Variation in Concentration of Selected Water-Quality Constituents in the Sacramento River at Bend Bridge, California

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-14

Prepared in cooperation with the
California Department
of Water Resources

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle VARIATION IN CONCENTRATION OF SELECTED WATER-QUALITY CONSTITUENTS IN THE SACRAMENTO RIVER AT BEND BRIDGE, CALIFORNIA			5. Report Date March 1976 6.
7. Author(s) Linda J. Britton and Robert C. Averett			8. Performing Organization Rept. No. USGS/WRI 76-14
9. Performing Organization Name and Address U.S. Geological Survey Water Resources Division 345 Middlefield Road Menlo Park, Calif. 94025			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Geological Survey Water Resources Division 345 Middlefield Road Menlo Park, Calif. 94025			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

Prepared in cooperation with the California Department of Water Resources

16. Abstracts

During an intensive water-quality study of the Sacramento River at Bend Bridge, Calif., from September 4 to 7, 1973, differences in selected water-quality constituent concentrations were evaluated at three locations at a single site in the river for two 24-hour periods. Water temperature, dissolved oxygen, pH, specific conductance, selected major ions and plant nutrients, and phytoplankton were measured and analyzed to determine thoroughness of mixing in the transection. There were slight fluctuations in constituent concentrations with time although the vertical and horizontal differences were not statistically significant at the 0.05 probability level. Consequently, one location probably would have been sufficient to obtain representative concentrations of most water-quality constituents at this site. The measured concentration differences may be of some biological importance, especially in the plant nutrients, where slight fluctuations in low concentrations may cause limiting conditions for plant growth.

17. Key Words and Document Analysis. 17a. Descriptors

*Chemical properties, *Water quality, *Plant growth, *Mixing, Dissolved oxygen, Hydrogen ion concentration, Ions, Temporal distribution, California

17b. Identifiers/Open-Ended Terms

Sacramento River, Red Bluff

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution.	UNCLASSIFIED	19
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

VARIATION IN CONCENTRATION OF SELECTED WATER-QUALITY CONSTITUENTS IN THE SACRAMENTO RIVER AT BEND BRIDGE, CALIFORNIA

By Linda J. Britton and Robert C. Averett

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-14

Prepared in cooperation with the

California Department of Water Resources

6215-16

March 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

CONTENTS

ILLUSTRATIONS

TABLES

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)*
ft (feet)	3.048×10^{-1}	m (metres)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic metres per second)
in (inches)	25.40	mm (millimetres)
mi (miles)	1.609	km (kilometres)

VARIATION IN CONCENTRATION OF SELECTED WATER-QUALITY CONSTITUENTS IN THE SACRAMENTO RIVER AT BEND BRIDGE, CALIFORNIA

By Linda J. Britton and Robert C. Averett

ABSTRACT

During an intensive water-quality study of the Sacramento River at Bend Bridge, Calif., from September 4 to 7, 1973, differences in selected water-quality constituent concentrations were evaluated at three locations at a single site in the river for two 24-hour periods. Water temperature, dissolved oxygen, pH, specific conductance, selected major ions and plant nutrients, and phytoplankton were measured and analyzed to determine thoroughness of mixing in the transection.

Slight fluctuations in constituent concentrations occurred with time although the vertical and horizontal differences among sampling locations were not statistically significant at the 0.05 probability level. Consequently, one location probably would have been sufficient to obtain representative concentrations of most water-quality constituents at this site. The measured concentration differences, especially in the plant nutrients, may be of some biological importance where slight fluctuations in low concentrations may cause limiting conditions for plant growth. Phytoplankton concentrations were so erratic with time that if only one sample were collected, any collection time during a diel period would be as valid as any other.

INTRODUCTION

Water-quality data-collection programs and studies often are made assuming homogeneous distribution of dissolved and suspended materials in the system. Where this assumption is true, water samples collected at a single location are representative of concentrations for the entire site. The assumption of a well-mixed system often is true in small streams; however, complex flow patterns and significant natural and man-caused inputs in larger rivers often result in incomplete mixing of transported materials. Mohlman and others (1931), Velz (1950), and Haney and Schmidt (1958) concluded that variability testing in larger streams will require sampling at a number of points across the section, and that concentrated sampling during a short period of time probably will produce more useful results than extended periodic sampling. Specifically, incomplete mixing can occur when waste materials introduced into a river remain concentrated near one bank for considerable distances downstream.

In 1972 and 1973, the U.S. Geological Survey made an intensive water-quality study at several sites on the Sacramento River (Britton and Averett, 1974). A part of the study was to evaluate horizontal and vertical differences in the concentrations of selected water-quality constituents. The information was needed for design of future studies on the Sacramento River. This paper describes the variation in concentration of selected dissolved chemical constituents, temperature, and phytoplankton over two diel (24-hour) periods at a site on the upper Sacramento River.

STUDY SITE

The site for water-quality data collection was on the Sacramento River, immediately upstream from Bend Bridge (fig. 1). This was the upstream sampling site for the 1972-73 study, and is approximately 14 river miles (22 km) upstream from the city of Red Bluff and approximately 256 mi (412 km) from the mouth of the river at San Francisco Bay.

The site was chosen because the river changes direction near the bridge, resulting in a variable flow pattern and an irregular bottom configuration (fig. 2). The flow pattern and variable depth were expected to influence the concentration of dissolved materials and distribution of phytoplankton. Early September was chosen as the study period because the discharge is nearly constant and at a minimum for the year (fig. 2). Furthermore, the water is warm in September, resulting in increased biological production. Consequently, the study was made during a seasonal period when the variability of most commonly measured water-quality constituents was expected to be at a maximum because of biological action.

At the time of sampling, the river at Bend Bridge was approximately 360 ft (110 m) wide, and had a maximum depth of approximately 12 ft (4 m) (fig. 2). The river bottom material ranged from large cobbles 6 in (150 mm) in diameter, to sand. During the study period, the discharge ranged from 9,390 to 9,550 ft^3/s (266 to 270 m^3/s); the difference, 160 ft^3/s (4.5 m^3/s) represented only 1.7 percent of the mean discharge (fig. 2).

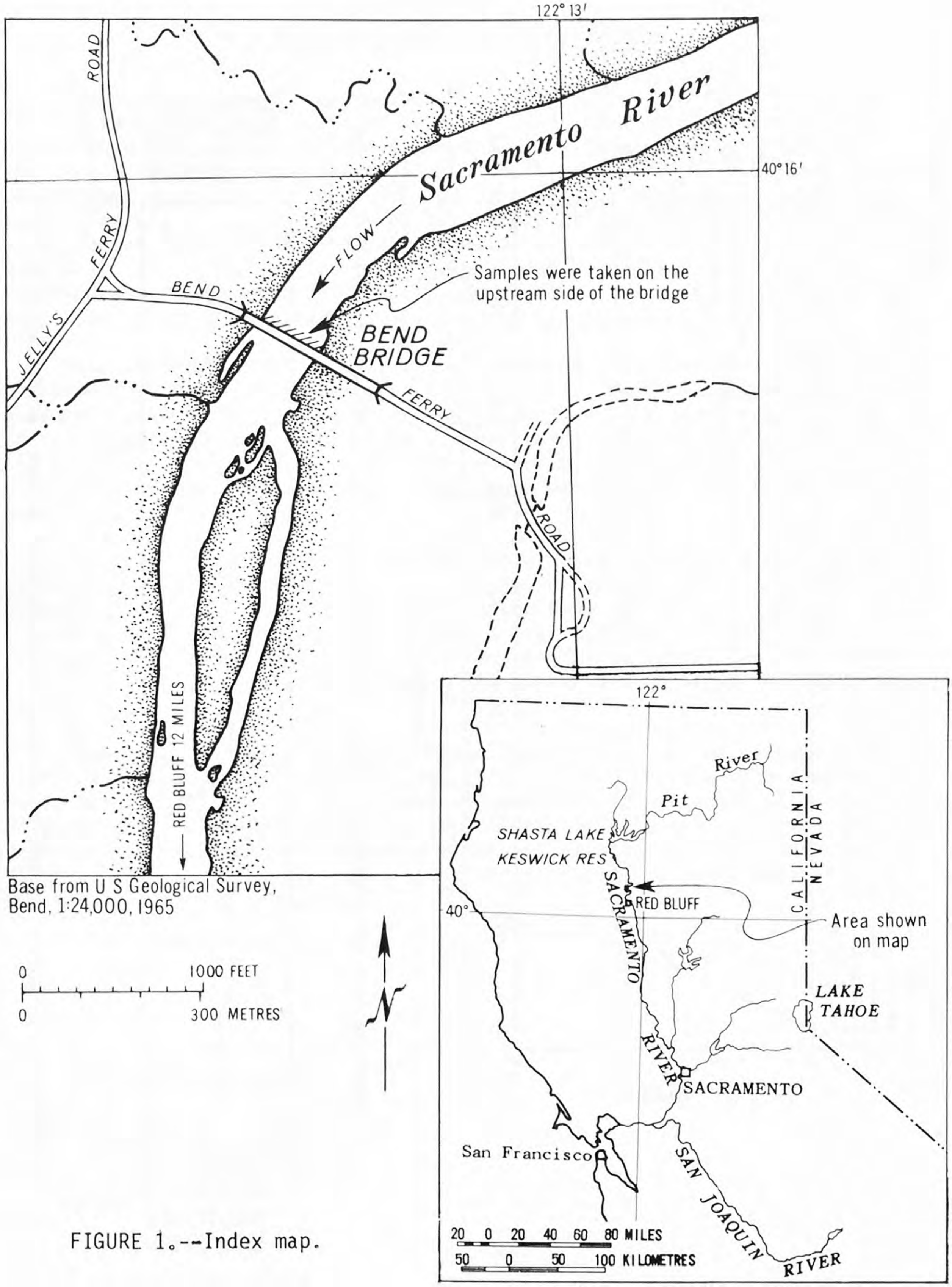
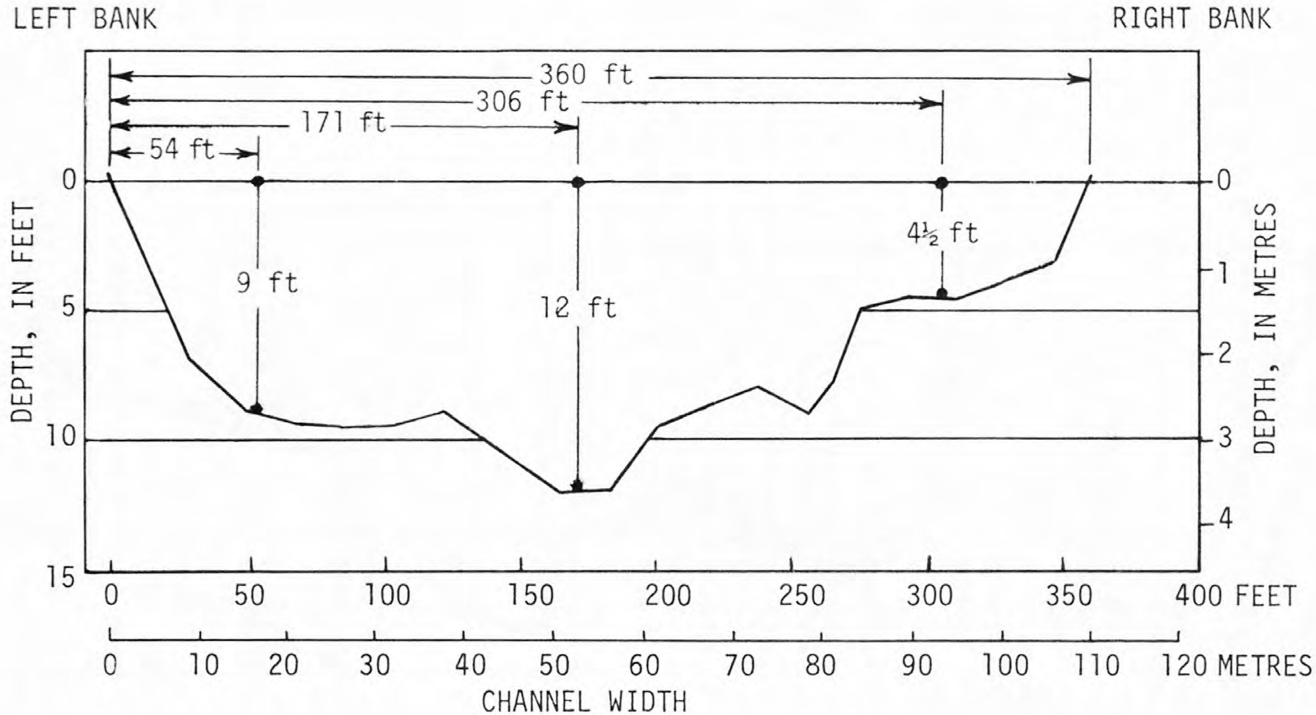
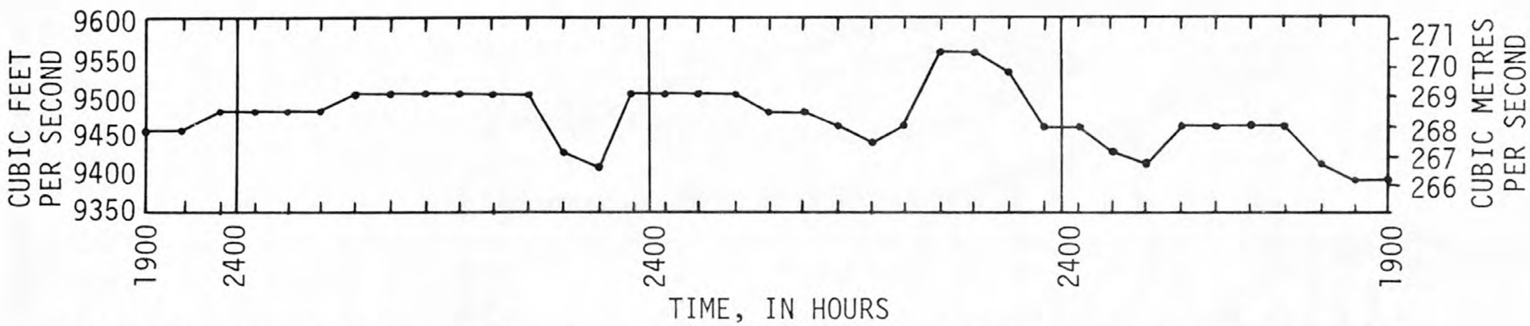


FIGURE 1.--Index map.



Cross section of Sacramento River at Bend Bridge. Dot indicates sampling location



Instantaneous discharge of the Sacramento River at Bend Bridge, September 4-7, 1973

FIGURE 2.--Cross section of river and short-term hydrographs.

DATA COLLECTED AND STUDY METHODS

The study was made from September 4 to 7, 1973. The first period of field data and sample collection began at 1900 hours on September 4 and continued until 1900 hours on September 5. The second period began at 1900 hours on September 6 and continued until 1900 hours on September 7. Established sampling stations were approximately 54 ft (16 m) from the left bank; near the river center, or approximately 171 ft (52 m) from the left bank; and near the right bank, or approximately 306 ft (93 m) from the left bank (fig. 2). Sample collection always began at the left-bank sampling location and proceeded to the center and right-bank sampling locations. All sample collections were made from a boat.

Water temperature, specific conductance, pH, and dissolved oxygen were measured in-place at each sampling location every two hours with a multi-parameter unit. The instrument was calibrated at least once during each 24-hour sampling period. Measurements were made near the surface and near the bottom at the left-bank and river-center sampling locations. Because of the shallow depth, only surface measurements were made at the right-bank sampling location.

Water samples for selected major ions and plant nutrients were collected every 6 hours at the left-bank and river-center sampling locations described above, with a D-49 depth-integrating sampler (Guy and Norman, 1970, p. 6). The water samples were filtered through a 0.45-micrometre membrane filter, treated in the field, and analyzed at the Geological Survey Central Laboratory in Salt Lake City, Utah, using the methods described in Brown and others (1970).

Water samples for phytoplankton analysis were collected every two hours at the left-bank and river-center sampling locations with a D-49 depth-integrating sampler. The phytoplankton samples were preserved with Lugol's solution and analyzed at a private laboratory for counts and species identification, using the inverted microscope method described in Slack and others (1973). The types, numbers, and locations of collected water-quality constituents are in table 1.

Table 1.--*Types and number of water-quality constituent measurements and sample collections*

On-site measurements	Number of measurements					
	Left bank		Center		Right bank	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
Temperature	25	25	25	25	25	0
Dissolved oxygen	25	25	25	25	25	0
pH	24	24	24	24	24	0
Specific conductance	23	23	25	25	25	0

Laboratory analysis	Number of samples collected (all samples depth integrated)	
	Left bank	Center
	Dissolved chemical constituents	
Calcium	10	10
Magnesium	10	10
Sodium	10	10
Bicarbonate	10	10
Sulfate	10	10
Chloride	10	10
Nitrate	10	10
Ammonia + organic nitrogen	10	10
Phosphorus	10	10
Organic carbon	9	10
	Biological constituents	
Phytoplankton	26	26

RESULTS

The results of the on-site water-quality measurements are shown in figure 3. Data points on the graphs represent the mean values of the surface and bottom measurements. Water temperatures ranged from 12° to 15°C (Celsius) during the two 24-hour sampling periods at the three sampling locations. The lowest water temperature (12°C) occurred at 0900 and 1000 hours during the first sampling period, and at 0800 hours during the second sampling period. After gradual temperature increases on the afternoon of the second sampling period, a maximum water temperature of 15°C occurred at 1900 hours. Measured differences in water temperature did not exceed 1°C between sampling locations or between surface and bottom at each location at any given sampling interval. At most times, the vertical and horizontal temperatures, taken at the same time period, were equivalent.

The dissolved-oxygen concentration ranged from 9.0 to 11.6 mg/ℓ (milligrams per litre) among the three sampling locations over the two 24-hour sampling periods. However, the maximum variation in dissolved-oxygen concentration vertically and horizontally at the sampling locations, for the same sampling intervals, was only 0.5 mg/ℓ. Percent saturation of dissolved oxygen (not in figure 3) ranged from 86 to 109. Undersaturation (less than 100 percent) occurred from 0100 to 1300 hours during the first 24-hour sampling period and from 1900 to 1300 hours during the second 24-hour sampling period. Supersaturation (greater than 100 percent) occurred from 1900 to 0100 hours and from 1300 to 1900 hours during the first 24-hour sampling period, and from 1300 until 1900 hours during the second 24-hour sampling period (fig. 3).

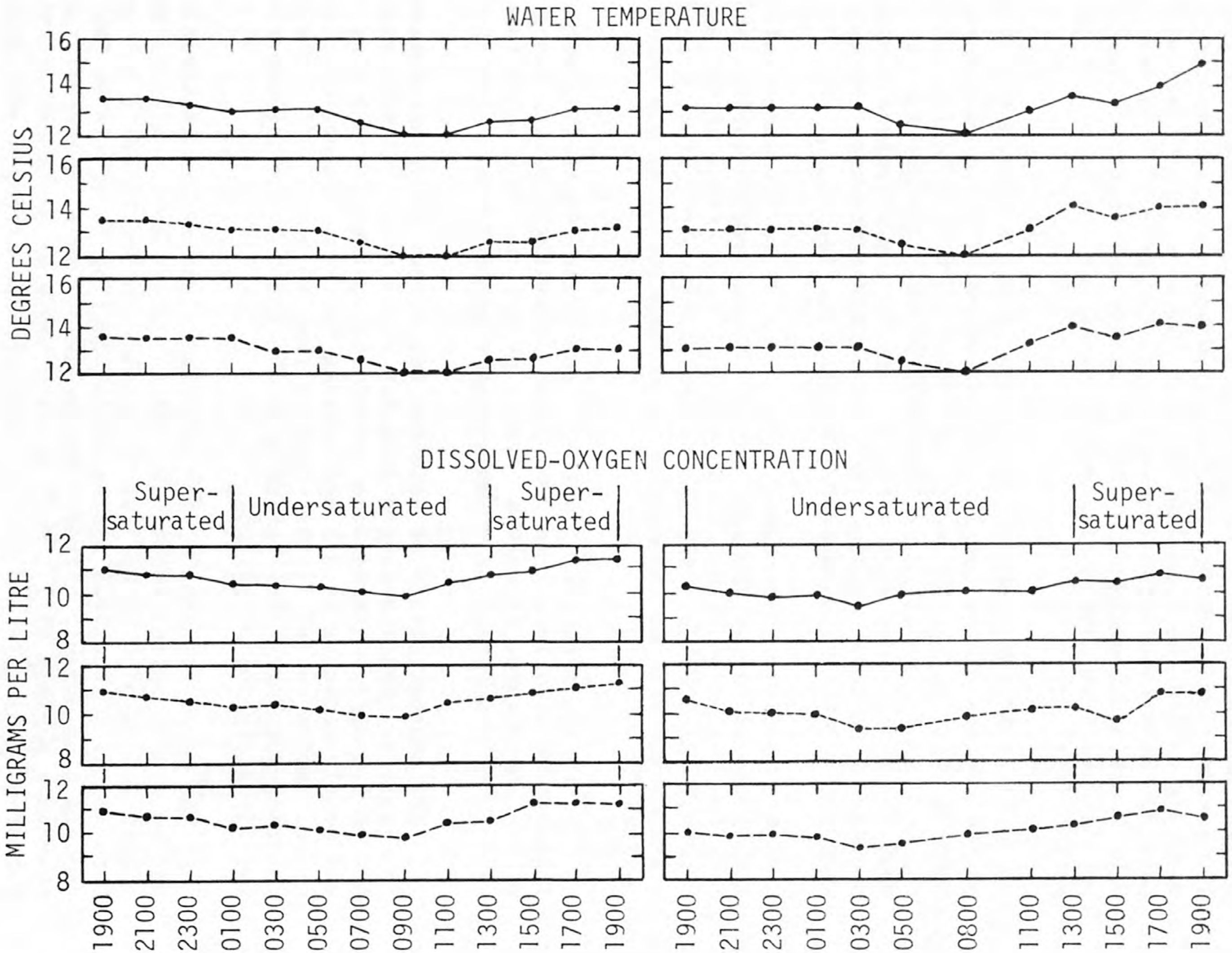
The pH of the water varied little during the first 24-hour sampling period, maintaining a nearly constant value of 7.5. During the second 24-hour sampling period, the pH decreased from 7.6 at 2100 hours to 6.1 at 0300 hours and then rose steadily to 7.6 at 0800 hours. The decrease in pH to 6.1 at 0300 hours coincided with a slight drop in the dissolved-oxygen concentration. Because of equipment malfunction, pH measurements were not made during one sampling interval (shown as blank areas in fig. 3).

The specific conductance ranged from 97 to 121 μmhos (micromhos) per centimetre at 25°C. The greatest variation between surface and bottom at any location was 9 μmhos, and between sampling locations at the same sampling interval was 5 μmhos. Because of equipment malfunction, specific conductance measurements were not made during two sampling intervals (shown as blank areas in fig. 3).

A Student's t-test of paired comparisons revealed no significant differences at p less than 0.05 (0.05 probability level) among measurements of water temperature, dissolved oxygen, pH, or specific conductance, among the three sampling locations or between the surface and bottom at each location.

The concentrations of selected major ions and plant nutrients are shown in figure 4. Calcium ranged from 8.6 to 13 mg/ℓ, and magnesium ranged from 4.8 to 5.3 mg/ℓ. The maximum sodium concentration was 6.1 mg/ℓ, but otherwise was nearly constant at 5.5 mg/ℓ during the sampling period. The bicarbonate concentration varied little, ranging from 60 to 66 mg/ℓ. The sulfate and chloride concentrations varied only 1.6 and 1.3 mg/ℓ, respectively, during the two 24-hour sampling periods.

The concentrations of the selected plant nutrients varied more with time and between sampling locations than the major ions. Nitrate had a maximum concentration of 0.05 mg/ℓ at 0100 hours on September 5, but was undetected at both sampling locations during three sampling intervals on September 6 and 7. Ammonia plus organic nitrogen was below 0.2 mg/ℓ in most of the samples, but reached a maximum of 1.2 mg/ℓ at 0100 hours on September 5. The concentration patterns of nitrate and ammonia plus organic nitrogen were quite dissimilar between the two 24-hour sampling periods. Dissolved phosphorus showed a similar concentration pattern for both 24-hour sampling periods, but the concentrations were slightly higher during the second period of collection. The concentrations of dissolved organic carbon varied erratically, and ranged from 1 to 6.5 mg/ℓ.


WATER TEMPERATURE
DEGREES CELSIUS
16
14
12
DISSOLVED-OXYGEN CONCENTRATION
Super-saturated
Undersaturated
Super-saturated
Undersaturated
Super-saturated
MILLIGRAMS PER LITRE
12
10
8
1900
2100
2300
0100
0300
0500
0700
0900
1100
1300
1500
1700
1900
1900
2100
2300
0100
0300
0500
0800
1100
1300
1500
1700
1900

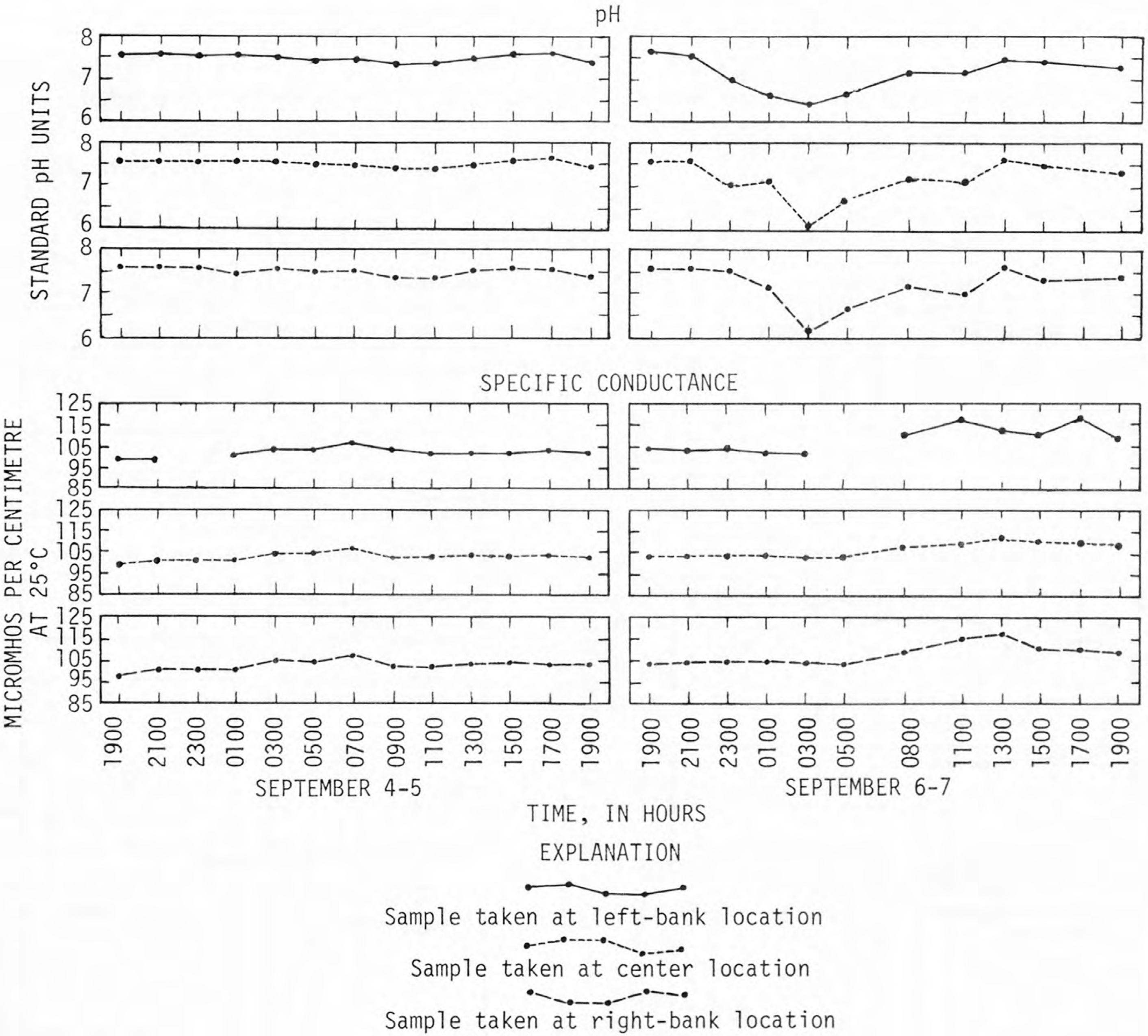


FIGURE 3.--Results of on-site water-quality measurements.

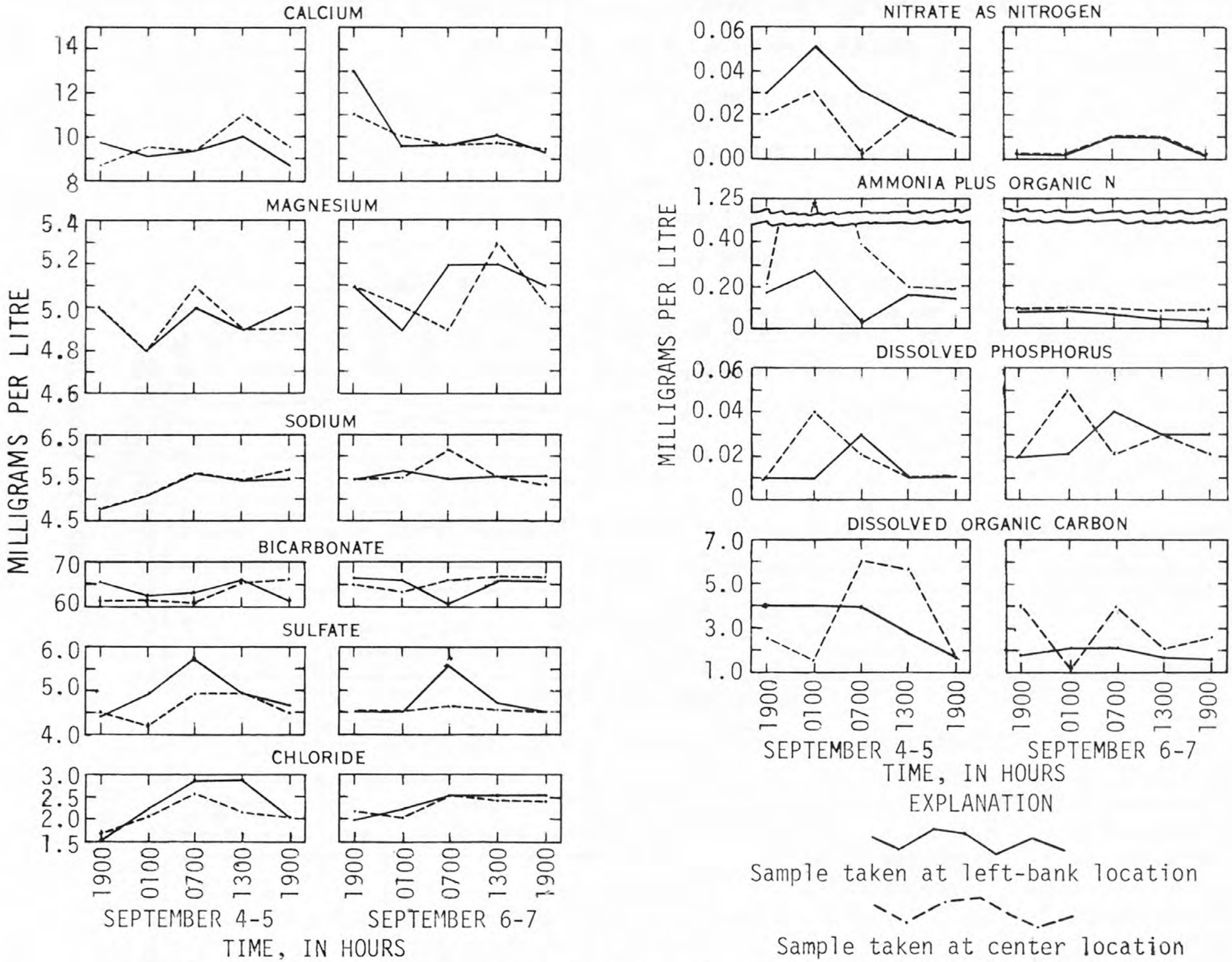


FIGURE 4.--Concentrations of selected dissolved major ions and plant nutrients.

A Student's t-test for paired comparisons showed no significant differences (p less than 0.05) among the concentrations of selected major ions and plant nutrients between the two sampling locations during the same sampling intervals.

Total phytoplankton concentrations ranged from 220 to 570 organisms per millilitre during the study period (fig. 5). During the first sampling period (September 4-5), a slight decrease in blue-green algal concentrations (class, Myxophyceae) occurred. There was no consistent pattern in phytoplankton concentrations for the two sampling periods or between sampling locations because maximum concentrations at one sampling location often coincided with minimum concentrations at the other location. Of the three algal groups (fig. 5), the blue-green algae (class, Myxophyceae) had the highest concentrations, followed by the diatoms (class, Bacillariophyceae) and the green algae (class, Chlorophyceae).

Although there was usually a difference in the concentrations of phytoplankton in the samples collected at the left-bank and river-center sampling locations, the mean concentration was not significantly different at the 0.05 probability level.

The frequency of occurrence of phytoplankton taxa collected at the left-bank and river-center sampling locations was similar (table 2). The diatoms (class, Bacillariophyceae) comprise the greatest number of individual taxa, with *Achnanthes lanceolata* the most dominant (occurring in every sample). The alga comprising the largest percentage of the total number of phytoplankton and occurring in every sample was *Synechocystis* sp., a small blue-green algae (class, Myxophyceae). Unidentified flagellates (class, Chlorophyceae) were numerous and occurred in nearly every sample collected during the study period.

DISCUSSION

The concentration patterns of the measured water-quality constituents within each sampling location were erratic with time. The concentration differences vertically and horizontally among sampling locations during a particular sampling interval were not statistically significant at the 0.05 probability level. Consequently, sampling at one location probably would have been sufficient to obtain representative concentrations of most water-quality constituents.

Results of other studies have shown variations in some water-quality constituents at different locations within one sampling site. Hasle (1954) found that surface temperatures varied only 0.4°C among four cross-sectional sites in a Norwegian fjord, and Platner (1946) found variation in cross-sectional temperatures measured in the Mississippi River every 6 hours for a 24-hour period. The largest difference within one site over 24 hours was 1.8°C and between sites for the same period was 1.8°C. Mohlman and others (1931) found a range of 0.8 to 7.0 mg/ℓ of dissolved oxygen among cross-sectional samples at a site in the Illinois River, a much wider concentration range than was found in the Sacramento River. Odum (1957) found carbon dioxide samples to be extremely variable between sites across Silver Springs River.

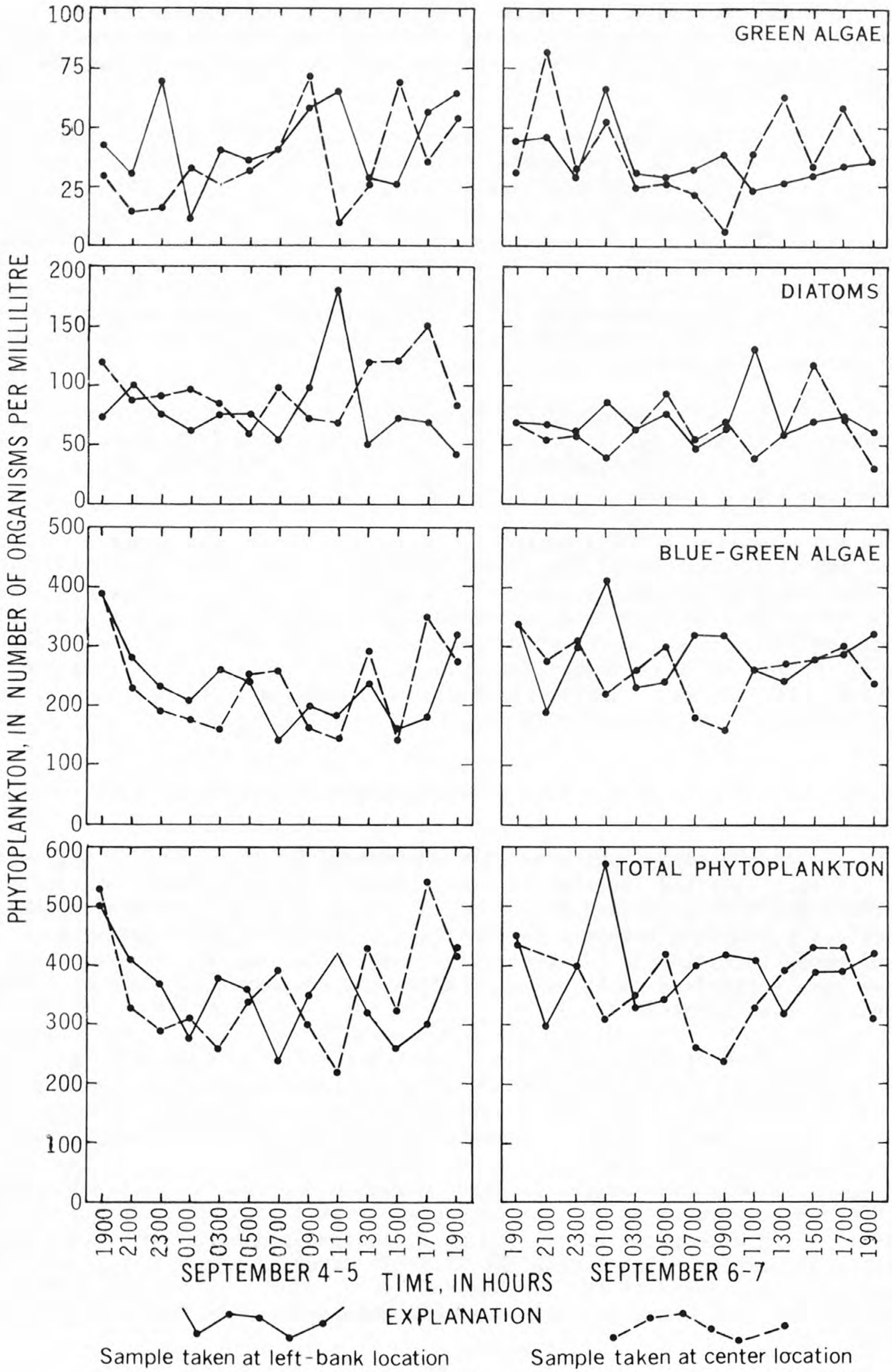


FIGURE 5.--Concentrations of the major groups of phytoplankton.

Table 2.--*Types, occurrence, and ranges of phytoplankton concentrations*

[A total of 26 samples were collected at each sampling location during the two 24-hour sampling periods.]

Algal types	Occurrence in samples		Concentration, in organisms per millilitre					
			Left bank			Center		
	Left bank	Center	Mean	High	Low	Mean	High	Low
CHLOROPHYTA								
Chlorophyceae (green algae)								
Cladophora sp.	1	0	1	1	1	0	0	0
Eudorina elegans	1	1	2	2	2	1	1	1
*Flagellates (*misc.*)*	26	24	29	60	12	31	74	10
Micractinium pusillum	1	0	1	1	1	0	0	0
Pandorina morum	4	1	2	2	1	1	1	1
Pediastrum tetras	1	0	1	1	1	0	0	0
Scenedesmus bijuga	24	22	11	18	3	10	17	5
Scenedesmus dimorphus	1	1	1	1	1	2	2	2
CHRYSOPHYTA								
Bacillariophyceae (diatoms)								
Achnanthes lanceolata	26	26	41	70	25	46	100	20
Cymbella ventricosa	20	20	10	28	5	11	23	5
Diatoma vulgare	1	0	1	1	1	0	0	0
Fragilaria crotonensis	1	2	32	32	32	10	14	7
Fragilaria sp.	0	3	0	0	0	26	30	20
Melosira varians	10	10	13	32	5	9	12	2
Nitzschia acicularis	3	3	3	5	1	6	8	4
Nitzschia linearis	4	1	4	5	3	5	5	5
Nitzschia romana	22	19	16	31	7	20	39	7
Nitzschia sp.	3	2	13	18	4	11	14	8
Surirella angustata	1	1	1	1	1	1	1	1
Surirella ovata	10	3	9	16	5	9	12	6
Tabellaria fenestrata	3	1	10	20	1	12	12	12
CYANOPHYTA								
Myxophyceae (blue-green algae)								
Merismopedia sp.	0	2	0	0	0	3	5	1
Oscillatoria sp.	20	15	12	18	1	13	26	5
Synechocystis sp.	26	26	250	400	140	240	360	140

An important factor to consider in any sampling program is the statistical significance versus biological significance of constituent concentrations. The measured concentrations of the major ions were not limiting to plant growth and slight changes in concentrations between sampling locations probably were of no biological significance. However, when plant-nutrient concentrations are low, as were the nitrogen and phosphorus concentrations in the Sacramento River, slight fluctuations in concentrations of one or more constituents may limit plant growth.

If, after sufficient investigation in any river, a single sample collected at one location is deemed to be representative of the entire site, the question still remains as to whether the concentration at the particular time of day selected for sampling is the minimum or maximum concentration for the study period. The minimum and maximum concentrations (not the means) of chemical constituents are the critical values that control growth and reproduction and thus influence biological water quality. The results of the Sacramento River study revealed a cyclic diel pattern for temperature and dissolved oxygen. Because they are controlling factors for aquatic life, dissolved-oxygen-concentration ranges are important. Diel variations of the concentrations of some water-quality constituents have been observed in a number of studies (Mohlman and others, 1931; Velz, 1950; Kelso and Maccrimmon, 1969), indicating the necessity to sample throughout a 24-hour period to determine the variability at a sampling site.

The concentration patterns of phytoplankton in the Sacramento River were so erratic with time and location that one sample collected at one location during any sampling interval may not even approximate the population mean. Although one sample may provide a general idea of types and abundance, studies by Hasle, 1954; Morgan, 1961; and Michalski, 1969, have implied that phytoplankton are not uniformly distributed in the environment. Michalski (1969) found that comparing samples of phytoplankton collected once a week with those collected daily, was inadequate to accurately define extreme changes in phytoplankton levels. Studies on the Ohio River using chlorophyll a concentrations as indicators of algal populations, showed that a single grab sample could differ significantly from the mean of samples obtained from a cross section (Morgan, 1961). Hasle (1954) found that an uneven distribution of phytoplankton caused a variation in total numbers of phytoplankton in cross-sectional samples collected in a Norwegian fjord. The variations within cross sections were often equal to or larger than the variations between cross sections.

The results of the Sacramento River study, as well as previous research, have shown that concentrations of chemical constituents vary with time and place of sampling. In the Sacramento River at Bend Bridge, a grab sample for analysis of chemical constituents was found to be representative of the entire site. However, this finding cannot necessarily be extrapolated to other sites in the river or other times of the year. As pointed out by similar studies, the diel fluctuations of temperature and dissolved oxygen dictate a need to collect samples more than once daily in order to describe total variability.

REFERENCES CITED

Britton, L. J., and Averett, R. C., 1974, Water-quality data of the Sacramento River, California, May 1972 - April 1973: U.S. Geol. Survey open-file rept., 59 p.

Brown, Eugene, Skougstad, M. W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A1, 160 p.

Guy, H. P., and Norman, V. W., 1970, Field methods for measurement of fluvial sediment: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. C2, 59 p.

Haney, P. D., and Schmidt, John, 1958, Representative sampling and analytical methods in stream studies: Robert A. Taft Sanitary Eng. Center Tech. rept. W58-2, p. 133-140.

Hasle, G. R., 1954, The reliability of single observations in phytoplankton surveys: Oslo, Nytt Magasin for Botanikk, Broggers Boktr. Forlag, v. 2, p. 121-137.

Kelso, J. R., and Maccrimmon, H. R., 1969, Diel and seasonal variations in physiochemical limnology, Speed River, Ontario: Water Resources Research, v. 5, no. 6, p. 1388-1394.

Michalski, M. F. P., 1969, Investigations of daily variations in chemical, bacteriological and biological parameters at two Lake Ontario locations near Toronto--Part III - Biology: Proc. 12th Conf. Great Lakes Res., p. 69-79.

Mohlman, F. W., Herrick, T. L., and Swope, H. G., 1931, Technic of stream-pollution investigations: Indus. and Eng. Chemistry, v. 23, no. 2, p. 209-213.

Morgan, P. V., 1961, Evaluation of chlorophyll measurements in the Dashields pool of the upper Ohio River, in Shapiro, M. A., Ficke, J. F., Morgan, P. V., Spear, R. D., and Kisiel, C. C., 1964, Some factors of importance in evaluating sites for nuclear industry as determined by a limnological study of the upper Ohio River: Verh. Internat. Verein. Limnol., v. 15, p. 299-306.

Odum, H. T., 1957, Trophic structure and productivity of Silver Springs, Florida: Ecological Monographs, v. 27, p. 55-112.

Platner, W. S., 1946, Water quality studies of the Mississippi River: U.S. Fish and Wildlife Service, Spec. Sci. rept. no. 30, 77 p.

Slack, K. V., Averett, R. C., Greeson, P. E., and Lipscomb, R. G., 1973, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geol. Survey Techniques Water-Resources Inv., book 5, chap. A4, 165 p.

Velz, C. J., 1950, Sampling for effective evaluation of stream pollution: Sewage and Indus. Wastes, v. 22, no. 5, p. 666-682.

Britton and Averett — VARIATION OF WATER-QUALITY CONSTITUENTS, SACRAN
VER AT BEND BRIDGE, CALIFOR
14