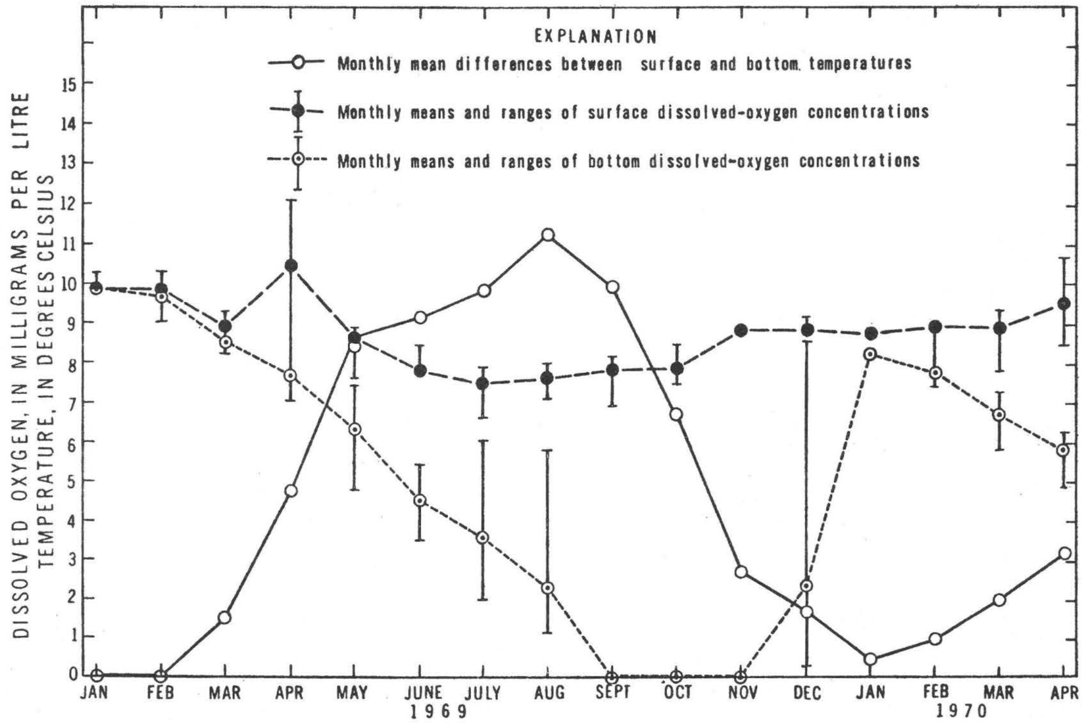


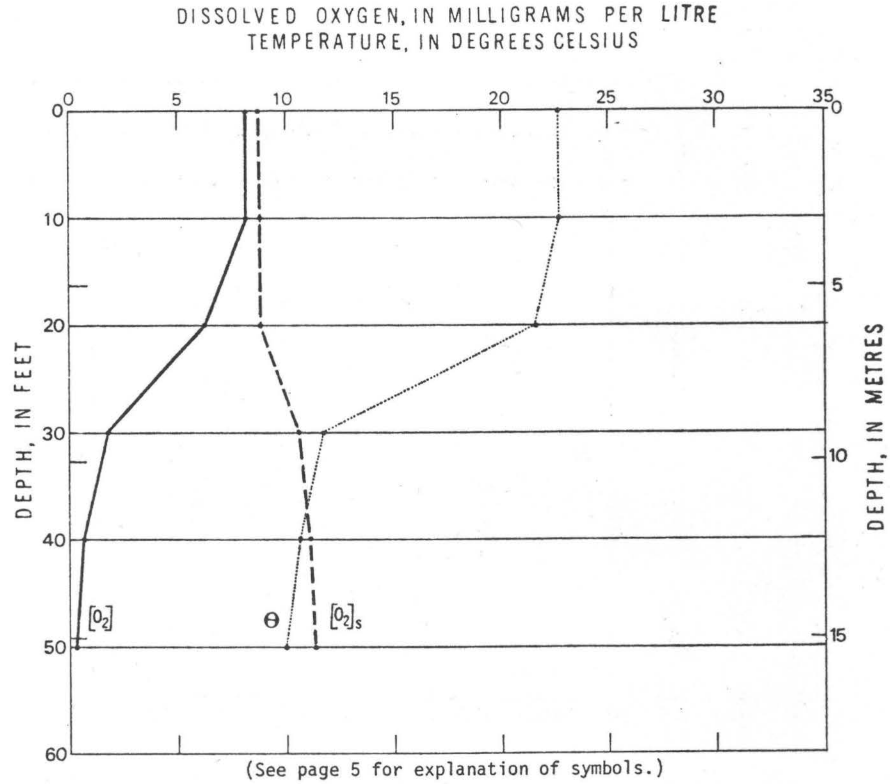
FIGURE 11.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of San Pablo Reservoir, 1969-70.

Upper San Leandro Reservoir

In 1926, a dam was built across San Leandro Creek to form Upper San Leandro Reservoir. The reservoir collects the runoff from a watershed area of 31.0 mi^2 (80 km^2), has a storage capacity of 41,436 acre-ft (51 hm^3) and a water surface area of 1.23 mi^2 (3.19 km^2). Most of the watershed is in a management preserve area and is classified by the East Bay Municipal Utility District as ranchland. Developed and primitive recreation areas are located at the end of the reservoir arms, along several shore areas, and along several tributaries. The reservoir is closed to fishing and boating.

Thermal stratification of the reservoir was evident at the time of the August survey (fig. 12). A well-defined metalimnion was present between the 20- and 30-ft (6- and 9-m) depths. The dissolved oxygen was undersaturated at all depths, with the concentration dropping from a high of 8.1 mg/l at the surface to nearly zero at the 40-ft (12-m) depth. Monthly temperature differences and dissolved-oxygen concentrations in the surface and bottom water in 1969-70 are shown in figure 13. In January and February 1969, the mean dissolved-oxygen concentrations at the surface and bottom were uniform and moderately high. In the bottom water, the dissolved-oxygen concentration steadily decreased from February to July, and became anaerobic from July through December.

The results of a chemical analysis for Upper San Leandro Reservoir are shown in table 3.



(See page 5 for explanation of symbols.)

FIGURE 12.--Temperature and dissolved-oxygen profiles of Upper San Leandro Reservoir, August 21, 1969.

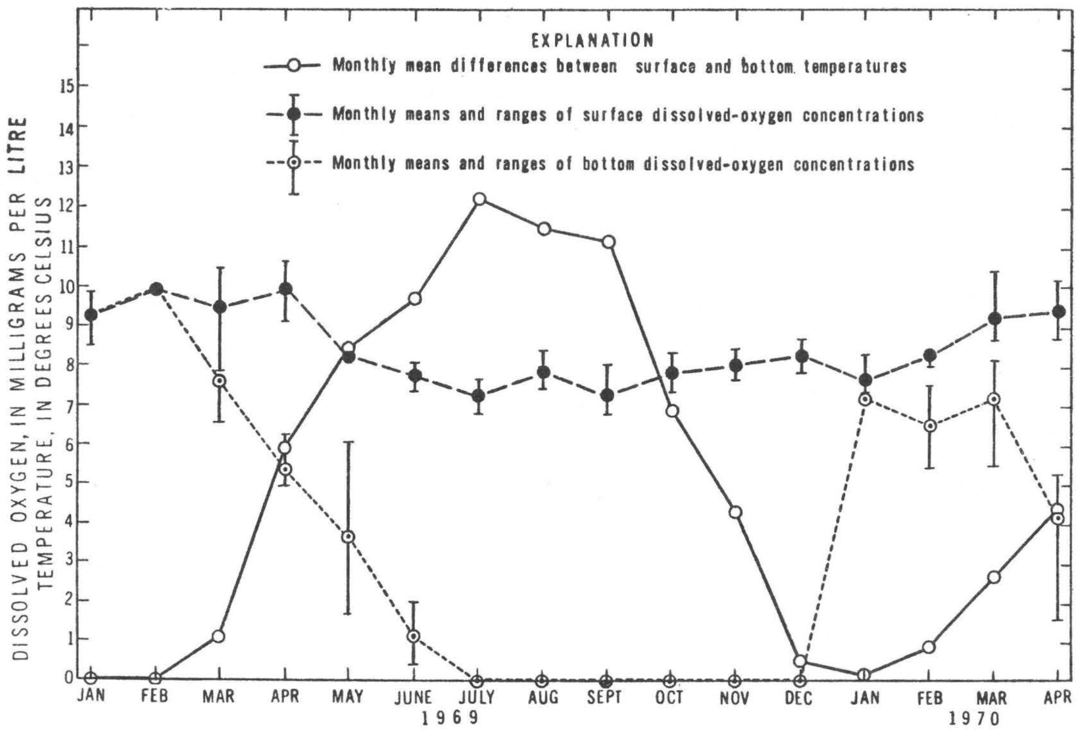


FIGURE 13.--Surface and bottom dissolved-oxygen concentrations and monthly mean differences between surface and bottom temperatures of Upper San Leandro Reservoir, 1969-70.

LAKES OWNED BY MARIN MUNICIPAL WATER DISTRICT

The Marin Municipal Water District was formed in 1912. Presently it serves an area of 140 mi^2 (363 km^2) within Marin County, with an estimated customer service of 167,000. The water district's major objectives are to provide an adequate and high quality water supply and to preserve and enhance its watershed lands for outdoor recreation. The water supply for the Marin District is derived from rainfall and local runoff, which is stored in five reservoirs. These reservoirs are Kent, Nicasio, Bon Tempe, Lagunitas, and Alpine. The combined storage capacity of the five reservoirs is 52,680 acre-ft (65 hm^3). Kent and Nicasio are the reservoirs of the Marin Municipal Water District which are discussed in this report. District watershed property is open for public use and the lakes are open to fishing, but motor boats are prohibited.

Methods

The 1970 temperature and dissolved-oxygen measurements were made by the Geological Survey near the dams of each reservoir. The 1971 and 1972 temperature and dissolved-oxygen measurements were made by personnel of the Marin Municipal Water District, near the dams of the two reservoirs. Temperature was measured with a thermister, and dissolved oxygen with a meter and probe. Phytoplankton samples were collected by personnel of the Marin Municipal Water District with a water-sampling bottle at depths of 1, 5, and 10 ft (0.3, 1.5, and 3 m). Samples were collected at one site near the dam at Kent Lake, and at one site near the dam and at two sites north of the dam in Nicasio Reservoir. A 100-ml aliquot from each depth and site was composited, and the 300-ml subsample was filtered through a 1.2-micrometre filter. Further subsampling was carried out, ultimately resulting in the removal of a 1-ml aliquot which was placed in a Sedgwick-Rafter counting cell, for phytoplankton identification and enumeration. The counts were then calculated on the basis of organisms per 100 millilitres of water. For the filamentous forms of algae, an organism was arbitrarily assumed to be equivalent to a 100-micrometre length.

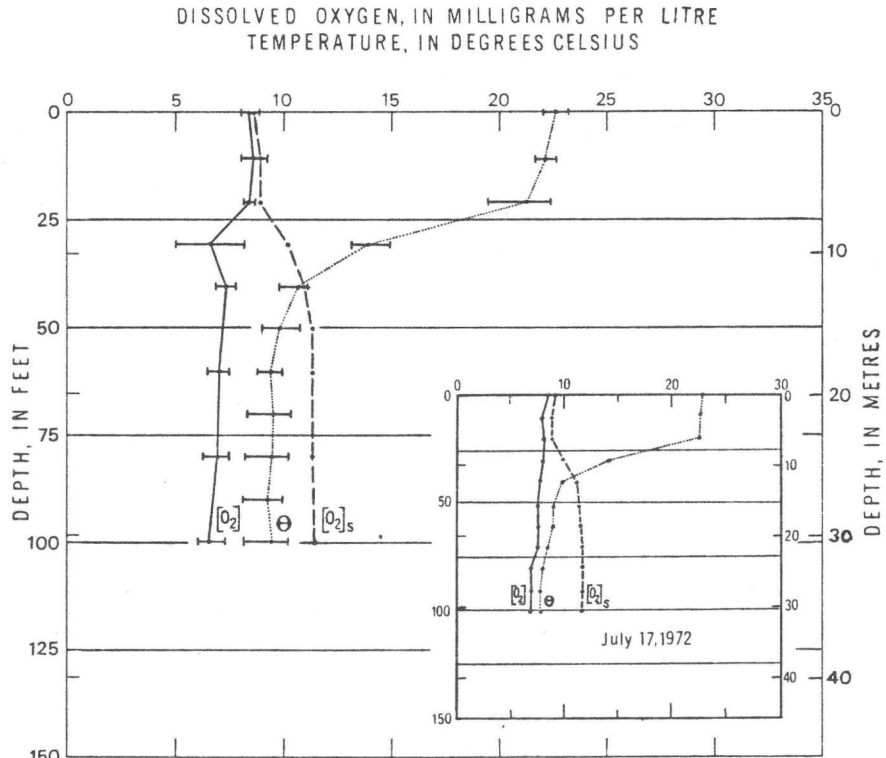
Water samples for chemical analyses were collected near the dam, at a depth of about 2 ft (0.6 m) by personnel of the Geological Survey.

Kent Lake

Kent Lake is in Marin County near the town of San Geronimo. The lake's only source of water is runoff from its watershed area of 22.0 mi^2 (57 km^2). The watershed contains picnic areas and hiking trails. Although the lands surrounding this lake are open to the public, strict regulations protect the watershed from disturbances, thus preserving its role as a water-storage area.

Sufficient data were available to provide a range of temperature and dissolved-oxygen values at selected depths for the summers of 1970, 1971, and 1972 (fig. 14). Kent Lake was thermally stratified during the summer sampling periods. The greatest range in dissolved oxygen was at the 30-ft (9-m) depth, where a dissolved-oxygen minimum was present. This minimum dissolved-oxygen concentration probably resulted from decomposing organic material falling through the water mass and being suspended by a density barrier at the 30-ft (9-m) depth (Hutchinson, 1957, p. 621). Nonetheless, the presence of a dissolved-oxygen minimum is a relatively unusual condition in lakes. Another cause may be the morphometry of the lake basin which may cause horizontal water movements in the metalimnion and hypolimnion of stratified lakes, affecting the circulation pattern of dissolved constituents (Hutchinson, 1957, p. 625). The single profile on July 17, 1972, is shown in the inset. The single summer profile is typical of the mean summer profile.

The concentrations of the chemical constituents analyzed on August 8, 1972, showed a relatively low calculated dissolved-solids concentration of 110 mg/l (table 4). The hardness, as calcium carbonate, was 78 mg/l, which is moderately hard (Hem, 1970, p. 225).



(Large graph presents means of measurements in July 1970, August 1971, and July 1972. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

FIGURE 14.--Temperature and dissolved-oxygen profiles of Kent Lake.

Samples for phytoplankton analyses were collected four times during the summer of 1971 (table 5). In the June composite sample, only green algae were present. In July and August additional genera were found in the samples. On August 3, *Anabaena sp.*, a nuisance blue-green algae, was found in relatively high concentrations.

Nicasio Reservoir

Nicasio Reservoir is near the town of Nicasio in northern Marin County. The lake collects the runoff from 36.0 mi^2 (93 km^2) and has a capacity of 22,500 acre-ft (27.8 hm^3), the largest capacity of any reservoir in Marin County. The surrounding watershed lands are open to the public for hiking and picnicking, and the lake is open to fishing.

Nicasio Reservoir was thermally unstratified in July and August 1970, 1971, and 1972 (fig. 15), which is unusual for a lake of this depth. Possible continuous wind-mixing of this narrow, elongated lake may prevent the formation of a stable metalimnion, and thus prevent thermal stratification. The mean surface temperature was only 3°C higher than the mean bottom temperature. However, the mean dissolved-oxygen concentration was below saturation at all depths, and was reduced to 2.0 mg/l near the bottom. The single profile on August 1, 1972, is shown in the inset in figure 15.

Table 4.--*Chemical analyses of water samples from Marin Municipal Water District reservoirs*

KENT LAKE

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Aug., 1972								
08...	12	10	13	11	8.1	0.8	93	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Aug.										
08...	76	7.6	8.4	0.2	0.00	40	110	78	188	7.9

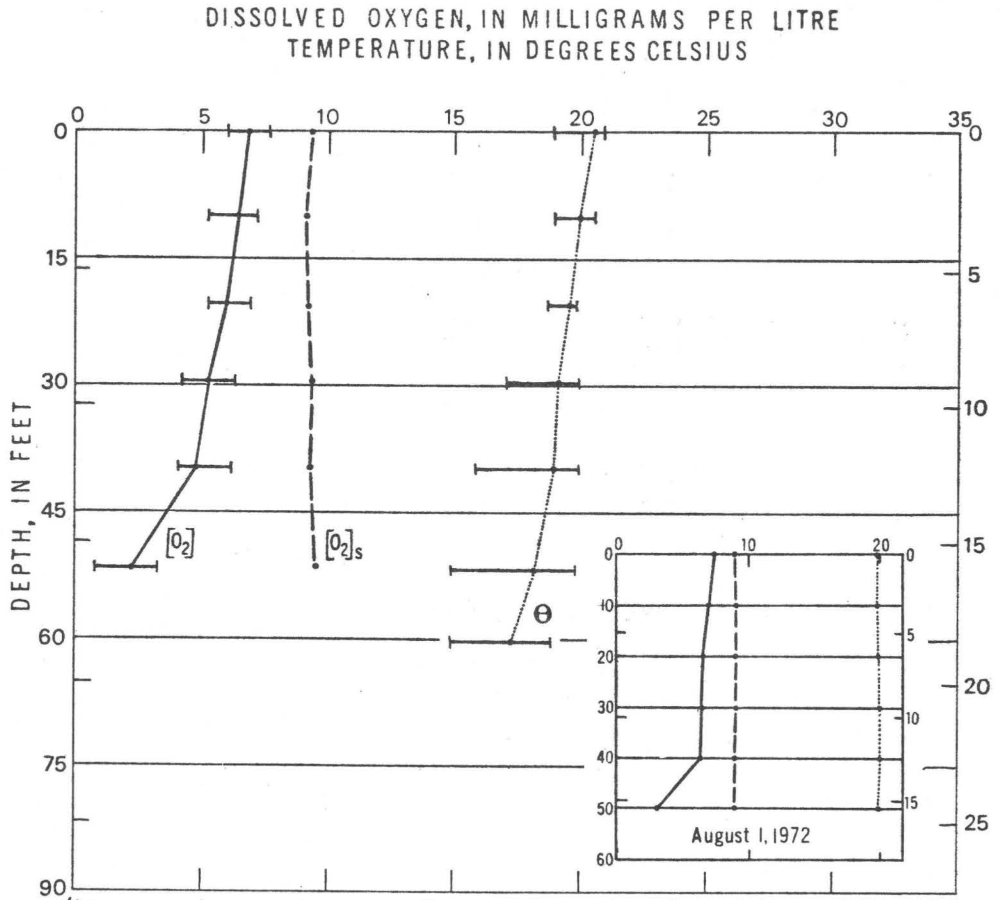
NICASIO RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Aug., 1972								
08...	2.5	20	15	11	11	4.1	90	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Aug.										
08...	74	15	16	0.2	0.33	60	120	83	224	7.6

Table 5.--*Types and occurrence of phytoplankton in samples from Kent Lake*

Date of sample collection	6-23-71	7-7-71	7-13-71	8-3-71
Time of collection (hours)	1015	1500	1310	1230
Algal types (organisms per 100 millilitres of water):				
PHYTOPLANKTON				
Chlorophyta				
Chlorophyceae (green algae)				
Ankistrodesmus sp.	--	--	192	265
Oocystis sp.	172	--	176	
Scenedesmus sp.	--	--	88	
Sphaerocystis sp.	86	172	176	
Staurastrum sp.	258	172	88	
Chrysophyta				
Bacillariophyceae (diatoms)				
Asterionella sp.		64	22	
Chrysophyceae (yellow-brown algae)				
Dinobryon sp.		258	9	
Cyanophyta				
Myxophyceae (blue-green algae)				
Anabaena sp.			250	30,056
Pyrrophyta				
Dinophyceae (dinoflagellates)				
Ceratium sp.			176	86



(Large graph presents means of measurements in July and August 1970, 1971, and 1972. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explantation of symbols.)

FIGURE 15.--Temperature and dissolved-oxygen profiles of Nicasio Reservoir.

The concentrations of chemical constituents for Nicasio Reservoir are shown in table 4. The nitrate concentration was 0.33 mg/l as compared to 0.00 for Kent Lake. Calcium and bicarbonate were the dominant ions in Nicasio Reservoir. The hardness was 83 mg/l, which is considered moderately hard (Hem, 1970, p. 225).

The phytoplankton results revealed some daily changes between depth composites of phytoplankton collected at three sites on the same day, July 6, 1970 (table 6). For example, there was a maximum of 6,581 organisms per 100 millilitres of *Oocystis sp.* in the 1200-hour sample with a decrease to 2,499 organisms per 100 millilitres in the 1300-hour sample. Other types of phytoplankton also changed in concentration throughout the day. These daily changes in phytoplankton concentrations are probably a result of wind action which mixes this shallow thermally unstratified lake and affects the daily vertical movements of phytoplankton. In the June 1971 samples, *Aphanizomenon sp.* was found in high concentrations. The presence of *Aphanizomenon sp.* is undesirable because it has a large cellular volume and is capable of rapid production, often forming blooms and causing unpleasant taste and odors in the water. In general, Nicasio Reservoir exhibited higher quantities and a greater number of types of phytoplankton than Kent Lake.

Table 6.--*Types and occurrence of phytoplankton in samples from Nicasio Reservoir*

Date of sample collection	7-6-70	7-6-70	7-6-70	6-23-71	6-28-71	7-6-71	7-17-71
Time of collection (hours)	1015	1200	1300	0915	1000	1000	1000
Algal types (organisms per 100 millilitres of water):							
PHYTOPLANKTON							
Chlorophyta							
Chlorophyceae (green algae)							
Ankistrodesmus sp.	916	1,999	333	--	--	--	705
Coelastrum sp.	--	250	--	--	--	--	--
Cosmarium sp.	--	83	--	--	86	--	--
Eudorina sp.	250	167	583	773	1,718	3,092	2,997
Oocystis sp.	3,998	6,581	2,499	4,982	6,185	4,639	6,523
Pediastrum sp.	83	--	83	172	344	--	--
Scenedesmus sp.	--	--	417	86	--	--	--
Sphaerocystis sp.	1,250	1,166	--	687	430	344	15,162
Chrysophyta							
Bacillariophyceae (diatoms)							
Asterionella sp.	42	42	--	--	--	--	176
Cyclotella sp.	3,332	2,499	7,414	515	1,460	859	2,644
Fragilaria sp.	--	--	--	--	86	--	--
Melosira sp.	107	333	1,333	513	--	--	--
Chrysophyceae (yellow-brown algae)							
Mallomonas sp.							176
Cyanophyta							
Myxophyceae (blue-green algae)							
Aphanizomenon sp.				47,231	99,154		
Euglenophyta							
Euglenophyceae (euglenoids)							
Trachelomonas sp.				86		344	
Pyrrophyta							
Dinophyceae (dinoflagellates)							
Ceratium sp.				172	86		1,234

LAKE OWNED BY NAPA CITY WATER DEPARTMENT

The Napa City Water Department was formed as a private company in 1883. In 1923, the company was purchased by the city of Napa. Initially all the water came from the Napa River. However, since 1946, supplemental water has been supplied from Lake Hennessey, which is the single Napa City Water Department reservoir included in this report.

Methods

Temperature, dissolved-oxygen, and pH measurements were made at selected depths near the dam by personnel of the Geological Survey.

All water samples for chemical analyses were collected by personnel of the Napa City Water Department. These samples were collected near the surface at the intake tower of the dam. The samples were analyzed at Brown and Caldwell Laboratories in San Francisco, using the methods in American Public Health Association and others (1965).

Lake Hennessey

Lake Hennessey is 65 mi (105 km) north of San Francisco. The reservoir has a storage capacity of 30,000 acre-ft (37 hm^3) and impounds the runoff from a 52.3-mi^2 (135-km^2) drainage area. The reservoir, which is used as a domestic water supply and for recreation, contains both warm and cold water fish species.

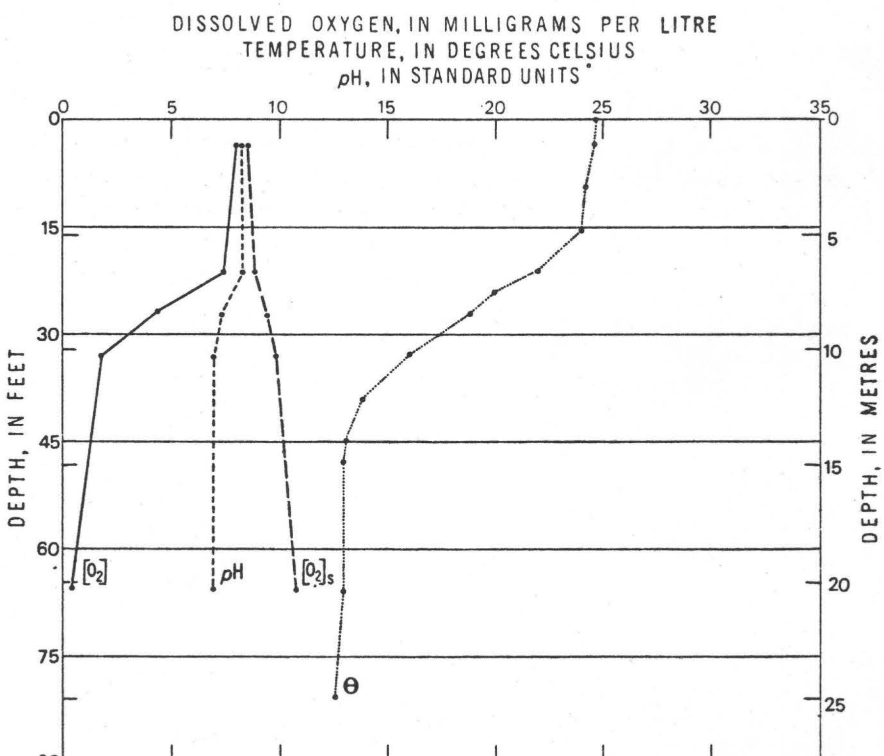
Lake Hennessey was thermally stratified during the July 1970 survey (fig. 16). The dissolved-oxygen concentration was near saturation in the epilimnion, but was noticeably undersaturated below the 20-ft (6-m) level. At the 65-ft (20-m) depth, the dissolved-oxygen concentration was near zero. Concentrations of major chemical constituents are shown in table 7.

Table 7.--*Chemical analyses of water samples from Napa City Water Department lake*

LAKE HENNESSEY

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Mar., 1967 28...	20		13	18	9.0	1.3	122	0
Oct. 10...	19		25	16	8.5	1.3	146	0
Sept., 1968 11...	15		20	21	8.8	1.6	160	0
Sept., 1969 24...	20		22	18	10	.8	151	0
Mar., 1971 22...	27		18	18	7.9	.9	137	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Mar., 1967 28...	100	14	9.0	0.1	0.20	100	140	110	205	8.0
Oct. 10...	120	15	9.0	.2	.20		170	130	256	7.7
Sept., 1968 11...	131	17	9.0	.1	.00		170	140	322	8.1
Sept., 1969 24...	124	16	9.0	.3	.05		170	130	269	7.8
Mar., 1971 22...	112	16	4.0	.0	.27		160	120	259	8.1



(See page 5 for explanation of symbols.)

FIGURE 16.--Temperature, dissolved-oxygen, and pH profiles of Lake Hennessey, July 14, 1970.

LAKES OWNED BY SAN FRANCISCO WATER DEPARTMENT

The San Francisco Water Department supplies water for a 500-mi^2 (1,295-km^2) area, which includes the city of San Francisco, the neighboring communities in San Mateo County, and parts of Santa Clara and Alameda Counties. Water supplies are obtained from local sources and from Hetch Hetchy Reservoir in the Sierra Nevada. These waters are distributed through the Hetch Hetchy system, the peninsula system, and the Alameda system. The local bay area reservoirs that will be discussed in this section are Calaveras, Crystal Springs, Lake Merced, Pilarcitos, San Andreas, and San Antonio.

The Hetch Hetchy system comprises water from Hetch Hetchy Reservoir (Tuolumne River), Lake Lloyd (Cherry River), and Lake Eleanor (Eleanor Creek). The water is brought by gravity flow through the Hetch Hetchy aqueduct and bay crossing lines to Crystal Springs Reservoir in San Mateo County. The Hetch Hetchy system supplies over 75 percent of the total water consumed in the Department's water service area.

The peninsula system is located in San Mateo County and consists of three terminal reservoirs: Pilarcitos, San Andreas, and Crystal Springs, which have a combined capacity of 91,100 acre-ft (112 hm^3) of water. The distribution system includes pumps and transmission mains which can deliver water from Crystal Springs Reservoir to San Andreas Lake, or to consumers and other distribution facilities on the peninsula.

The principal sources of supply in the Alameda system are Calaveras and San Antonio Reservoirs. These reservoirs are in the Alameda Creek drainage in the Coast Range, east of San Francisco Bay. The two reservoirs store water from local runoff. San Antonio Reservoir also provides terminal storage for water piped from the Hetch Hetchy aqueduct. The water is first treated at the Sunol Valley Water Treatment Plant, and then released into the aqueduct to help meet periodic demands in the South Bay and peninsula areas. During interruption of the Hetch Hetchy supply, Alameda source water must supply the South Bay and the peninsula east of Crystal Springs Reservoir.

Lake Merced, which lies in San Francisco, is maintained for recreation and as an emergency water supply. If needed, water from Lake Merced can be pumped into the city system.

The soft waters of low mineral content from the Hetch Hetchy system mix with the harder waters of a higher mineral content in the local reservoirs, resulting in a water that is moderately soft and low in dissolved solids. The runoff water to the five local storage and impounding reservoirs can be classified as calcium magnesium bicarbonate type.

Local storage and impounding reservoirs periodically receive copper sulfate treatment to control algal growth. Suspended matter in the reservoirs is eliminated by artificial clarification, when needed. The peninsula watersheds are a part of the California Fish and Game Preserve and are closed to the public. Similarly, fishing, boating, and hunting in the Alameda watershed are prohibited.

Methods

Unless stated otherwise, all water-sample collections and water-quality measurements for the San Francisco reservoirs were made near the dams. In Lake Merced, the sample collections and measurements were made near the lake center. These sites generally correspond to the deepest part of each body of water. Temperature and dissolved-oxygen measurements prior to 1971 were made by personnel of the San Francisco Water Department, using a thermister for temperature and a meter and probe for dissolved-oxygen determinations. Temperature and dissolved-oxygen measurements in 1971 and 1972 were made by personnel of the Geological Survey.

Prior to 1972, water samples for chemical analyses were collected near the dam, at the 2-ft (0.6-m) depth by personnel of the San Francisco Water Department. The samples were analyzed at the San Francisco Water Department purification division, using the methods described in American Public Health Association and others (1955, 1965). Chemical determinations made prior to 1955 are included for historical interest, but methods of analyses are unknown. Water samples collected in 1972 for chemical analyses were collected at the 2-ft (0.6-m) depth, but off the shores of each lake, by personnel of the Geological Survey.

Plankton were collected at mid-depth in each reservoir with a size 25 (0.064 mm [millimetre]) mesh plankton net by personnel of the San Francisco Water Department. The methods of collection and analyses are described in American Public Health Association and others (1965).

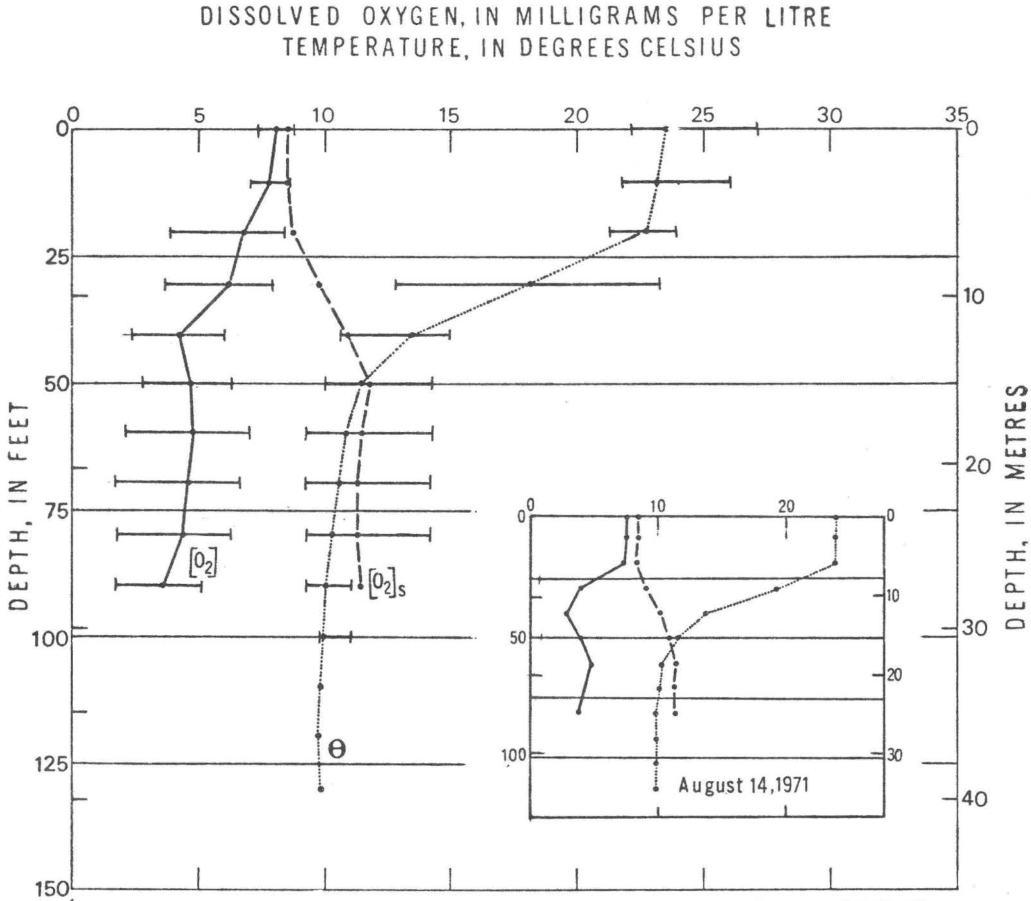
Calaveras Reservoir

Calaveras Reservoir lies in Alameda and Santa Clara Counties, and collects the runoff from about 100 mi^2 (259 km^2) off the slopes of Mount Hamilton. It also stores water from a 35-mi^2 (91-km^2) drainage area of Upper Alameda Creek, which is diverted into the reservoir through a tunnel.

The earthen and rockfill dam impounding the 100,000 acre-ft (123 hm^3) of water within the reservoir was completed in 1925. The dam, one of the largest in the bay area, is 1,200 ft (366 m) long and 155 ft (47 m) wide at the base, with a height of 210 ft (64 m) above bedrock.

The water from the reservoir is normally released to an aerating basin. From the aerating basin, the water can be transported directly into the Hetch Hetchy aqueduct, but is usually treated at a filtration plant before transport to the aqueduct for deliveries to the peninsula distribution system. Water can also be delivered to San Antonio Reservoir for storage. The reservoir is closed to all public use.

Calaveras Reservoir was thermally stratified during the summer months, with a mean surface temperature of 23.5°C and a mean bottom temperature of 10°C (fig. 17). The thermal profile of this relatively deep lake showed a well-developed metalimnion extending from the 20-ft (6-m) depth to the 50-ft (15-m) depth. The mean dissolved-oxygen concentrations were undersaturated at all



(Large graph presents means of measurements in July and August 1965-67 and 1969-71. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

FIGURE 17.--Temperature and dissolved-oxygen profiles of Calaveras Reservoir.

depths, with a mean low of 3.5 mg/l at the 90-ft (27-m) level. A single summer profile on August 14, 1971, is shown in the inset in figure 17. This profile indicates an oxygen minimum condition at the 40-ft (12-m) depth, probably caused by the accumulation of oxidizable material in the metalimnion.

The results of the chemical analyses of Calaveras Reservoir are given in table 8. The lake is a calcium-bicarbonate type with concentrations of these two constituents comprising over 60 percent of the calculated dissolved solids.

A summary of the plankton genera found in Calaveras Reservoir in 1971 is shown in table 9. Diatoms were the most diverse phytoplanktonic organisms present during the winter and spring, but were nearly absent from samples collected during the remainder of the sampling period. *Stephanodiscus sp.* was the most frequently collected diatom. *Staurastrum sp.*, a green alga, was present at least every month, except September and November. The blue-green algae were represented by *Anabaena sp.* and *Oscillatoria sp.*, and were found infrequently during the sampling period.

Table 8.--*Chemical analyses of water samples from San Francisco Water Department reservoirs*

CALAVERAS RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Feb., 1939 03...	8.0		27	8.6	5.8	--	110	0
Apr., 1949 05...	7.5		22	--	9.6	--	96	0
Apr., 1955 06...	3.6		31	8.6	11	--	130	0
Aug., 1962 07...	4.4		27	9.3	8.9	2.8	114	0
June, 1972 05...	6.7		31	10	11	1.4	142	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Feb., 1939 03...	90	19	5.5	--	--	--	130	110	--	7.5
Apr., 1949 05...	79	13	6.0	0.1	0.05	150	110	85	195	7.5
Apr., 1955 06...	106	21	4.0	.2	.00	90	140	110	254	8.3
Aug., 1962 07...	94	19	8.4	.1	.11	--	140	110	245	7.7
June, 1972 05...	116	24	7.7	.2	--	--	160	120	286	7.9

LOWER CRYSTAL SPRINGS RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
June, 1972 05...	3.9	20	10	2.2	7.9	0.4	46	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
June, 1972 05...	38	6.3	4.8	0.0	0.00	40	58	34	84	8.0

Table 8.--*Chemical analyses of water samples from San Francisco Water Department reservoirs*--Continued

UPPER CRYSTAL SPRINGS RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
June, 1972 05...	4.7	20	8.3	1.6	2.5	0.4	29	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
June, 1972 05...	24	4.6	3.8	0.0	0.00	40	40	27	67	8.0

NORTH LAKE MERCED

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Apr., 1955 11...	19		26	24	50	--	157	0
Dec., 1958 19...	8.0		28	30	57	2.4	207	0
June, 1972 05...	27	90	35	35	62	2.0	253	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Apr., 1955 11...	--	29	76	--	0.11	50	300	--	537	8.3
Dec., 1958 19...	171	19	92	0.1	.02	--	340	200	640	7.9
June, 1972 05...	208	35	96	.2	.00	60	420	230	743	7.6

Table 8.--*Chemical analyses of water samples from San Francisco Water Department reservoirs*--Continued

SOUTH LAKE MERCED

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Apr., 1955 11...	33		26	27	53	--	181	0
Dec., 1958 19...	13		29	30	58	2.2	180	10
June, 1967 23...	20		29	30	52	2.1	201	0
Apr., 1969 29...	40		27	24	45	1.9	164	3

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Apr., 1955 11...	--	21	82	--	0.07	20	330	--	563	8.3
Dec., 1958 19...	167	16	96	0.1	.54	--	330	200	650	9.0
June, 1967 23...	165	17	95	.1	--	80	340	200	560	8.2
Apr., 1969 29...	138	25	69	.3	.11	50	310	170	560	8.6

PILARCITOS LAKE

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Apr., 1951 17...	6.5		13	5.5	12	--	65	0
Dec., 1958 19...	13		14	4.7	13	0.5	65	0
June, 1972 05...	13	40	20	5.4	14	.6	76	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Apr., 1951 17...	53	11	17	0.1	0.02	80	97	55	157	7.8
Dec., 1958 19...	54	7.4	16	.1	.02	--	100	54	175	7.6
June, 1972 05...	62	14	22	.2	.05	40	130	72	220	7.7

Table 8.--*Chemical analyses of water samples from San Francisco Water Department reservoirs*--Continued

SAN ANDREAS LAKE

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
June, 1972 05...	4.0	20	12	3.0	3.9	0.4	47	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
June, 1972 05...	39	6.8	5.4	0.0	0.00	40	59	42	99	7.1

SAN ANTONIO RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
June, 1967 23...	6.5		41	5.4	10	1.9	139	0
Apr., 1969 29...	6.5		32	12	16	2.2	132	5
June, 1972 06...	2.7	20	35	14	17	2.3	171	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
June, 1967 23...	114	22	10	0.1	0.07	100	170	130	320	8.1
Apr., 1969 29...	117	22	14	.2	.11	200	170	130	259	8.8
June, 1972 06...	140	28	17	.3	--	210	200	150	370	7.9

Table 9.--*Frequency of occurrence of plankton in Calaveras Reservoir in 1971*

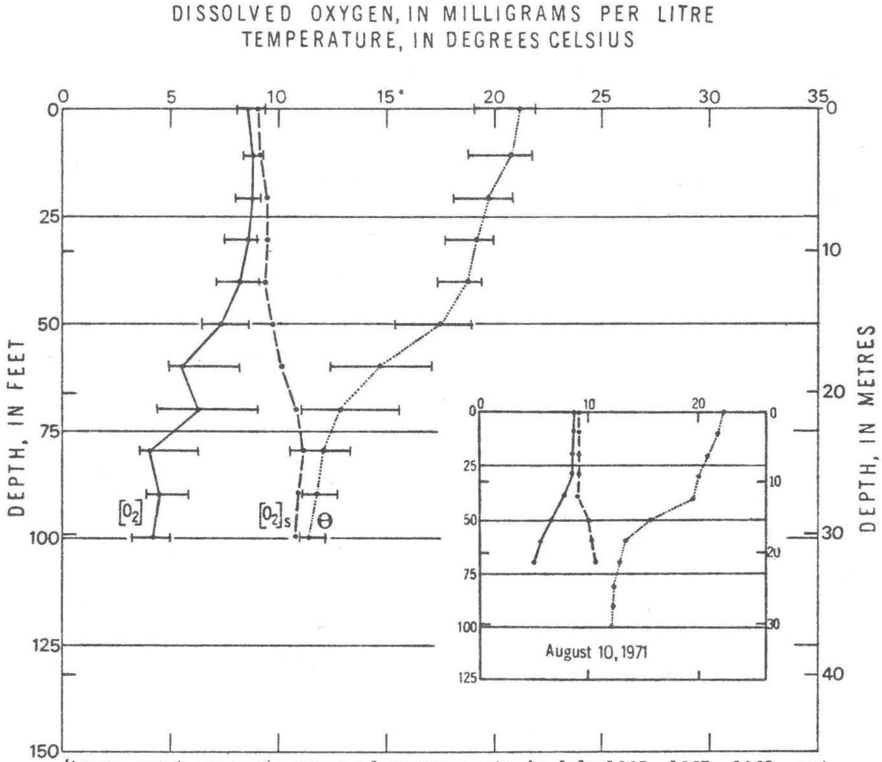
Date	PHYTOPLANKTON: Chlorophyta, Chlorophyceae (green algae): *Dictyosphaerium sp.*	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	Chrysophyta, Bacillariophyceae (diatoms): *Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	Chrysophyceae (yellow-brown algae): *Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	Cyanophyta, Myxophyceae (blue-green algae): *Anabaena sp.*	*Oscillatoria sp.*	Pyrrophyta, Dinophyceae (dinoflagellates): *Ceratium sp.*	ZOOPLANKTON: Rotifera, Monogononta (rotifers): *Keratella sp.*	*Polyarthra sp.*
CALAVERAS RESERVOIR																				
Jan., 1971																				
3...									X										X	
10...									X	X									X	
17...					X				X	X									X	
24...					X					X									X	
31...			X						X	X		X							X	X
Feb.																				
7...									X	X									X	
14...									X										X	
21...					X				X										X	
28...																	X		X	
Mar.																				
8...		X							X		X								X	X
13...											X							X	X	
20...					X						X								X	
22...					X						X								X	
28...			X		X													X	X	
31...																		X	X	
Apr.																				
3...									X									X	X	
10...					X				X									X	X	
17...					X				X	X	X							X	X	
24...					X				X		X							X	X	
July																				
3...					X														X	
12...																			X	
19...					X														X	
26...					X														X	
Aug.																				
2...																			X	X
9...																			X	X
14...					X														X	
16...					X														X	
23...					X														X	X
30...					X													X	X	
Sept.																				
6...																	X		X	
13...																			X	
20...																		X	X	
27...																		X	X	
Oct.																				
4...																X		X	X	
6...																X		X	X	X
11...					X											X			X	
18...					X														X	
22...																			X	
26...																		X	X	
Nov.																				
1...																			X	
7...																			X	
15...										X								X	X	
22...																			X	
29...											X								X	

Crystal Springs Reservoir

Crystal Springs is the largest storage and impounding reservoir on the San Francisco Peninsula and provides terminal storage for Hetch Hetchy and Alameda source water. The reservoir has a capacity of 69,500 acre-ft (85.8 hm^3) and serves as a catchment basin for local runoff from a 29.8-mi^2 (77-km^2) drainage area. The reservoir is divided into an upper and lower section, separated by an earthfill dam. This dam was constructed in 1877, but is no longer used except to support a roadway across the reservoir. The present Crystal Springs dam was built in 1888 on San Mateo Creek, about 1.5 mi (2.4 km) south of the original dam. Both sections of the reservoir, as well as the surrounding watershed lands, are closed to the public.

Lower Crystal Springs

Temperature and dissolved-oxygen stratification occur in Lower Crystal Springs Reservoir during the summer (fig. 18). The mean dissolved-oxygen concentration was undersaturated at all depths, with a difference of 4 mg/l from top to bottom. The measurements on August 10, 1971, show thermal and dissolved-oxygen stratification that is typical of the mean summer profile.



(Large graph presents means of measurements in July 1965, 1967, 1968, and August 1965, 1967, and 1971. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

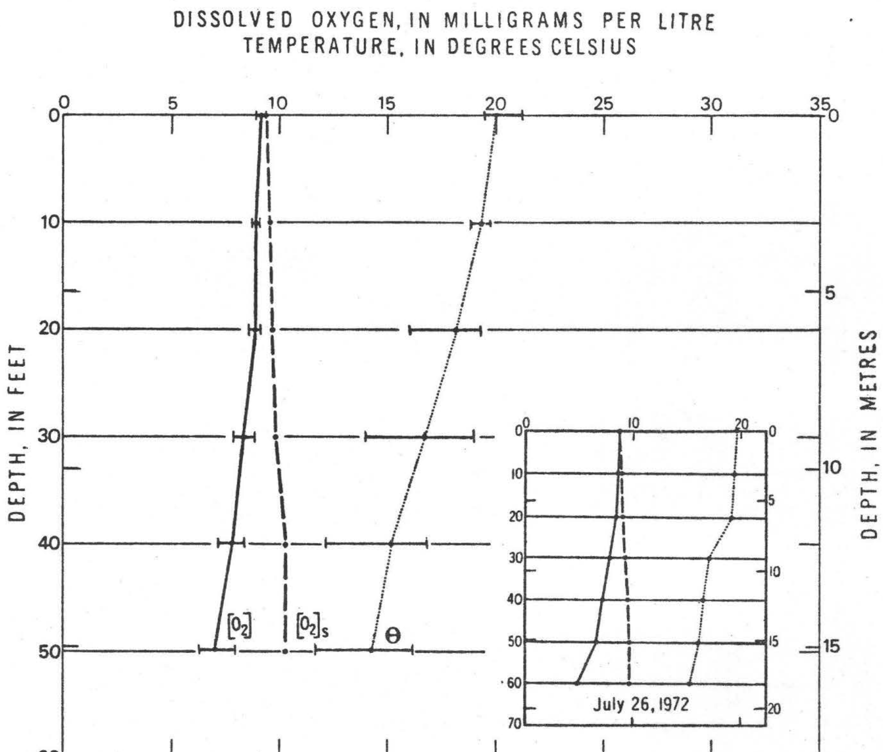
FIGURE 18.--Temperature and dissolved-oxygen profiles of Lower Crystal Springs Reservoir.

The results of a single chemical analysis of the water from Lower Crystal Springs are shown in table 8. The calculated dissolved solids were only 58 mg/l, indicating the dilute nature of the water. The reservoir water was very soft, with a hardness of only 34 mg/l as $CaCO_3$.

Lower Crystal Springs Reservoir had a low number of planktonic genera when compared to other San Francisco lakes investigated in 1971 (table 10). No blue-green algae were collected during the sampling period. This absence is important since blue-green algae often are responsible for impaired water conditions (Palmer, 1959; Mackenthun and Ingram, 1967). The most consistently found phytoplankton organisms were *Staurastrum sp.*, a green algae, *Ceratium sp.*, a dinoflagellate, and *Synedra sp.*, a diatom. Another diatom, *Surirella sp.*, was frequently found in the late autumn samples. The most frequently collected zooplankton was the rotifer, *Keratella sp.*

Upper Crystal Springs

Summer thermal stratification was poorly developed in Upper Crystal Springs Reservoir (fig. 19). The dissolved-oxygen concentration was slightly undersaturated at all depths and exhibited an orthograde (uniform) distribution from top to bottom. The mean dissolved-oxygen concentration was moderately high at all depths. A single set of thermal and dissolved-oxygen measurements is shown in the inset in figure 19.



(Large graph presents means of measurements in July 1967, August 1967, and July 1972. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

FIGURE 19.--Temperature and dissolved-oxygen profiles of Upper Crystal Springs Reservoir.

Table 10.--*Frequency of occurrence of plankton in Lower Crystal Springs Reservoir in 1971*

	PHYTOPLANKTON																		ZOOPLANKTON	
Date	Chlorophyta Chlorophyceae (green algae) *Dictyosphaerium sp.*	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	Chrysophyta Bacillariophyceae (diatoms) *Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	Chrysophyceae (yellow-brown algae) *Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	Cyanophyta Myxophyceae (blue-green algae) *Anabaena sp.*	*Oscillatoria sp.*	Pyrrophyta Dinophyceae (dinoflagellates) *Ceratium sp.*	Rotifera Monogononta (rotifers) *Keratella sp.*	*Polyarthra sp.*
LOWER CRYSTAL SPRINGS RESERVOIR																				
Jan., 1971																				
3...					X					X	X								X	
10...					X						X							X	X	
17...					X						X							X	X	X
25...					X					X	X							X	X	
31...					X						X							X	X	
Feb.																				
7...					X						X							X	X	
15...					X						X							X	X	X
21...					X						X							X	X	X
28...					X						X							X	X	X
Mar.																				
6...					X						X							X	X	
13...					X						X							X	X	X
20...					X						X							X	X	
27...					X						X		X					X	X	
Apr.																				
3...					X					X	X							X	X	
9...	X				X						X							X	X	
17...	X				X						X		X					X		
24...					X						X		X					X	X	X
July																				
5...					X						X		X					X	X	
14...					X						X							X	X	
27...					X						X							X	X	
Aug.																				
3...					X					X	X		X	X				X	X	X
10...					X						X							X	X	
17...					X						X							X		
25...					X						X							X	X	
30...					X						X							X	X	
Sept.																				
7...					X						X		X					X	X	X
15...					X						X							X	X	
20...					X						X							X	X	
27...					X														X	
Oct.																				
5...					X						X							X	X	
12...					X					X	X							X	X	
19...					X						X							X	X	
26...					X						X		X					X	X	
Nov.																				
1...					X					X	X		X						X	
8...					X						X		X		X			X	X	
15...					X					X	X				X			X	X	X
22...					X						X				X			X	X	
29...					X					X	X				X				X	
Dec.																				
6...					X					X	X				X				X	
9...					X					X	X									
15...					X					X	X							X	X	
17...					X						X							X	X	

Upper Crystal Springs Reservoir is the first catchment basin for Hetch Hetchy water. As a result, the reservoir water had a low dissolved-solids content of 40 mg/l, as well as being extremely soft with a hardness of only 27 mg/l (table 8).

The green alga, *Staurastrum sp.*, and the diatom, *Synedra sp.*, were present in most plankton samples collected in 1971 (table 11). No blue-green algae were present in the samples. The dinoflagellate, *Ceratium sp.*, was also found consistently throughout the year. This organism is prevalent in California waters and produces a fishy to pronounced septic odor. It is capable of rapid growth and may develop in large numbers during any season.

Lake Merced

Lake Merced is a natural lake lying within San Francisco. The lake is divided into a north and south section by a narrow strip of land. The two sections of the lake are connected by a culvert. Lake Merced water is used for recreation and for an emergency water supply for San Francisco.

Lake Merced is a true urban lake. Not only does it contain docks where the public can rent boats, but a golf course, clubhouse, and parking lot are located on its shores. Consequently, the lake is used heavily by the public.

North Lake Merced

North Lake Merced is only 15 ft (4.6 m) deep. This shallow depth, coupled with almost daily onshore winds, probably accounts for the lack of any temperature or dissolved-oxygen stratification (fig. 20). The dissolved-oxygen concentration at the time of the survey was 5 mg/l throughout the water column and was severely undersaturated.

The North Lake had relatively high concentrations of all analyzed chemical constituents (table 8). The calculated dissolved-solids content was 420 mg/l in 1972, and the specific conductance was 743 micromhos.

South Lake Merced

South Lake Merced was not thermally stratified at the time of the survey (fig. 21). The South Lake had a higher dissolved-oxygen concentration at all depths than did North Lake Merced. Emersed plants are found around the shores of this section of the lake, and photosynthesis at the surface could account for the dissolved-oxygen concentration being above saturation. Wind-mixing of the lake waters probably accounts for the homogeneous temperature and dissolved-oxygen profiles.

The results of the chemical analyses of water samples from South Lake Merced are shown in table 8. On comparable dates, South Lake Merced had similar concentrations of chemical constituents and calculated dissolved solids as North Lake Merced.

Table 11.--*Frequency of occurrence of plankton in Upper Crystal Springs Reservoir in 1971*

Date	PHYTOPLANKTON																		ZOOPLANKTON	
	Chlorophyta Chlorophyceae (green algae)							Chrysophyta Bacillariophyceae (diatoms)					Chrysophyceae (yellow-brown algae)			Cyanophyta Myxophyceae (blue-green algae)		Pyrrophyta Dinophyceae (dinoflagellates)	Rotifera Monogononta (rotifers)	
	Dictyosphaerium sp.	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	*Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	*Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	*Anabaena sp.*	*Oscillatoria sp.*	*Ceratium sp.*	*Keratella sp.*	*Polyarthra sp.*
UPPER CRYSTAL SPRINGS RESERVOIR																				
Jan., 1971																				
3...					X					X	X							X	X	
10...					X					X	X							X	X	
17...					X						X							X	X	
24...					X						X									
31...					X						X							X	X	
Feb.																				
7...					X					X	X								X	
14...					X						X								X	
21...					X						X							X		
28...	X				X						X								X	
Mar.																				
6...					X						X							X	X	
13...					X						X							X	X	
20...					X						X							X	X	
27...					X		X				X								X	
Apr.																				
3...					X						X								X	X
7...					X						X		X						X	
10...					X						X		X						X	
13...					X						X		X						X	X
17...					X						X		X						X	X
23...					X						X		X						X	
May																				
1...					X						X		X						X	
July																				
6...					X						X							X	X	
12...					X						X							X		X
19...					X						X							X	X	
26...					X	X					X							X	X	X
Aug.																				
2...					X	X					X							X	X	
9...					X						X							X	X	X
16...					X	X					X							X	X	
23...					X	X					X							X		X
30...											X							X	X	
Sept.																				
6...					X						X							X	X	
13...											X							X	X	
20...					X						X							X	X	
27...					X						X							X	X	
Oct.																				
4...					X						X							X	X	
11...					X						X							X	X	
19...					X						X							X	X	
25...					X						X	X						X	X	
Nov.																				
1...					X						X								X	
8...					X						X							X	X	
15...					X						X							X	X	
22...					X						X							X	X	
29...					X						X							X	X	
Dec.																				
6...					X			X	X	X	X							X	X	

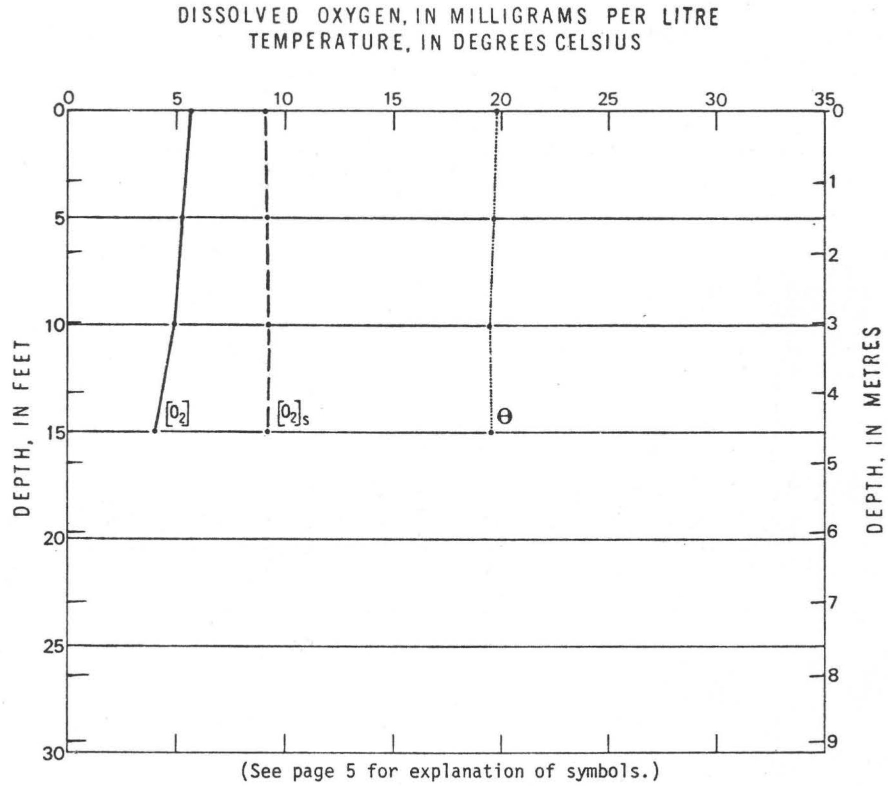


FIGURE 20.--Temperature and dissolved-oxygen profiles of North Lake Merced, July 26, 1972.

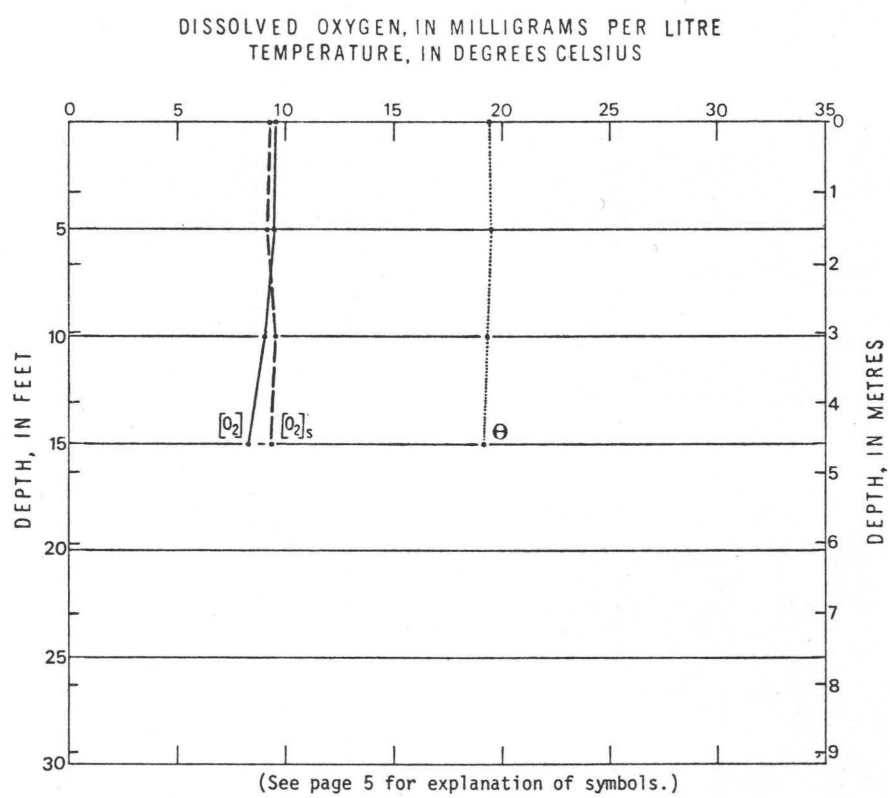


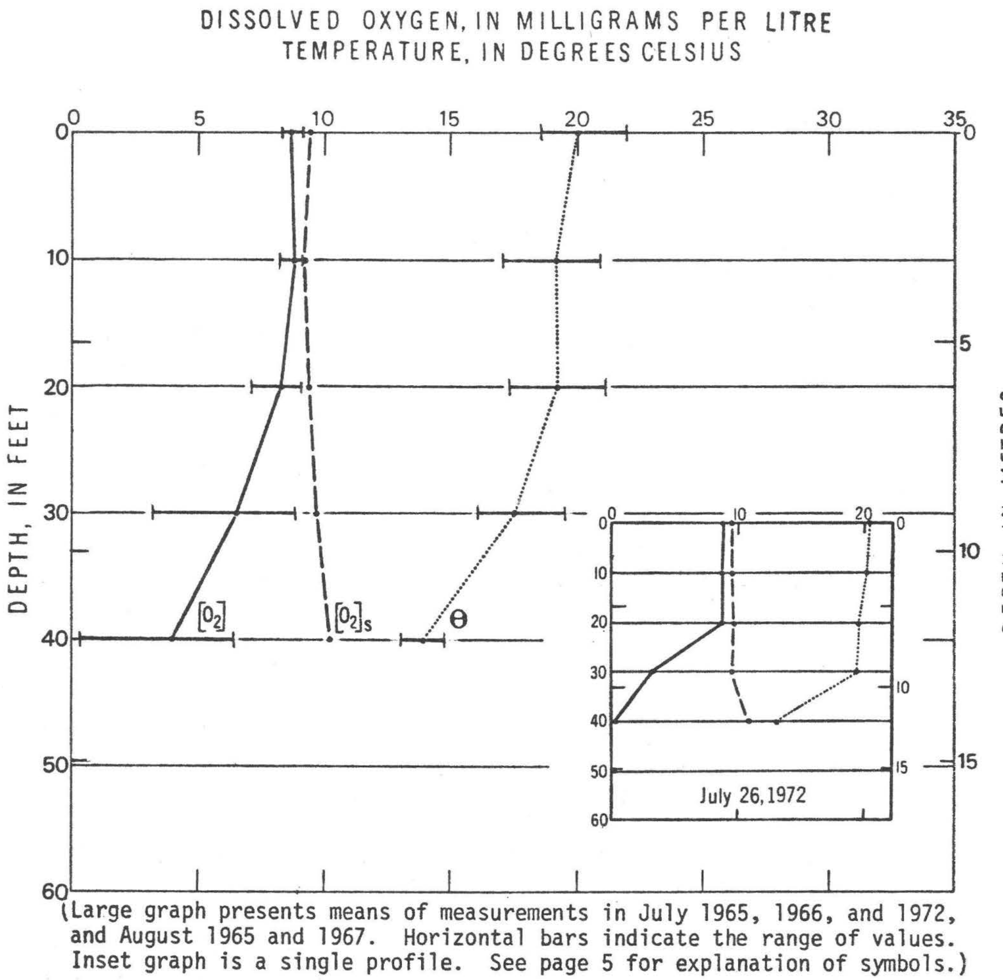
FIGURE 21.--Temperature and dissolved-oxygen profiles of South Lake Merced, July 26, 1972.

Pilarcitos Lake

This small reservoir is located on the western slope of the coastal mountains between San Francisco Bay and the Pacific Ocean, and collects runoff from a 3.80-mi^2 (9.8-km^2) drainage area. The watershed has an average annual rainfall of 46 in (117 cm). The earthfill dam forming the reservoir was built in 1866 and has a height of 103 ft (31 m) and a length of 520 ft (158 m). The outlet is through a tunnel and pipeline to San Andreas Lake. Runoff into Pilarcitos Lake is usually in excess of its capacity of 3,100 acre-ft (3.8 hm^3), and thus the release to San Andreas Lake permits additional catchment. The reservoir and surrounding watershed lands are closed to the public.

The mean summer temperature profile of Pilarcitos Lake indicates slight thermal stratification near the reservoir bottom (fig. 22). The mean dissolved oxygen had a nearly uniform concentration of 8 mg/l to the 20-ft (6-m) level, but was reduced to 4 mg/l at the bottom. However, the single profile on July 26, 1972 (fig. 22, inset), showed that the water was anaerobic at the 40-ft (12-m) depth.

The concentrations of chemical constituents analyzed from Pilarcitos Lake are shown in table 8.



(Large graph presents means of measurements in July 1965, 1966, and 1972, and August 1965 and 1967. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

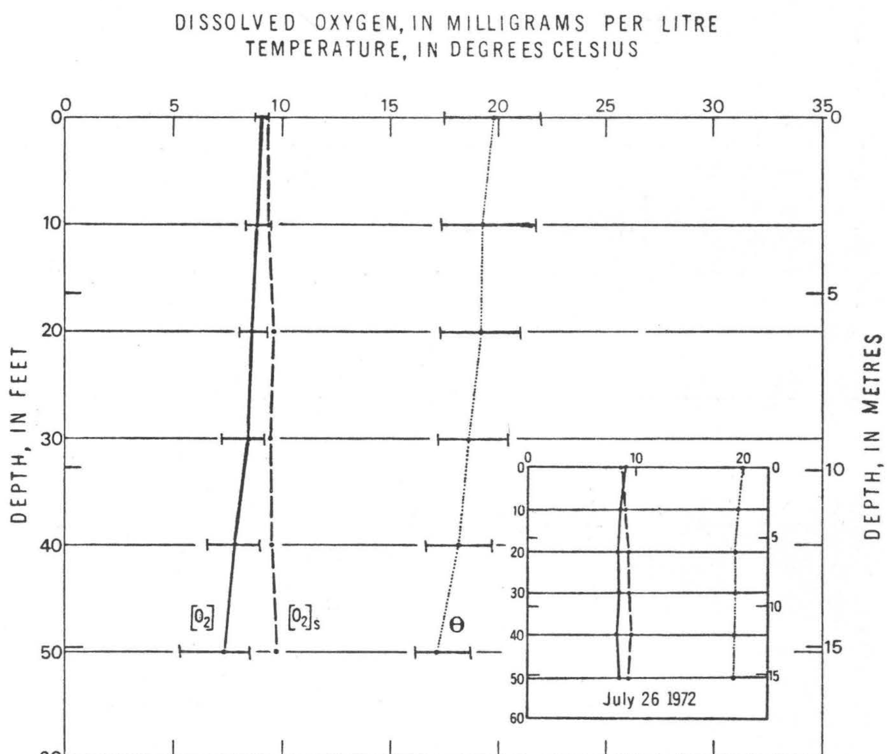
FIGURE 22.--Temperature and dissolved-oxygen profiles of Pilarcitos Lake.

Plankton found in water samples from Pilarcitos Lake in 1971 are shown in table 12. Diatoms were the phytoplankton organisms collected most frequently, with *Synedra sp.* being found in every sample. The blue-green algae, *Anabaena sp.* and *Oscillatoria sp.*, were found infrequently in the winter and late summer. *Staurastrum sp.*, a green alga, was collected at least once every month.

San Andreas Lake

San Andreas Lake is located on San Mateo Creek. It has a storage capacity of 18,500 acre-ft (22.8 hm^3). The dam forming the reservoir was built in 1870 and is 107 ft (32.6 m) high with a crest length of 727 ft (222 m). The reservoir impounds the runoff from about 4.5 mi^2 (11.7 km^2) of watershed, but its water supply is also supplemented by diversions from Pilarcitos Lake and by pumping from Crystal Springs Reservoir. The reservoir is used exclusively as a domestic water supply and is closed to the public.

San Andreas Lake had a near orthograde summer dissolved-oxygen profile with a mean difference of only 1.5 mg/l from the surface to the bottom (fig. 23). The mean dissolved-oxygen concentration was near saturation at all depths, and on July 26, 1972, the surface water was supersaturated (fig. 23, inset graph). The mean temperature difference between the surface and bottom waters was only 2.5°C.



(Large graph presents means of measurements in July 1965, 1966, 1967, and 1972, and August 1967. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

FIGURE 23.--Temperature and dissolved-oxygen profiles of San Andreas Lake.

Table 12.--*Frequency of occurrence of plankton in Pilarcitos Lake in 1971*

Date	PHYTOPLANKTON: Chlorophyta, Chlorophyceae (green algae): *Dictyosphaerium sp.*	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	Chrysophyta, Bacillariophyceae (diatoms): *Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	Chrysophyceae (yellow-brown algae): *Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	Cyanophyta, Myxophyceae (blue-green algae): *Anabaena sp.*	*Oscillatoria sp.*	Pyrrophyta, Dinophyceae (dinoflagellates): *Ceratium sp.*	ZOOPLANKTON: Rotifera, Monogononta (rotifers): *Keratella sp.*	*Polyarthra sp.*
PILARCITOS LAKE																				
Jan., 1971																				
3...											X							X	X	
10...					X						X								X	
17...								X			X								X	
24...					X						X				X		X		X	
31...					X			X			X				X				X	
Feb.																				
7...					X			X	X		X									
14...					X			X	X		X							X		
21...					X			X			X								X	
28...											X							X	X	
Mar.																				
6...											X							X		
13...											X									
20...					X			X		X	X								X	
27...					X			X			X							X	X	
Apr.																				
3...					X			X			X							X		
9...					X			X			X							X	X	
17...					X			X			X							X	X	
24...					X			X			X							X		
May																				
1...	X				X			X			X		X		X			X	X	X
July																				
6...					X			X		X	X							X	X	
12...					X			X		X	X		X						X	
19...			X		X			X			X								X	
26...					X			X			X					X		X	X	X
Aug.																				
1...					X						X							X	X	
8...					X						X							X	X	
16...					X			X			X					X		X	X	
24...											X		X					X	X	
30...					X						X							X	X	
Sept.																				
6...					X						X		X					X	X	
13...					X						X							X	X	
20...					X						X							X		
27...					X						X							X	X	
Oct.																				
4...					X						X							X	X	
11...					X						X							X	X	
19...					X						X							X	X	
25...					X						X							X	X	
Nov.																				
1...					X						X							X	X	
7...		X			X			X	X		X							X	X	X
15...	X				X			X			X		X					X	X	X
22...	X							X			X							X	X	X
29...	X			X							X						X	X	X	X
Dec.																				
6...					X					X	X		X		X		X	X	X	
13...					X						X			X					X	
20...					X						X	X		X				X	X	X

All major chemical constituents were in low concentrations, resulting in a calculated dissolved-solids concentration of only 59 mg/l (table 8).

The green alga, *Staurastrum sp.*, was the prevalent type of phytoplankton collected from the reservoir during 1971 (table 13). This alga was found consistently throughout the year. *Oscillatoria sp.* was the only blue-green alga collected in the samples, and was found only twice, in December. The diatoms were represented most frequently by *Synedra sp.* and *Surirella sp.* The rotifer, *Keratella sp.*, was present in nearly every sample.

San Antonio Reservoir

San Antonio Reservoir is within Alameda County near the town of Sunol. The James H. Turner Dam, an earthfill structure, was completed in 1965, forming the 50,500 acre-ft (62.3 hm^3) reservoir. The reservoir is on San Antonio Creek and collects the runoff from a 40.0-mi^2 (104-km^2) watershed which has an average runoff of 9,855 acre-ft (12.2 hm^3) per year. The reservoir also provides terminal storage for water from Hetch Hetchy Reservoir, as well as other sources, including Calaveras Reservoir. These supplies assure continuous water service to customers in the peninsula and South Bay areas during possible interruption of the Hetch Hetchy supply. The reservoir is closed to the public.

Thermal and dissolved-oxygen stratification occurred in San Antonio Reservoir in the summer months (fig. 24). Photosynthetic activity resulted in a slight supersaturation of dissolved oxygen at the surface. However, the dissolved oxygen was undersaturated at all lower depths, and was reduced to a mean of 1.1 mg/l at the 60-ft (18-m) depth. The inset in figure 24 shows a single summer profile on July 25, 1972.

The reservoir water is a calcium bicarbonate water type, with these ions making up 18 and 42 percent, respectively of the calculated dissolved solids in 1972 (table 8).

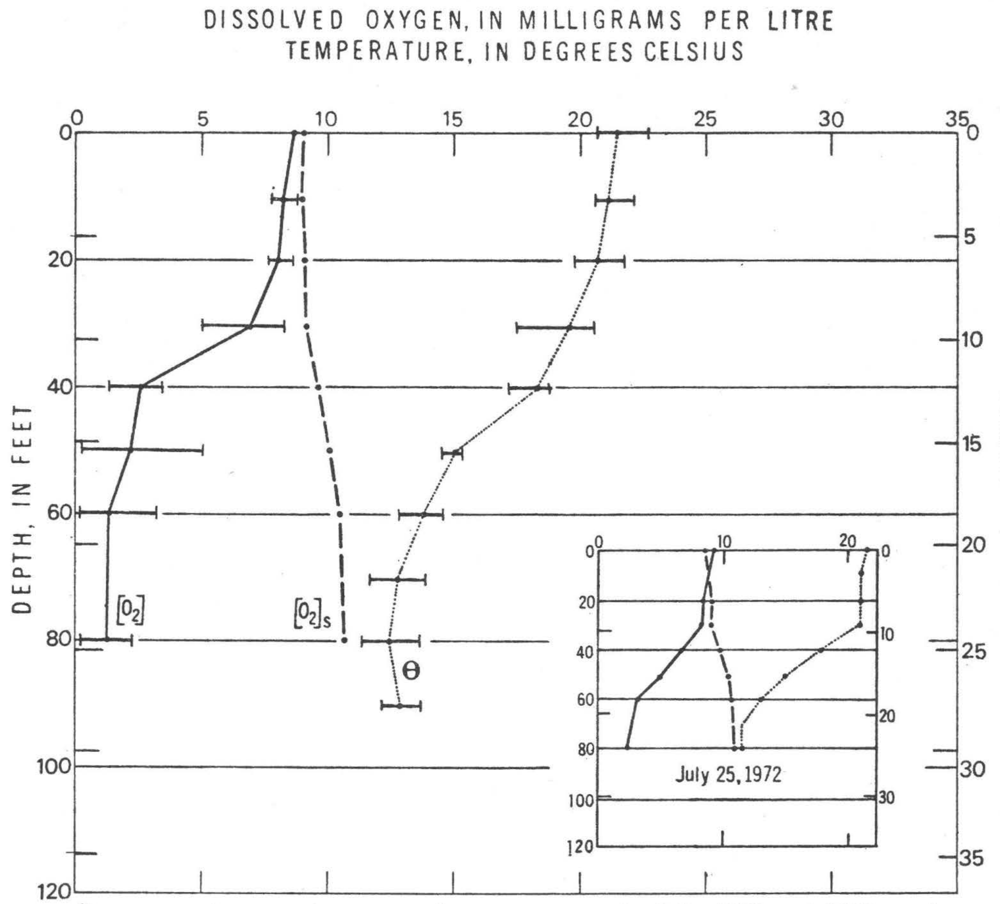
Pediastrum sp. and *Staurastrum sp.* were the green algae collected from San Antonio Reservoir in 1971 (table 14). Diatoms were found only in the winter and spring, with *Stephanodiscus sp.* the most commonly occuring genus. The blue-green alga, *Oscillatoria sp.*, was collected twice, once in January and once in October, and *Anabaena sp.* was found only once in an October sample.

Table 13.--*Frequency of occurrence of plankton in San Andreas Lake in 1971*

Date	PHYTOPLANKTON																		ZOOPLANKTON	
	Chlorophyta **Chlorophyceae (green algae)** *Dictyosphaerium sp.*	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	**Chrysophyta** **Bacillariophyceae (diatoms)** *Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	**Chrysophyceae (yellow-brown algae)** *Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	**Cyanophyta** **Myxophyceae (blue-green algae)** *Anabaena sp.*	*Oscillatoria sp.*	**Pyrrophyta** **Dinophyceae (dinoflagellates)** *Ceratium sp.*	**Rotifera** **Monogononta (rotifers)** *Keratella sp.*	*Polyarthra sp.*
SAN ANDREAS LAKE																				
Jan., 1971																				
3...									X	X	X							X		
10...									X		X								X	
17...			X		X					X	X							X	X	
24...			X								X							X	X	
31...									X	X	X							X	X	
Feb.																				
7...					X					X								X	X	
14...					X														X	
21...					X						X							X	X	
28...					X						X							X	X	
Mar.																				
6...					X				X	X	X							X	X	
14...			X				X		X	X	X								X	
20...									X	X									X	
27...					X				X	X									X	
Apr.																				
3...					X				X	X									X	
9...					X				X	X									X	
17...					X				X	X									X	
24...					X				X	X									X	
May																				
1...					X		X			X									X	
June																				
2...					X						X							X	X	
8...					X													X	X	
15...					X						X							X	X	
21...					X													X	X	
28...					X						X		X					X	X	
July																				
5...					X		X				X							X	X	
12...					X						X								X	
19...					X						X							X	X	
26...					X													X	X	
Aug.																				
2...					X	X					X							X	X	X
9...					X						X		X					X	X	
15...					X						X		X						X	
23...					X						X								X	
30...					X						X							X	X	
Sept.																				
8...	X				X						X							X	X	
13...		X			X						X							X	X	
20...					X						X							X	X	
27...					X						X							X	X	
Oct.																				
5...				X	X		X		X	X	X							X	X	
11...					X		X				X									
18...					X		X				X							X	X	
26...					X						X							X	X	
Nov.																				
1...			X		X				X	X	X							X	X	
8...					X				X	X	X							X	X	
15...					X				X		X							X	X	
22...					X					X	X							X	X	
29...			X		X					X	X							X	X	
Dec.																				
6...					X					X	X		X		X		X	X	X	
13...					X		X				X		X						X	
20...					X		X		X		X			X			X	X	X	

Table 14.--*Frequency of occurrence of plankton in San Antonio Reservoir in 1971*

Date	PHYTOPLANKTON																		ZOOPLANKTON	
	Chlorophyta Chlorophyceae (green algae) *Dictyosphaerium sp.*	*Mougeotia sp.*	*Pediastrum sp.*	*Spirogyra sp.*	*Staurastrum sp.*	*Volvox sp.*	*Zygnema sp.*	Chrysophyta Bacillariophyceae (diatoms) *Asterionella sp.*	*Stephanodiscus sp.*	*Surirella sp.*	*Synedra sp.*	*Tabellaria sp.*	Chrysophyceae (yellow-brown algae) *Dinobryon sp.*	*Mallomonas sp.*	*Synura sp.*	Cyanophyta Myxophyceae (blue-green algae) *Anabaena sp.*	*Oscillatoria sp.*	Pyrrophyta Dinophyceae (dinoflagellates) *Ceratium sp.*	Rotifera Monogononta (rotifers) *Keratella sp.*	*Polyarthra sp.*
SAN ANTONIO RESERVOIR																				
Jan., 1971																				
3...			X		X					X	X						X		X	X
13...			X		X					X	X							X	X	
27...			X							X								X	X	X
Feb.																				
7...			X						X	X								X	X	
14...									X									X	X	
Mar.																				
7...			X						X										X	
13...					X													X	X	
22...			X																X	
25...			X								X							X	X	
Apr.																				
3...			X		X													X	X	
10...			X		X				X									X	X	
17...			X		X													X		
24...			X		X													X	X	
May																				
1...			X		X				X									X		
July																				
23...					X														X	
Aug.																				
11...																			X	
Sept.																				
10...			X		X														X	
Oct.																				
6...			X		X											X	X		X	
14...			X		X													X	X	
18...			X		X													X	X	
22...			X		X													X	X	
26...			X		X													X	X	
Nov.																				
2...			X															X	X	
9...			X		X													X	X	
10...			X		X				X									X	X	X
22...			X		X													X	X	



(Large graph presents means of measurements in July 1970 and 1972, and August 1970 and 1971. Horizontal bars indicate the range of values. Inset graph is a single profile. See page 5 for explanation of symbols.)

FIGURE 24.--Temperature and dissolved-oxygen profiles of San Antonio Reservoir.

LAKES OWNED BY SANTA CLARA VALLEY WATER DISTRICT

The Santa Clara Valley Water District has as its function the reduction of flood hazards and the providing of an adequate supply of water to the residents of the county.

Water-supply demands in the area are met by the storage of underground and surface-water supplies. The underground water basin is the primary source of water for the District. However, the District also maintains and operates eight reservoirs having a combined capacity of 155,000 acre-ft (191 hm^3). Some of the impounded water is released into percolation ponds for ground-water recharge and some is released for downstream irrigation. The reservoirs which are included in this section are Anderson, Calero, Coyote, and Lexington. These reservoirs provide water storage for supply, flood control, and recreation.

In 1970, evidence of mercury contamination from abandoned mercury mines was found in some surface water in the Santa Clara Valley. Therefore, in September 1970, water samples for mercury analyses were collected in Alamitos Creek, a major drainage basin in Santa Clara County, by the California Regional Water Quality Control Board--San Francisco Bay Region. The water contained concentrations of mercury greater than the acceptable limits of 5.0 μg/l recommended by the U.S. Public Health Service (1962). The following month, several agencies collected fish samples for mercury analysis from Calero Reservoir, which receives water from Alamitos Creek. The fish contained concentrations greater than 0.5 μg/g (micrograms per gram), which is the maximum acceptable limit of mercury content in fish, established by the U.S. Food and Drug Administration (Sport Fishing Institute, 1973). As a result of the findings, signs warning of mercury contamination have been posted at this reservoir and mercury analyses have been made on water, sediment, and fish samples collected from other surface waters in Santa Clara County. Some of the results will be included in the discussion of each lake.

Methods

Temperature and dissolved-oxygen measurements were made at selected depths near each dam by personnel of the Geological Survey.

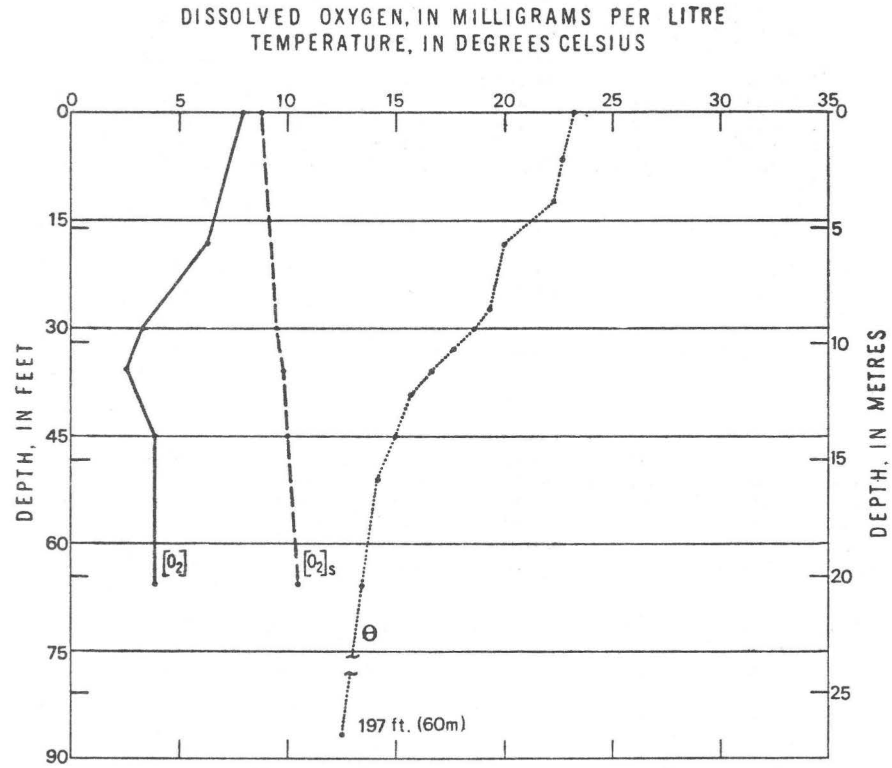
Water samples collected for chemical analyses prior to 1972 were collected by personnel of the Santa Clara Valley Water District. The samples were collected at the surface near the dams, and were analyzed at the Santa Clara Valley Water District laboratory using the methods in American Public Health Association and others (1965). In 1972, water samples for chemical analyses were collected near the shore, at the 2-ft (0.6-m) depth by personnel of the Geological Survey.

Water, sediment, and fish samples for mercury analyses were collected by several agencies in 1971. The analyses of these samples were made by the laboratories listed in the table for each lake. The reader should consult the individual laboratories for a description of the methods used.

Anderson Reservoir

Anderson Reservoir is located in southern Santa Clara County, and impounds the flow of the north fork and lower main fork of Coyote Creek. Anderson is the largest reservoir in the Santa Clara Valley Water District, with a storage capacity of 91,300 acre-ft (113 hm^3) and a surface area of 1.53 mi^2 (3.96 km^2). The reservoir has become a favorite recreation area for water sports.

Anderson Reservoir was thermally stratified at the time of the June 1970 survey (fig. 25). The dissolved oxygen was undersaturated at all depths, with a concentration minimum of 2.5 mg/l at the 35-ft (10.7-m) depth.



(See page 5 for explanation of symbols.)

FIGURE 25.--Temperature and dissolved-oxygen profiles of Anderson Reservoir, June 23, 1970.

Water samples for chemical analyses were collected from Anderson Reservoir four times in 1971 (table 15). The calculated dissolved solids ranged from 200 to 230 mg/l, and the specific conductance values ranged from 353 to 390 micromhos. The mercury concentrations of fish from Anderson Reservoir (table 16) were below the minimum levels (0.5 μg/g) designated by the U.S. Food and Drug Administration (Sport Fishing Institute, 1973).

Table 15.--*Chemical analyses of water samples from Santa Clara Valley Water District reservoirs*

ANDERSON RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Mar., 1971 01...			53	10	37	2.2	171	0
June 01...			60	4.0	19	1.6	176	0
Sept. 01...			54	7.0	19	3.0	183	0
Dec. 12...	2.5		56	9.0	19	3.1	182	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Mar., 1971 01...	140	28	17	--	0.07	100	230	170	358	8.1
June 01...	144	25	12	0.1	.05	100	210	170	359	8.1
Sept. 01...	168	18	12	.3	.41	100	200	160	353	8.0
Dec. 12...	150	25	12	.2	.05	140	220	180	390	8.2

CALERO RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Mar., 1971 01...			53	10	20	2.2	171	0
June 01...			54	7.0	11	1.1	188	0
Sept. 09...			40	15	11	2.6	200	0
Dec. 12...	2.5		88	25	13	3.1	285	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Mar., 1971 01...	140	9.0	14	--	0.11	--	190	170	303	8.1
June 01...	154	10	5.0	0.1	.02	300	180	160	388	8.1
Sept. 09...	164	2.0	6.0	.2	.02	100	180	160	317	8.0
Dec. 12...	234	5.0	13	.2	.05	170	290	320	360	8.2

Table 15.--*Chemical analyses of water samples from Santa Clara Valley Water District reservoirs*--Continued

COYOTE RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1972								
18...	9.8	20	54	22	23	2.1	227	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept., 1972										
18...	186	67	16	0.3	0.00	200	310	230	509	8.1

LEXINGTON RESERVOIR

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Mar., 1971								
01...			44	11	28	2.2	134	0
June								
01...			56	5.0	14	1.6	142	0
Sept.								
01...			45	14	15	2.6	161	0
Dec.								
12...	3.0		88	22	18	2.8	285	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Mar., 1971										
01...	110	--	14	--	0.23	100	170	160	347	8.0
June										
01...	116	45	11	0.2	.11	300	200	160	342	7.5
Sept.										
01...	132	27	10	.3	.25	60	190	170	321	7.7
Dec.										
12...	234	70	13	.2	.05	140	360	310	620	8.0

Table 16.--*Concentrations of mercury in sediment and fish samples collected from Anderson Reservoir*

[Total mercury content in sediment and fish samples is expressed in μg/g]

Type of sample	Date	Length (centimetres)	Weight (grams)	Total mercury content	Remarks	Laboratory
Sediment	5-21-71			0.2	Dry weight	Stoner Laboratories, Inc., Campbell, Calif.
Do.	6-71			.1	do.	California Department of Fish and Game
Fish					All fish samples on wet-weight basis	
Catostomus sp. (Sucker)	6-11-71	33		.2	1 fish	Do.
Cyprinus carpio (Carp)	6-11-71	51		.3	do.	Do.
Lepomis gibbosus (Pumpkinseed)	6-11-71	[1]12		[1].1	Composite of 2 fish	Do.
Lepomis macrochirus (Bluegill)	4-3-71	11	85	.4	1 fish	Stoner Laboratories, Inc., Campbell, Calif.
Micropterus salmoides (Largemouth bass)	6-11-71	[1]22		[1].4	Composite of 3 fish	California Department of Fish and Game
Micropterus salmoides (Largemouth bass)	6-11-71	[1]16		[1].2	Composite of 2 fish	Do.
Pomoxis nigromaculatus (Black crappie)	6-11-71	[1]18		[1].2	Composite of 3 fish	Do.

[1] Average.

Calero Reservoir

Calero Reservoir was formed in 1935 as part of a multiple reservoir construction project. The reservoir is located on Calero Creek and has a storage capacity of 9,300 acre-ft (11.5 hm^3). Calero Creek has a very small drainage area (7.10 mi^2 [18.4 km^2]) in relation to the storage capacity of Calero Reservoir. The evaporation rate in the reservoir is too high in relation to the inflow from Calero Creek to permit attainment of a full pool (Santa Clara County School Department and Santa Clara Valley Water Conservation District, 1960). Therefore, additional water is conveyed to the reservoir by means of a 4.5-mi (7.2-km) canal from Alamitos Creek, which has a much larger drainage area, but lacks an adequate reservoir site. Calero Reservoir is used for water conservation and flood control.

Calero Reservoir was thermally stratified on June 25, 1970 (fig. 26). The dissolved oxygen was undersaturated at all measured depths, and the concentrations dropped to zero at the 25-ft (7.6-m) depth.

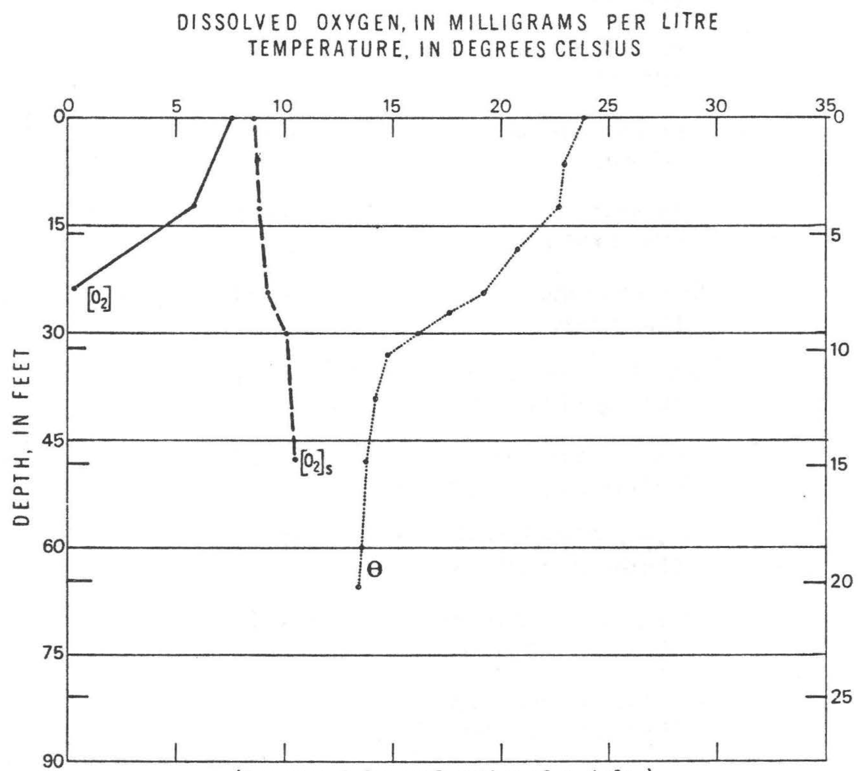


FIGURE 26.--Temperature and dissolved-oxygen profiles of Calero Reservoir, June 25, 1970.

Table 17.--*Concentrations of mercury in water, sediment,*

[Total mercury content in water is expressed in μg/l,

Type of sample	Date	Length (centimetres)	Weight (grams)
Water	3-27-71		
Do.	3-27-71		
Do.	5-5-71		
Do.	9-7-71		
Sediment	4-8-71		
Do.	4-8-71		
Fish			
Cyprinus carpio (Carp)	4-71	48	1,800
Cyprinus carpio (Carp)	4-71	13	170
Cyprinus carpio (Carp)	4-71	[1]19	[1]78
Ictalurus sp. (Catfish)	4-71	11	85
Ictalurus sp. (Catfish)	4-71	22	132
Lepomis macrochirus (Bluegill)	4-71	13	60
Lepomis macrochirus (Bluegill)	4-71	[1]12	[1]42
Lepomis microlophus (Redear sunfish)	4-71	8	32
Micropterus salmoides (Largemouth bass)	4-71	49	2,770
Micropterus salmoides (Largemouth bass)	4-71	33	7,159
Micropterus salmoides (Largemouth bass)	4-71	23	252
Pomoxis nigromaculatus (Black crappie)	4-71	[1]19	[1]87

[1] Average.

and fish samples collected from Calero Reservoir

in sediment and fish samples in µg/g]

Total mercury content	Remarks	Laboratory
0.0		Cook Research Laboratories, Inc., Menlo Park, Calif.
3.0		California Water Service Co., San Jose, Calif.
2.0		California Department of Fish and Game
.0		Stoner Laboratories, Inc., Campbell, Calif.
1.0	Dry weight	California Department of Fish and Game
3.0	do.	Stoner Laboratories, Inc., Campbell, Calif.
	All fish samples on wet-weight basis	
1.1	1 fish	California Department of Fish and Game
.6	do.	Stoner Laboratories, Inc., Campbell, Calif.
[1]1.4	Composite of 3 fish	California Department of Fish and Game
.5	1 fish	Stoner Laboratories, Inc., Campbell, Calif.
.9	do.	California Department of Fish and Game
.7	do.	Stoner Laboratories, Inc., Campbell, Calif.
[1].8	Composite of 3 fish	California Department of Fish and Game
.2	1 fish	Stoner Laboratories, Inc., Campbell, Calif.
5.1	do.	California Department of Fish and Game
1.3	do.	Do.
.6	do.	Stoner Laboratories, Inc., Campbell, Calif.
[1]1.4	Composite of 3 fish	California Department of Fish and Game

The predominant ions in the lake water were calcium and bicarbonate, with calcium values ranging as high as 88 mg/l in December 1971 (table 15). The high calcium and magnesium concentrations in December resulted in a hardness value of 320 mg/l $CaCO_3$. Consequently, this water would be classified as very hard and could be objectionable when used for ordinary domestic purposes (Hem, 1970, p. 225).

Mercury concentration in a *Micropterus salmoides* (largemouth bass) collected from the reservoir in April 1971 (table 17) was 5.1 μg/g, a value well above the acceptable limit of 0.5 μg/g designated by the U.S. Food and Drug Administration (Sport Fishing Institute, 1973). Most of the other fish analyzed also exceeded this limit. Warnings of mercury contamination have been posted at Calero Reservoir, and the reservoir and surrounding lands have been closed to the public.

Coyote Reservoir

Coyote Reservoir is the largest of six multipurpose reservoirs formed in 1936 as a part of a South Bay area water construction project. The reservoir impounds the water of Coyote Creek. It has a drainage area of 116 mi^2 (300 km^2) and stores 24,500 acre-ft (30.2 hm^3) of water. Runoff water stored in the winter is released into Coyote Creek and a canal network in the summer, for percolation into aquifers.

Temperature and dissolved-oxygen measurements were made in Coyote Reservoir on June 24, 1970 (fig. 27). At the time of the survey, the dissolved oxygen was supersaturated to the 12-ft (3.7-m) depth, but was noticeably under-saturated below this depth. The concentration of dissolved oxygen decreased from 10 mg/l at the surface to about 2 mg/l at the 40-ft (12-m) level. The temperature profile showed that the reservoir was stratified, with a surface temperature of 24°C and a bottom temperature of 14°C.

A water sample collected on September 18, 1972, was analyzed for chemical constituents (table 15). The calculated dissolved-solids concentration was 310 mg/l and the specific conductance was 509 micromhos. The concentrations of mercury in fish from Coyote Reservoir were below minimum public health standards (0.5 μg/g) except in one *Micropterus salmoides* (largemouth bass) in which the concentration was 0.9 μg/g (table 18).

Lexington Reservoir

The dam forming Lexington Reservoir was completed in 1952. The reservoir lies within the Los Gatos Creek watershed and has a drainage area of 38.0 mi^2 (98 km^2) and a capacity of 21,430 acre-ft (26.4 hm^3). The reservoir provides domestic water and is used for recreation.

Table 18.--*Concentrations of mercury in water, sediment, and fish samples collected from Coyote Reservoir*

[Total mercury content in water is expressed in μg/l, in sediment and fish samples in μg/g]

Type of sample	Date	Length (centimetres)	Weight (grams)	Total mercury content	Remarks	Laboratory
Water	6-71			0.0		California Department of Fish and Game
Sediment	5-26-71			.3	Dry weight	Stoner Laboratories, Inc., Campbell, Calif.
Do.	6-71			.1	do.	California Department of Fish and Game
Fish					All fish samples on wet-weight basis	
Lavinia exilicauda (Hitch)	4-3-71	[1]20	[1]155	[1].5	Composite of 2 fish	Do.
Lepomis gibbosus (Pumpkinseed)	4-3-71	14	135	.3	1 fish	Do.
Lepomis macrochirus (Bluegill)	4-3-71	[1]8	[1]24	[1].2	Composite of 3 fish	Do.
Lepomis macrochirus (Bluegill)	4-3-71	[1]9	[1]43	[1].2	do.	Do.
Micropterus salmoides (Largemouth bass)	4-3-71	32	1,200	.9	1 fish	Do.
Micropterus salmoides (Largemouth bass)	4-3-71	[1]16	[1]113	[1].5	Composite of 3 fish	Do.
Micropterus salmoides (Largemouth bass)	4-3-71	10	27	.3	1 fish	Do.
Micropterus salmoides (Largemouth bass)	4-3-71	15	--	.4	do.	Do.
Micropterus sp. (Bass)	4-3-71	--	92	.4	do.	Stoner Laboratories, Inc., Campbell, Calif.
Pomoxis nigromaculatus (Black crappie)	4-3-71	12	50	.3	do.	California Department of Fish and Game
Salmo sp. (Trout)	4-3-71	--	92	.3	do.	Stoner Laboratories, Inc., Campbell, Calif.
Salmo sp. (Trout)	4-3-71	11	--	.3	do.	California Department of Fish and Game

[1]Average.

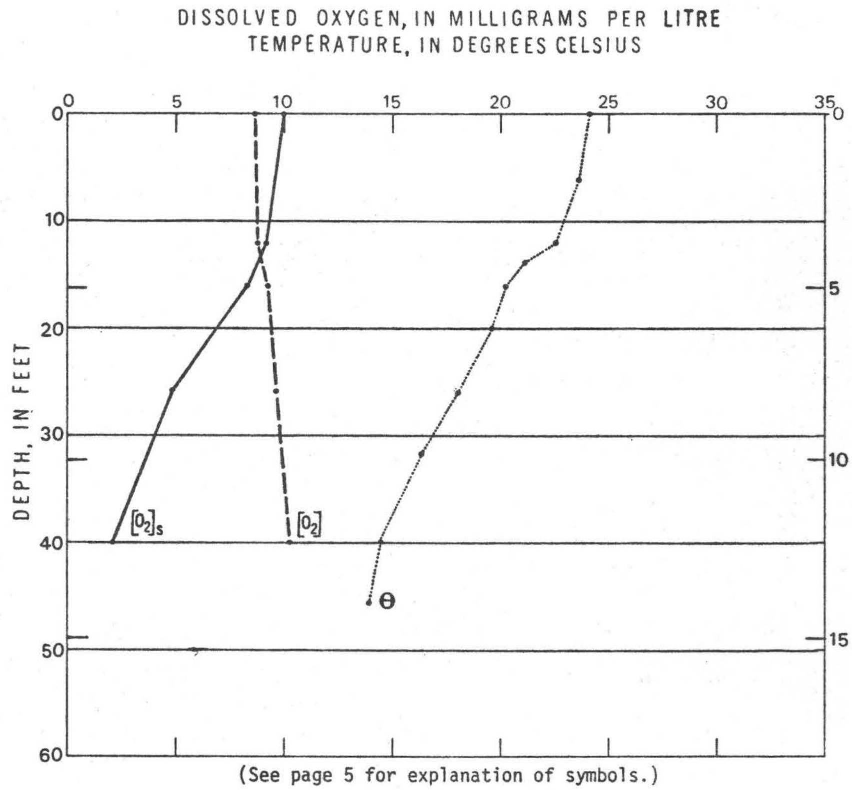


FIGURE 27.--Temperature and dissolved-oxygen profiles of Coyote Reservoir, June 24, 1970.

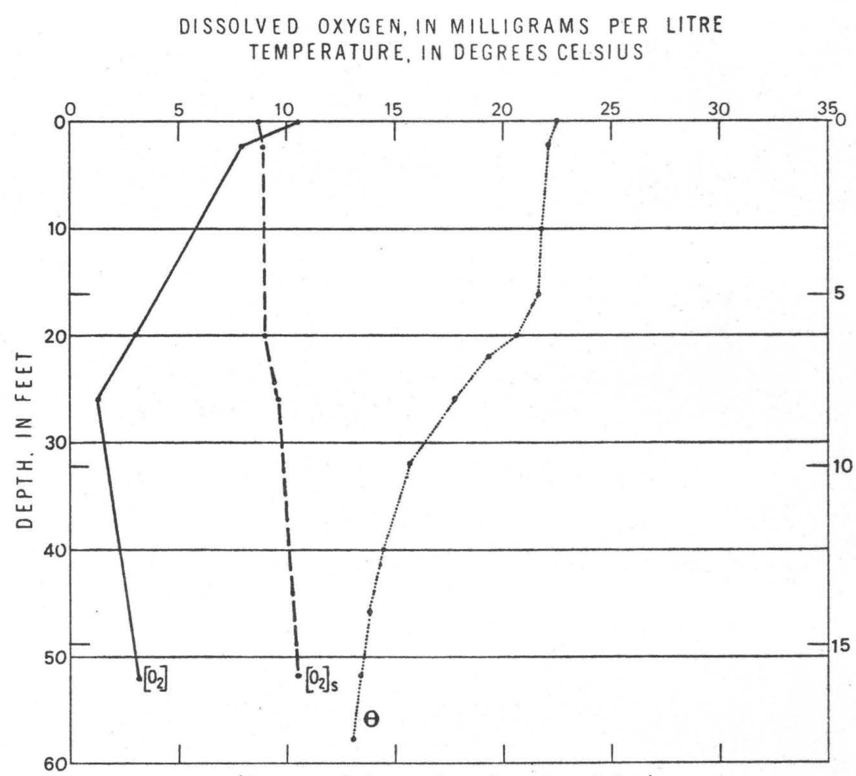


FIGURE 28.--Temperature and dissolved-oxygen profiles of Lexington Reservoir, June 30, 1970.

Lexington Reservoir was thermally stratified on June 30, 1970 (fig. 28). The temperature ranged from 22.5°C at the surface to 13.1°C at the bottom. The dissolved oxygen was supersaturated at the surface, with a concentration of 10.5 mg/l. At the 26-ft (8-m) level, the dissolved-oxygen concentration was only 0.7 mg/l, as compared to 3.1 mg/l at the bottom. This minimum concentration was probably due to the decomposition of organic material which had dropped from the surface and was held by a density barrier (Hutchinson, 1957, p. 621).

The results of the chemical analyses of Lexington Reservoir water showed the highest concentrations of most major ions and total solids (360 mg/l) in December 1971 (table 15). The specific conductance at this time was 620 micromhos. Concentrations of mercury in fish showed that the *Micropterus salmoides* (largemouth bass) collected on May 24, 1972, contained the highest concentrations of mercury (table 19). These mercury concentrations were above the acceptable limits designated by the U.S. Food and Drug Administration (Sport Fishing Institute, 1973).

LAKE OWNED BY SANTA CRUZ WATER DEPARTMENT

The city of Santa Cruz has a population of approximately 34,500 and is situated 70 mi (113 km) south of San Francisco, along the shore of Monterey Bay. The climate is mild, resulting in the utilization of both mountain and seashore sites for extensive resort and recreational facilities.

Santa Cruz has owned and operated its own water supply and water distribution system since 1890. At present, the water department provides both surface and underground sources of water to customers within a 42-mi^2 (109-km^2) area, including the city and outlying areas.

The Newell Creek source is the most recent addition to the city's water supply system. Newell Creek, a tributary of the San Lorenzo River, was dammed about 10 mi (16 km) north of Santa Cruz to form Loch Lomond Reservoir. The Santa Cruz Water Department is entitled to 8,300 acre-ft (10.2 hm^3) of the reservoir water, the San Lorenzo Valley County Water District has a claim of 500 acre-ft (0.62 hm^3) from the reservoir, and releases for fish enhancement are 730 acre-ft (0.91 hm^3) per year. Much of the latter water can be recovered at the downstream San Lorenzo intake (Blythe and Co., Inc., 1968).

Fifty percent of the water needs of the city are supplied by coastal sources comprising water diverted from Laguna Creek, Leddel Springs, and Majors Creek. The San Lorenzo River and its tributary, Newell Creek, and six wells provide the remaining water supply needs of the city. Loch Lomond is the only reservoir owned by the city of Santa Cruz that is included in this report.

Table 19.--*Concentrations of mercury in sediment and fish samples collected from Lexington Reservoir*

[Total mercury content in sediment and fish samples is expressed in μg/g]

Type of sample	Date	Length (centimetres)	Weight (grams)	Total mercury content	Remarks	Laboratory
Sediment	6-12-71			0.3	Dry weight	California Department of Fish and Game
Do.	5-24-72			.1	do.	Stoner Laboratories, Inc., Campbell, Calif.
Fish					All fish samples on wet-weight basis	
Ictalurus melas (Black bullhead)	5-24-72	25	--	.1	1 fish	California Department of Fish and Game
Lavinia exilicauda (Hitch)	5-24-72	[1]17	--	[1].3	Composite of 2 fish	Do.
Lepomis macrochirus (Bluegill)	4-3-71	--	99	.3	1 fish	Stoner Laboratories, Inc., Campbell, Calif.
Lepomis macrochirus (Bluegill)	5-24-72	22	--	.0	do.	California Department of Fish and Game
Lepomis macrochirus (Bluegill)	5-24-72	[1]17	--	[1].1	Composite of 2 fish	Do.
Lepomis macrochirus (Bluegill)	5-24-72	[1]13	--	[1].1	Composite of 3 fish	Do.
Micropterus salmoides (Largemouth bass)	5-24-72	42	--	.9	1 fish	Do.
Micropterus salmoides (Largemouth bass)	5-24-72	[1]30	--	[1].8	Composite of 2 fish	Do.
Micropterus salmoides (Largemouth bass)	5-24-72	[1]23	--	[1].6	do.	Do.
Micropterus salmoides (Largemouth bass)	5-24-72	[1]20	--	[1].6	do.	Do.
Micropterus sp. (Bass)	4-3-71	--	319	.0	1 fish	Stoner Laboratories, Inc., Campbell, Calif.
Pomoxis nigromaculatus (Black crappie)	5-24-72	21	--	.4	do.	California Department of Fish and Game

[1]Average.

Methods

Temperature, dissolved-oxygen, and pH measurements were made at station 1 by personnel of the Geological Survey (fig. 29).

All water samples for chemical analyses were collected from station 1. The 1969 water sample for chemical analysis was collected by personnel of the Santa Cruz Water Department. The sample was analyzed at the Santa Cruz Water Department, Water Quality Control Laboratory, using the methods in American Public Health Association and others (1965). In 1972, a water sample for chemical analysis was collected by personnel of the Geological Survey.

Water samples for analyses of phytoplankton were collected from the surface at station 2 by personnel of the Santa Cruz Water Department (fig. 29). Samples were collected weekly, using a water-sampling bottle. The water samples were concentrated using the Sedgwick-Rafter sand-filter method described in Welch (1948) and American Public Health Association and others (1955). A 1-ml aliquot was placed in a counting cell and identification and enumeration of cells was made using the Sedgwick-Rafter method (American Public Health Association and others, 1971).

Loch Lomond

Loch Lomond reservoir was formed in 1960 when a dam was built across Newell Creek (fig. 29). The reservoir has a storage capacity of 8,400 acre-ft (10.3 hm^3) and drains a watershed of over 8 mi^2 (20.7 km^2). At full pool, the elevation of the water surface is 590 ft (180 m) above mean sea level. Water can be withdrawn from outlets at elevations of 550, 530, 510, 490, and 470 ft (168, 162, 155, 149, and 143 m) above mean sea level.

The primary function of the reservoir is for domestic water supplies. However, the reservoir and surrounding watershed lands are used for recreation, including fishing, boating, picnicking, and hiking. The reservoir is stocked with rainbow trout (*Salmo gairdneri*) by the California Department of Fish and Game. Partly because of this fish-stocking program, the deeper part of the reservoir has been aerated in an effort to increase the oxygen concentration of the water, as well as to lower the surface water temperature, and hence reduce evaporation. The aerator is at the 90-ft (27-m) depth and lies 25 ft (7.6 m) upstream from the dam (Cross, 1971).

Aeration has also been used to produce aerobic conditions in the deeper water and thus to depress high manganese levels before the water enters the distribution system. Manganese is undesirable in domestic water supplies above concentrations of 0.05 mg/l because it can cause discoloration of the water and lead to deposits in pipelines and filters in treatment plants (Mackenthun and Ingram, 1967).

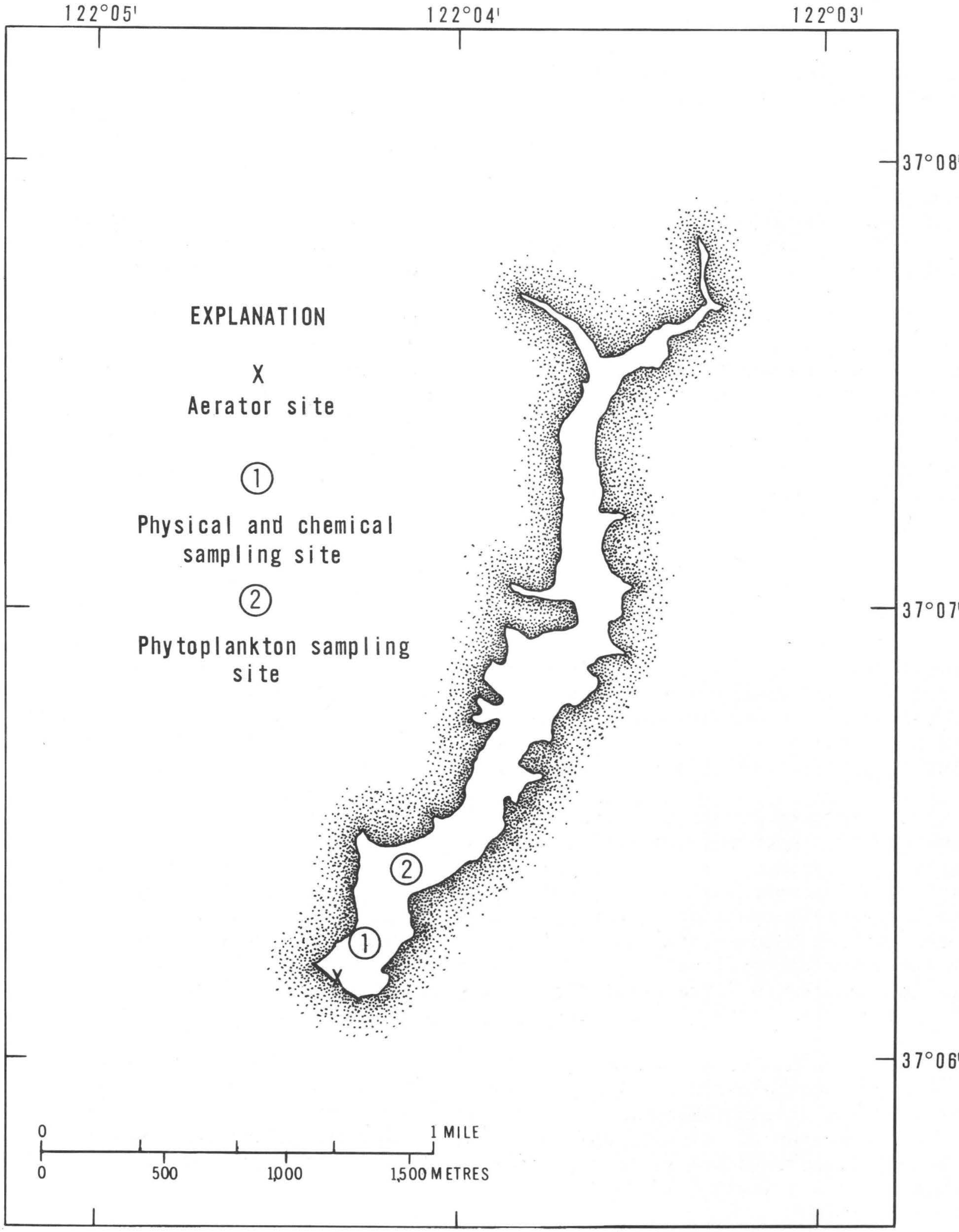


FIGURE 29.--Loch Lomond showing approximate locations of aerator and chemical, physical, and biological sampling sites.

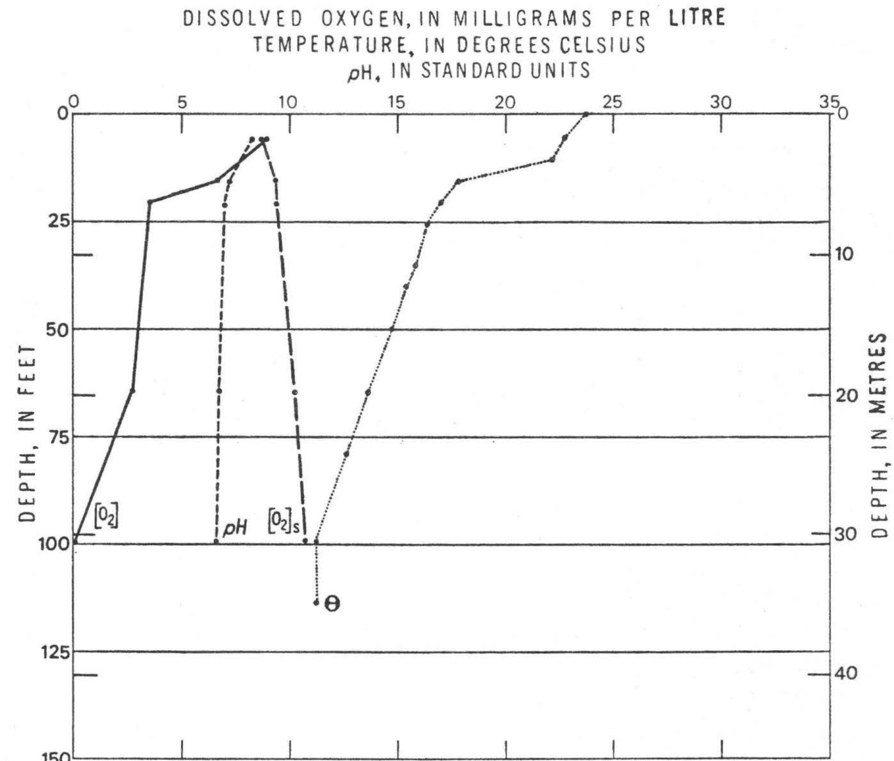
Under aerobic conditions, the solubility of manganese is reduced and it is sorbed on the bottom sediments. When oxidation of organic material by bacteria decreases the dissolved-oxygen concentration of the water, the solubility of manganese increases, it goes into solution, and may be withdrawn from the reservoir. Aeration has also been used to reduce the soluble ferrous iron concentration (which goes out of solution under aerobic conditions) and the build-up of hydrogen sulfide concentrations, caused by anaerobic bacteria decomposing organic matter. Because of extensive aeration, a lowering of the metalimnion and hence destratification occurs, providing a greater amount of aerated water, free from high concentrations of manganese, iron, and hydrogen sulfide.

The aerator began operation in July 1967. During the period from June 1967 to July 1969, the aerator was operated for periods ranging from 8 to 2,856 hours at a time. A time clock system was installed in June 1970, permitting the aerator to operate at preset periods. Aeration of the reservoir has not been in effect since August 1971.

Prior to the reservoir survey on July 16, 1970, by the Geological Survey, the aerator had been operated for 144 hours, at frequencies of 12 hours on and 12 hours off. The reservoir was thermally stratified, with a shallow metalimnion at the 15-ft (4.6-m) depth (fig. 30). The dissolved oxygen was supersaturated near the surface, but the concentration was reduced to 3.5 mg/l at the 20-ft (6-m) level and was anaerobic at the 100-ft (30-m) depth.

The results of the chemical analyses showed an increase in concentrations of most constituents in 1972, as compared to 1969 (table 20). However, the silica concentration decreased from 23 mg/l in 1969 to 1.8 mg/l in 1972. This decrease may be a result of greater diatom production in 1972, and subsequent extraction and utilization of silica for their frustule (shell) formation.

Water samples for phytoplankton types and abundance were collected weekly from 1967 to 1969 (fig. 31). The numbers were averaged on a monthly basis and grouped according to class. Cross (1971) stated that the organisms of major concern in Loch Lomond reservoir were blue-green algae, particularly *Anabaena sp.*, and the diatoms, especially *Fragilaria sp.* The diatoms were found throughout the year from 1967 to 1969, and reached their highest numbers in the spring (April) and early fall (October). Major production periods of the blue-green alga, *Anabaena sp.*, usually last about two to three weeks each, with about four major periods from May to October. The reservoir is treated with copper sulfate to reduce the algal numbers (California Department of Water Resources, 1966; Cross, 1971). Green algae occurred throughout the year, but were present in low numbers and therefore were of little concern from a water-quality standpoint.



(See page 5 for explanation of symbols.)

FIGURE 30.--Temperature, dissolved-oxygen, and pH profiles of Loch Lomond, July 16, 1970.

Table 20.--*Chemical analyses of water samples from Santa Cruz Water Department reservoir*

LOCH LOMOND

Date	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (ug/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)
Sept., 1969 11...	23		37	7.8	13		110	0
Sept., 1972 18...	1.8	50	59	12	23	2.3	176	0

Date	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (ug/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca,Mg) (mg/l)	Specific conductance (micromhos)	pH (units)
Sept., 1969 11...	90	53	9.0	0.3	0.11		200	130	316	7.1
Sept., 1972 18...	144	76	18	.4	.00	80	280	200	473	8.1

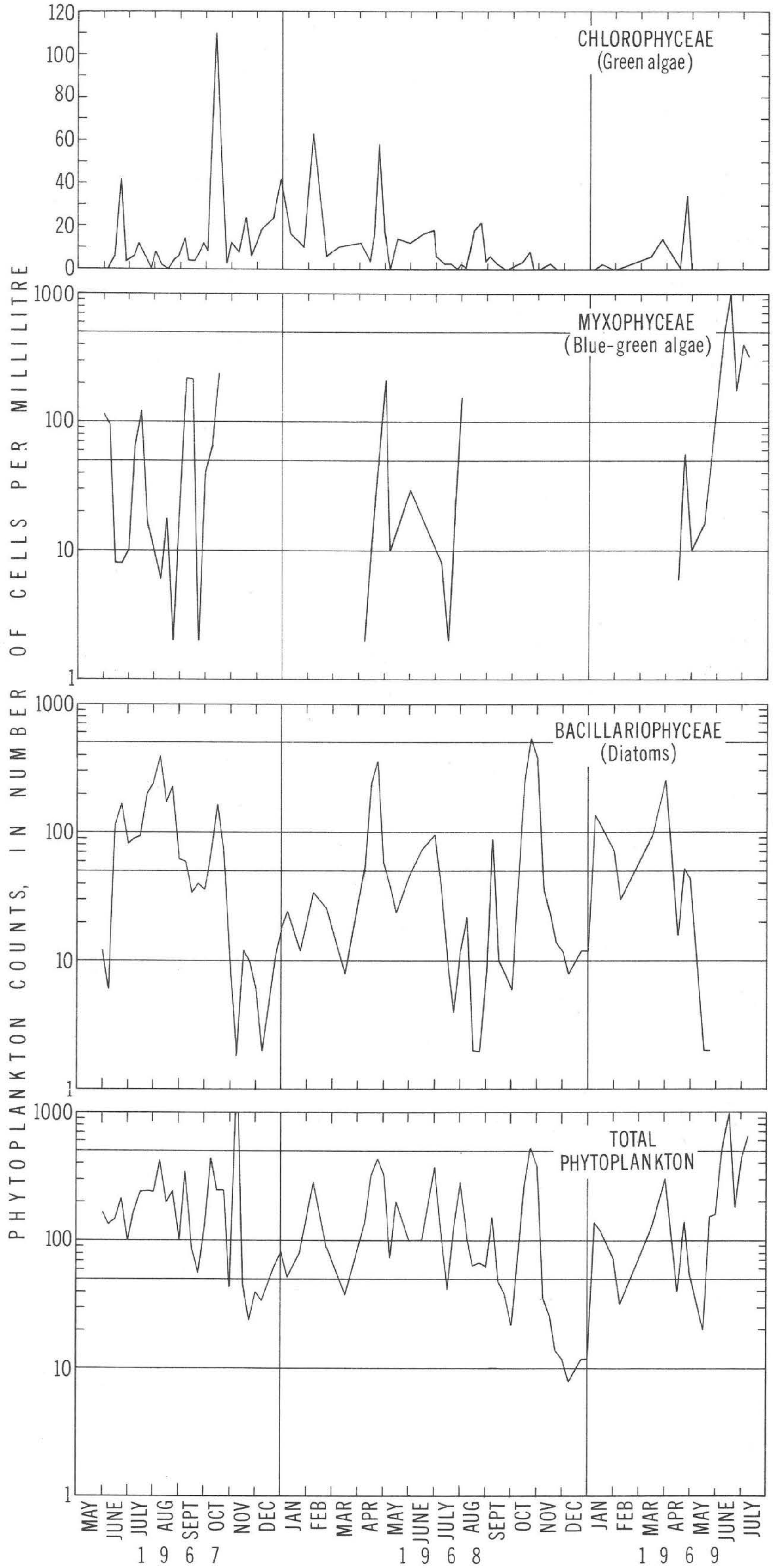


FIGURE 31.--Numbers of phytoplankton cells comprising the major groups of algae in Loch Lomond.

LAKE OWNED BY U.S. BUREAU OF RECLAMATION

The U.S. Bureau of Reclamation develops systems for the conservation and distribution of water. The agency was authorized by Congress in 1902 to develop multi-purpose water projects throughout the western United States. An example of such a project is Lake Berryessa, which was built as a part of the California Solano Water Project, and stores surplus water from Putah Creek. Lake Berryessa is the only Bureau of Reclamation reservoir that is included in this report.

Methods

All physical measurements and water samples for chemical analyses were collected by the Bureau of Reclamation. The values for dissolved solids and hardness were calculated by the Geological Survey. The sampling site was at the intersection of the old Putah Creek channel and a line between Sugar Loaf Peak and Gunn Ranch (fig. 32). Temperature and dissolved-oxygen measurements were made at selected depths. Temperature was measured with a thermister, and water samples for dissolved-oxygen analyses were collected with a water-sampling bottle. The Alsterberg azide modification of the Winkler method was used for determining the dissolved-oxygen concentrations. Water samples for chemical analyses were collected at the 5-ft (1.5-m) depth, using a water-sampling bottle. The samples were analyzed at the McClellan Air Force Base, using the methods described in American Public Health Association and others (1965, 1971).

Lake Berryessa

Lake Berryessa is about 30 mi (48 km) west of Sacramento. Monticello Dam, which forms the lake, was completed in 1957 by the Bureau of Reclamation. The reservoir is one of the largest in northern California, and stores the surplus flows of Putah Creek for agricultural, municipal, and industrial use. The reservoir has a storage capacity of 1,600,000 acre-ft (1,975 hm^3) and a drainage area of 576 mi^2 (1,490 km^2).

The reservoir and surrounding area are used intensively for recreation. The lake is heavily fished and has a variety of warm and cold water species. Presently, there are 12 campgrounds, 15 concession areas, and about 1,125 boat docks. Since parts of the shoreline are highly developed (fig. 33), the reservoir should be closely observed for signs of accelerated enrichment.

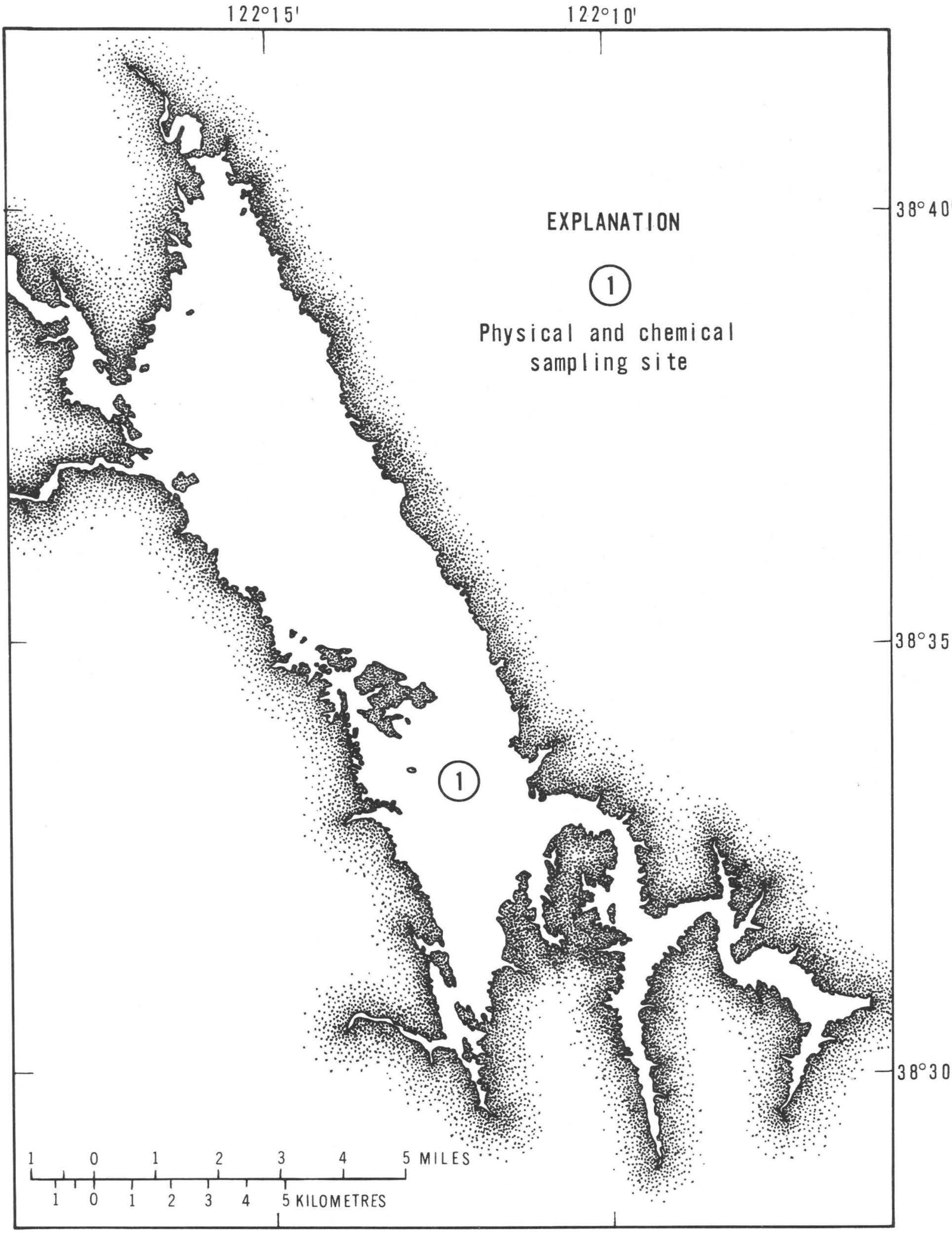


FIGURE 32.--Lake Berryessa showing approximate location of physical and chemical sampling site.

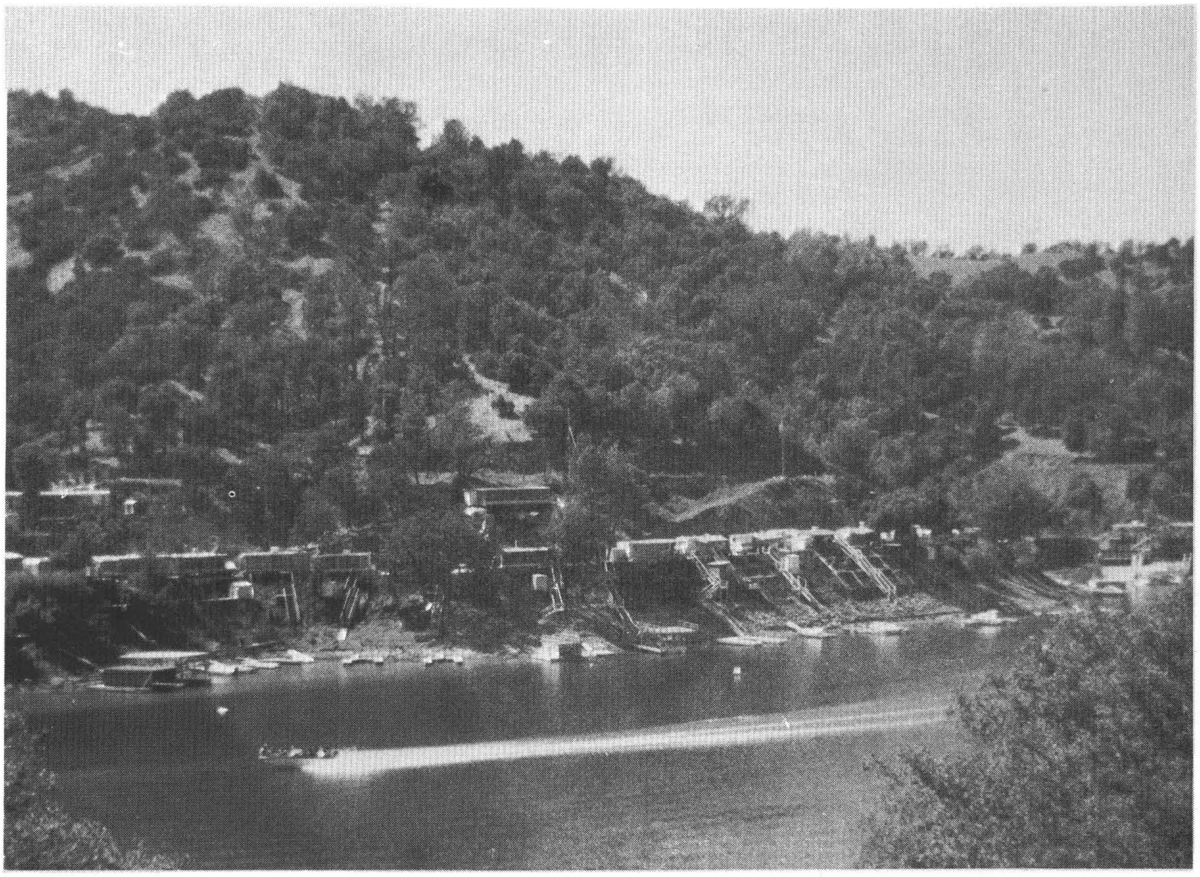


FIGURE 33.--A section of Lake Berryessa showing shoreline development.

Seasonal temperature and dissolved-oxygen profiles for Lake Berryessa in 1970 are shown in figure 34. On February 26, the lake was well-mixed with a homogeneous thermal and dissolved-oxygen profile. The dissolved-oxygen concentration was above 10 mg/l at all depths. On May 22, the lake was slightly thermally stratified and the dissolved-oxygen concentration decreased to about 9 mg/l throughout the water column. At the time of the July 22 survey, the reservoir was strongly thermally stratified, with temperatures ranging from 24.4°C at the surface to 11.5°C at the bottom. The dissolved oxygen was supersaturated at the surface. On October 28, thermal stratification had decreased, and the lake water had become almost thermally uniform, with a temperature of 18°C at the surface and 15°C at the bottom. The dissolved-oxygen concentration was 8 mg/l at the surface, but because of respiratory uptake of oxygen by organisms, it was reduced to 2.5 mg/l at the 65-ft (20-m) depth.

Concentrations of major chemical constituents from the reservoir are shown in table 21. The results show no discernible concentration differences for the month of September over the 4-year period.

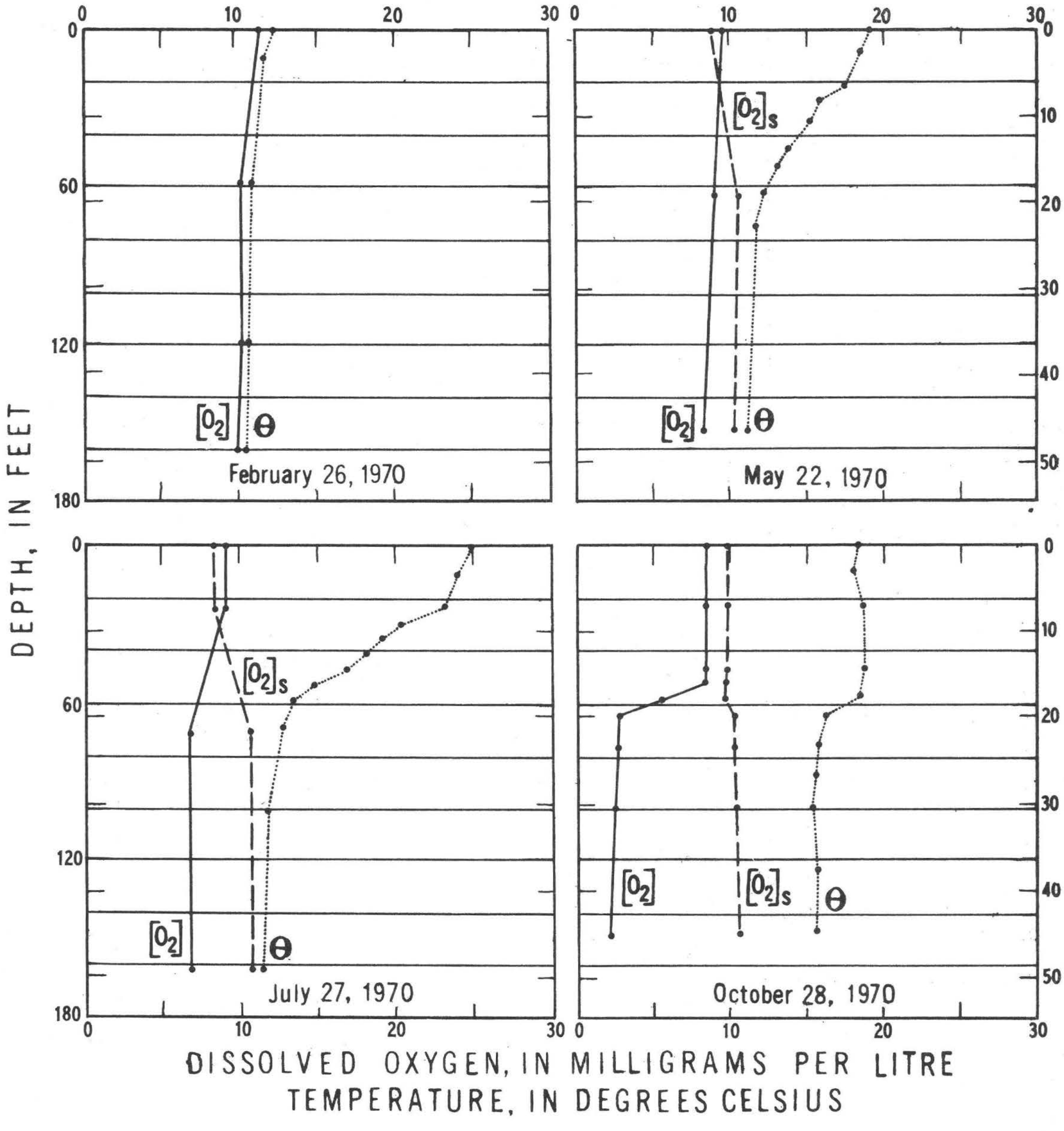


FIGURE 34.--Selected seasonal temperature and dissolved-oxygen profiles of Lake Berryessa for 1970.

Table 21.--*Chemical analyses of water samples from U.S. Bureau of Reclamation lake*

LAKE BERRYESSA

Date	Dis-solved silica (SiO_2) (mg/l)	Dis-solved iron (Fe) (ug/l)	Dis-solved cal-cium (Ca) (mg/l)	Dis-solved mag-ne-sium (Mg) (mg/l)	Dis-solved sodium (Na) (mg/l)	Dis-solved po-tas-sium (K) (mg/l)	Bicar-bonate (HCO_3) (mg/l)	Car-bonate (CO_3) (mg/l)
Sept., 1968 17...	--		17	32	10	1.2	194	0
Sept., 1969 11...	15		19	27	10	1.8	169	9
Sept., 1970 23...	16		17	25	9.0	1.5	170	1
Sept., 1971 23...	18		27	16	9.7	1.0	159	10

Date	Alka-linity as $CaCO_3$ (mg/l)	Dis-solved sulfate (SO_4) (mg/l)	Dis-solved chlo-ride (Cl) (mg/l)	Dis-solved fluo-ride (F) (mg/l)	Dis-solved nitrate (N) (mg/l)	Dis-solved boron (B) (ug/l)	Dis-solved solids (sum of consti-tuents) (mg/l)	Hard-ness (Ca,Mg) (mg/l)	Spe-cific con-duct-ance (micro-mhos)
Sept., 1968 17...	194	17	5.0				180	170	305
Sept., 1969 11...	153	19	2.0				180	160	370
Sept., 1970 23...	140	17	4.0				170	150	305
Sept., 1971 23...	130	22	5.0				190	150	318

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GLOSSARY OF SELECTED TERMS

[Note: Most of the following definitions were obtained or modified from Slack and others (1973), which is not specifically cited. This reference and others are given under the References Cited heading in this report.]

Aerate (v), aerator (n). To charge or treat with air or other gases, usually with oxygen.

Aerobic (adj). Having oxygen.

Alga, algae (n), algal (adj). A group of simple primitive plants that live in wet or damp places, and generally are microscopic in size, containing chlorophyll and lacking roots, stems, and leaves.

Algal bloom (n). A large number of a particular algal species, often amounting to 0.5 to 1 million cells per litre of water.

Aliquot (n). An equally divided portion of a whole sample.

Anaerobic (adj). Devoid of oxygen.

Bacterium, bacteria (n), bacterial (adj). Microscopic, unicellular organisms. Some bacteria cause disease while others perform an essential role in the recycling of materials.

Biology (n), biological (adj). The science or study of life.

Bloom (n). See algal bloom.

Blue-green algae (n). A group of algae with a blue pigment, in addition to the green chlorophyll. Blue-green algae are the group that usually causes nuisance conditions in water.

Decomposition, decomposer (n). The breakdown of dead plant and animal tissue by bacteria to the elemental state.

Density (n). The quantity or mass of a substance per unit volume. Computed as grams per cubic centimetre, in the case of water.

Diatom (n). A unicellular or colonial alga having a siliceous shell.

Dinoflagellate (n). Typically a yellow-brown unicellular alga that swims by means of two laterally attached appendages called flagella.

Dissolve (v). To put into solution.

Emersed plant (n). A rooted aquatic plant with leaves or other structures extending above the water surface (sometimes called emergent plant).

Enrichment (n). Addition or accumulation of plant nutrients within a body of water (Greeson, 1971).

Epilimnion (n), epilimnetic (adj). The upper relatively warm, circulating zone of water in a thermally stratified lake.

Eutrophication (n), eutrophic (adj). The natural process of enrichment and aging of a body of water that may be accelerated by the activities of man. Pertaining to waters in which primary production is high as a consequence of a large supply of available nutrients.

Filtration, filter (n). Removal of suspended and/or colloidal material from a liquid by passing it through a relatively fine porous medium.

Genus, genera (n). The taxonomic category consisting of species, and the first part of the scientific name of organisms.

Green algae (n). Algae that have pigments similar in color to those of higher green plants. Some forms produce algal mats or floating "moss" in lakes.

Growth (n). The increase in biomass by synthesis of living matter.

Homothermous (adj). Same water temperature throughout all depths of the lake.

Hypolimnion (n), hypolimnetic (adj). The lower, relatively cold, noncirculating water zone in a thermally stratified lake.

Limnology (n). The science or study of inland waters.

Metalimnion (n), metalimnetic (adj). The middle layer of water in a thermally stratified lake, in which temperature decreases rapidly with depth.

Nutrient (n). Any chemical element, ion, or compound that is required by an organism for the continuation of growth, reproduction, and other life processes.

Organic (n). Pertaining or relating to a compound containing carbon.

Organism (n). Anything that is alive; that is, respiring.

Orthograde (adj). A uniform distribution of some physical or chemical parameter in a body of water.

Oxidation (n). The process in which oxygen is added to a substance or in which an element loses electrons.

Oxygen saturation (n). A dissolved-oxygen concentration in water that is equal to the equilibrium concentration that the water would normally hold at the existing temperature, pressure, and salinity. Water having a dissolved-oxygen concentration below the equilibrium concentration is undersaturated, and that in excess is supersaturated.

Photosynthesis (n), photosynthetic (adj). A process whereby green plants utilize light as an energy source and convert chemical compounds to carbohydrates. In the process, carbon dioxide is utilized and oxygen is released.

Phytoplankton (n), phytoplanktonic (adj). The plant part of the plankton.

Plankton (n), planktonic (adj). The community of suspended or floating organisms which drift passively with water currents.

Production (n). The total amount of energy or organic matter produced from raw materials in an area per unit time, regardless of the fate of the material.

Reduction (n). The process in which oxygen is lost from a substance, or in which an element gains electrons.

Respiration (n). A life process in which carbon compounds are oxidized to carbon dioxide and water, and the liberated energy is used in the metabolic processes of living organisms.

Rotifer (n). A group of many-celled, microscopic, aquatic invertebrate animals of the zooplankton.

Sample (n). A small separated part of something that is representative of the whole.

Sediment (n). Fragmental material, both mineral and organic, that is in suspension or is being transported by the water mass or has been deposited on the bottom of the aquatic environment (Gary and others, 1972).

Sorb (v), sorption (n). To take up and hold by either adhesion or incorporation.

Species (n), sing. and pl. The basic or final unit for the classification of organisms.

Suspended sediment (n). Fragmental material, both mineral and organic, that is maintained in suspension in water.

Thermal stratification (n). A temperature distribution in which the lake water is distinctly layered because of thermal-density differences.

Water quality (n). That phase of hydrology that deals with the kinds and amounts of matter dissolved and suspended in natural water, the physical characteristics of the water, and the ecological relationships between aquatic organisms and the environment.

Watershed (n). The area drained by, or contributing to a stream, lake, or other body of water.

Zooplankton (n), zooplanktonic (adj). The animal part of the plankton.

GPO 965-636

Britton and others--LIMNOLOGICAL DATA FROM SELECTED LAKES IN THE SAN FRANCISCO BAY REGION, CALIFORNIA