WATER-QUALITY ASSESSMENT OF THE AMERICAN RIVER, CALIFORNIA

By Michael V. Shulters

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CONVERSION FACTORS

For readers who prefer to use the International System of units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acre-ft (acre-feet)	1233	m^3 (cubic meters)
ft (feet)	.3048	m (meters)
ft/mi (feet per mile)	.1894	m/km (meters per kilometer)
ft^3/s (cubic feet per second)	.02832	m^3/s (cubic meters per second)
in (inches)	2.540	cm (centimeters)
in (inches)	25.40	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
μmho/cm (micromhos per centimeter)	1.000	μS/cm (microsiemens per centimeter)

Degree Fahrenheit is converted to degree Celsius by using the formula:

Temp °C = (temp °F-32)/1.8

Explanation of abbreviations

mg/L	Milligrams per liter
μg/L	Micrograms per liter
μg/g	Micrograms per gram
mL	Milliliters
rm	River miles

ALTITUDE DATUM

National Geodetic Vertical Datum (NGVD) of 1929: a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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ABSTRACT

Water-quality data have been collected at more than 168 documented sites in the American River basin since early in the century by several universities and State and Federal agencies, but comprehensive water-quality studies of a year or more are few. These data were used collectively in this study to assess the river's present condition.

Based on this assessment, the American River was found to be a stream of overall good quality and to be suitable for all beneficial uses as specified by the State of California, even though its natural condition has been altered by man's activities in the basin.

Time-trend analyses indicate an increase in specific conductance (dissolved solids), hardness, and alkalinity during the past 20 years in the lower American River near Sacramento downstream from treated effluent and urban runoff sources. Dissolved oxygen and pH have remained steady. Ammonia concentrations in this reach show a close correlation with specific conductance (correlation coefficient = 0.89).

Most violations of specific water-quality objectives for the basin have occurred in the lower American River. Water-quality conditions in this reach are expected to improve in late 1982 when sewage-treatment-facility discharges into the river will be discontinued.

Extensive water storage and flow regulation on the Middle and South Forks of the American River since the early 1960's appears to have altered the natural characteristics of these streams. However, insufficient data are available to make a complete assessment. Channel characteristics and beneficial uses have changed markedly in the lower American River since 1955 when Folsom Dam was completed and flows through this reach became regulated.

Recreational overuse, improper land use, or poorly managed mining operations are potential sources of future water-quality problems in the upper American River basin. Recreational overuse and increased urban runoff are potential threats to water quality in the lower American River.

Proposed monitoring activities include low-flow investigations on the lower American to measure diel variations in water-quality characteristics and studies in the upper basin to determine the impact of increasing recreation and development as well as the effects of mine drainage on the river system.

INTRODUCTION

Background

The American River is a prime example of a multiple-use, water-resource system. Its basin covers 2,163 mi^2 of the western slope of the central Sierra Nevada (fig. 1) east of Sacramento, Calif. This intricate system consists of three major parts--the North and Middle Forks, the South Fork, and the lower American River downstream from Folsom Lake (fig. 1). These major forks and Folsom Lake represent a natural and modified system of streams and impoundments designed to meet the recreational and water-supply needs of many Californians.

The beginning of rapid development in the basin came with the discovery of gold in 1848 on the South Fork of the American River at the site of Sutter's lumber mill near Coloma (shown as Marshall Gold Discovery State Historical Park on plate 1). This discovery caused a tremendous increase in water use as mining techniques progressed rapidly from pan and sluice box to hydraulic mining and to dredging (fig. 2). The methods used to remove the gold created problems by increasing sediment input to the streams as mining debris was continually washed into them. Increased sedimentation led to increased flooding as the debris settled into and began filling the channels. Low-water levels were increased by as much as 5 ft in the area of downtown Sacramento due to sediment deposition in the American and Sacramento Rivers (California Department of Water Resources, 1965, p. 7). The increasing demands of mining for water led to the construction of many small dams and canals, and the creation of water-supply companies.

The gold fervor gradually decreased except for a brief spurt in activity during the depression years of 1930-33. The next period of rapid development was after World War II when other mining resources were developed and agriculture grew in importance, particularly in the lower basin. Fields of grain as well as orchards were being irrigated using the ditches and canals built for mining purposes. Lumbering activities were also important in the area. Stands of ponderosa pine, sugar pine, white and Douglas fir, and incense cedar, although often small, were profitable sources of lumber.

The continuing growth of these activities and increased urbanization in the lower American River basin has created ever-increasing stresses on the river system. Also, the water and power needs of a mostly arid State have given rise to a complex system of water storage and diversion in the basin, affecting the natural free-flowing conditions of its rivers.

For these reasons the California State Water Resources Control Board and the California Regional Water Quality Control Board, Central Valley Region, have designated the American River a top priority stream for monitoring and assessment, and have asked the U.S. Geological Survey to assist in this effort.

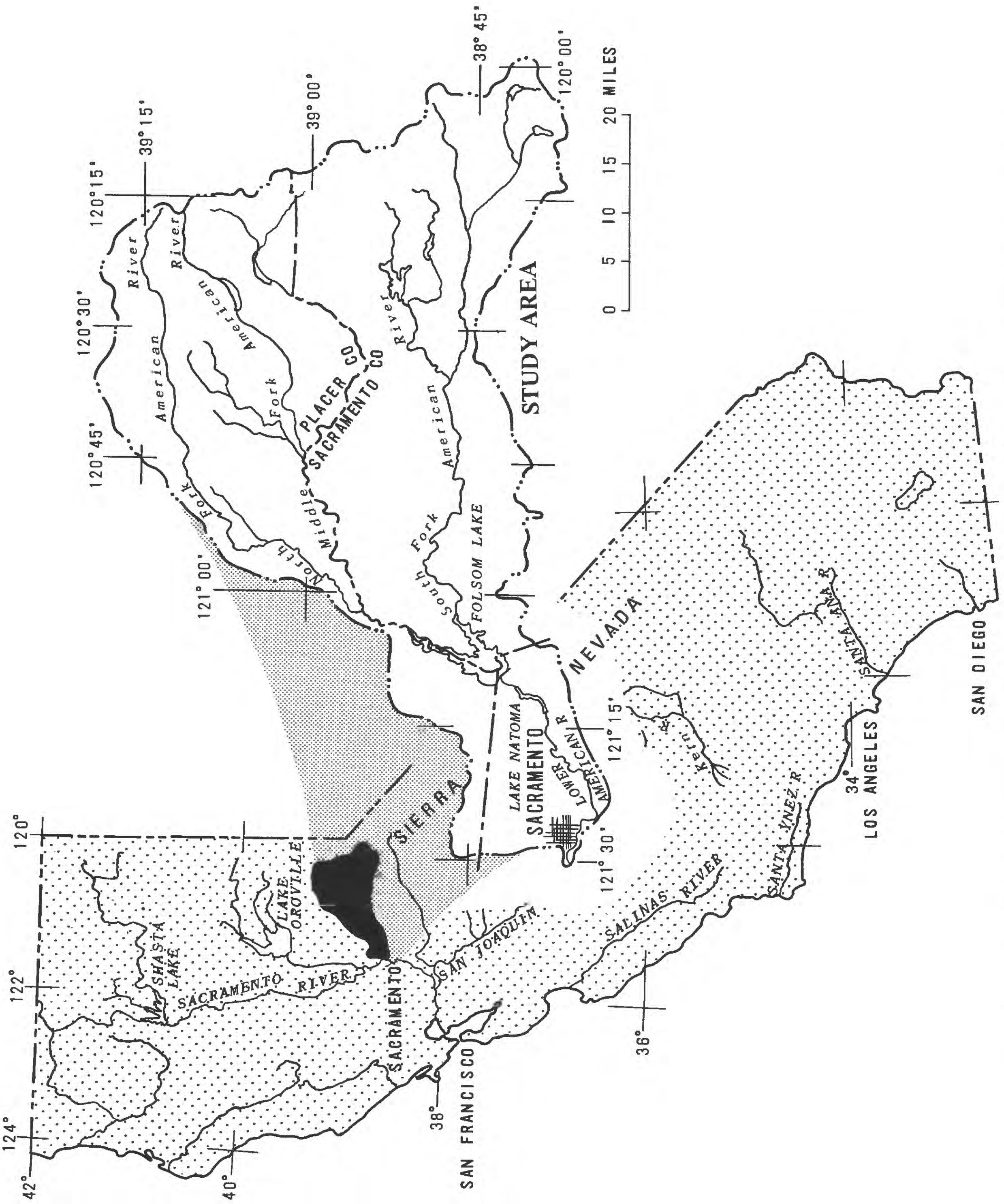


FIGURE 1. – Index map of California showing the location of the American River basin and the major forks of the river.

FIGURE 2. – Typical dredge tailings in the American River basin resulting from gold dredging operations. The tailings here range in depth from 20–25 feet. (Courtesy of U.S. Bureau of Reclamation)

Purpose and Scope

The objective of this study is to identify, as much as available data will allow, any water-quality problems or apparent trends which can be related to man's activities in the American River basin and to assess the river's present condition.

To accomplish this, water-quality and land-use data were obtained from various reports and computer data storage systems. After initially screening and editing the available data, three different analytical procedures were used to address the stated objective. The first was to compare recently collected water-quality data with the historical data from selected sampling sites and identify those data which did not meet the water-quality objectives established for that stream segment. The second was to determine bivariate correlation coefficients between selected pairs of the same water-quality measurements from different sampling sites. The third was to develop relationships between those paired measurements which showed a high degree of correlation for several successive time periods, using simple linear regression. The relationships determined for the successive time periods were then tested against each other using an analysis of covariance to determine if any significant changes in the relationship had occurred over time.

FIGURE 3. – Canyon of the Silver Fork American River. (Courtesy of California Department of Water Resources)

BASIN DESCRIPTION

Physical Features

The American River basin is generally mountainous except for the small valley area on the west end between the Sacramento River and Folsom Lake. This valley area comprises less than 2 percent of the total area but supports about 85 percent of the nearly 573,000 people living in the basin (1980 census).

Altitudes range from about 5 ft near the confluence with the Sacramento River to 10,380 ft at Round Top Mountain, which overlooks the Silver Fork American River in the southeast corner of the basin (fig. 3). Basin characteristics for each subbasin of the river upstream from Folsom Lake are shown in table 1. The drainage density and basin order, which are measures of the amount of basin dissection, are greatest in the North Fork basin above the Middle Fork confluence, and are least in the South Fork basin where the terrain is somewhat less rugged. Drainage density and basin order, which are dependent on map scale, are used only for comparisons within the American River basin and should not be compared directly with values from other basins. Stream profiles, shown on plate 1, illustrate the steep terrain in the upper basin.

TABLE 1. - Basin characteristic statistics for the American River basin upstream from the North Fork and South Fork confluence near Folsom Dam

Segment	Drainage area (mi^2) (1)	Altitude (ft) (2)		Basin order (3)	Length of streams (mi) (4)		Drainage density (mi/mi^2) (5)
		Low	High		Main stem	Total	
North Fork to confluence with South Fork	1,012	240	9,000	7	94	1,130	1.1
North Fork to confluence with Middle Fork	396	520	9,000	7	70	500	1.3
Middle Fork to confluence with North Fork	616	520	9,000	6	62	570	.9
South Fork to confluence with North Fork	848	240	10,380	5	86	680	.8
Total	1,860	240	10,380	7	242	1,810	1.0

(1) Drainage Area--The area of a river basin, measured in a horizontal plane, that is enclosed by a topographic divide, such that direct surface runoff from precipitation normally would drain by gravity into the river basin.

(2) Altitude--The low altitude is that elevation, in feet above National Geodetic Vertical Datum of 1929, where the stream exits the drainage basin. The high altitude represents that elevation that is the highest point on the drainage basin perimeter.

(3) Basin Order--Same as the highest stream order in the drainage basin. First-order streams have no tributaries; second-order streams have only first-order streams as tributaries and so forth.

(4) Stream Length--The main stem length is measured from the outlet of the basin to the basin divide following that fork with the largest drainage area. The total stream length is computed by measuring and summing with the main stem length all of the lower ordered tributaries in the basin.

(5) Drainage Density--Stream length per unit area. Determined by dividing the total stream length by the drainage area.

Downstream from Folsom Lake, the lower American River meanders through its flood plain, constrained by bluffs in its upper reach and by levees, constructed for flood control, farther downstream. The stream gradient of about 3 ft/mi is in stark contrast with the steeper upper basin. Backwater from the Sacramento River and tidal influence affect the river stage in the lower American (see plate 1 stream profile). Bottom materials consist of gravels (fig. 4) in the high velocity upstream sections and mostly sand and silt in the more sluggish lower section near the mouth.

FIGURE 4. – View of the lower American River showing the gravelly bottom material upstream from the Sunrise Avenue bridge. (Courtesy of U.S. Bureau of Reclamation)

Geology

The present Sierra Nevada range, which comprises the entire upper American River basin above the Folsom Lake area, is considered by most authorities to be a single block of the Earth's crust that was uplifted along fractures on its eastern edge and tilted westward towards what is now the Central Valley. The interstream divides in the American River basin area are capped by fragmental volcanic rocks formed during the later Tertiary Period as part of a once nearly continuous volcanic plain. Subsequent uplift and erosion has removed most of this material, exposing the granitic base material that is the primary component of the Sierra Nevada. An area of alluvial uplands near the city of Folsom separates the upper basin from the flood plains below. The river in this area has been cutting laterally northward during recent geologic time, forming the steep bluffs on the north bank, which are about 125 ft high in the vicinity of Folsom (Olmsted and Davis, 1961, p. 16).

Soils

Three major soil zones have been broadly described for the upper American River basin above Folsom Lake. These are the Foothill Zone, the Upland Agricultural Zone, and the Forest-recreational Zone. The following description of these zones is taken from the California Department of Water Resources, 1965, p. 18:

> "The Foothill Zone is comprised of rather shallow, somewhat rocky, red-colored upland soils that are presently being utilized largely for range grazing. The area is typified by a generous cover of oaks and grasses or spotty stands of dense chaparral. This zone occupies an elevation band beginning on the valley floor on the west, running east to about the 1,800-foot contour.
>
> "The Upland Agricultural Zone comprises a broad belt that runs in a northwesterly direction across the watershed extending from the Cool-Georgetown area on the north to the Placerville-Camino area on the south. Soils in this zone are characteristically deep, reddish-brown in color, fertile, and quite permeable. Some scattered surface and profile rock can be observed in some areas. Native vegetation varies from oaks and grasses at lower elevations to commercially important mixed coniferous timber stands at higher elevations. As evidenced by the large acreages of pears and apples planted in this zone, the area is highly suited for deciduous orchards.
>
> "The third major soil zone, the Forest-recreational Zone, comprises the major acreage of the watershed. This zone is typified by large areas of rough, broken and stony land normally found in the higher elevations of the Sierra Nevada Range. Many of the soils in this zone, though they possess physical properties normally associated with agricultural lands, were classified as being best suited to remain in some sort of forest management program due to climatic limitations."

A more detailed soil survey of parts of El Dorado County can be found in a report by the U.S. Soil Conservation Service (1974).

Climate

The American River basin is very diverse climatically. Summers are typically very warm and dry; winters are cool and wet. The influence of the Pacific Ocean is felt during the winter as strong flows of marine air move over the area, bringing heavy precipitation, particularly at intermediate levels in the mountains. Precipitation amounts range from about 16 inches per year at Sacramento to more than 70 inches per year near Echo Summit in the upper basin. With the snowline at 5,000 ft above sea level, about 55 percent of the basin is covered with snow. Approximately 35 to 75 percent of the precipitation occurring above this elevation falls as snow, creating a much-needed supply of water which lasts into the summer (California Department of Water Resources, 1965, p. 19).

Temperatures range from hot in the summer near the Sacramento Valley to very cold in the winter in the higher areas of the basin. Daily summer highs in the valley and upland areas are generally in the 90°F range and often exceed 100°F, and winter lows can drop below 0°F in the higher elevations. Freezing temperatures are common in most of the basin except at the lower elevations in the western part.

Land Use

The relative percentages of each major land-use category in the American River basin along with the major components that make up each category are shown in the bar graph of figure 5. The percentages were determined by planimetering the areas of each land-use category as delineated on the 1:250,000 scale land-use maps published by the Geological Survey.

Forest land is the most dominant land-use feature in the basin (fig. 6). Above Folsom Lake, less than 1 percent of the area is categorized as urban and only about 2 percent as agricultural. A comparison between the land-use maps and a study made in 1960 (California Department of Water Resources, 1965, p. 91) indicates very little change in land-use designation for this area. The biggest change has been an increase in water-supply development and recreation. Urban and agricultural lands make up the largest part of the lower American River basin downstream from Folsom Lake. According to the land-use maps, nearly 50 percent of this area is classified as urban, 31 percent agricultural, 15 percent barren and forest, and 4 percent rangeland. Agricultural land in the lower basin has been giving way rapidly to urban development as the Sacramento population center spreads eastward. Projections by local planning organizations indicate an even greater increase in population and urban sprawl can be expected. Recreational use of the lower American has also increased sharply and has benefited from the development of a continuous parkway along the entire reach between Lake Natoma and the mouth (fig. 7).

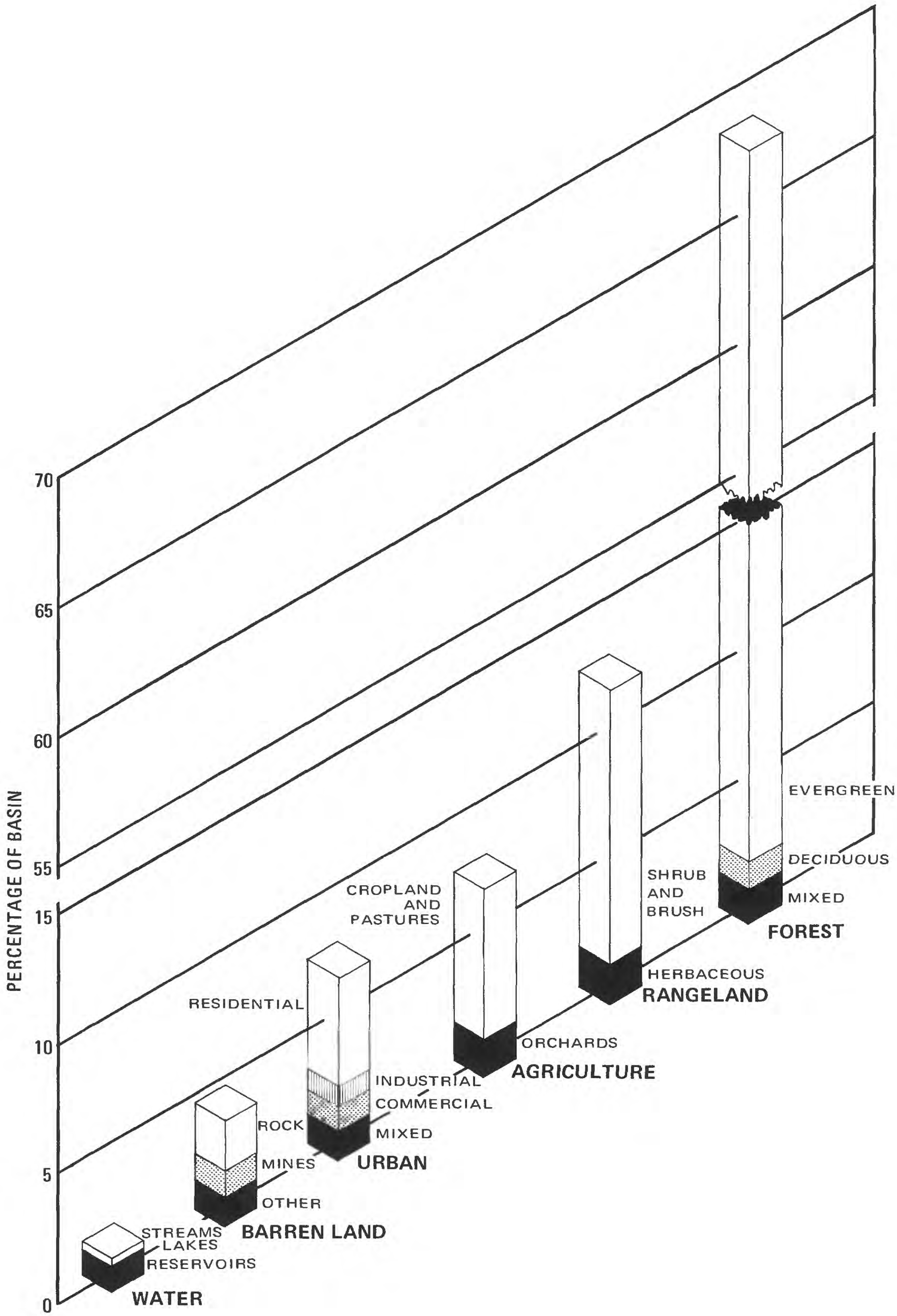


FIGURE 5. – Percentage of American River basin in different land–use categories.

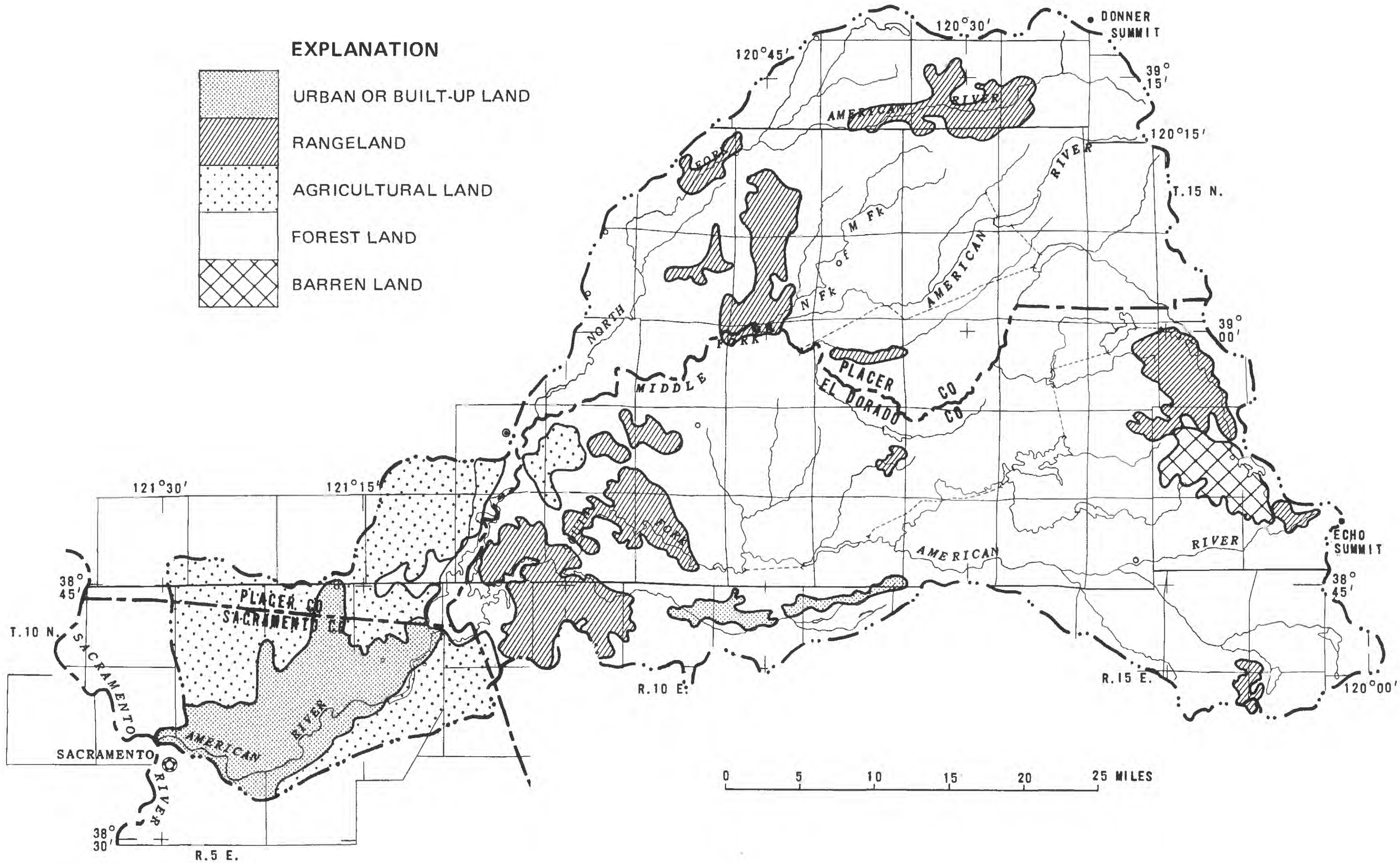


FIGURE 6. – Distribution of major land–use categories in the American River basin.

FIGURE 7. – View of the lower American River looking upstream from the Watt Avenue bridge. The heavy plant cover on the banks is typical in this area and, together with the parkway that has been developed along the lower American, provides a buffer zone between the heavily urbanized area and the stream. (Courtesy of U.S. Bureau of Reclamation)

BENEFICIAL USES OF WATER AND WATER-QUALITY OBJECTIVES

Beneficial uses and water-quality objectives for the American River are found in the report "Water Quality Control Plan Report for the Sacramento River Basin, the Sacramento-San Joaquin Delta Basin, and the San Joaquin Basin" (California Regional Water Quality Control Board, Central Valley Region, 1975). The water-quality objectives are established by the Regional Water Quality Control Board as specified in the California Water Code. In order to establish these objectives, it is necessary for the Regional Board to identify all beneficial uses of the river.

Beneficial Uses

Protection and enhancement of beneficial uses are the primary objectives of water-quality management. Beneficial uses identified for the American River are described in the following paragraphs.

Municipal and domestic supply--Water in all reaches of the American River is for community and individual domestic water systems.

Irrigation--Water is used for irrigation in all reaches of the American River except the South Fork upstream from Placerville. Irrigation use in the North Fork and Middle Fork is probably not significant.

Stock watering--The Middle Fork of the American River is used for a small amount of stock watering.

Water-contact recreation--Water-contact recreation includes all recreational uses involving actual body contact with water, such as swimming, wading, and sport fishing. All reaches of the American River are used for water-contact recreation, including the difficult-to-reach upper North Fork.

Canoeing and rafting--Whitewater canoeing and rafting are very popular on all reaches of the American River. Commercial rafting is especially heavy on the South Fork. Downstream from Nimbus Dam the river is crowded with canoes and rafts every weekend throughout the summer.

Non-contact water recreation--These activities involve the presence of water but do not require contact with the water, such as picnicking, sunbathing, hiking, camping, and pleasure boating. These activities take place along all reaches of the American River.

Hydroelectric power generation--Water in all reaches of the river except the North Fork, is used to generate electrical power.

Industrial service supply--Industrial service supply includes uses of water for which water quality is not usually a consideration, such as mining, cooling, water supply, gravel washing, and fire protection. Water is currently used for this purpose from Folsom Dam to the mouth of the American River. Water from Folsom Lake is a potential source for this purpose.

Warm freshwater habitat--Warm freshwater habitats are for warm-water native and introduced game and nongame fishes and other aquatic plants and animals. The reach of the South Fork downstream from Placerville, Folsom Lake, and the reach from Folsom Dam to the mouth are good warm-water habitats.

Cold freshwater habitat--All reaches of the American River are cold-water habitats for at least part of the year.

Spawning (warm water)--Warm-water fish spawn in Folsom Lake and downstream to the mouth of the American River.

Spawning (cold water)--The South Fork from the headwaters to Placerville, North Fork, Middle Fork and the lower reach from Nimbus Dam to the mouth provide habitats suitable for spawning of cold-water fish.

Migration--The lower reach of the American River from Nimbus Dam to the mouth provides a migration route and temporary environment for cold- and warm-water fish, such as Chinook salmon and American shad.

Wildlife habitat--The upper reaches of the Middle and North Forks of the American River are still in a natural state and provide excellent habitat for native wildlife. The South Fork and the area around Folsom Lake have been moderately affected by man but still provide habitat for many types of native wildlife. From Folsom Dam to the mouth, urban and suburban development cover both sides of the river. However, State and county parks adjacent to the river preserve riparian vegetation and provide a habitat for small native wildlife.

Water-Quality Objectives

Water-quality objectives are designed to meet all State and Federal requirements for maintenance of water quality. One primary source of information used in the development of water-quality objectives is California State Water Resources Control Board Resolution No. 68-16, "Statement of Policy with Respect to Maintaining High Quality of Waters in California." The objectives established for the American River follow.

Bacteria--In all reaches except Folsom Lake, the concentration of fecal-coliform bacteria, based on a minimum of five samples for any 30-day period, shall not exceed a geometric mean of 200 colonies per 100 mL, nor shall more than 10 percent of the total number of samples (90th percentile) taken during any 30-day period exceed 400 colonies per 100 mL. In Folsom Lake, fecal coliform concentration, based on a minimum of not less than five samples for any 30-day period, shall not exceed a geometric mean of 100 colonies per 100 mL, nor shall more than 10 percent of the total number of samples taken during any 30-day period exceed 200 colonies per 100 mL.

Biostimulatory substances--Water shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

Chemical constituents--Water in the North, Middle, and South Forks of the American River shall not contain concentrations of chemical constituents in excess of those given in tables 2, 3, and 4, which are taken from the California Domestic Water Quality and Monitoring Regulations (California Department of Health, 1977, p. 1112). Water in Folsom Lake and from Folsom Dam to the mouth shall not contain concentrations in excess of the following: Arsenic, 0.01 mg/L; barium, 0.1 mg/L; copper, 0.01 mg/L; cyanide, 0.01 mg/L; iron, 0.3 mg/L; manganese, 0.05 mg/L; silver, 0.01 mg/L; and zinc, 0.1 mg/L.

Dissolved solids in all reaches of the river except Folsom Lake shall not exceed 125 mg/L at the 90th percentile. In Folsom Lake, dissolved solids shall not exceed 100 mg/L at the 90th percentile.

Color--Water shall be free of discoloration that causes nuisance or adversely affects beneficial uses.

Dissolved oxygen--The monthly median of daily mean dissolved-oxygen concentrations shall not fall below 85 percent of saturation in the main water mass and the 95th percentile concentration shall not fall below 75 percent of saturation. Dissolved-oxygen concentrations shall not be reduced below the following minimum levels at any time:

Water designated as warm-water habitat-----------------5.0 mg/L
Water designated as cold-water habitat-----------------7.0 mg/L
Water designated for warm- or cold-water spawning------7.0 mg/L

Floating material--Water shall not contain floating material in amounts that cause nuisance or adversely affect beneficial uses.

Oil and grease--Water shall not contain oils, grease, waxes, or other materials in concentrations that cause nuisance, result in a visible film or coating on the surface of the water or on objects in the water, or otherwise adversely affect beneficial uses.

TABLE 2. - Maximum contaminant levels of inorganic chemicals for the North, Middle, and South Forks of the American River

Constituent	Maximum contaminant level, in milligrams per liter
Arsenic	0.05
Barium	1.
Cadmium	.010
Chromium	.05
Lead	.05
Mercury	.002
Nitrate (as NO_3)	45.
Selenium	.01
Silver	.05

TABLE 3. - Maximum contaminant levels of organic chemicals for the North, Middle, and South Forks of the American River

Constituent	Maximum contaminant level, in milligrams per liter
Chlorinated hydrocarbons	
Endrin	0.002
Lindane	.004
Methoxychlor	.1
Toxaphene	.005
Chlorophenoxys	
2,4-D	.1
2,4,5-TP Silvex	.01

TABLE 4. - Limiting concentrations of fluoride for the North, Middle, and South Forks of the American River

Annual average of maximum daily air temperature		Fluoride concentration, in milligrams per liter			
Degrees Fahrenheit	Degrees Celsius	Lower	Optimum	Upper	Maximum contaminant level
53.7 and below	12.0 and below	0.9	1.2	1.7	2.4
53.8 to 58.3	12.1 to 14.6	.8	1.1	1.5	2.2
58.4 to 63.8	14.7 to 17.6	.8	1.0	1.3	2.0
63.9 to 70.6	17.7 to 21.4	.7	.9	1.2	1.8
70.7 to 79.2	21.5 to 26.2	.7	.8	1.0	1.6
79.3 to 90.5	26.3 to 32.5	.6	.7	.8	1.4

pH--The pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.5 pH units in fresh waters designated as cold- or warm-water habitats.

Pesticides--Water in the North, Middle, and South Forks of the American River shall not contain concentrations of pesticides in excess of the limiting concentrations set forth in table 3. Water in Folsom Lake and from Folsom Dam to the mouth shall not contain a sum of individual concentrations of pesticides in excess of 0.1 μg/L.

Radioactivity--Water in all reaches and in Folsom Lake shall not contain concentrations of radionuclides in excess of the limits given in table 5.

Sediment--Suspended-sediment discharge of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Settleable material--Waters shall not contain substances in concentrations that result in the deposition of material that causes nuisance or adversely affects beneficial uses.

Suspended material--Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

Tastes and odors--Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to domestic or municipal water supplies or to fish flesh or other edible products of aquatic origin, or that cause nuisance, or otherwise affect beneficial uses.

Temperature--The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the presiding California Regional Water Quality Control Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of warm-water intrastate waters be increased more than 5°F above natural receiving water temperature.

Toxicity--All waters shall be maintained free of toxic substances in concentrations that are toxic to or that produce detrimental physiological responses in human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, bioassays of appropriate duration, or other appropriate methods as specified by the California Regional Water Quality Control Board, Central Valley Region.

Turbidity--In the North, Middle, and South Forks, waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water-quality factors shall not exceed the following limits: Where natural turbidity is between 0 and 50 JTU (Jackson turbidity units), increases shall not exceed 20 percent; where natural turbidity is between 50 and 100 JTU, increases shall not exceed 10 JTU; and where natural turbidity is greater than 100 JTU, increases shall not exceed 10 percent. In Folsom Lake and from Folsom Dam to the mouth, the turbidity shall be less than or equal to 10 JTU, except for periods of high runoff.

TABLE 5. - Maximum contaminant levels of radioactivity for all forks of the American River

[From California Department of Health, 1977, p. 16]

Constituent	Maximum contaminant level, in picocuries per liter
Combined radium-226 and radium-228	5
Gross alpha particle activity (including radium-226 but excluding radon and uranium	15
Tritium	20,000
Strontium-90	8
Gross beta particle activity	50

WATER-QUALITY DATA COLLECTION

Water-quality data have been collected at over 168 documented stations (table 6) in the American River basin by several State and Federal agencies and universities, but comprehensive water-quality studies of a year or more are few, and water-quality trend studies have never been done.

Data collected by the Geological Survey, in cooperation with the California Department of Water Resources, between February and October 1979, and the collection and analysis methods used, are reported by Shay (1982). Data were collected basinwide at 14 stream sites and at 3 sites on Folsom Lake.

The following discussion summarizes other water-quality data collected in the basin to date.

North Fork American River

Historical water-quality data are few and sites are scattered spatially and temporally throughout the North Fork American River drainage basin. Twenty-seven intermittently sampled stations have been identified upstream of the Middle Fork confluence. The most recent water-quality data collection, other than that by the Geological Survey in 1979, was done by the U.S. Forest Service from May 1976 to May 1977 at three sites along the North Fork American River (numbers 2, 8, and 15 on plate 1). Water-quality data were collected by the Forest Service in conjunction with the North Fork American River study, which was part of a proposal to designate a 41.1-mi reach of the North Fork as a wild and scenic river under the national system. The proposal was subsequently approved by the U.S. Congress and the President in November 1978, and the river was officially designated. No plans have been developed to continue sampling this reach of the river. Water-quality data have been collected by the U.S. Bureau of Reclamation at a station near the Auburn damsite (number 28 on plate 1). Samples obtained at the Auburn-Foresthill Road bridge were used in the preparation of the Auburn Dam proposal. Currently, data are being collected routinely by the Bureau of Reclamation at a station (number 27 on plate 1) just upstream from the confluence of the Middle Fork American River.

Middle Fork American River

Only a minimal amount of water-quality data on this part of the river system are available. Although 26 sampling sites with mostly intermittent data records have been identified, no comprehensive water-quality studies have been done on the Middle Fork and no effort has been made to document any site-specific water-quality problems. Currently, the Bureau of Reclamation routinely collects data at a site (number 56 on plate 1) just upstream from the North Fork American River.

South Fork American River

No comprehensive water-quality studies have ever been done on the South Fork. The El Dorado National Forest staff has obtained water samples along parts of the river where numerous summer homes are located in close proximity to the river. The California Department of Water Resources has collected a large amount of data on the South Fork American River at numerous sites and is currently collecting data routinely near Kyburz (number 84 on plate 1). A total of 63 sampling sites with intermittent data records have been identified in the South Fork drainage.

FIGURE 8. — View of Folsom Dam and Lake looking northeast towards the North Fork American River drainage. (Courtesy of U.S. Bureau of Reclamation)

Folsom Lake

Historical water-quality data for Folsom Lake (fig. 8) are scattered and do not provide the data base needed to establish long-term trends in water quality. The Bureau of Reclamation has obtained water samples from Folsom Lake in the past and maintains active lake sampling stations. No comprehensive water-quality studies of Folsom Lake have ever been done to evaluate land-use/water-quality relationships. A study on Folsom Lake, currently in progress by the Geological Survey in Sacramento, will address some of these issues.

Lower American River

An extensive amount of water-quality data exists for the lower river system and most of these data have been entered into the U.S. Environmental Protection Agency's STORET system. California State University at Sacramento, in conjunction with the Bureau of Reclamation, conducted a hydrobiologic study of the lower American River in 1968 (Hom, 1968). The purpose of the study was to determine the potential impacts of nutrient loading on water quality. The California Department of Water Resources sampled water quality in the American River near the H Street Bridge from 1951 to 1966. Data obtained at this location were used in the preparation of a lower American River water-quality study (Federal Water Pollution Control Administration, 1969).

In the mid-1960's, the California Department of Water Resources began sampling two sites on a routine basis in the lower river, one just upstream from the H Street Bridge site and one just below Nimbus Dam, with partial funding support from the Environmental Protection Agency in the early 1970's. Beginning in 1978, the sites were sampled by the Geological Survey for 2 years, after which the State again took over the sampling responsibility.

In addition to these three sites, the Department of Water Resources has collected data at numerous sites along the lower river during the last 25 years. The Bureau of Reclamation has collected a large amount of data below the Nimbus Fish Screen and at Nimbus Dam. Currently, they collect data at Folsom Bridge and at the 16th Street Bridge.

The California State Water Resources Control Board and the California Department of Fish and Game have collected freshwater organisms in the vicinity of the American River at Sacramento (plate 1, locations 156 and 157) annually since 1976 and have analyzed them for toxic substances. The fish and invertebrate organisms are analyzed for selected trace metals and synthetic organic compounds as part of a statewide screening program for toxic substances (California State Water Resources Control Board, 1979a, 1979b, 1980a, and 1981).

Data Storage and Review

Past and present sampling stations basinwide that are in the Environmental Protection Agency's Water Quality Control Information System (STORET), along with the collecting agency, relative frequency of collection, and current status are given in table 6. The station locations are shown on plate 1.

Because many agencies have been responsible for collecting and analyzing water-quality data in the American River basin, the available data represent a wide variety of collection and analysis methodologies, not all of which are known. The STORET system, which handles data from numerous sources, records only the value of a constituent and not the way in which it was collected or analyzed, which can create problems with data interpretation. Keypunching errors during data input to the system can go unnoticed and cause additional problems.

To minimize any discrepancies in the data base, the initial step in this assessment was to scan all appropriate data, using various plotting and tabling procedures, and eliminate any unusual or erroneous values. This editing process eliminated obvious discrepancies in the data, but did not account for the more subtle differences that may be caused by dissimilar collection and analysis methods. This needs to be considered when weighing the results of any analytical interpretation.

TABLE 6. - Sampling-station information by subbasin as listed in the U.S. Environmental Protection Agency's STORET system

[Collecting agency: USGS, U.S. Geological Survey; DWR, California Department of Water Resources, USBR, U.S. Bureau of Reclamation, USEPA, U.S. Environmental Protection Agency. Frequency of sampling: 1 = very infrequent (<5 analyses); 2 = infrequent (5-25 analyses); 3 = frequent (>25 analyses); A = ongoing]

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	NORTH FORK AMERICAN RIVER			
1.	American River North Fork at The Cedars	A7282501	DWR	1
2.	North Fork American River below Serena Creek	391515120225300	USGS	1
3.	American River North Fork of North Fork near Emigrant Gap	A7267201	DWR	1
4.	American River East Fork of North Fork at Tunnel Mill Campground	A7265001	DWR	1
5.	Fulda Creek near Blue Canyon	A7262701	DWR	1
6.	American River North Fork of North Fork above Blue Canyon	A7262001	DWR	1
7.	Blue Canyon Creek near Baxter	A7260501	DWR	1
8.	American River North Fork of North Fork below Blue Canyon	A7260401	DWR	1
9.	North Fork American River near Dutch Flat	11426194	USGS	1
10.	Iron Point Run near Baxter	A7259001	DWR	1
11.	Canyon Creek at Towle	A7256001	DWR	1
12.	Canyon Creek at Gold Run	A7255501	DWR	1
13.	American River North Fork near Monona Flat	A7253001	DWR	1
14.	American River North Fork at Colfax	A7250001	DWR	2
15.	North Fork American River above Slaughter Ravine	11426197	USGS	1

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	NORTH FORK AMERICAN RIVER--Continued			
16.	American River 3 feet from Iowa Hill Bridge	052559	USBR	2
17.	Indian Creek at Iowa Hill	A7248501	DWR	1
18.	Shirttail Canyon Creek above Devils Canyon Creek	A7235801	DWR	1
19.	American River North Fork near Colfax	A7235000	DWR	1
20.	Bunch Canyon Creek near Colfax	A7232001	DWR	1
21.	Bunch Canyon Creek at mouth	A7230101	DWR	1
22.	Owl Creek at Grey Eagle Mine	A7226001	DWR	1
23.	American River North Fork at Ponderosa Way	A7225001	DWR	1
24.	Lake Clementine above North Fork Dam	A7R85621014	DWR	1
25.	North Fork American River at North Fork Dam	11427000	USGS	1
26.	American River North Fork above Middle Fork near Auburn	A7219001	DWR	2
27.	North Fork American River upstream of Middle Fork	052557	USBR	3,A
	NORTH FORK BELOW MIDDLE FORK AMERICAN RIVER			
28.	American River near Auburn Dam	052556	USBR	3
29.	American River North Fork at Auburn Damsite	A7216001	DWR	2
30.	North Fork American River below Auburn Damsite	11433800	USGS	1
31.	Paymaster Creek near Cool	11433900	USGS	3
32.	French Meadows Reservoir at spillway	A7R90680282	DWR	1
33.	Middle Fork American River at French Meadows	11427500	USGS	1

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	NORTH FORK BELOW MIDDLE FORK AMERICAN RIVER--Continued			
34.	American River Middle Fork below French Meadows Dam	A7380010	DWR	1
35.	American River Middle Fork above Rubicon River	A7327301	DWR	1
36.	Hell Hole Reservoir at boat ramp	A7R90360247	DWR	1
37.	Rubicon River below Hell Hole Dam	A7531000	DWR	1
38.	Pilot Creek near Georgetown	A7520000	DWR	1
39.	Long Canyon Creek at Ramsey crossing	A7511701	DWR	1
40.	Long Canyon Creek at mouth	A7510201	DWR	1
41.	Rubicon River near Foresthill	A7510000	DWR	2
42.	Rubicon River below Ralston Powerhouse	A7505001	DWR	1
43.	Peavine Creek at Peavine Ridge Road	A7329801	DWR	1
44.	American River North Fork of Middle Fork near Foresthill	A7328000	DWR	2
45.	Middle Fork American River near Foresthill	11433300	USGS	1
46.	Volcano Canyon Creek at Mosquito Ridge Road	A7325205	DWR	1
47.	Canyon Creek near Georgetown	A7320000	DWR	1
48.	Todd Creek near Georgetown	A7328001	DWR	1
49.	American River Middle Fork at Greenwood Bridge	A7317501	DWR	1
50.	Gas Canyon Creek near Georgetown	A7316501	DWR	1
51.	Maine Bar Canyon Creek near Greenwood	11433420	USGS	3
52.	Buckeye Canyon Creek Tributary near Greenwood	11433430	USGS	2

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	MIDDLE FORK AMERICAN RIVER--Continued			
53.	Wildcat Canyon Creek near Cool	11433440	USGS	2
54.	Browns Bar Canyon Creek near Cool	11433450	USGS	2
55.	Middle Fork American River near Auburn	11433500	USGS	3
56.	Middle Fork American River upstream of North Fork	052558	USBR	3,A
57.	American River Middle Fork near Auburn	A7310000	DWR	3
	SOUTH FORK AMERICAN RIVER			
58.	Echo Lake Conduit at Highway 50	A7495001	DWR	1
59.	American River South Fork below Echo Lake Conduit	A7479001	DWR	1
60.	American River South Fork below Huckleberry Creek	A7478001	DWR	1
61.	American River South Fork at Phillips	A7477001	DWR	2
62.	South Fork American River at Ski Ranch Road	052650	USBR	2
63.	American River South Fork at Camp Sacramento Ski Lift	A7475001	DWR	2
64.	Pyramid Creek below Desolation Lake	A7472901	DWR	1
65.	Pyramid Creek at Highway 50	A7472801	DWR	3
66.	South Fork American River at Strawberry Bridge	052649	USBR	2
67.	American River South Fork Strawberry	A7472704	DWR	2
68.	American River South Fork at 42-Mile Camp	A7472701	DWR	1
69.	Strawberry Creek at Sciots Camp	A7472601	DWR	1

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	SOUTH FORK AMERICAN RIVER--Continued			
70.	Lot 3 at 39 Milestone, South Fork American River	052648	USBR	2
71.	American River South Fork at 39-Mile Tract	A7472201	DWR	2
72.	American River South Fork Tributary 1A	A7472104	DWR	2
73.	American River South Fork Tributary 1	A7472101	DWR	2
74.	Chimney Creek above Highway 50	A7472002	DWR	2
75.	Chimney Creek at mouth	A7471901	DWR	2
76.	Lower Champagne Canyon Creek	052645	USBR	2
77.	American River South Fork at 36-Mile Tract	A7471601	DWR	2
78.	Wildwood Way bridge near Kyburz	052675	USBR	1
79.	Silver Lake Outlet near Kirkwood	A7466000	DWR	2
80.	Caples Lake Outlet near Kirkwood	A7462000	DWR	2
81.	American River South Fork at Silver Fork	A7469201	DWR	3
82.	Silver Fork at mouth to South Fork American River	A7458001	DWR	2
83.	El Dorado Canal near Kyburz	A7493000	DWR	2
84.	American River South Fork near Kyburz	A7455000	DWR	3,A
85.	South Fork American River near Kyburz	11439500	USGS	1
86.	American River South Fork at Alder Creek Campground	A7452301	DWR	2
87.	Alder Creek at Diversion Dam	A7493200	DWR	1
88.	Alder Creek near Whitehall	A7452000	DWR	2

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	SOUTH FORK AMERICAN RIVER--Continued			
89.	Alder Creek at Alder Creek Campground	A7451901	DWR	1
90.	American River South Fork at Riverton	A7449001	DWR	2
91.	South Fork American River at Riverton	052647	USBR	2
92.	American River South Fork at Maple Grove Campground	A7448901	DWR	1
93.	American River South Fork	A7445001	DWR	1
94.	Silver Creek South Fork at Ice House	A7439700	DWR	3
95.	Silver Creek at Union Valley	A7443000	DWR	2
96.	Silver Creek at Camino Tunnel Adit	A7437010	DWR	1
97.	Silver Creek near Placerville	A7437000	DWR	2
98.	South Fork American River below Silver Creek near Pollock Pines	11442500	USGS	3
99.	American River South Fork below Silver Creek	A7430000	DWR	3
100.	American River South Fork near Camino	A7430000	DWR	3
101.	American River Flume near Camino	A7492000	DWR	2
102.	South Canyon Creek near Camino	A7428001	DWR	1
103.	Rock Creek near Mosquito Camp	A7424201	DWR	1
104.	American River South Fork near Placerville	A7420000	DWR	1
105.	Dutch Creek at Coloma	A7417501	DWR	1
106.	American River South Fork at Coloma	A7417000	DWR	1
107.	Indian Creek near Coloma	A7416501	DWR	1
108.	Shingle Creek at Lotus	A7416301	DWR	1

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	SOUTH FORK AMERICAN RIVER--Continued			
109.	Granite Creek at Lotus	A7416201	DWR	1
110.	South Fork American River near Lotus	11445500	USGS	3
111.	American River South Fork near Lotus	A7415000	DWR	3
112.	12-inch downdrain on Highway 50 at post mile 15.5	TMENVPLACERVILLE	DWR	3
113.	Weber Creek near Placerville	A7411200	DWR	1
114.	Hangtown Creek near Placerville	A7410801	DWR	1
115.	Cold Spring Creek Tributary at Cold Spring Creek	A7410602	DWR	1
116.	Cold Spring Creek near Placerville	A7410603	DWR	1
117.	Weber Creek below Pinehem Creek	A7410010	DWR	1
118.	Weber Creek near Salmon Falls	A7410000	DWR	1
119.	American River South Fork at Weber Creek	A7409701	DWR	1
120.	American River South Fork near Pilot Hill	A7408001	DWR	2
	FOLSOM LAKE STATIONS			
121.	Folsom Lake sample site No. 2 on North Fork	384730121061900	USGS	2
122.	Folsom Lake, North Fork Arm	A7R8471062	DWR	2
123.	Folsom Lake at Salmon Falls Bridge	052555	USBR	3,A
124.	South Fork Arm Folsom Lake near Folsom	384449121044700	USGS	2
125.	Folsom Lake, South Fork Arm	A7R84471052	DWR	2
126.	Folsom Lake sample site No. 1 on South Fork	384410121055100	USGS	1
127.	Folsom Lake approximately 2 miles above Dam	052554	USBR	1

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	FOLSOM LAKE STATIONS--Continued			
128.	Folsom Lake near Folsom	A7R84251094	DWR	1
129.	Folsom Lake near Folsom	11446200	USGS	1
130.	Folsom Lake near Folsom Dam	A7R84271087	DWR	2
131.	Folsom Lake 1000 feet above Dam	052553	USBR	3,A
	LOWER AMERICAN RIVER			
132.	American River at Folsom	A7111601	DWR	2
133.	American River at Folsom bridge	052552	USBR	3,A
134.	Willow Creek at Natoma	A7111401	DWR	1
135.	American River at Nimbus Dam	11446400	USGS	3
136.	Lower American River below Nimbus Dam	WB05A0718000	DWR	3,A
137.	American River below Nimbus Dam	A0718000	DWR	3,A
138.	American River at Nimbus Dam Fish Screen	052551	USBR	3,A
139.	American River at Fair Oaks	11446500	USGS	3
140.	Buffalo Creek at Highway 50 near Nimbus	A0716701	DWR	1
141.	Buffalo Creek at American River	000005	USEPA	1
142.	American River above Sunrise Bridge	000004	USEPA	1
143.	American River at Fair Oaks Bridge	052560	USBR	1
144.	American River at Fair Oaks	A0717500	DWR	1
145.	American River below Sunrise Bridge	000006	USEPA	1
146.	American River at river mile 19.8 Fair Oaks Bridge North Bank	WB000SCRM198	DWR	3
147.	American River at Elmanto Street	000008	USEPA	1
148.	American River Cordova STP R2	WB050079855R2	DWR	3

TABLE 6. - Sampling-station information--Continued

Location No. (pl. 1)	Station name	Station No.	Collecting agency	Frequency of sampling
	LOWER AMERICAN RIVER--Continued			
149.	American River at river mile 14.3 North Bank Claremont Road	WB00SCRM143	DWR	3
150.	American River above Northeast STP	A0715301	DWR	1
151.	American River Northeast STP R2	WB050079871R2	DWR	3
152.	American River Northeast STP R1	WB050079871R1	DWR	3
153.	American River below Northeast STP above pipeline	A0715001	DWR	3
154.	American River below Northeast STP below pipeline	A0714901	DWR	1
155.	American River river mile 9.3 Watt Avenue Bridge North Bank	WB00SCRM93	DWR	3
156.	American River at Sacramento	11447000	USGS	3
157.	American River at Sacramento	A0714000	DWR	3,A
158.	American River near H Street	052550	USBR	2
159.	Strong Ranch Slough at El Camino High School near Sacramento	383630121214300	USGS	1
160.	Strong Ranch Slough at Country Club Centre near Sacramento	383626121230800	USGS	2
161.	Strong Ranch Slough at Sacramento	11447030	USGS	3
162.	American River above Arden/Howe STP	A0713811	DWR	1
163.	American River Arden STP R2	WB050079847R2	DWR	3
164.	American River Arden STP R1	WB050079847R1	DWR	3
165.	American River below Arden/Howe STP	A0713701	DWR	1
166.	American River river mile 4.0 29th Street Bridge	WB00SCRM40	DWR	3
167.	American River at 16th Street Bridge	11447230	USGS	1
168.	American River at 16th Street Bridge	052549	USBR	3,A

FIGURE 9. – North Fork Lake on the North Fork American River below the section designated as a Federal and State Wild and Scenic River. The dam was constructed in 1938 – 39. (Courtesy of U.S. Bureau of Reclamation)

HYDROLOGIC ANALYSIS

Streamflow

North and Middle Forks American River

Forty-one miles of the North Fork American River is designated as a Wild and Scenic River by both the Federal Government and the State of California. As such this upper reach has no artificial impoundments or controls on the main stem between North Fork Lake (fig. 9) and the area upstream known as The Cedars (plate 1).

At this writing, the construction of Auburn Reservoir is still being debated because of concerns over dam safety and economic feasibility. The reservoir, when completed, would extend from about rm 20 (fig. 10), just upstream from Folsom Lake, to the Colfax-Iowa Hill Bridge about 25 mi upstream.

FIGURE 10. — Auburn damsite on the North Fork American River. View is downstream. (Courtesy of U.S. Bureau of Reclamation)

The only diversion in the North Fork basin occurs at Lake Valley Reservoir near the headwaters of the North Fork of the North Fork where water is exported to the Bear River basin for hydroelectric power generation and domestic water supply. This combined storage and diversion is minimal and has little effect on the natural flow as recorded at the North Fork American River at North Fork Dam gaging station (11427000, number 25 on plate 1). Minor regulation is provided by the North Fork Reservoir, which has a usable capacity of 12,800 acre-ft.

The streamflow hydrograph for the North Fork (fig. 11) is typical for an unregulated stream emanating from the high western slopes of the Sierra Nevada. Low flows, which are primarily ground-water discharge, occur in the late summer. At the onset of the rainy season in autumn, flows increase until January. With much of the precipitation in the upper basin being stored as snow between January and March, there is a resulting drop in streamflow during this period. As spring approaches and air temperatures increase, a period of rapid snowmelt occurs and streamflows increase. After peak flow occurs in May or early June with the depletion of the snowpack, streams recede rapidly and return to low flow conditions again by late summer.

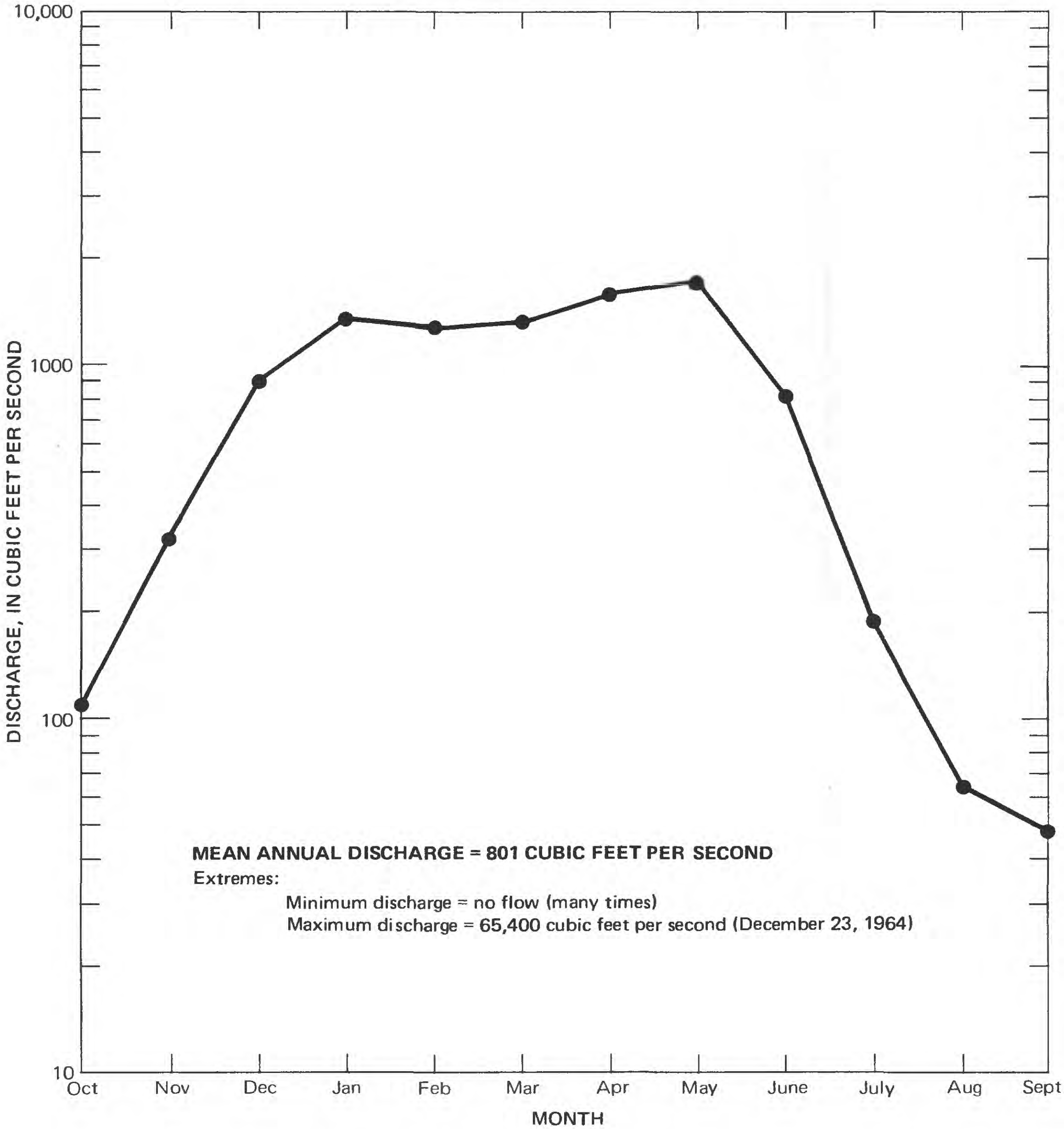


FIGURE 11. — Hydrograph of mean monthly discharge for the period 1942–80 at North Fork American River at North Fork Dam (11427000; location number 25 on plate 1).

The Middle Fork basin, which is somewhat more complicated in terms of impoundments and diversions, is tributary to the North Fork. The lower reach of the Middle Fork would be partially flooded by Auburn Reservoir. The complexity of diversions and storage in the Middle Fork basin is shown schematically in figure 12. This series of storage and diversion structures does impact the natural flow characteristics as recorded at the Middle Fork American River near Auburn gaging station (11433500, number 55 on plate 1). Water storage in the reservoirs tends to reduce peak flows and raise minimum flows at locations downstream, moderating seasonal streamflow variability. This moderating effect can be seen in the postregulation (1961-80) streamflow hydrograph in figure 13. Some water is diverted out of the basin at the Robbs Peak Powerhouse to Union Valley Reservoir in the South Fork American River basin for hydroelectric power generation.

South Fork American River

As in the Middle Fork basin, the seasonal variability in streamflow for the South Fork American River has been moderated by the many upstream diversions and storage reservoirs in the basin (see fig. 14). Figure 15 illustrates the change from preregulation (1952-62) to postregulation (1963-79) in the streamflow hydrograph for the South Fork American River near Lotus (11445500, number 110 on plate 1). The mean annual discharge for the period of record prior to extensive regulation (1952-62) was 1,109 ft^3/s and for the period following (1963-79) it was 1,403 ft^3/s. The minimum discharge for the entire period was 14 ft^3/s on July 13, 15-18, and 24, 1977, and the maximum was 71,800 ft^3/s on December 23, 1955.

The lower part of the South Fork downstream from the vicinity of Chili Bar is used extensively for white-water rafting and kayaking. This free-flowing stretch of river is being considered by several groups for development of hydroelectric facilities. Environmental impact statements and several alternative plans are being prepared, and no final decision on development has yet been made.

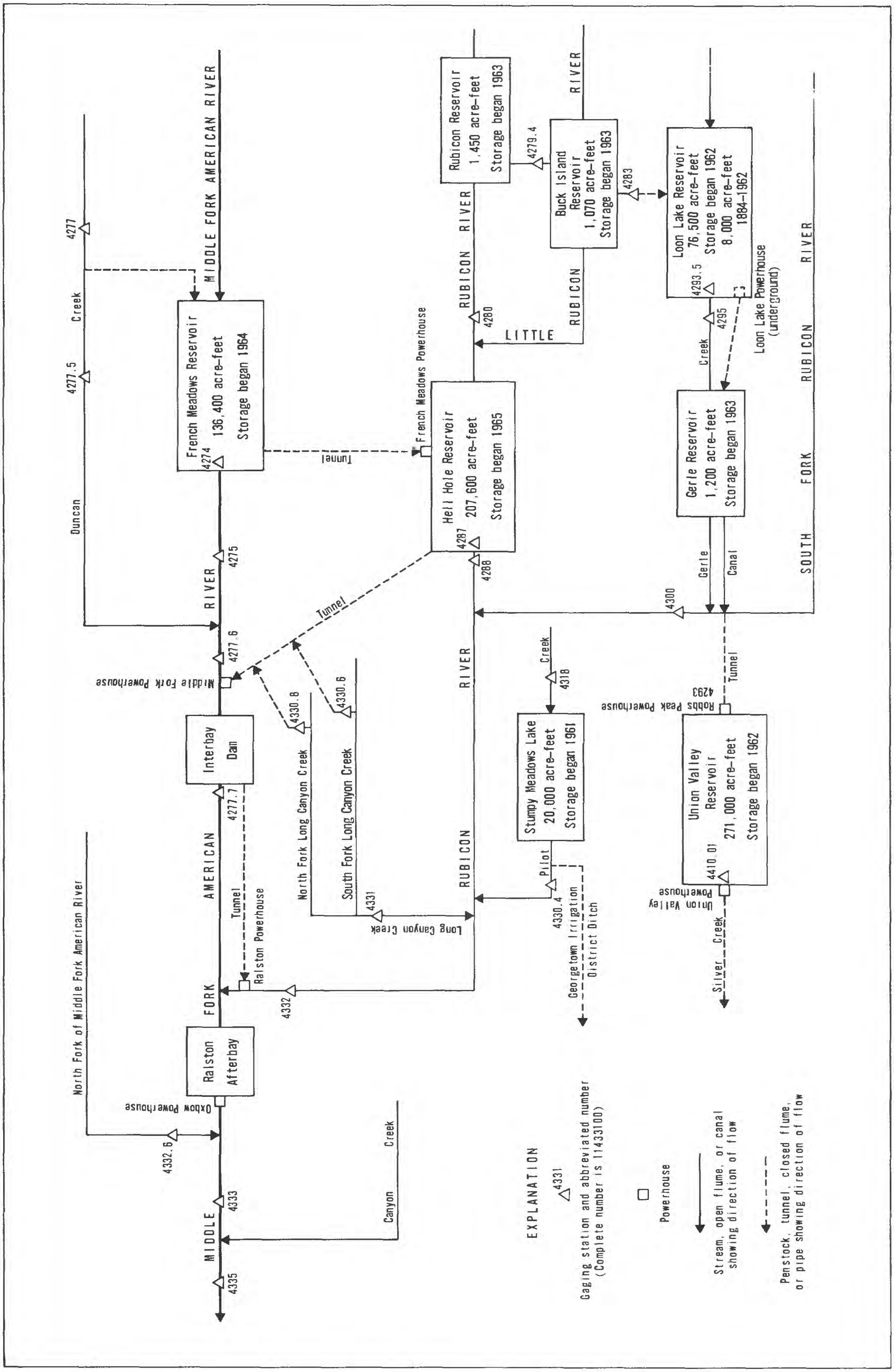


FIGURE 12. – Schematic diagram showing diversions and storage in Middle Fork American River basin.

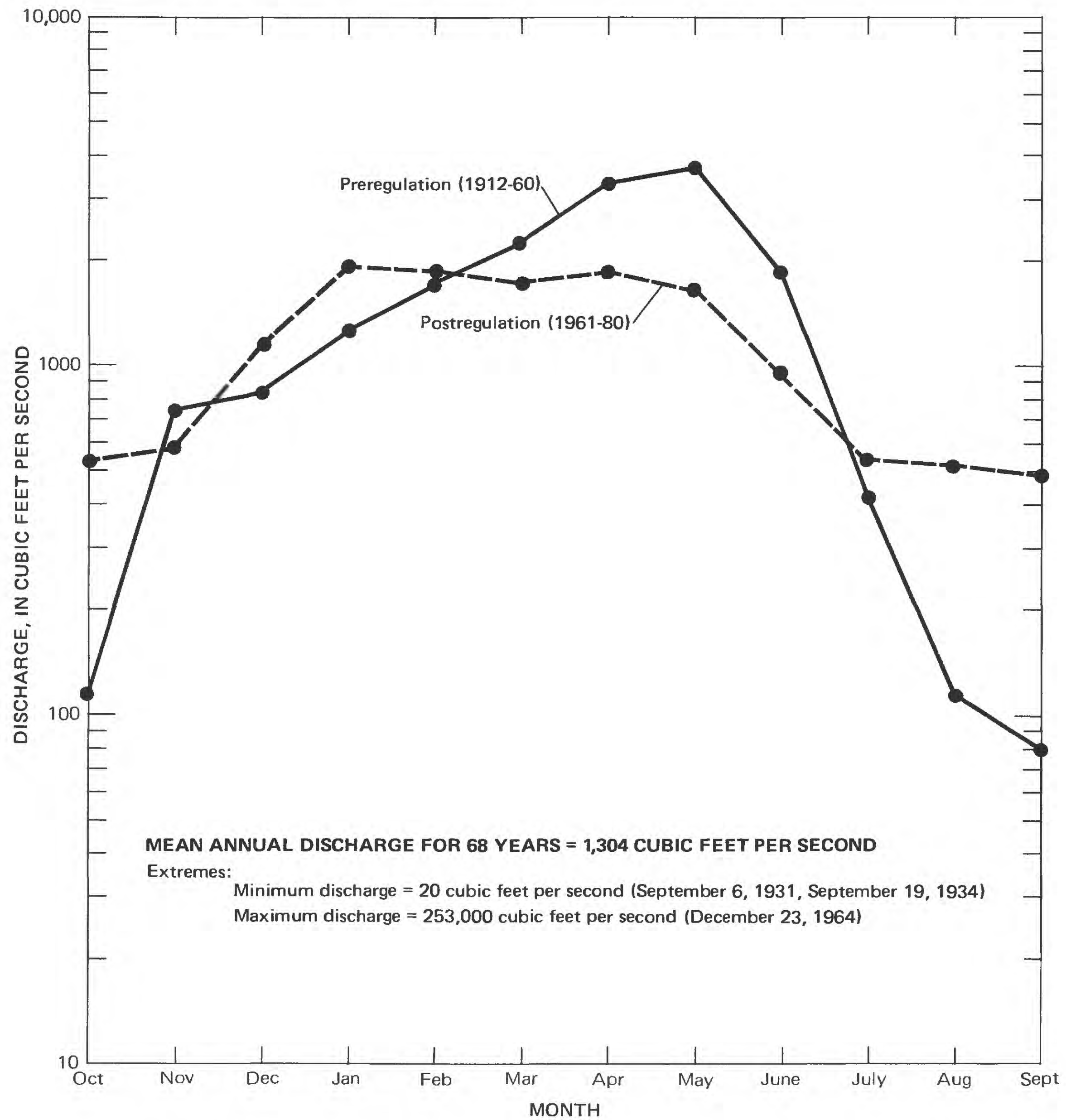


FIGURE 13. – Preregulation and postregulation hydrographs of mean monthly discharge at Middle Fork American River near Auburn (11433500; location number 55 on plate 1).

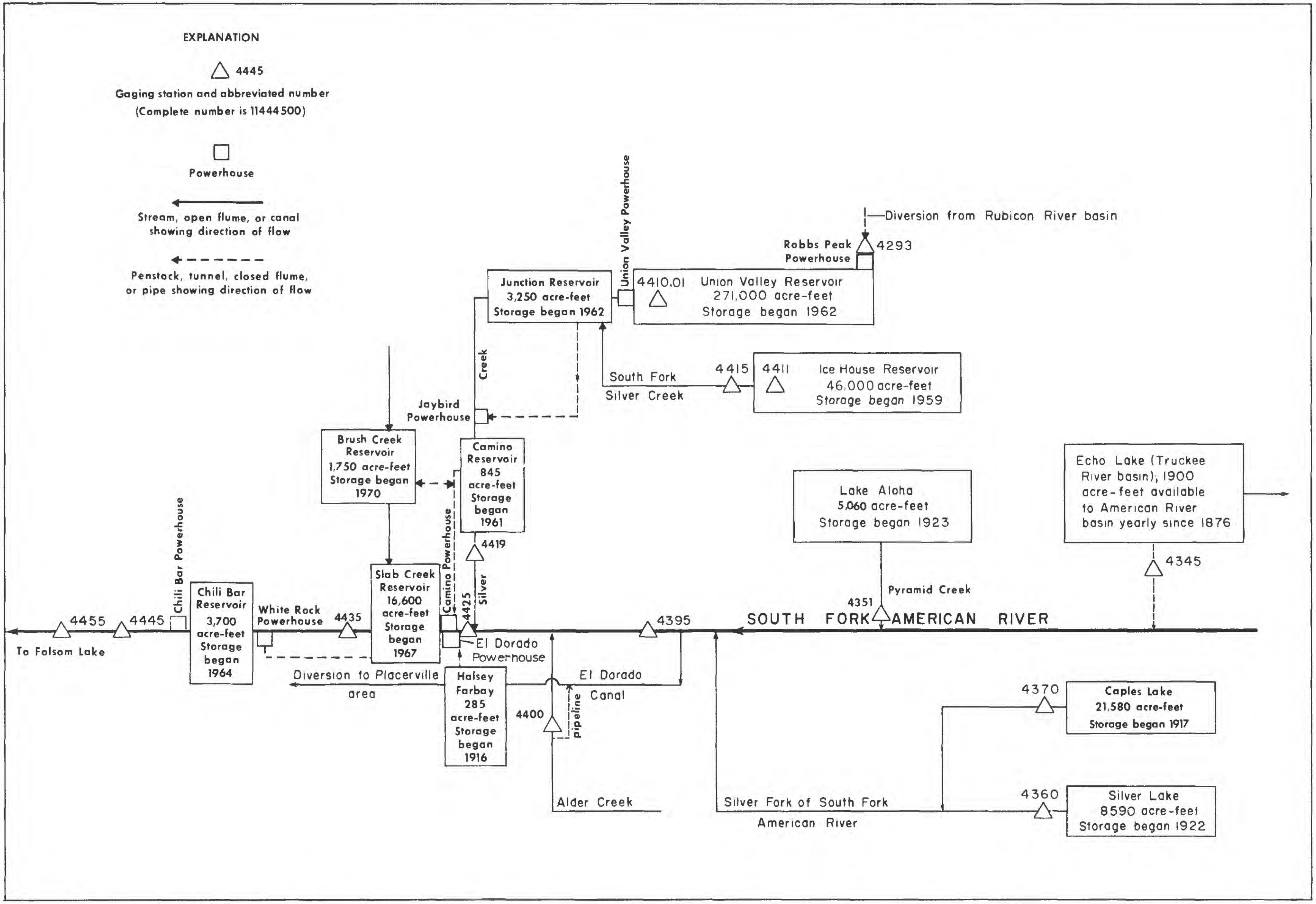


FIGURE 14. – Schematic diagram showing diversions and storage in South Fork American River basin.

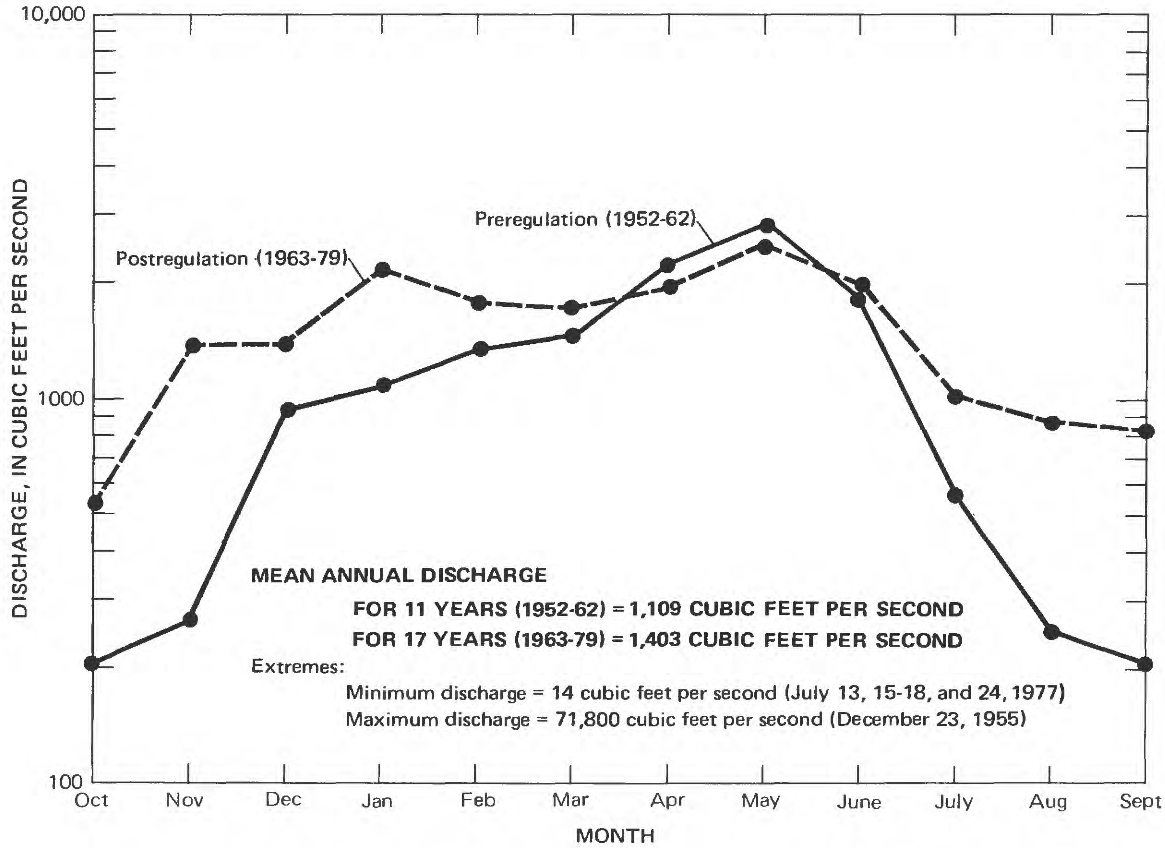


FIGURE 15. — Preregulation and postregulation hydrographs of mean monthly discharges at South Fork American River near Lotus (11445500; location number 110 on plate 1).

Lower American River

Streamflow in the lower American River has been regulated since 1955. Nimbus Dam, which forms Lake Natoma, is used to re-regulate diurnal fluctuations created by hydropower generation at Folsom Dam. Numerous diversions occur at Folsom Dam for irrigation, and municipal and domestic water supply. Users include San Juan Suburban Water District, Cordova Water Service, City of Folsom, City of Roseville, and the State of California. Diversion to the Folsom-South Canal from Lake Natoma began in 1973. Mean annual discharge since 1955 at the American River at Fair Oaks gaging station (11446500, number 139 on plate 1) is 3,595 ft^3/s. Adjusting for diversions, change in reservoir contents, and evaporation, the mean annual natural discharge at station 11446500 since 1955 is 3,750 ft^3/s. The mean annual natural discharge for the period of record (1905-80) is 3,712 ft^3/s. The moderating effect of storage on the streamflow hydrograph at this station can be seen in figure 16.

With the available storage in Folsom Lake and the development of levees along the lower reaches of the American River, the potential for devastating floods in this area has been greatly reduced. The peak floodflow recorded at station 11446500 was 180,000 ft^3/s on November 21, 1950. Larger flows which have occurred since the construction of Folsom Dam have been moderated by storage and gradual releases from Folsom Lake. The maximum discharge recorded since construction of the dam was 115,000 ft^3/s on December 23-25, 1964. The flow calculated by the Bureau of Reclamation into Folsom Lake at that time was 214,000 ft^3/s.

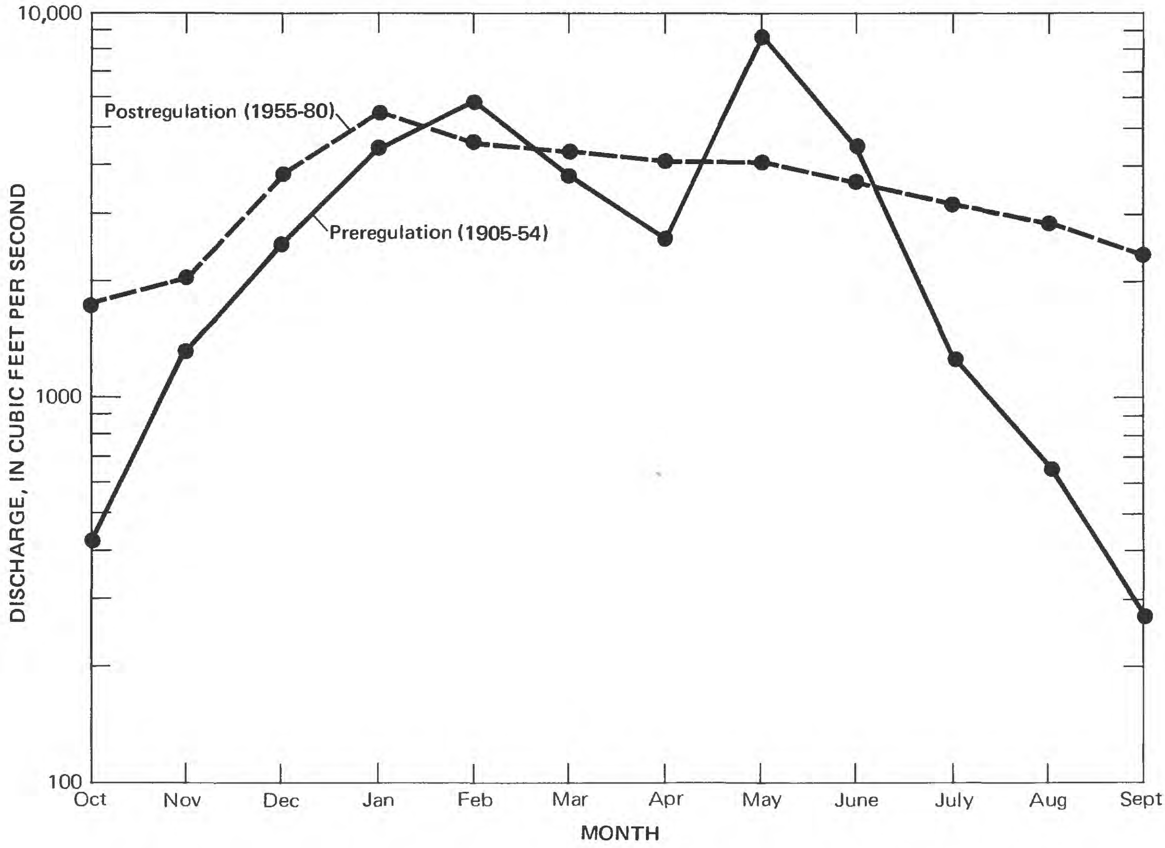


FIGURE 16. – Preregulation and postregulation hydrographs of mean monthly discharge for the indicated periods at American River at Fair Oaks (11446500).

Minimum flow for the period of record is 3.6 ft^3/s on August 16, 1924. The minimum recorded since the reservoir initially reached normal pool was 86 ft^3/s on April 7, 1955. Minimum flow criteria established by the State Water Resources Control Board in 1972 by Decision 1400 are shown in table 7. These minimums were considered to represent the "free flowing natural condition" of the river, but are actually much higher than the historical minimums under natural conditions. Flow releases of Folsom and Nimbus Dams are regulated by the Bureau of Reclamation, where policy is to try to maintain the minimum flow at 1,500 ft^3/s. In an operating agreement prior to Decision 1400, the Bureau of Reclamation agreed to maintain minimum flow from Nimbus Dam at 500 ft^3/s, except in a critically dry year when the minimum would be 250 ft^3/s. A critical year is one in which deficiencies are placed on all contracts with the Bureau of Reclamation for supplied water. The increased flows during the summer and autumn months, made possible by timed release of stored reservoir water, have increased recreational use of the river during these low run-off periods, and provided a mean monthly discharge considerably higher than the "free flowing natural condition."

TABLE 7. - Minimum flows for the lower American River as designated by State Water Resources Control Board, Decision 1400, 1972

Flow (ft^3/s)	Purpose	Period of time
1,250	Fish and wildlife	Oct. 15 to July 14
800	Fish and wildlife	July 15 to Oct. 15
1,500	Recreation	May 15 to Oct. 14

Discharge points of tributaries, storm drains, and sewage treatment outfalls, which affect both the quantity and quality of water in the lower American River, are shown in figure 17. Discharge from the three sewage treatment plants was scheduled to end during late 1982. Effluent from these plants will be transferred via a series of pipelines to the new Sacramento County Regional Waste Treatment Plant on the Sacramento River, south of Sacramento. Transfer is now scheduled for late 1982.

EXPLANATION

DISCHARGE POINT DESIGNATION	SITE NAME
A	Buffalo Creek
B	Minnesota Creek
C	Carmichael Creek
D	Rancho Cordova Sewage Treatment Plant
E	Storm Drain D-11
F	Northeast Sewage Treatment Plant
G	Storm Drain D-1
H	Storm Drain D-6
I	Mayhew Road Diversion
J	Storm Drain D-10
K	Storm Drain D-2
L	Storm Drain D-37
M	Arden Avenue Sewage Treatment Plant
N	Storm Drain D-5

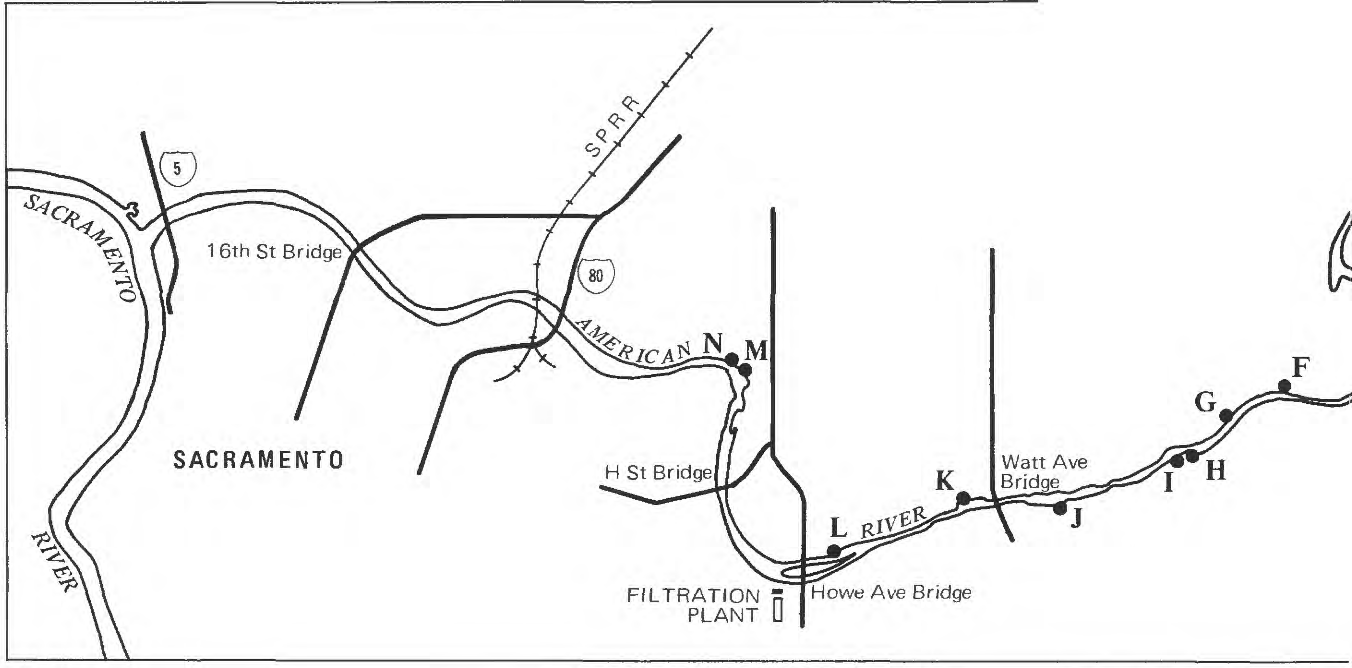
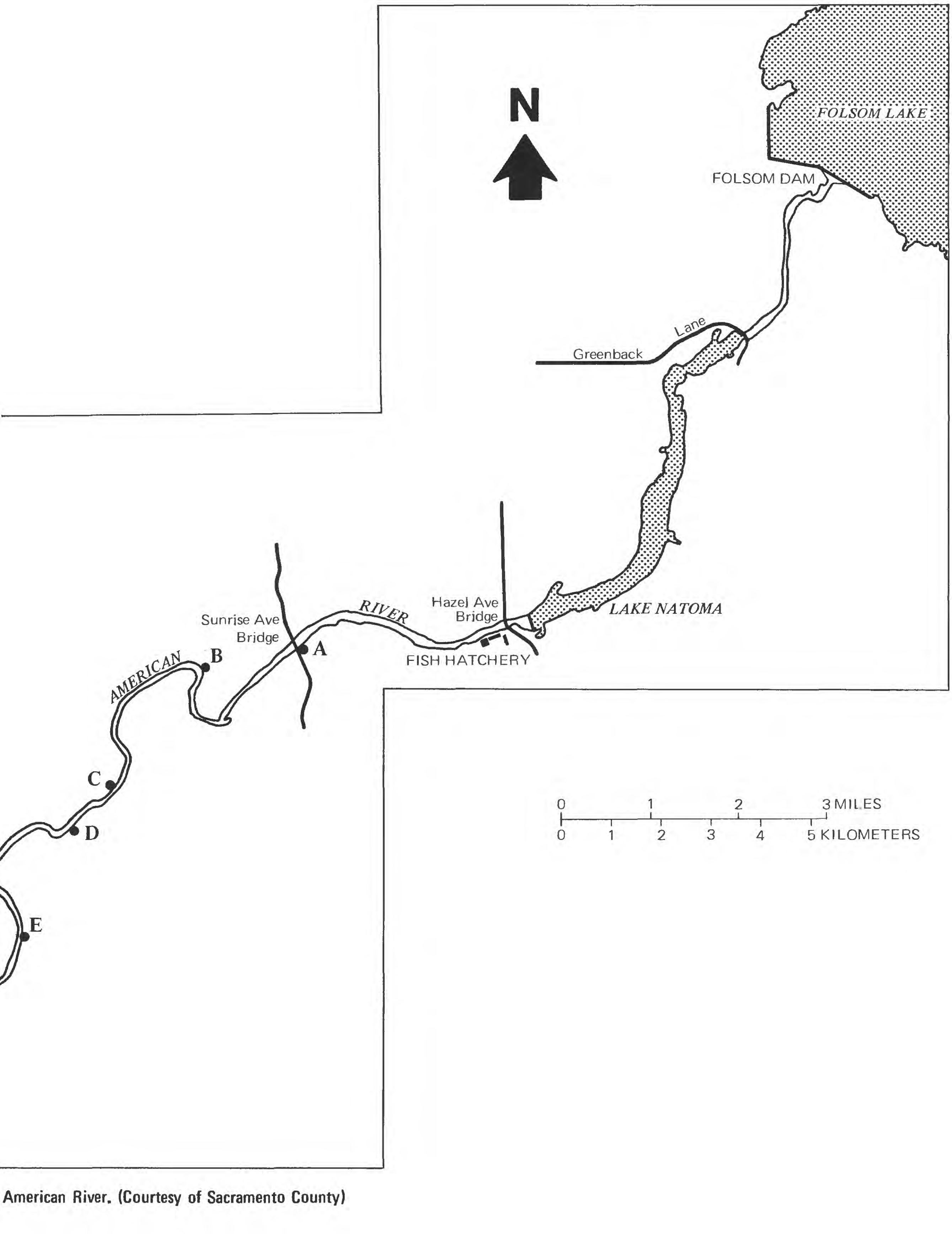


FIGURE 17. – Discharge points (solid circles) on the lower



American River. (Courtesy of Sacramento County)

Water Quality

After an initial scan of the water-quality data available from the stations shown in table 6, selected sites were chosen for data analysis based on location and quantity of data available. Data collected by different agencies at the same location were combined to increase the number of observations available for analyses.

The stream sites selected for data analysis are given in table 8.

Areal Quality

Schematic plots (Tukey, 1977, p. 47) provide a convenient means for comparing "batches" of data side by side. Schematic plots for temperature, dissolved oxygen, specific conductance, pH, alkalinity, hardness, and phosphorus and nitrogen forms at the six sites are shown in figures 18 through 27, respectively. Each schematic plot represents the range of a particular measurement at a particular site. Instantaneous values from samples collected by the Geological Survey during 1979 are displayed on the schematic plots to compare recently collected data with the overall range for the constituent at that site. Water-quality objectives are indicated for dissolved oxygen, dissolved solids (in terms of specific conductance), and pH. Recommended limits for ammonia and phosphorus are also shown.

Comparison of figures 18 and 19 shows that generally water temperatures are lower and dissolved-oxygen concentrations are higher at sites MF3, SF3, and NF3, upstream from Folsom Lake, and water temperatures are higher and dissolved-oxygen concentrations are lower downstream from the lake at AR1, AR2, and NAT1. Concentrations of dissolved oxygen (fig. 19) of less than the specified lower limit of 7.0 mg/L have been observed a few times at both AR1 and AR2. However, most of the observations are above this lower limit.

TABLE 8. - Stream sites selected for data analysis

[Location numbers refer to location on plate 1 and listing in table 6]

Site	Stream, and location number
NF3	North Fork American River, numbers 14, 15 and 16.
MF3	Middle Fork American River, numbers 55, 56, and 57.
SF3	South Fork American River, numbers 110 and 111.
AR1	American River below Nimbus Dam, numbers 135, 136, 137, and 138.
AR2	American River at Sacramento, numbers 156 and 157.
NAT1	American River (Lake Natoma) at Folsom, numbers 132 and 133.

To assess stream conditions with respect to the water-quality objective for dissolved solids, the objective limit of 125 mg/L was converted to specific conductance using an estimated dissolved-solids-to-specific-conductance ratio of 0.75. All measured specific conductance values are below the converted limit of 167 μmho/cm (fig. 20). Because dissolved-solids data are lacking, this ratio is only an approximation.

In figure 21, the pH variation (excluding outside values) is small at each site, ranging from about 6.8 to 7.9. The pH plots for AR1 and AR2 are similar, the primary difference being the range of the values outside of the 25th and 75th percentile range. Four sites--AR1, AR2, MF3, and NAT1--have values outside the water-quality objective range of 6.5 to 8.5 for pH. This pH range is considered normal for most unpolluted natural waters (Hem, 1970, p. 93, and National Academy of Sciences and National Academy of Engineering, 1973, p. 140). Values of pH outside of this range could become detrimental to the specified beneficial uses. The high values at these sites are probably attributable to the photosynthetic activity of aquatic plants which take up dissolved carbon dioxide during daylight hours, causing pH to increase.

Alkalinity, while not given a specific criterion, is acceptable for all specified beneficial uses as measured at each of the six sites (fig. 22).

An arbitrary hardness scale (U.S. Environmental Protection Agency, 1976, p. 75) established the range for soft water as that with a hardness between 0 and 75 mg/L as $CaCO_3$. All the hardness values at each site are in the soft water range (fig. 23).

Site NF3, an unregulated stream, has a greater range in values and generally higher values for specific conductance, pH, alkalinity, and hardness. This is typical of an unregulated Sierra stream where seasonal flows vary considerably. By contrast there is a diluting effect in the heavily regulated Middle and South Forks due to the augmented flow during what is normally low-flow conditions in these streams. The higher values in the North Fork are moderated downstream by inflow from the more dilute Middle Fork American River. It should be noted that the schematic plots for NF3 are somewhat skewed because of the limited amount of data available at that site. The box portion of the plot, representing the middle 50 percent of the data, would probably be shortened in a manner similar to the other plots, if more data were available. South Fork (SF3) water is the most dilute as evidenced by the plots of specific conductance, hardness, and alkalinity.

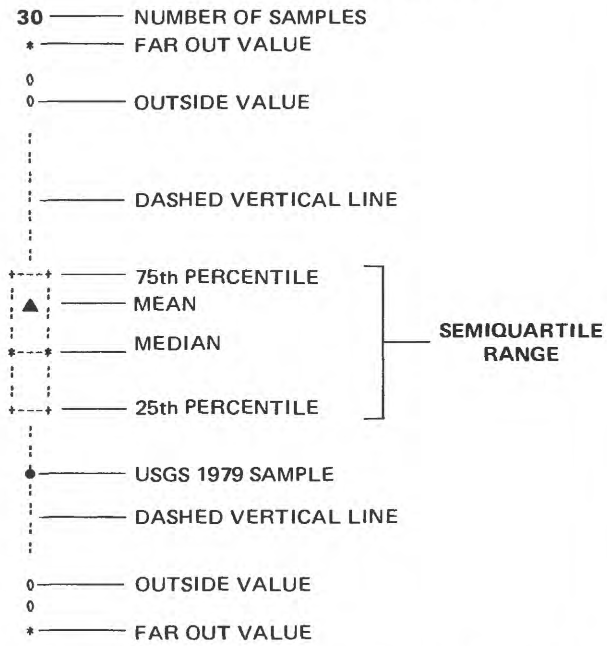
Figures 24 through 27 show schematic plots for some major plant nutrients including nitrate (dissolved as NO_3), ammonia (total as N), Kjeldahl nitrogen (total as N), and phosphorus (total as P). Most evident in these plots is the predominance of high nutrient values at site AR2. This is to be expected because AR2 is downstream from both wastewater treatment and urban drain outfalls. The large number of "far out" values at AR1 and AR2 illustrates that while concentrations are normally low, high concentrations are known to occur periodically.

The specified limit for nitrate (as NO_3) of 45 mg/L has not been exceeded at any of the five sites (fig. 24). Although no limits have been established by the Regional Water Quality Control Board for ammonia, some recommended levels have been established by others. Ammonia concentrations in excess of 0.1 mg/L (as nitrogen) may suggest sewage or industrial contamination, and a limit for public water supply sources of 0.5 mg/L is recommended in "Water Quality Criteria, 1972" (National Academy of Sciences and National Academy of Engineering, 1973, p. 55). The 0.5 mg/L recommended limit was exceeded on occasion at AR1, AR2, NAT1, and NF3 (fig. 25). The only site where a large percentage of the data exceeds 0.1 mg/L is AR2, which is downstream from wastewater treatment and urban drain outfalls. The Environmental Protection Agency criterion of 0.02 mg/L ammonia (U.S. Environmental Protection Agency, 1976, p. 10) applies to the un-ionized form of ammonia which is not likely to occur at the pH values in the basin. The plots for Kjeldahl nitrogen, ammonia plus organic nitrogen (fig. 26), follow the same general pattern as the ammonia. No recommended levels have been suggested.

Phosphorus, like nitrogen, is essential for plant growth, but when present in excessive amounts, can accelerate the eutrophication process. Concentrations of total phosphorous which exceed 0.1 mg/L (as P) can cause nuisance aquatic growths and therefore should be avoided (U.S. Environmental Protection Agency, 1976, p. 186). The Environmental Protection Agency further suggests that concentrations should not exceed 0.05 mg/L in streams which enter lakes or reservoirs such as at sites NF3, SF3, and MF3. Levels of total phosphorus have exceeded 0.05 mg/L at all of the sites but only at site AR2 has a large percentage of the data approached the suggested limits (fig. 27).

Analysis of aquatic organisms for selected toxic metals and synthetic organic compounds has been made annually since 1976 at site AR2 (California State Water Resources Control Board, 1979a, 1979b, 1980a, 1981). There have been no instances where the tolerance levels specified by the U.S. Food and Drug Administration (for animal tissue consumed by humans) have been exceeded. However, maximum concentrations recommended by the National Academy of Sciences and National Academy of Engineering (1973) for protection of predator species were exceeded in the American River on August 9, 1977, for DDT (limit = 1.0 µg/g, value = 1.5 µg/g, California State Water Resources Control Board, 1979a, p. 23), on September 18, 1979, for chlordane (limit = 0.1 µg/g, value = 0.13 µg/g, California State Water Resources Control Board, 1980a, p. 13), and on July 8, 1980, for mercury (limit = 0.5 µg/g, value = 0.88 µg/g, California State Water Resources Control Board, 1981, p. 6). Accumulations in fish tissue have been calculated in some studies to be over 100,000 times that of the ambient concentrations in water for DDT and chlordane and over 10,000 times for mercury (U.S. Environmental Protection Agency, 1976, p. 98, 134, and 139).

EXPLANATION (FIGURES 18 - 27)
SCHEMATIC PLOTS (Tukey, 1977)



Far out values are more than 1.5 times the **semiquartile range** from the top or bottom of the rectangle

Outside values are between 1 and 1.5 times the **semiquartile range** from the top or bottom of the rectangle

Dashed vertical lines extend a distance equal to the **semiquartile range** away from the top or bottom of the rectangle or to the limit of the data, whichever is least

See table 8 for description of sampling sites.

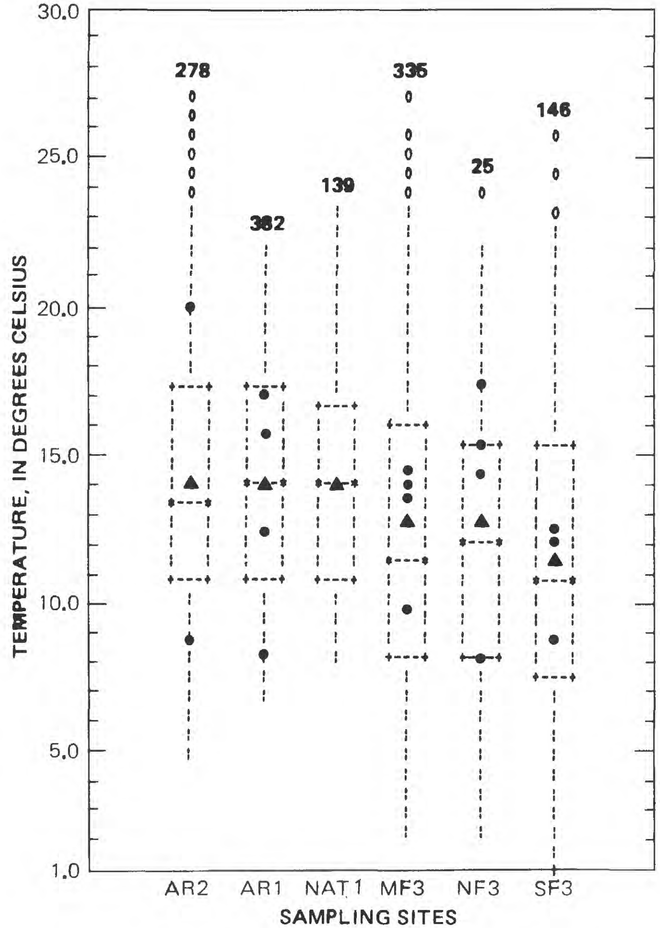


FIGURE 18. – Schematic plots showing the range of all values for temperature and the results of instan–taneous samples collected during 1979 at selected sites.

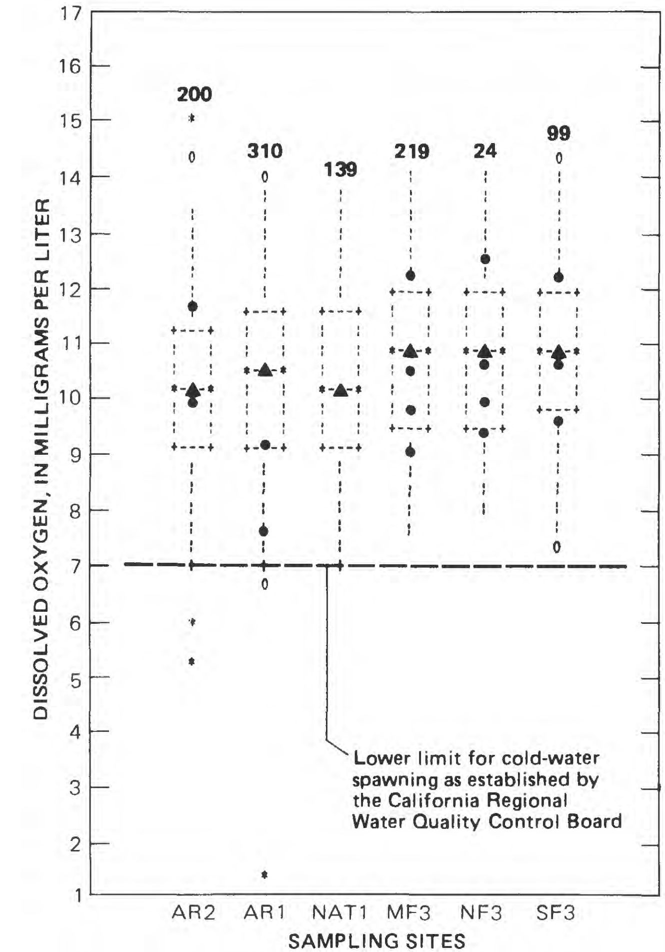


FIGURE 19. – Schematic plots showing the range of all values for dissolved oxygen and the results of instan–taneous samples collected during 1979 at selected sites.

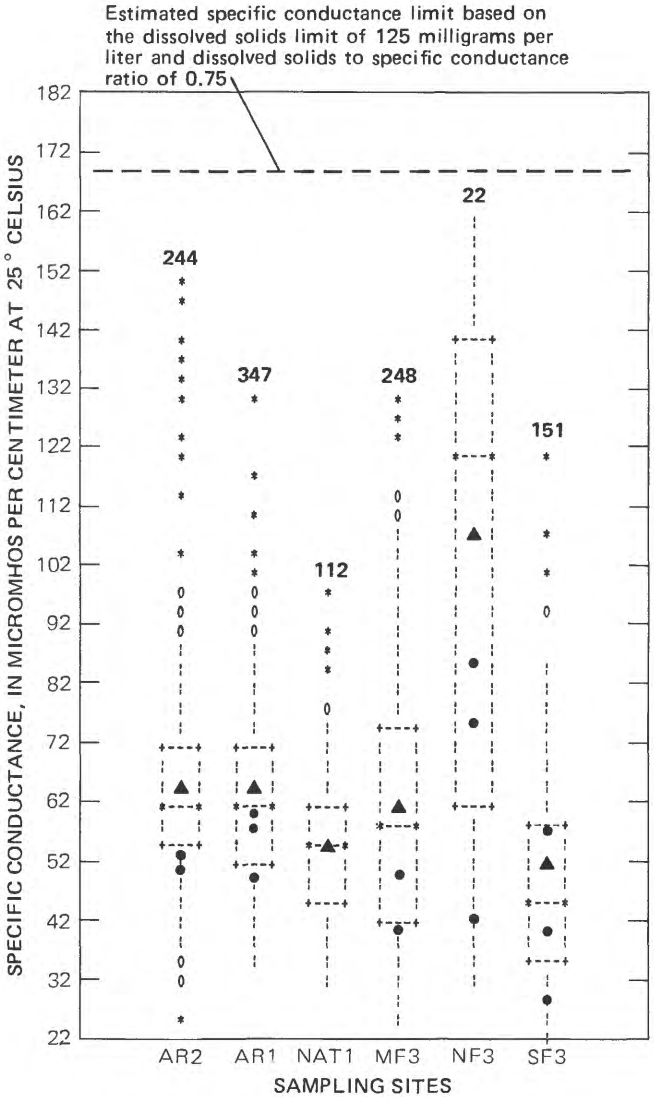


FIGURE 20. – Schematic plots showing the range of all values for specific conductance and the results of instantaneous samples collected during 1979 at selected sites.

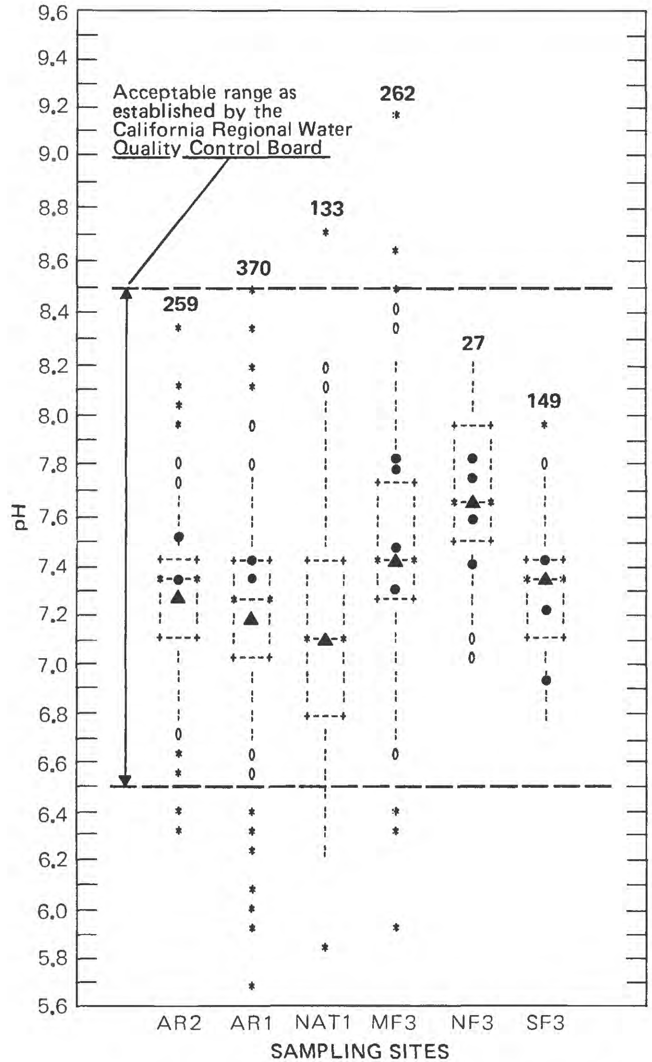


FIGURE 21. – Schematic plots showing the range of all values for pH and the results of instantaneous samples collected during 1979 at selected sites.

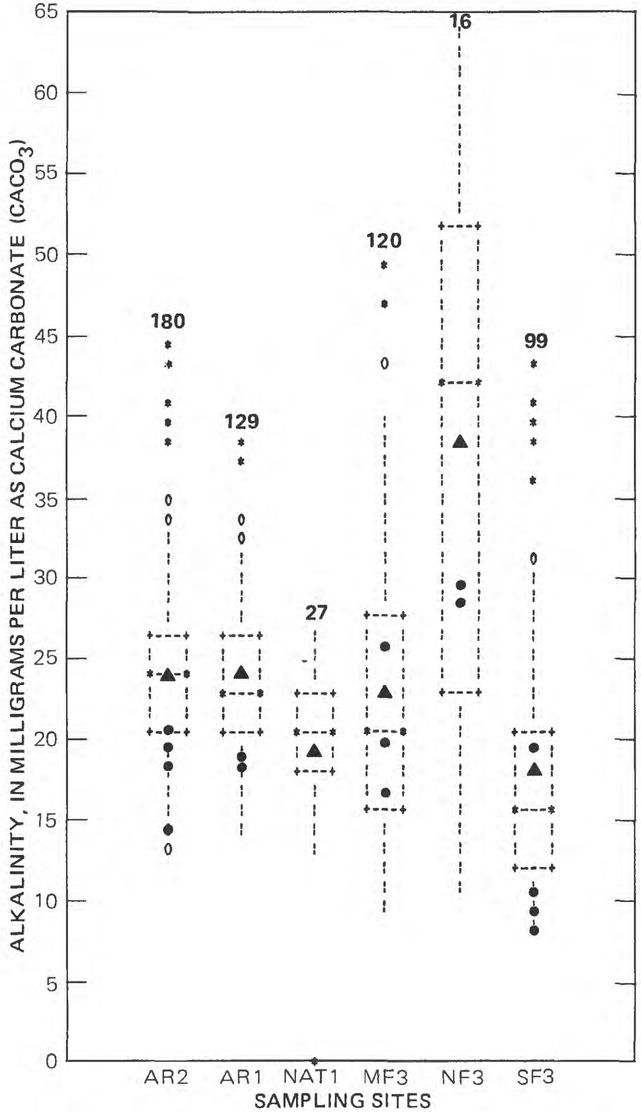


FIGURE 22. – Schematic plots showing the range of all values for alkalinity and the results of instantaneous samples collected during 1979 at selected sites.

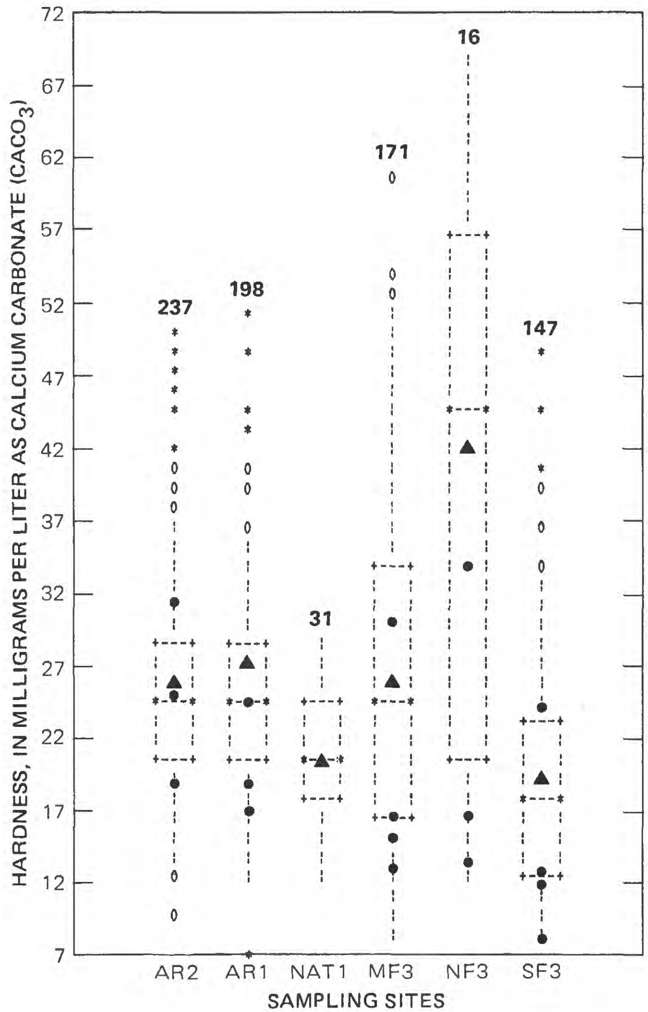


FIGURE 23. – Schematic plots showing the range of all values for hardness and the results of instantaneous samples collected during 1979 at selected sites.

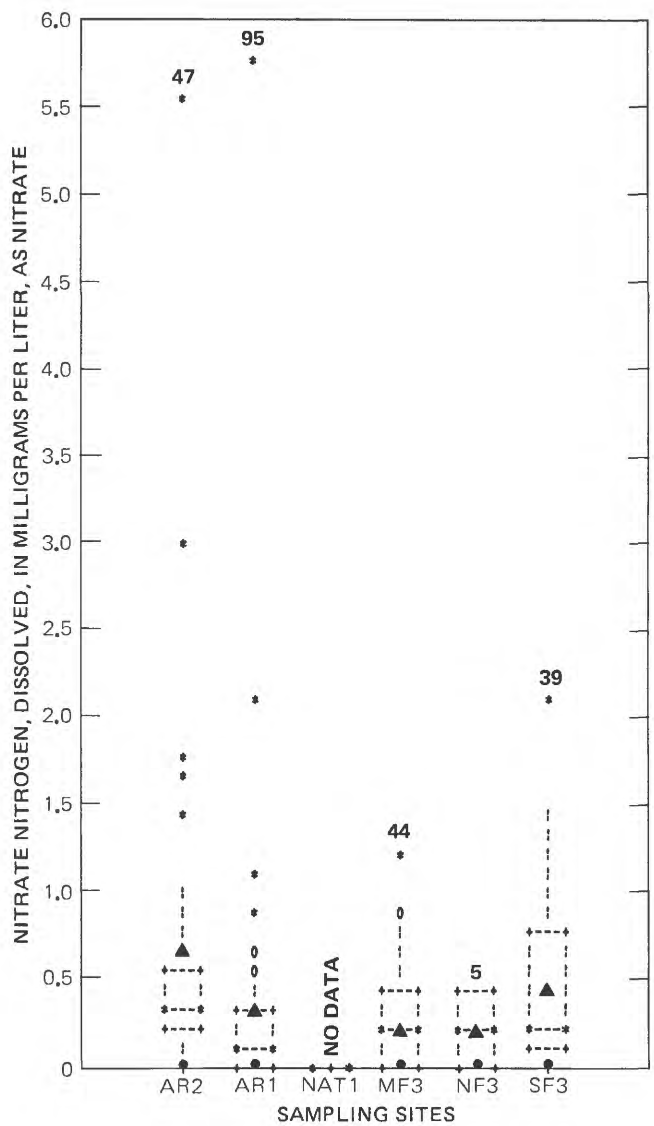


FIGURE 24. – Schematic plots showing the range of all values for dissolved nitrate nitrogen and the results of instantaneous samples collected during 1979 at selected sites.

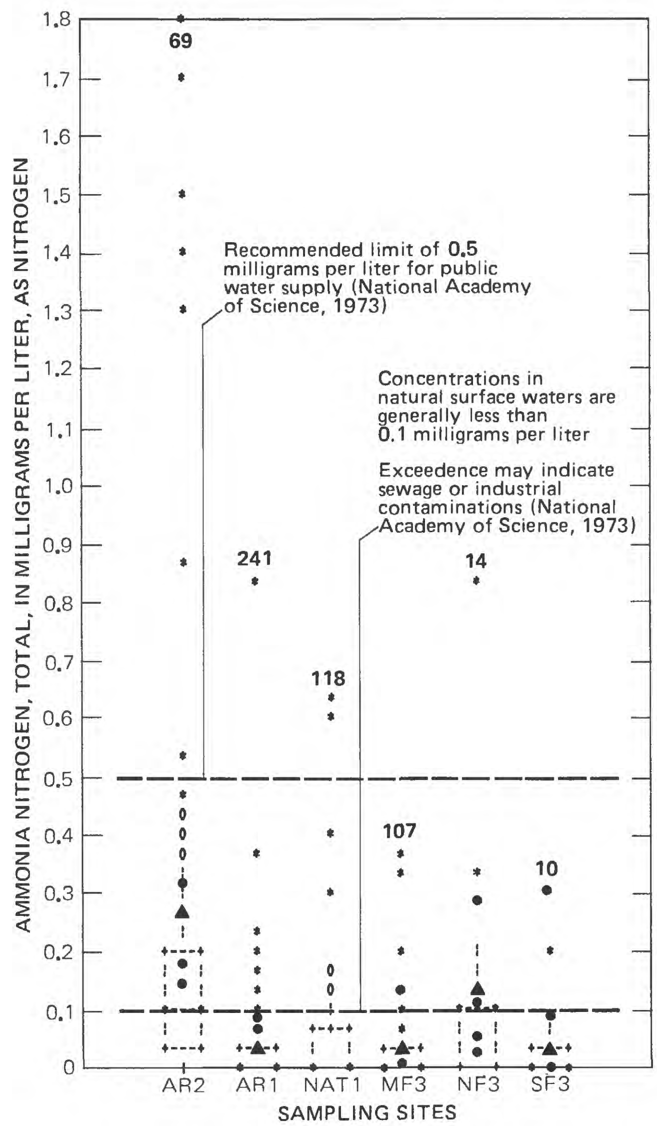


FIGURE 25. – Schematic plots showing the range of all values for ammonia nitrogen and the results of instantaneous samples collected during 1979 at selected sites.

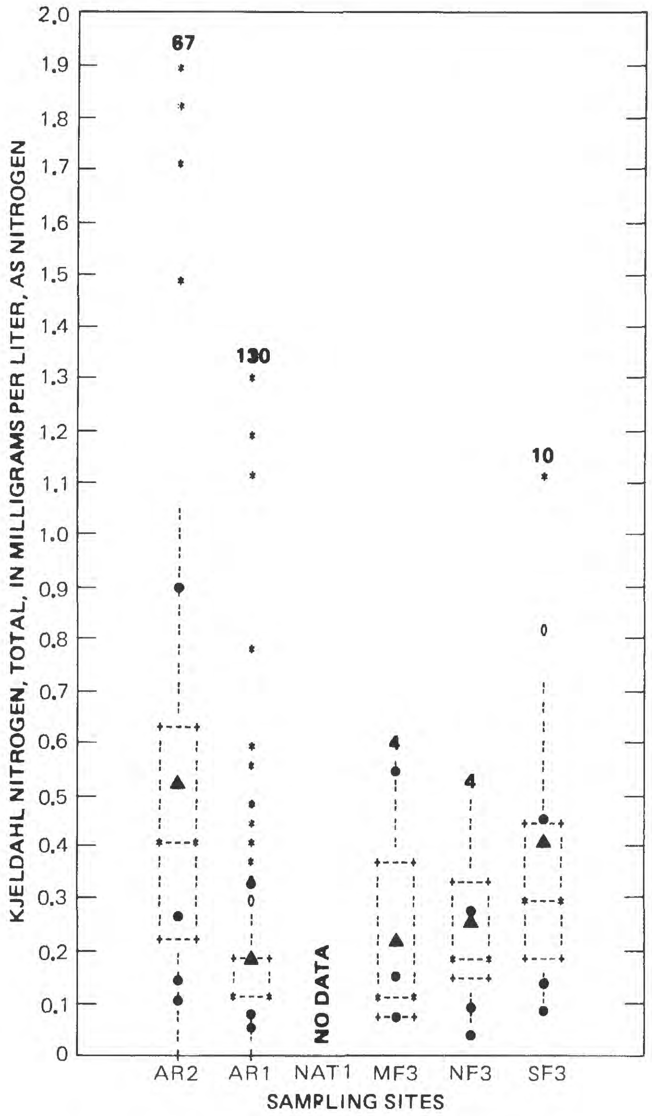


FIGURE 26. – Schematic plots showing the range of all values for kjeldahl nitrogen and the results of instantaneous samples collected during 1979 at selected sites.

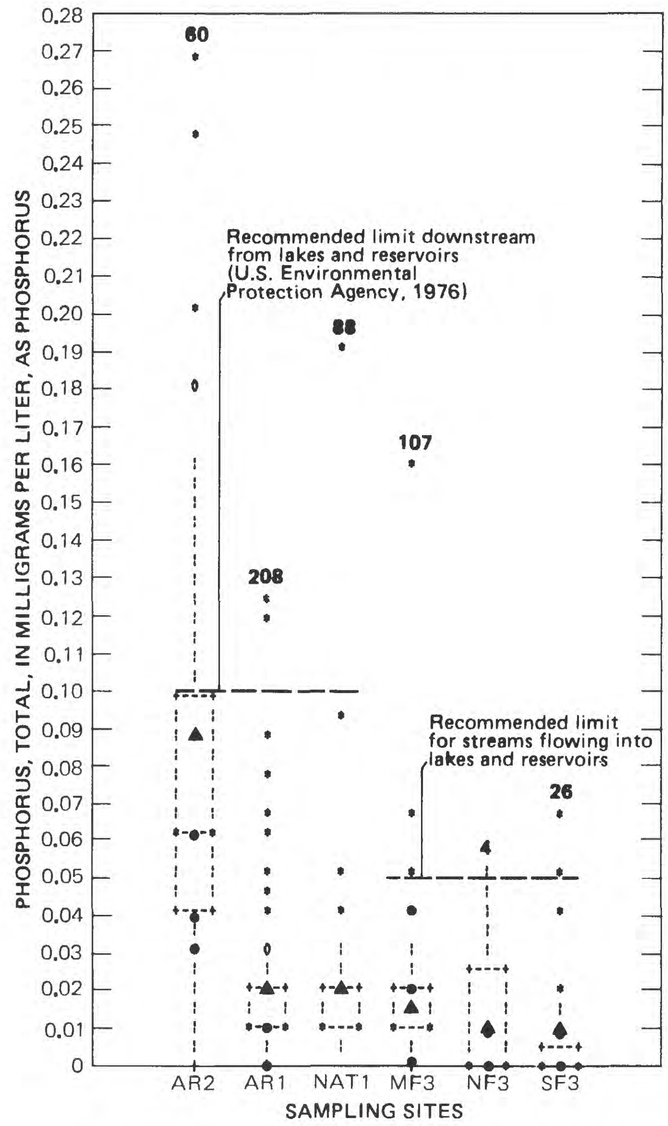


FIGURE 27. – Schematic plots showing the range of all values for total phosphorus and the results of instantaneous samples collected during 1979 at selected sites.

Time Trends

Several methods are commonly used in hydrologic studies to examine time trends in data. The most common are plots of time versus concentration, time versus discharge, and concentration versus flow. Each of these techniques is statistically defensible, but each also has some inherent problems. The biggest drawback that is generally common to each method is the large amount of scatter which occurs in the plotted data. This large scatter, which can often obscure valuable information, is generally caused by such things as year to year variations in climatic conditions, streamflow, soil saturation, or other natural conditions.

Streams which are heavily regulated, such as in the American River basin, are also difficult to analyze using these procedures. For instance, correlation analysis showed that only in the North Fork, which is still unregulated, did good correlation between streamflow and individual water-quality constituents exist ($R>|0.8|$).

A technique that would be statistically defensible and would eliminate most variations due to natural and manmade conditions is desirable. One such method, which is used in this study, compares identical constituents (paired data) from different but closely related sampling sites where the data were collected nearly simultaneously and over a wide range of conditions (Ponce, 1980b, p. 16). Related sampling sites are ones within a relatively close proximity to each other that have similar characteristics.

Developing relations between two constituents using this method neutralizes many of the variations already discussed because of the simultaneity of the samples. Variation caused by change in streamflow between test periods is not removed. The data should plot linearly and be statistically correlated. Regression techniques are used to develop a relation between the sites for the particular constituent. After a relation is defined for a selected base period, relations for other time periods can be checked for deviations at a given probability level using analysis of covariance (Riggs, 1968, p. 33; Ponce, 1980a, p. 124).

For this analysis, site AR2 is paired with AR1 and SF3 is paired with MF3 for specific conductance, hardness, alkalinity, pH, and dissolved oxygen. The selection of time periods for this analysis was dependent primarily on the quantity and quality of the stored data for the period of record. Two-year time periods were selected (except for 1961-63 and 1965-67 for SF3/MF3 and 1978-80 for AR1/AR2) to allow for an adequate number of data pairs during a period and an adequate number of periods to test for trends. Data from water years 1969 to 1977 were not used for AR1/AR2 because of insufficient paired data. The selected periods also represent a wide range in annual mean discharge at each site, which enhances the paired-data analysis by providing data collected under differing hydrologic conditions. The annual mean values of discharge for each water year and the time period groupings used at each site are shown in table 9.

TABLE 9. - Annual mean discharges for each water year, selected sites, and time period groupings used in the paired-data analysis

Time period groupings, in water years	Annual mean discharge (cubic feet per second) Sites AR1/AR2	Site MF3	Site SF3
1959		631*	530*
1960		923*	609*
1961	1,654*	581	445
1962	2,802*	1,088	905
1963	4,557	1,883	1,170
1964	2,391	787	1,003
1965	5,802	1,879	2,271
1966	1,906	398	978
1967	5,243	1,833	1,906
1968	2,768		
1978	3,242		
1979	2,972		
1980	5,406		

*Base Period

Paired data from related sites were first compared by correlation analysis. Bivariate correlation coefficients define the degree of association between two variables. Correlation coefficients are, by definition, mathematical associations and do not by themselves imply a cause-and-effect relation nor even that the association is the result of a common cause (Riggs, 1968, p. 6). However, the mathematical relation can be further examined for a possible hydrological cause-and-effect relation.

Paired data were selected for regression analysis if the correlation coefficient was greater than |0.9| during at least one of the time periods tested. The results are shown in table 10. The letter "A" in the table for the paired sites indicates time periods when poor correlations were shown or insufficient data were available. This is probably indicative of problems in the stored data. Correlation analysis between sites AR1 and AR2 showed R>|0.9| for specific conductance, hardness, alkalinity, pH, and dissolved oxygen. Correlation analysis between sites MF3 and SF3 showed poor correlations for all constituents except dissolved oxygen, which had R>|0.9| for each time period tested. Insufficient data since 1967 did not allow for analysis beyond that date. The limited amount of data over an extended period of time at NF3 does not justify using this site in the analysis.

Table 10 also summarizes the results of each analysis-of-covariance test where the regression lines for each period of time were tested for significance with the base period at the 95 percent confidence level. If a significant difference did occur, the lines were tested for equal slopes. Only pH and dissolved oxygen show no significant deviation at a 95 percent confidence level when subsequent time periods are compared with the base period of 1961-62. This indicates the pH and dissolved oxygen relations could be represented by a single regression line for all periods combined as shown in the plots of the regression lines (figs. 28 and 29). To retain clarity, only the 95 percent confidence envelope for values predicted by the relation during the base period, not the actual data points, are shown. While the relations for pH and dissolved oxygen, which are largely a measure of a stream's biological viability, have remained the same, the relations for hardness, specific conductance, and alkalinity, which to a large degree reflect the amount of dissolved constituents in a stream, have changed significantly between the base period and the most recent period of 1978-80 (figs. 30, 31, and 32). The analysis-of-covariance test indicates that the relations for hardness and alkalinity could be represented by a single regression line for the period 1961-68. Specific conductance (fig. 31) is the only relation that shows a significant deviation from the base period during each subsequent time period. This deviation indicates a trend of increasing dissolved solids at site AR2 relative to AR1. Increasing contributions from urban runoff and treated sewage during this period of increasing urbanization (1960-80) could well account for this trend. The constituents showing trends are all towards increasing concentrations at site AR2 relative to site AR1. This trend direction is opposite of what would result if differing flow conditions between base period and test periods were the cause of the trends.

TABLE 10. - Correlation coefficients for paired data at sites AR1/AR2 (American River Below Nimbus Dam/American River at Sacramento) and SF3/MF3 (South Fork American River/Middle Fork American River) during the specified time periods

[Letter beneath correlation coefficient indicates significance of regression when compared with the base period. A, insufficient data or poor correlation. B, significant difference at a 95-percent confidence level; regression lines not parallel. C, significant difference at a 95-percent confidence level; regression lines parallel. D, no significant difference at a 95-percent confidence level]

	Data pair AR1/AR2					Data pair SF3/MF3			
Water years:	1961-62[1]	63-64	65-66	67-68	78-80	1959-60[1]	61-62	63-64	65-67
	Correlation coefficient/number of paired data points								
Specific conductance (micromhos per centimeter at 25°C)	0.72/14 D	0.02/24 A	0.91/16 B	0.97/9 B	0.86/58 B	A	A	A	A
Hardness (milligrams per liter as $CaCO_3$)	.78/14 D	.06/24 A	.91/16 D	.96/8 D	.96/46 B	A	A	A	A
pH	.82/15 D	.86/23 D	.54/18 A	.97/9 D	.75/55 D	A	A	A	A
Dissolved oxygen (milligrams per liter)	.68/15 D	.91/24 D	.86/18 D	.95/9 D	.65/57 D	0.97/21 D	0.97/23 D	0.92/17 B	0.94/16 B
Alkalinity (milligrams per liter as $CaCO_3$)	.85/14 D	.05/16 A	.87/17 D	.96/8 D	.94/46 C	A	A	A	A

[1]Base period.

At site AR2 there is also a strong correlation (R = 0.89) between specific conductance and ammonia (total as N). The relation between these variables for the time period 1976-80 is shown by the regression line in figure 33. Because ammonia appears to increase with increasing specific conductance, the trend in increasing specific conductance at site AR2 suggests that other nutrient levels are also increasing. Because correlations between ammonia at AR2 with ammonia at AR1 were low (R<0.2), a paired-data analysis could not be done. Graphs of instantaneous values for specific conductance and ammonia at sites AR1 and AR2 near the end of the 1977 drought are shown in figure 34. These graphs show that high ammonia values are associated with high specific conductance values at AR2.

Effluent from the two upstream sewage treatment plants on the lower American River is probably sufficient to provide the increases in specific conductance and ammonia at AR2. If this is true, the trend towards increasing dissolved solids load and nutrient levels should reverse when the new Regional Sewage Treatment Plant at Freeport is put into operation in late 1982. The stable relations shown in figures 28 and 29 for pH and dissolved oxygen seem to indicate that the noted increases in the dissolved load and nutrient levels have not at the present time exceeded the overall capacity of the stream to assimilate the increases. However, periodically higher than normal pH values at site AR2 and large accumulations of aquatic growth observed at several locations in the lower American indicate some adverse effects on the stream (fig. 35).

Figure 36 shows the regression relations for dissolved oxygen between sites MF3 and SF3 during different time periods. The time periods used (1959-67) coincide with the beginning of increased storage and regulation in both the Middle Fork (after 1961) and the South Fork (after 1963) basins.

Results of the analysis of covariance show a significant difference between the relations during the base period (1959-60) and the last period tested (1965-67). The test also indicates that the lines are not parallel (table 10). There appears to be a larger shift in the relations at the lower and medium values.

The regression lines for 1959-60 and 1961-62, which are preregulation and storage, are virtually the same and represent a nearly one-to-one relation. This relation is quite reasonable for two natural flowing streams in close proximity to each other with similar basin characteristics (table 1). The relation had changed enough by 1965-67 that a concentration of 10 mg/L measured at MF3 would correspond to a concentration of about 10.7 mg/L at SF3. Because the regression lines converge with increasing dissolved oxygen, the difference in concentrations increases for values less than 10 mg/L and decreases for values greater than 10 mg/L. The relative shift in the dissolved oxygen relation may be related to the onset of intensive streamflow regulation in the basin. Where the natural streamflow hydrographs for these two sites were very similar prior to regulation, increased development of the water resource has created some subtle dissimilarities (figs. 13 and 15). Augmented flow during normally low flow periods would tend to keep water temperatures lower and dissolved oxygen values higher, accounting for the noted shift in the relation. Differences in streamflow regulation in the two basins after 1962 probably accounts for the slopes of the regression lines being different. These same differences also provide a likely explanation for the poor correlations seen between other water-quality characteristics at these sites.

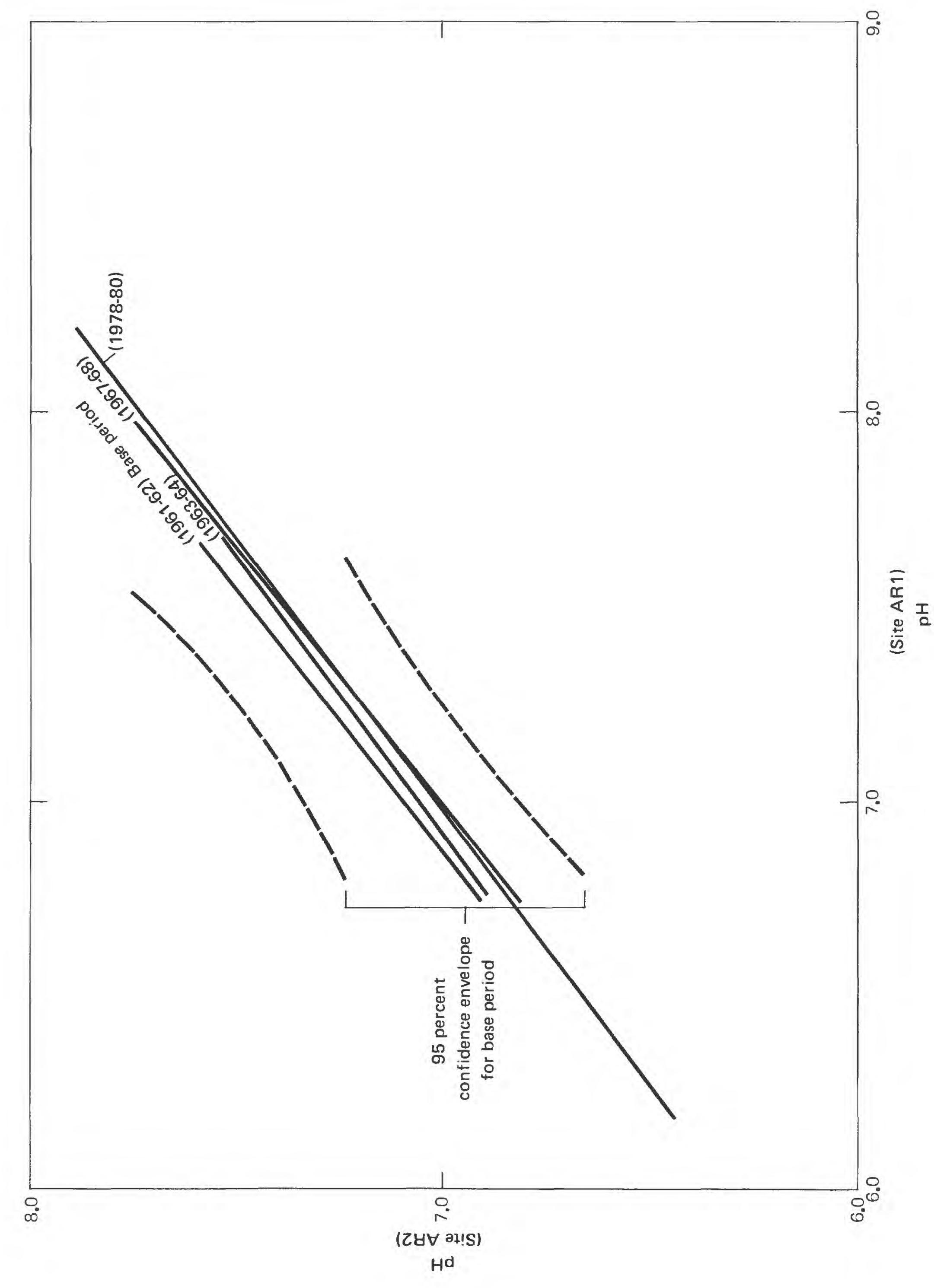


FIGURE 28. — Regression relations for pH between American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2) for selected time periods. Line length represents the range of the paired data.

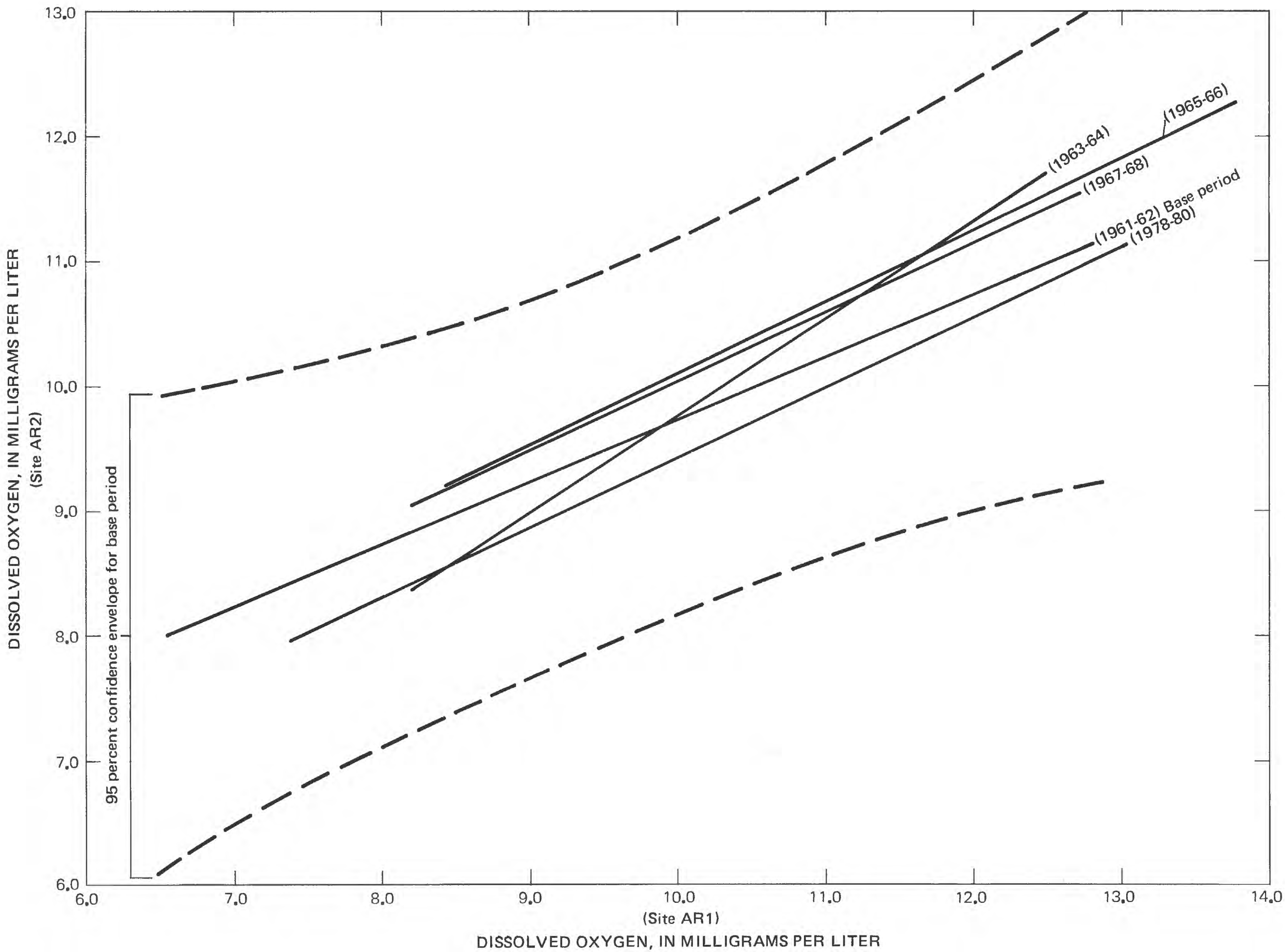


FIGURE 29. – Regression relations for dissolved oxygen between American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2) for selected time periods. Line length represents the range of the paired data.

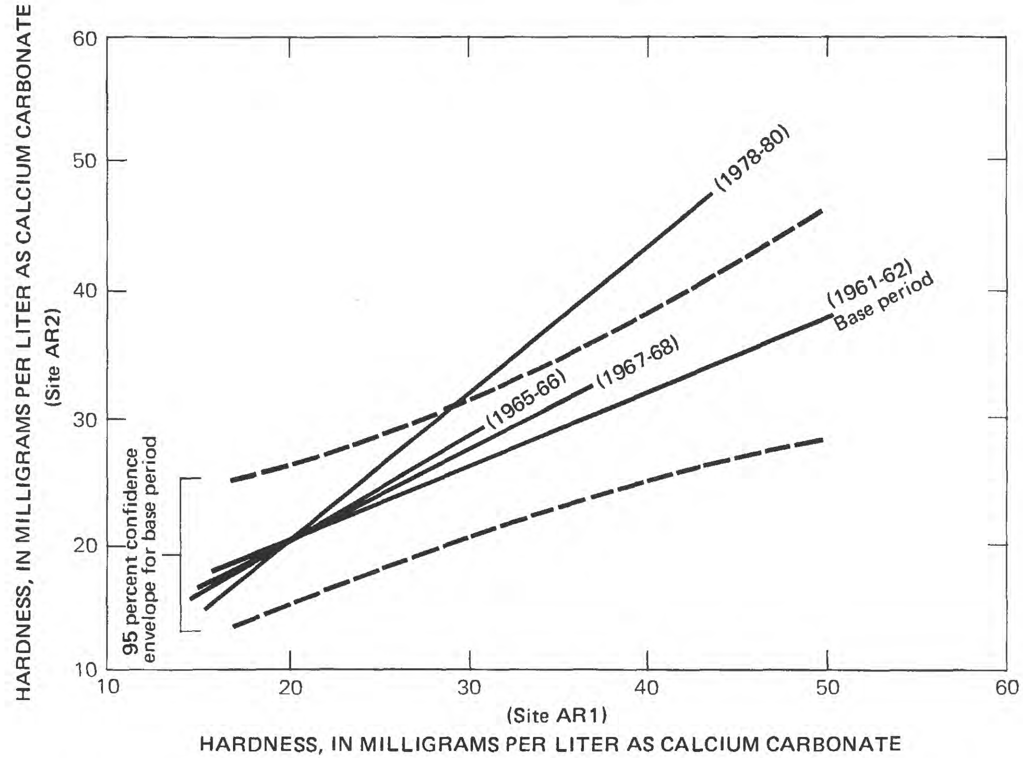


FIGURE 30. – Regression relations for hardness between American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2) for selected time periods. Line length represents the range of the paired data.

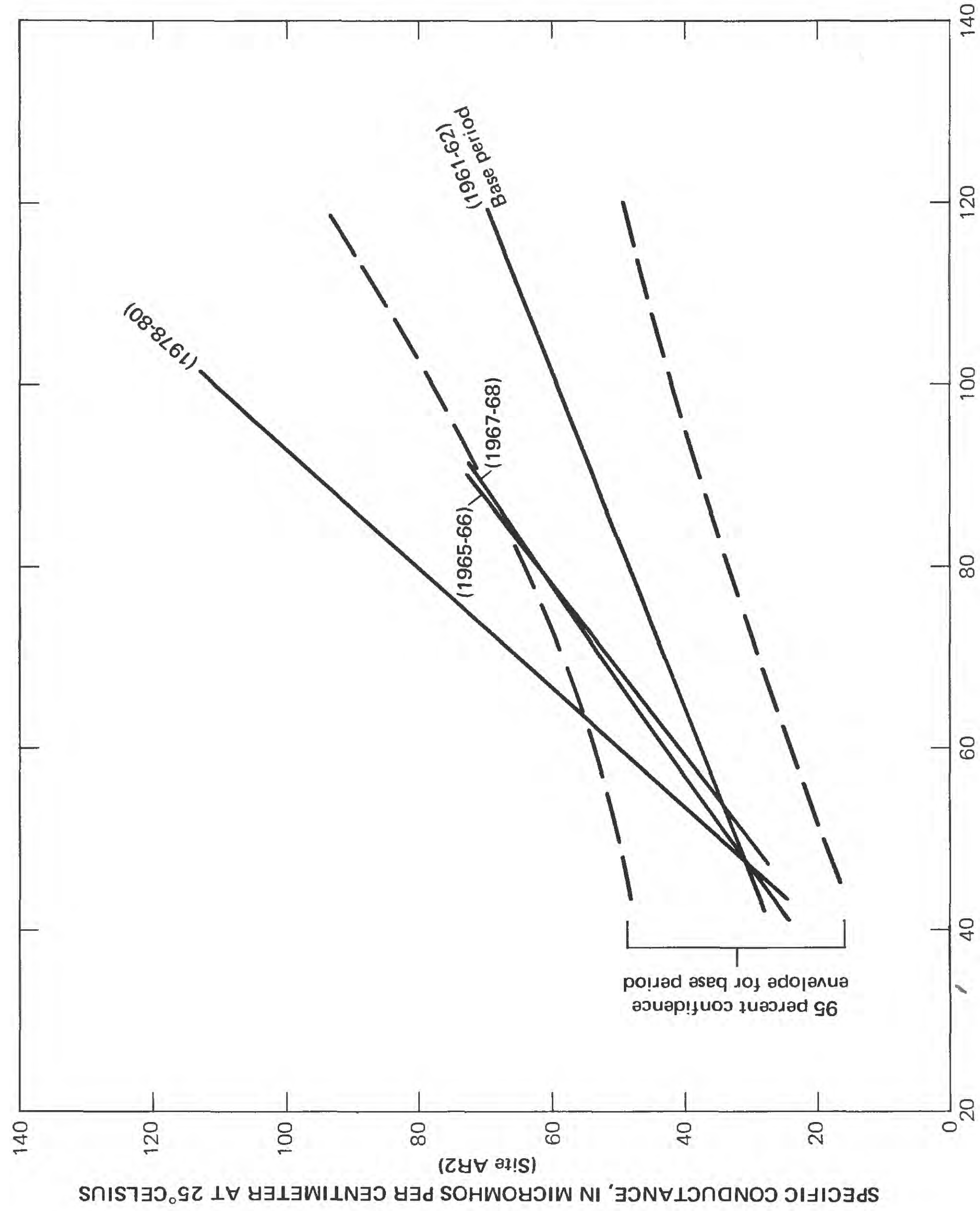


FIGURE 31. – Regression relations for specific conductance between American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2) for selected time periods. Line length represents the range of the paired data.

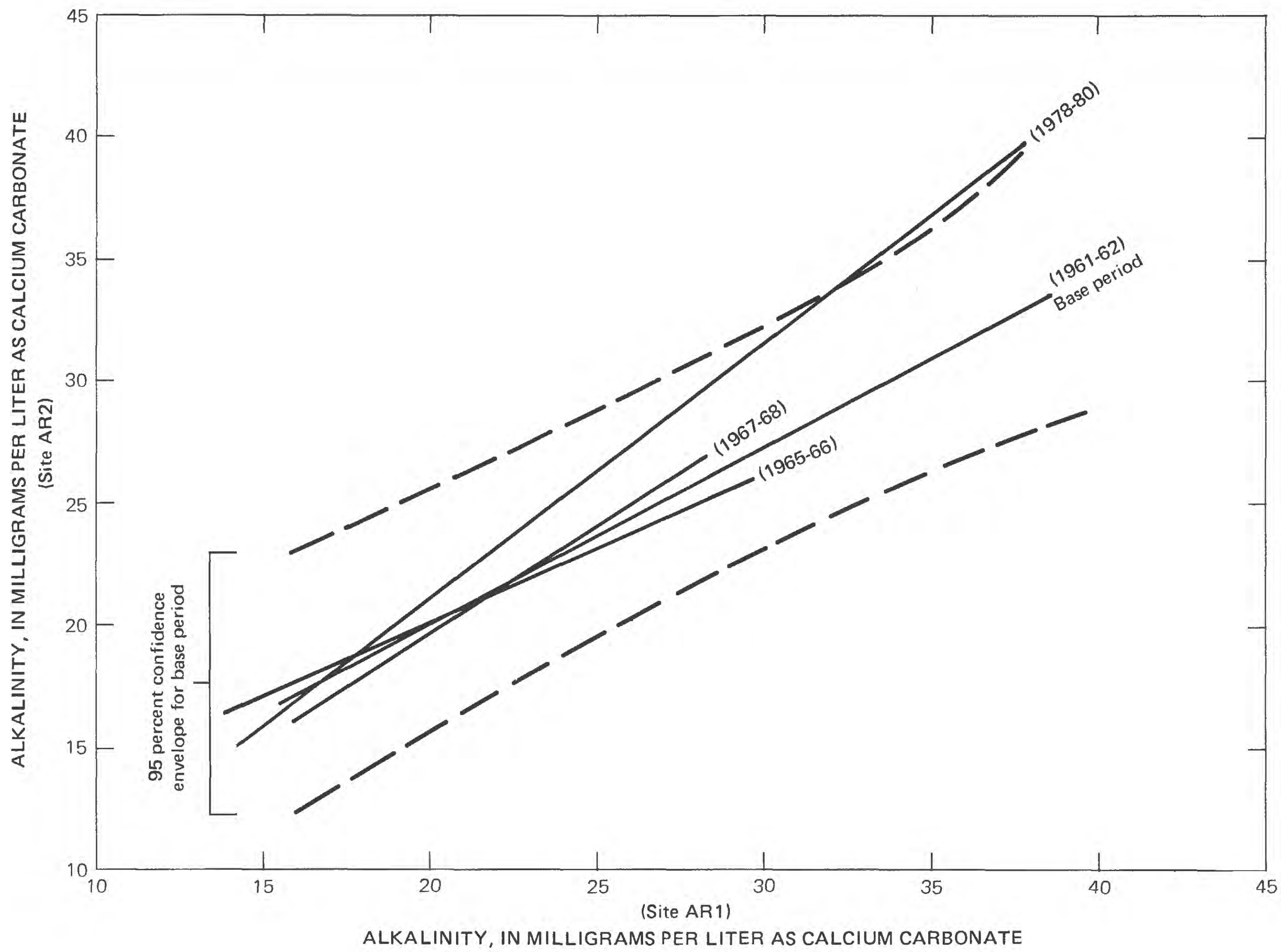


FIGURE 32. — Regression relations for alkalinity between American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2) for selected time periods. Line length represents the range of the paired data.

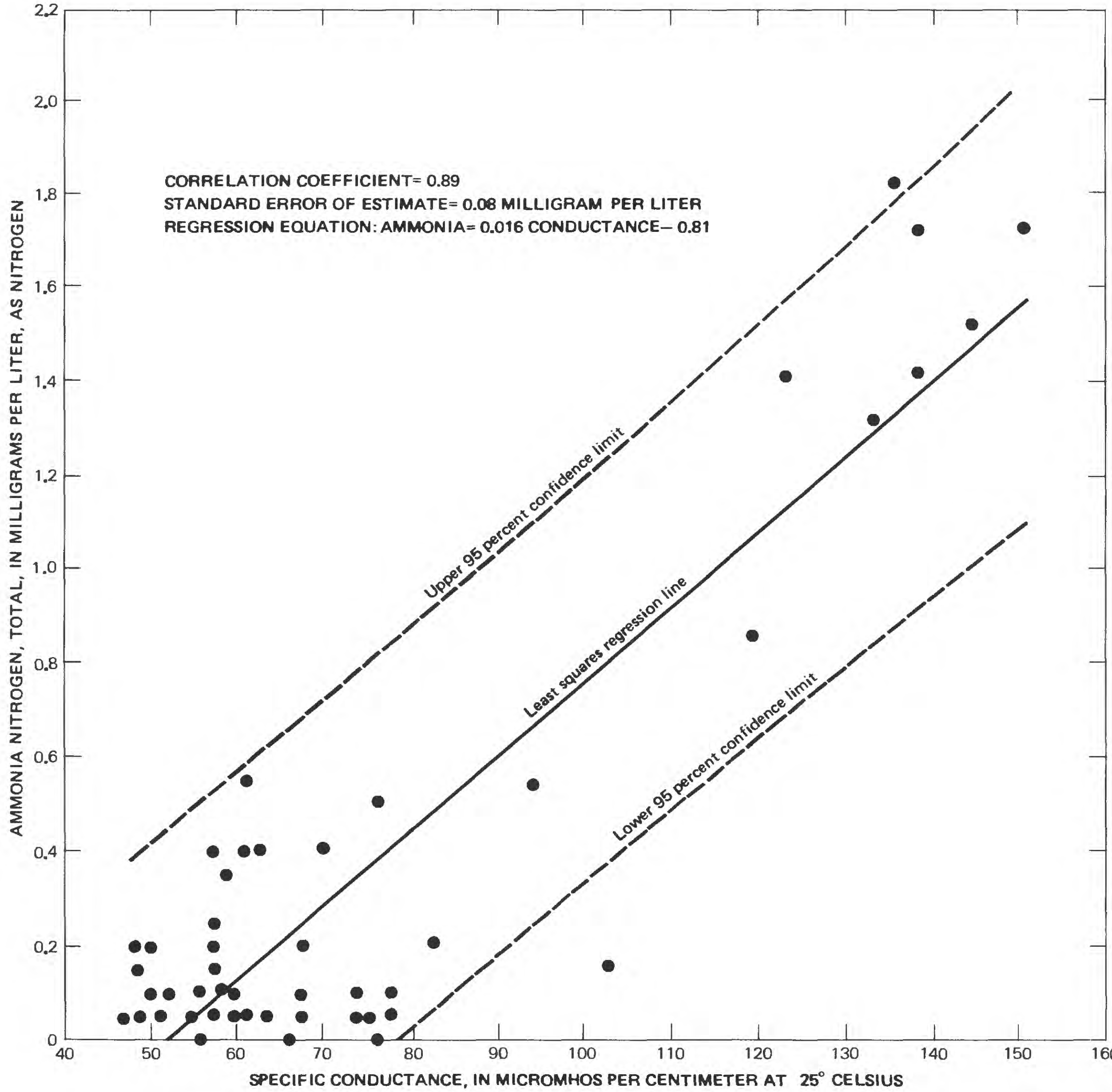


FIGURE 33. – Regression relations between specific conductance and ammonia for American River at Sacramento (site AR2), 1976–80.

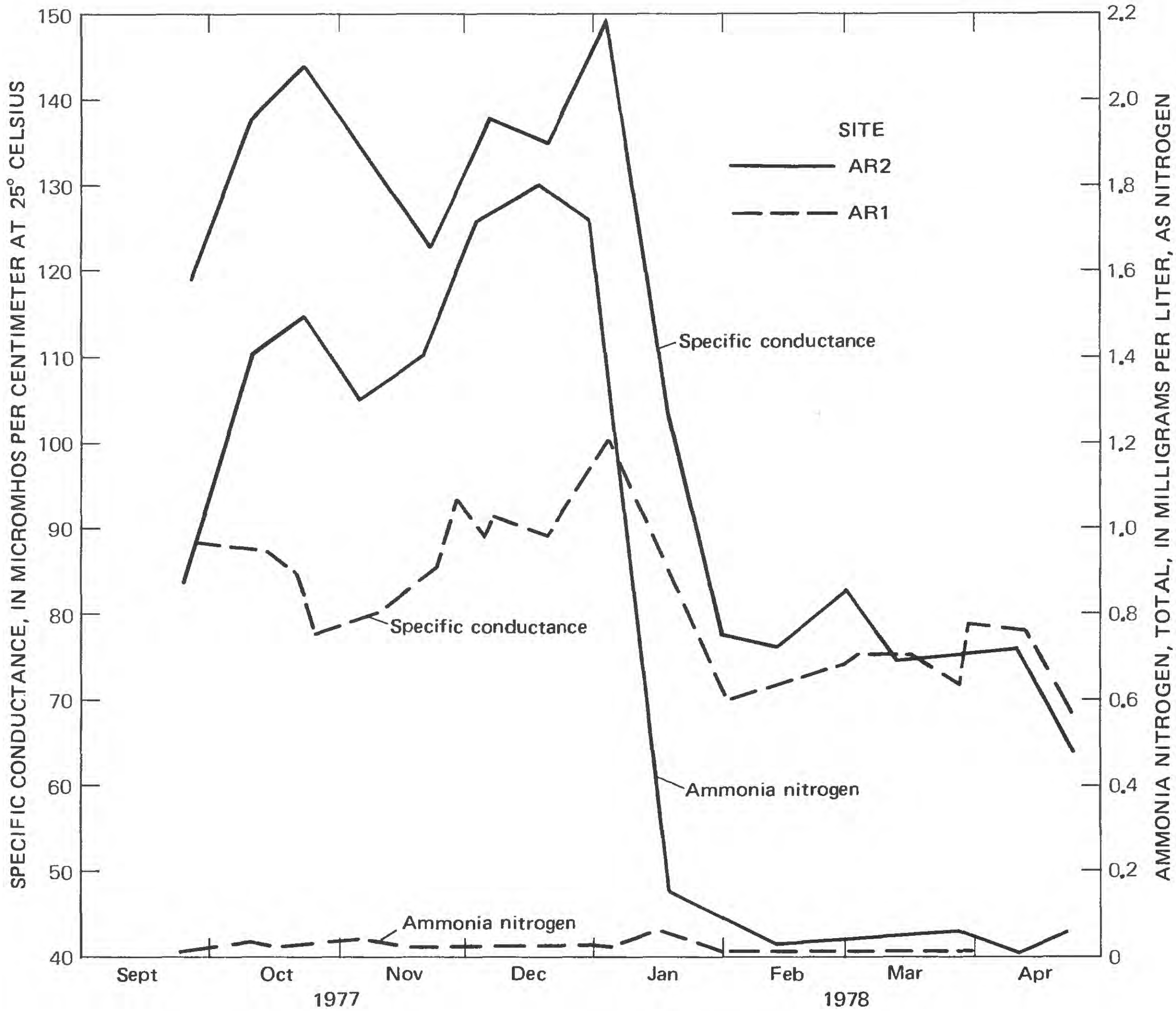


FIGURE 34. – Instantaneous ammonia concentrations and specific conductance at American River below Nimbus Dam (site AR1) and American River at Sacramento (site AR2), September 1977 to April 1978.

FIGURE 35. — Large accumulation of aquatic plant growth on the lower American River near river mile 5.4 . (Courtesy of U.S. Bureau of Reclamation)

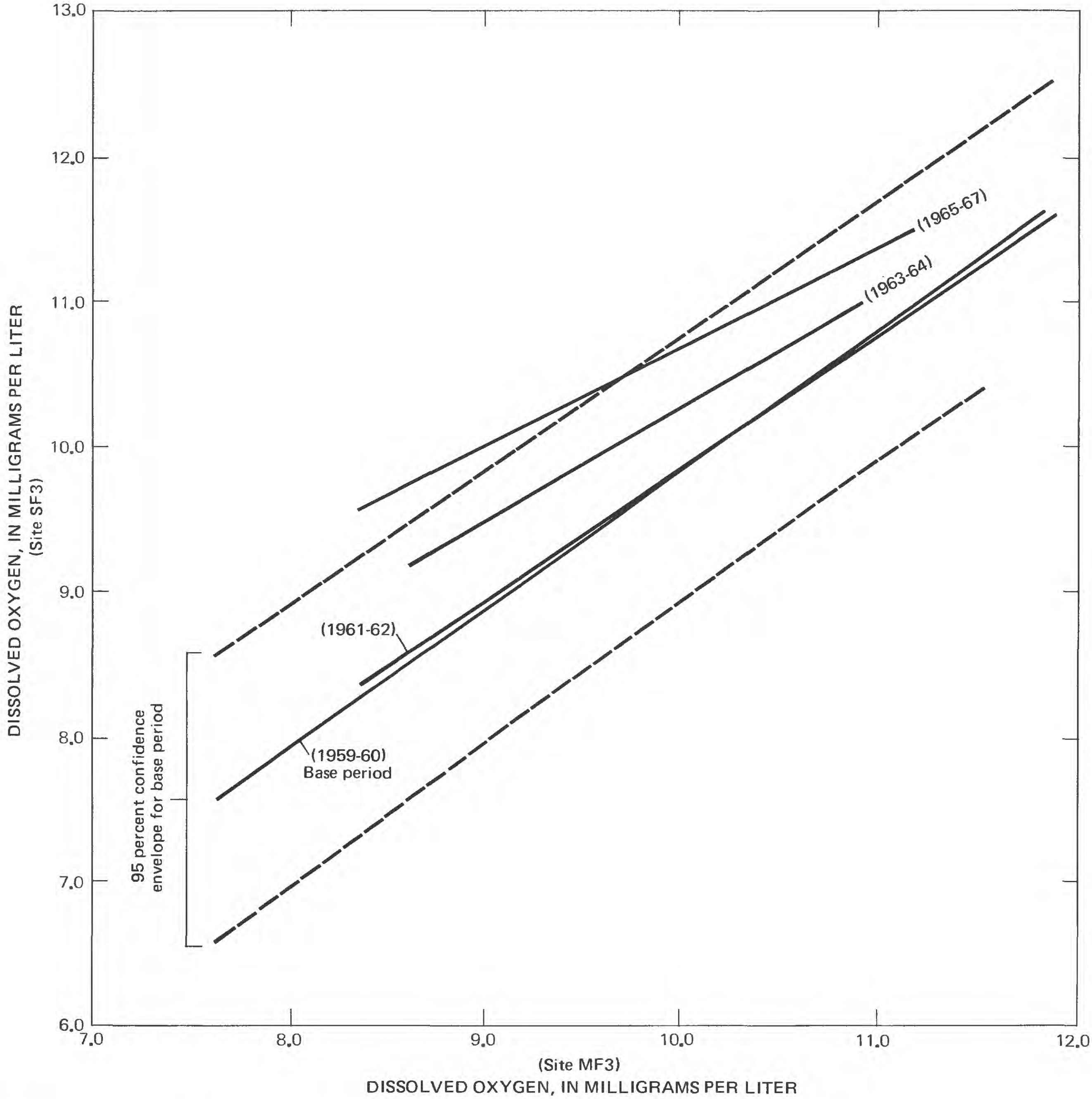


FIGURE 36. — Regression relations for dissolved oxygen between Middle Fork American River (site MF 3) and South Fork American River (site SF3) for selected time periods. Line length represents the range of the paired data.

The American River is a stream of overall good quality suitable for all beneficial uses as specified by the State of California, even though its natural condition has been altered by man's activities in the basin.

Water-quality degradation in the American River occurs primarily in the lower reach downstream from Folsom Dam and results from the effects of increased urbanization and recreation in this area (fig. 37). The impact on the stream of increased urban runoff and treated sewage has been pointed out in earlier studies (Hom, 1968; Federal Water Pollution Control Administration, 1969; U.S. Bureau of Reclamation, 1971) and is illustrated again in this study by the trends indicating increased dissolved solids and nutrient loads over the past 20 years. Further evidence of this impact are the violations of the water-quality objectives established for the American River (table 11). All but four of the sites in table 11 are on the lower American River. Violations have not been extensive considering the long period of time in which data have been collected, but they illustrate the potential for more severe problems. Large accumulations of aquatic plants and periphyton are visible evidence of nutrient concentration increases in this reach (Hom, 1968, Fraga and others, 1979).

FIGURE 37. – The lower American River is extremely popular with recreationists because of its location in the heart of the Sacramento urban area. With flows regulated by Folsom Dam, the river can be used year–round for activities such as swimming, skin diving, rafting, and fishing. (Courtesy of U.S. Bureau of Reclamation)

TABLE 11. - Violations of water-quality objectives

Location No. (pl. 1)	Station name	Station No.	Constit- uent	Number of violations	Total observations of constituent	Percentage in violation
27	North Fork American River upstream of Middle Fork	052557	pH	5	84	6
56	Middle Fork American River upstream of North Fork	052558	pH	6	98	6
84	American River South Fork near Kyburz	A7455000	Arsenic	2	18	11
			Selenium	1	9	11
85	South Fork American River at Kyburz	11439500	pH	1		
133	American River at Folsom Bridge	052552	pH	11	98	11
135	American River at Nimbus Dam	11446400	pH	1	113	<1
136	Lower American River below Nimbus Dam	WB05A0718000	DO	1	191	<1
137	American River below Nimbus Dam	A0718000	DO	2	192	1
138	American River at Nimbus Dam Fish Screen	052551	pH	13	112	12
139	American River at Fair Oaks	11446500	pH	1	43	2
148	American River Cordova Sewage Treatment Plant R2	WSB050079871R1	pH	1	125	<1
			DO	1	127	<1
152	American River Northeast Sewage Treatment Plant R1	WB050079871R1	pH	8	129	6
			DO	1	126	<1
156	American River at Sacramento	11447000	pH	2		
157	American River at Sacramento	A0714000	DO	2	217	<1
163	American River Arden Sewage Treatment Plant R2	WB050079847R2	DO	1	125	<1
164	American River Arden Sewage Treatment Plant R1	WB050079847R1	pH	27	109	25
			DO	5	111	5
168	American River at 16th Street Bridge	052549	pH	10		
			DO	1		

Data collected during the 1976-77 drought period indicate that during extremely low flows in this reach pollution loads are damaging to the quality of the water. The potential for severe water-quality problems during low water periods in the lower American River is reduced because of augmented flow from Folsom Lake. Low-flow augmentation tends to lower water temperature and dilute entering effluent waters.

The scheduled diversion of all sewage effluent from the American River to the treatment facilities on the Sacramento River at Freeport should initiate a return to earlier relations for specific conductance, hardness, and ammonia as discussed in the previous section and result in lower constituent concentrations in the river. The amount of change, however, depends on the impact from urban runoff which will remain a factor.

Streamflow modification caused by extensive storage and regulation on the Middle and South Forks has affected the natural dissolved-oxygen characteristics of the water, as illustrated by the shift in the dissolved-oxygen relation between sites SF3 and MF3. However, the lack of recent data makes it difficult to thoroughly assess this change.

FIGURE 38. – Rafting has become so popular on the South Fork American River that the number of rafts allowed on weekends is regulated to control overcrowding. (Courtesy of U.S. Bureau of Reclamation)

Water-quality data from stations in the upper basin above Folsom Lake are generally not adequate for defining water-quality trends. However, the small number of water-quality violations in table 11 indicates that observed problems in this part of the basin are minimal.

Recreational overuse, improper land use, or poorly managed mining operations are potential sources of future water-quality problems in the upper American River basin. Water-related recreation is increasing rapidly in the upper part of the basin, particularly on the South Fork where access to most of the river is good (fig. 38). Recreational homes have been built on the upper South Fork in close proximity to the stream (fig. 39), thereby increasing the risk of bacterial or viral contamination from wastewater. Heavy growths of aquatic plants stimulated by increased nutrient concentrations, warmer water temperatures, and increased exposure to sunlight could also occur. The potential for bacterial contamination, nutrient increases, or increased sedimentation due to soil disruption, depends in part on the degree of development that occurs and on the planning of that development.

FIGURE 39. – South Fork American River near Coloma. Note the close proximity of the houses to the river. (Courtesy of U.S. Bureau of Reclamation)

The Middle Fork and North Fork are more inaccessible and should receive less pressure from recreational development than the South Fork.

Commercial logging activities, which are common in the upper basin, can also create water-quality problems. Removal of the natural streamside vegetation canopy can result in higher water temperatures due to increased solar radiation reaching the stream. Commercial fertilizers applied to new plantings could enter the stream through rainfall runoff and together with elevated water temperatures stimulate excessive aquatic plant growth. Soil disruption on steep slopes can result in increased turbidity and sedimentation, effectively altering the natural stream bottom habitat and increasing the rate at which sediment trapping occurs in downstream reservoirs (Harris, 1977; Janda, 1977).

Mining operations have a history of assorted water-quality problems in the upper basin (fig. 40). A recent incident of increased sedimentation from the Pacific Slab Mine on the North Fork of the Middle Fork resulted in a significant reduction in the number of aquatic organisms downstream (Rectenwald, 1979). Increased sedimentation is a major concern, but trace metal contamination from mine spoils is also a possibility.

FIGURE 40. – Slate mine in the South Fork American River drainage. Note the close proximity of mined area to the river. (Courtesy of U.S. Bureau of Reclamation)

MONITORING NEEDS

The ongoing monitoring programs at the sites operated by the California Department of Water Resources in conjunction with the California State Water Resources Control Board and the Bureau of Reclamation on the lower American River are adequate for identifying violations of water-quality objectives, but not for defining the water-quality characteristics during differing hydrologic conditions. Because regulation by Folsom Dam results in long periods of nearly constant flows downstream, it is possible to sample monthly during the year without seeing much change in streamflow or water quality. A sampling schedule designed to cover specific ranges of streamflow rather than a particular time each month would provide more meaningful information for differing hydrologic conditions. Low-flow investigations, which would measure diel variations of dissolved oxygen, pH, specific conductance, temperature, and major plant nutrients would be desirable to characterize the stream under conditions of high water temperature and abundant sunlight which increase biological productivity.

Information is lacking on urban runoff and its impact on the lower American River and Lake Natoma. With the discharges from three major sewage treatment plants being removed from the American to the Sacramento River, urban runoff will be the primary source of pollutants to the stream.

Increasing commercial and residential development in the areas surrounding Lake Natoma represent an increasing threat to the quality of the lake. A detailed limnological appraisal of the lake itself and a study of the hydrologic characteristics of the surrounding basins that drain into the lake would help identify the potential for water-quality degradation.

Additional information on bacteria and nutrient levels in the South Fork American River would provide valuable information on impacts from increased recreation and development in the basin. Several sampling locations below areas of heavy use or development and one in the vicinity of site SF3 could provide the necessary information. The sampling schedule should be representative of differing streamflow conditions. Because water temperatures and nutrient concentrations are higher during the summer and autumn months, an emphasis needs to be placed on sampling during these periods.

Site-specific studies in the Middle Fork basin to evaluate the effects of mine drainage would be beneficial. Identifying specific problems in this area would help to determine the extent to which this activity actually impacts the river. Again, sampling should be representative of differing streamflow conditions to identify the relative differences between high and low flow contributions from a specific site. Depending on the type of mining being done, the number of years of activity, the amount of surface disruption which has occurred, and other complicating factors, the mechanism creating any particular problem may be quite complex. A detailed geochemical study may be required to gain a complete understanding of the problem.

The North Fork basin is unique because of its status as both a State and Federal Wild and Scenic River. A sampling location on the North Fork in the vicinity of site NF3 could provide reference data with which to pair data from both MF3 and SF3 to monitor relations in water-quality characteristics over time. Water-quality characteristics could include dissolved oxygen, pH, specific conductance, water temperature, suspended sediment, and nitrate nitrogen. Changes in the relation between sites of any of these characteristics could indicate a problem requiring further investigation. A sampling frequency should be selected that will emphasize both high and low streamflow. For trend analysis, the same technique used in this study could be used.

SELECTED REFERENCES

Bryan, Kirk, 1923, Geology and ground-water resources of Sacramento Valley, California: U.S. Geological Survey Water-Supply Paper 495, 285 p.

California Department of Fish and Game, 1977a, Lower American River waterway management plan: Wild and Scenic Rivers Program, 40 p.

_____1977b, North Fork American River waterway management plan: Wild and Scenic Rivers Program, 109 p.

California Department of Health, 1977, California Domestic Water Quality and Monitoring Regulations, excerpts from the California Health and Safety Code and the California Administrative Code, Title 22: Berkeley, Calif., 22 p.

California Department of Transportation, 1973, Water-quality report, widening project on State Highway 50 in El Dorado County in the vicinity of "Fred's Place": 03ED5052.0/54.0, 203 p.

California Department of Water Resources, 1965, Land and water use in American River hydrographic unit: California Department of Water Resources Bulletin 94-14, v. 1: text, 121 p.; v. 2: plates, 28 sheets.

California Regional Water Quality Control Board, Central Valley Region, 1975, Water quality control plan report for the Sacramento River basin, the Sacramento-San Joaquin Delta basin, and the San Joaquin basin: v. 1, 287 p.

California State Water Resources Control Board, 1979a, Toxic substances monitoring program, 1976-77: Water Quality Monitoring Report No. 7920, 28 p.

_____1979b, Toxic substances monitoring program, 1978: Water Quality Monitoring Report No. 7925, 79 p.

_____1980a, Toxic substances monitoring program, 1979: Water Quality Monitoring Report No. 806, 62 p.

_____1980b, Water quality inventory for water years 1978 and 1979: 168 p.

_____1981, Toxic substances monitoring program, 1980: Water Quality Monitoring Report No. 81-8TS, 56 p.

Clarke, F. W., 1924, The composition of the river and lake waters of the United States: U.S. Geological Survey Professional Paper 135, 199 p.

Federal Water Pollution Control Administration, 1969, Water-quality study, lower American River, California: 68 p.

Feth, J. H., Roberson, C. E., and Polzer, W. L., 1964, Sources of mineral constituents in water from granitic rocks, Sierra Nevada, California and Nevada: U.S. Geological Survey Water-Supply Paper 1535-I, 170 p.

Fraga, G. W., Lavenda, T. E., and Woodard, R., 1979, Color aerial photography in the plant sciences and related fields, in Proceedings of the Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences: Davis, Calif., University of California, p. 77-87.

Harris, D. D., 1977, Hydrologic changes after logging in two small Oregon coastal watersheds: U.S. Geological Survey Water-Supply Paper 2037, 31 p.

Heaser, Eileen, 1979, The American River, a bibliography: California State University, Sacramento, 44 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water, 2d edition: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hom, L. W., 1968, American River hydrobiologic potential, Central Valley Project, California: Submitted to U.S. Bureau of Reclamation, Final Report for November 1, 1966, through December 31, 1967, contract agreement number 14062003152A, 39 p.

Janda, R. J., 1977, Summary of watershed conditions in the vicinity of Redwood National Park, California: U.S. Geological Survey Open-File Report 7825, 81 p.

National Academy of Sciences and National Academy of Engineering, 1973, Water-quality criteria 1972, A report of the committee on water-quality criteria: U.S. Environmental Protection Agency, EPA R3-73-033, 594 p.

Olmsted, F. H., and Davis, G. H., 1961, Geologic features and ground-water storage capacity of the Sacramento Valley, California: U.S. Geological Survey Water-Supply Paper 1497, 241 p.

Ponce, S. L., 1980a, Statistical methods commonly used in water-quality data analysis: U.S. Forest Service, Watershed Systems Development Group Technical Paper 00001, 136 p.

_____1980b, Water-quality monitoring programs: U.S. Forest Service, Watershed Systems Development Group Technical Paper 00002, 66 p.

Rectenwald, Harry, 1979, Further studies of the effects of the Pacific Slab Mine discharge upon aquatic life in the North Fork of the Middle Fork American River, Placer County: California Department of Fish and Game, 6 p.

Riggs, H. C., 1968, Some statistical tools in hydrology: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chapter A1, 39 p.

Rogers, J. H., Soil survey of El Dorado area, California, 1974: U.S. Department of Agriculture, Soil Conservation Service and Forest Service, 89 p.

Shay, J. M., 1982, Water-quality data for the American River basin, California, February-October 1979: U.S. Geological Survey Open-File Report 82-363, 56 p.

Stabler, Herman, 1911, Some stream waters of the western United States: U.S. Geological Survey Water-Supply Paper 274, 188 p.

Tukey, J. W., 1977, Exploratory data analysis: Reading, Mass., Addison-Wesley Co., 688 p.

U.S. Bureau of Reclamation, 1971, Environmental study, lower American River interim status report: 58 p.

U.S. Department of Agriculture, 1978, North Fork American River Wild and Scenic River study report: 165 p.

U.S. Environmental Protection Agency, 1976 [1978], Quality criteria for water: U.S. Government Printing Office, 256 p.

U.S. Soil Conservation Service, 1974, Soil survey of El Dorado area, California: U.S. Department of Agriculture, 89 p.

U.S. Water and Power Resources Service, 1980, Auburn Dam seismicity and dam safety, Supplement no. 2 to the final environmental statement: 315 p.

Van Winkle, Walton, and Eaton, F. M., 1910, The quality of the surface waters of California: U.S. Geological Survey Water-Supply Paper 237, 142 p.