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AN APPRAISAL OF SURFACE-WATER QUALITY IN THE ALAMEDA CREEK BASIN, CALIFORNIA, OCTOBER 1974-JUNE 1979

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ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, ZONE 7
ALAMEDA COUNTY WATER DISTRICT

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO.

2.

3. Recipient's Accession No.

4. Title and Subtitle

An Appraisal of Surface-Water Quality in the Alameda Creek Basin, California, October 1974-June 1979

5. Report Date

December 1981

6.

7. Author(s)

Lari E. Lopp

8. Performing Organization Rept. No.

USGS/WRI 81-46

9. Performing Organization Name and Address

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

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

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

13. Type of Report & Period Covered

Final

14.

15. Supplementary Notes

Prepared in cooperation with the California Regional Water Quality Control Board, San Francisco Bay Region; Alameda County Flood Control and Water Conservation District, Zone 7; and Alameda County Water District

16. Abstract (Limit: 200 words)

Areal and seasonal variations in the quality of surface water in the Alameda Creek basin from 1974 to 1979 were analyzed to determine the effects of wastewater discharges and imported water releases. Statistically significant differences were found among mean values of constituents in streamflow below the discharge points for treated wastewater, imported water released from the South Bay Aqueduct, and the combined outflow at Alameda Creek near Niles. During periods before and after the drought of 1976-77, concentrations of dissolved solids, dissolved chloride, and total nitrate varied inversely with water discharge. From 1974 to 1976, decreases in nutrient values coincided with increases in imported water releases. Values of physical properties and chemical constituents decreased during the spring and summer of 1976. During the second winter of the drought, release of imported water was decreased, and concentrations of dissolved solids, chloride, and total nitrate increased dramatically in the water at Alameda Creek near Niles. At the upstream tributary, Arroyo de la Laguna, increased physical property and chemical constituent values during 1976 and 1977 were attributed to decreased natural flow, hence the greater contribution of wastewater treatment plant effluent. Concentrations of several constituents exceeded the State water-quality objectives for the basin. With the return to normal flow levels in 1978-79, some concentrations returned to predrought levels.

17. Document Analysis a. Descriptors

Water Quality, Water Analysis, Surface Water, Sampling, Water Properties, Wastewater

b. Identifiers/Open-Ended Terms

California, Water-Quality-Monitoring Program, Alameda Creek Basin

c. COSATI Field/Group

18. Availability Statement

No restriction on distribution

19. Security Class (This Report)

UNCLASSIFIED

20. Security Class (This Page)

UNCLASSIFIED

21. No. of Pages

38

22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

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By L. E. Lopp

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ALAMEDA COUNTY FLOOD CONTROL AND WATER
CONSERVATION DISTRICT, ZONE 7

ALAMEDA COUNTY WATER DISTRICT

3006-04

December 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

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

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For those readers who prefer to use metric units 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)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
mi (miles)	1.609	km (kilometers)
Mgal/d (million gallons per day)	3785	m^3/d (cubic meters per day)
mi^2 (square miles)	2.590	km^2 (square kilometers)
μmho/cm (micromhos per centimeter)	1.000	μS/cm (microsiemens per centimeter)

Symbols and abbreviations

°C (degrees Celsius)
μm (micrometer)
mg/L (milligrams per liter)
meq/L (milliequivalents per liter)
col/100 mL (colonies per 100 milliliters)
NTU (nephelometric turbidity unit)

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AN APPRAISAL OF SURFACE-WATER QUALITY IN THE ALAMEDA CREEK BASIN, CALIFORNIA OCTOBER 1974-JUNE 1979

By L. E. Lopp

ABSTRACT

Urban development from the 1930's until 1980 in the Livermore-Amador Valley area resulted in increased discharge of wastewater into the streams of the 675 square-mile Alameda Creek drainage basin. The streamflow of Alameda Creek drainage basin, which recharges the Niles Cone ground-water basin near the mouth of Alameda Creek, was threatening the water quality of wells supplying domestic, commercial, and agricultural needs of southern Alameda County. Since 1980, most of the wastewater has been exported via pipeline to the San Francisco Bay.

In 1974 five water agencies agreed to a cooperative study of the effects of wastewater discharges and imported water releases in the Alameda Creek basin. An ongoing water-quality monitoring program was started by the U.S. Geological Survey at two sites on Alameda Creek, seven tributary sites, two wastewater discharge sites, two percolation pits, a reservoir, and four wells in the Niles Cone ground-water basin.

From 1974 to 1979 the areal and seasonal variations in surface water were analyzed for five properties or water-quality constituents (turbidity, specific conductance, dissolved chloride, dissolved solids, and total nitrate). Statistically significant differences were found among mean values of constituents in streamflow below the discharge points for treated wastewater, imported water released from the South Bay Aqueduct, and their combined flow at Alameda Creek near Niles.

During periods before and after the drought of 1976-77, dissolved solids, dissolved chloride, and total nitrate varied inversely with water discharge. From 1974 to 1976, decreases in nutrient values coincided with increases in imported water releases. Normal seasonal variations in constituent values were noticeably affected by the drought. Values of physical properties and chemical constituents decreased during the spring and summer of 1976 because more imported high-quality water was released to the streams during the first year of the drought to dilute the nearly constant effluent loading from the treatment plants in the Livermore-Amador Valley area. During the second winter of the drought, release of imported water was decreased, and concentrations of dissolved solids, chloride, and total nitrate increased dramatically in the water of Alameda Creek near Niles. At the upstream tributary Arroyo de la Laguna, increased physical-property and chemical-constituent values during 1976 and 1977 were attributed to decreased natural flow, hence the greater contribution of wastewater treatment-plant effluent. Several constituents were found to exceed the State water-quality objectives for the basin. With the return of normal flow levels in 1978-79, some concentrations returned to predrought levels.

Background

In the early 1900's the agricultural and domestic water needs of the Livermore-Amador Valley and the San Francisco Bay communities of Alameda County were filled by the surface and ground water of the Alameda Creek drainage basin. When the increase in population from the 1930's to the 1960's increased the demand for surface and ground water from the drainage basin, the South Bay Aqueduct was constructed to import water into the drainage basin and parts of Santa Clara County.

The rapid urbanization of the Livermore-Amador Valley brought an increased demand for water with an accompanying increase of wastewater. Within the Alameda Creek drainage basin, disposal of large quantities of wastewater posed a threat to the quality of surface- and ground-water supplies. Historically, wastewater treated in the valley has been applied to agricultural land and a golf course and discharged to Alameda Creek and its tributaries.

In addition to adversely affecting local water supplies of the Livermore-Amador Valley, wastewater disposal in the valley was a threat to the quality of the ground water in the Niles Cone area of southern Alameda County. The normal streamflow of Alameda Creek and aqueduct-imported water replenishes the ground water in the Niles Cone wells, which in turn supply the domestic, commercial, and agricultural water needs of southern Alameda County. Although the release of imported water improved the quality of water in Alameda Creek, increased discharge of wastewater together with the occasional cessation of natural flow of some tributaries to Alameda Creek (during summer and drought conditions) can cause a degradation in water quality beyond the limits set by the Regional Board Discharge Prohibitions (California State Water Resources Control Board, 1975). The degradation of the quality of water in Alameda Creek would result in degradation of the quality of ground water in the Niles Cone basin.

The U.S. Geological Survey and California Department of Water Resources (1964), Consoer-Bechtel (1972), and Brown and Caldwell (1972) reported water-quality problems and proposed alternative plans for wastewater management in the Alameda Creek basin. The California Regional Water Quality Control Board (San Francisco Bay Region) outlined water-quality objectives applicable to surface waters in the bay region and set discharge and receiving water requirements for major wastewater dischargers in the basin. Beginning in 1974, Alameda County Water District, Alameda County Flood Control and Water Conservation District (Zone 7), the Livermore-Amador Valley Water Management Agency, and the U.S. Geological Survey cooperatively designed and coordinated a water-quality monitoring program to assess compliance with water-quality objectives and evaluate effects of wastewater discharges on the surface-water resources in the drainage basin. The Survey was selected as the lead agency responsible for reviewing and summarizing the data resulting from the monitoring program in annual data publications and for preparing an interpretative report.

Purpose and Scope

The purpose of this report is to describe the quality of the surface water in Alameda Creek drainage basin and to evaluate the effects of wastewater discharges and releases of imported water on the quality of surface water, some of which recharges the ground water in the Niles Cone area. Areal and temporal variations in water quality in the basin for the period October 1974 through June 1979 were documented by laboratory analysis of chemical constituents and field measurement of physical properties of water samples.

Acknowledgments

The Dublin-San Ramon Services District, City of Livermore Treatment Plant, Alameda County Flood Control and Water Conservation District (Zone 7), and Alameda County Water District provided assistance in analyzing data.

DESCRIPTION OF STUDY AREA

Location

The Alameda Creek basin upstream of Alameda Creek gage near Niles (11179000) has a drainage area of 633 mi^2 (figs. 1 and 2). The rest of the drainage basin and the Niles Cone ground-water recharge area increase the study area to 675 mi^2. Approximately 55 percent of the study area is in Alameda County, 35 percent in Santa Clara County, and 10 percent in Contra Costa County.

Topography and Drainage

Topography varies greatly in the drainage basin. The relatively flat Livermore-Amador and Sunol Valleys are surrounded by uplands. Tributaries drain the valleys to Alameda Creek, which flows westward through Niles Canyon to south San Francisco Bay. In the southern part of the drainage basin, ridges with elevations up to 4,300 ft alternate with narrow canyons. In the northern part of the drainage basin, Livermore-Amador and Sunol Valleys are bounded by the Diablo Range on the north, south, east, and west. The Alameda Creek main-stem gaging station (11179000) in Niles Canyon has an elevation of 120 ft. From this elevation at the gage the study area slopes downstream to the southern part of San Francisco Bay.

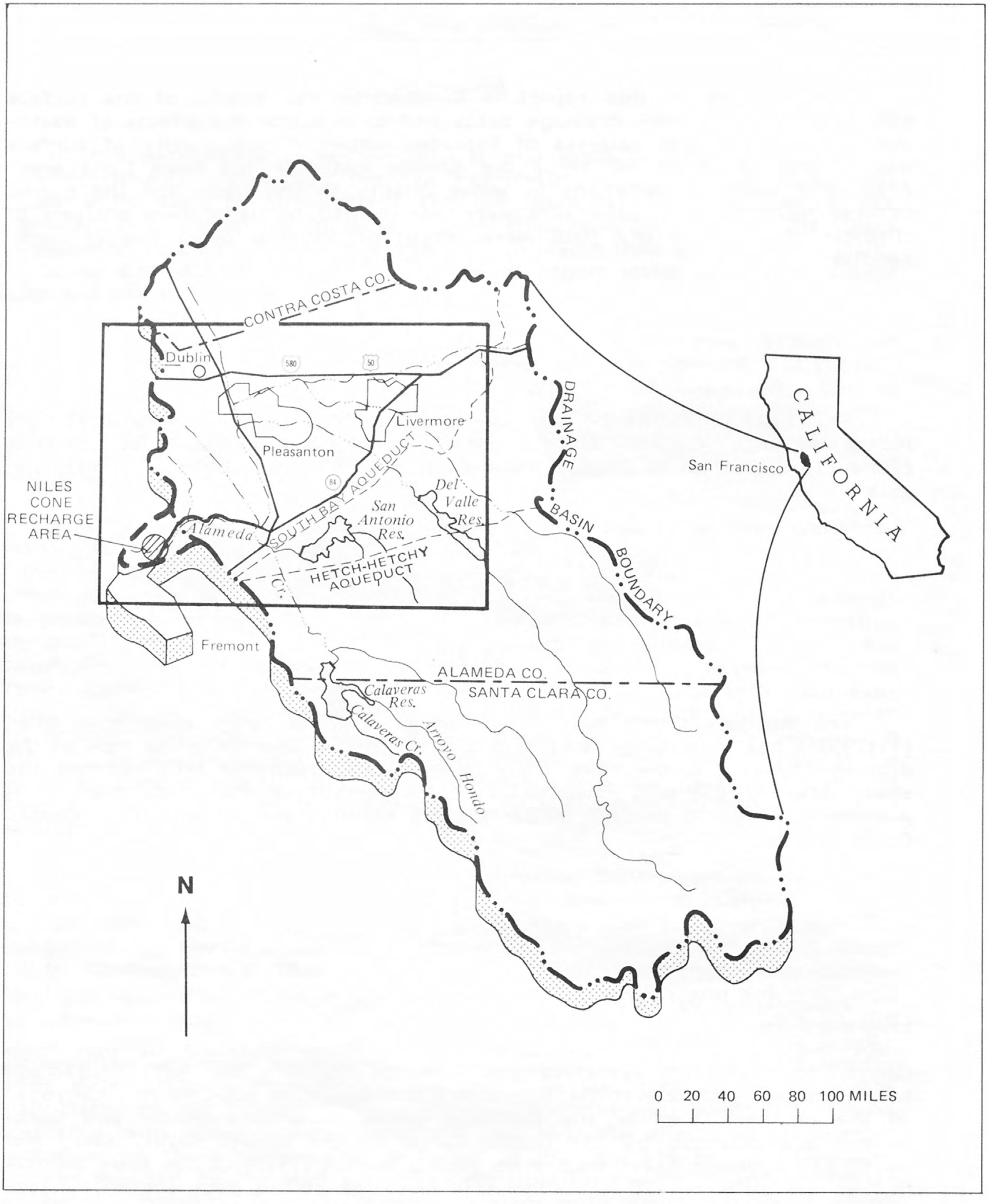

FIGURE 1.--Location of study area.

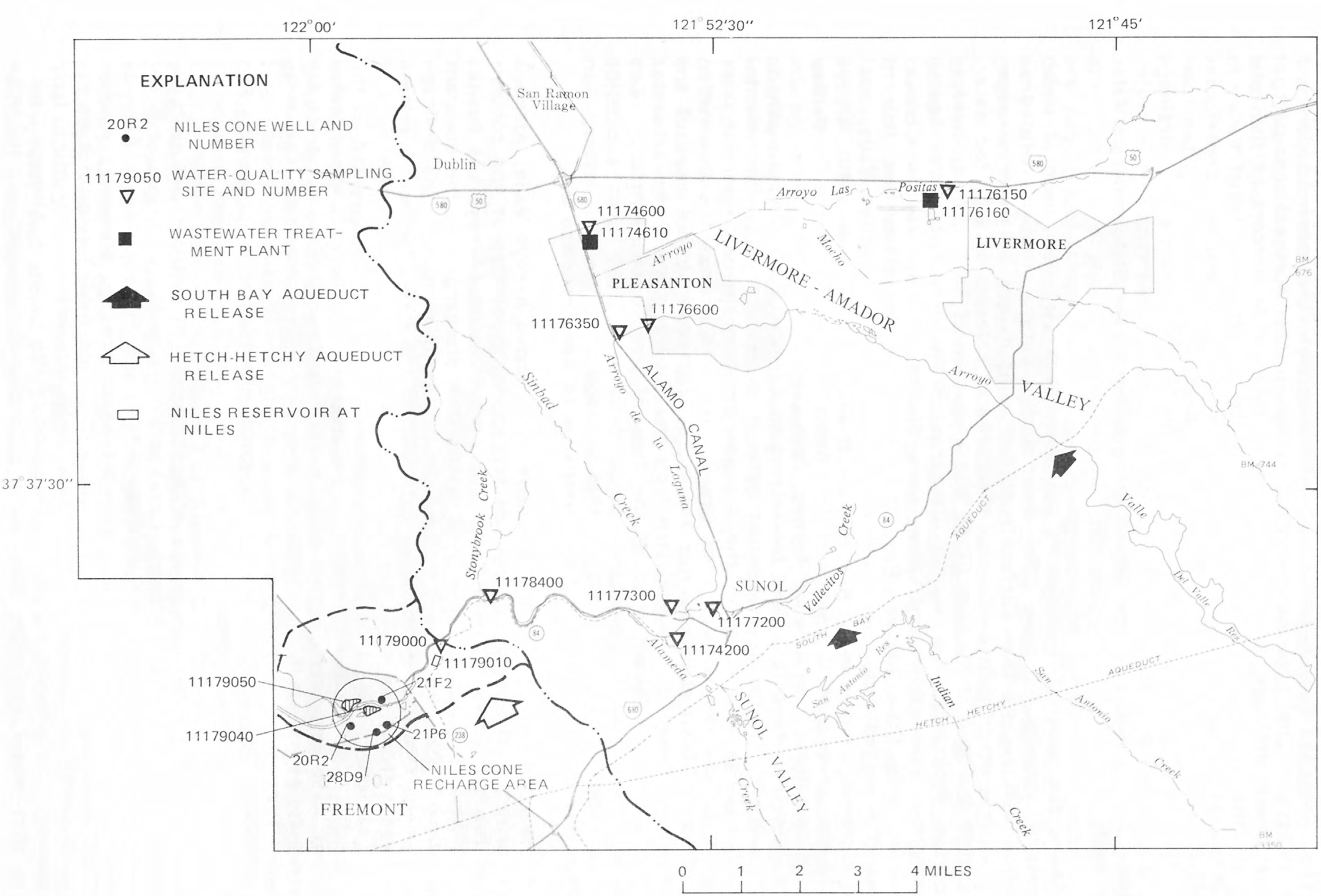

FIGURE 2.--Location of water-quality sampling sites.

The Alameda Creek drainage basin comprises Livermore-Amador and Sunol Valleys. The Livermore-Amador Valley in the northeastern part of Alameda Creek drainage basin contains approximately 66 percent of the total land but contributes only 33 percent of the total runoff. The Sunol Valley in the southwestern part contains about 34 percent of the land and contributes 67 percent of the total runoff (Hines, U.S. Geological Survey, written commun., 1973). Most of the natural runoff in the southern part of the drainage basin is diverted to reservoirs from which it is transported outside the drainage basin by the Hetch Hetchy Aqueduct operated by the San Francisco Water Department.

There are seven tributaries to Alameda Creek (fig. 2), none of which has natural year-round flow. For this study, natural flow is defined as streamflow that results from surface runoff of rainfall, ground water seepage, or any sources other than wastewater discharge or releases of imported water. Before 1980 the flow of Alameda Creek was a mixture of natural flow, releases of imported water, and wastewater discharges. The only tributaries having predominantly seasonal natural flow were Sinbad and Stonybrook Creeks. Tributaries with little natural flow and predominantly intermittent flow of releases of imported water or wastewater discharges were Arroyo Valle, Vallecitos Creek, Alamo Canal, Arroyo Las Positas (which flows into Arroyo Mocho), and Arroyo de la Laguna. Most imported water from the South Bay Aqueduct is released directly to Arroyo Valle (or during rainy season to Del Valle Reservoir, where it is held for release to Arroyo Valle), and directly to Vallecitos Creek. South Bay Aqueduct water is diverted from the Sacramento-San Joaquin Delta area north of the Alameda Creek drainage basin and composes most of the flow of Vallecitos Creek. Wastewater from the Dublin-San Ramon Services District wastewater treatment plant contributed most of the flow of Alamo Canal, and wastewater from the City of Livermore wastewater treatment plant contributed most of the flow of Arroyo Las Positas. The management of wastewater discharge changed in early 1980 when a pipeline began to export wastewater out of the drainage basin to the eastern San Francisco Bay area for treatment and discharge to San Francisco Bay.

In the northern part of the drainage basin above Arroyo Valle, Alameda Creek's principal tributary, Arroyo de la Laguna, originates at the convergence of two tributaries, Alamo Canal and Arroyo Mocho (Arroyo Las Positas flows into Arroyo Mocho). Until 1980 wastewater discharge was the dominant flow of Alamo Canal and Arroyo Mocho. In the southern part of the drainage basin, Alameda Creek at Sunol is an extension of the main stem and a release site for water from Calaveras and San Antonio Reservoirs. Although most of the water stored in Calaveras and San Antonio Reservoirs is diverted to the Hetch Hetchy Aqueduct and exported for use by the San Francisco Water Department, some may be directed by the Alameda County Water District for ground-water recharge in the Niles Cone area. Water stored in Calaveras Reservoir is runoff diverted from Arroyo Hondo and Calaveras Creek, and water stored in San Antonio Reservoir is runoff diverted from Indian and San Antonio Creeks.

Because the greater percentage of runoff comes from the Sunol drainage basin (southern part of the Alameda Creek drainage basin) southeast of Sunol and is exported, another source of water was needed to supplement Alameda Creek flow. The increase in municipal wastewater from the Livermore-Amador Valley (northern part of the Alameda Creek drainage basin) could not be diluted sufficiently by streamflow that was only intermittent, resulting from storm runoff. To prevent further degradation of the water in Alameda Creek at Niles that would recharge Niles Cone ground water, water was imported from the Sacramento-San Joaquin Delta via the South Bay Aqueduct. Maintaining Alameda Creek streamflow with imported water began in the early 1960's and continues.

Urbanization and Resource Change

The Alameda Creek drainage basin has been primarily an agricultural area, and some agricultural industry still exists in the basin. Major crops are hay, truck crops, and grapes. Agricultural pursuits are cultivation of crops in the valleys and grazing in the hilly borders of the valleys. Several sand and gravel plants excavate underlying ground layers extensively for gravel in the Livermore-Amador valley.

In the last 25 years, urbanization has been rapid in the Livermore-Amador Valley while Sunol Valley has remained almost entirely rural. Large tracts of Livermore-Amador Valley land that were used for viticulture and grazing are now subdivisions and small industrial sites. New housing and industry have increased the demand on the local ground- and surface-water supply. Increasing water use by a growing population has created more wastewater, and therefore a need for its disposal. Land application and stream disposal were the principal methods of disposal, with surface-water channels in Alameda Creek drainage basin as the principal conduits for wastewater discharge. The population of the two largest cities Livermore and Pleasanton increased rapidly during the late sixties and seventies as suburbs of San Francisco and the East Bay metropolitan area. The 1960 population for the entire Alameda Creek drainage basin above the Niles gage (11179000) was estimated to be 30,000, with 16,058 in Livermore and 4,203 in Pleasanton. The 1979 population for the entire basin was approximately 125,000, with 50,000 in Livermore, 35,000 in Pleasanton, and 15,000 and 21,000 in the unincorporated areas of Dublin and San Ramon, respectively.

DATA COLLECTION AND METHODS

Sampling Program--Laboratory and Field Methods

Water-quality grab samples were collected weekly from October 1974 through June 1979 at two sites on Alameda Creek and seven sites on tributaries to Alameda Creek. Samples were also collected at two wastewater discharge sites, two percolation pits, one reservoir containing imported water, and four wells in the Niles Cone recharge area (table 1). Samples were collected and analyzed by Dublin-San Ramon Services District (formerly Valley Community Services District), Livermore Waste Water Treatment Plant, Alameda County Water District, and Zone 7 of Alameda County Flood Control and Water Conservation District. Duplicate samples, collected quarterly by each organization, were analyzed by the U.S. Geological Survey Central Laboratory in Arvada, Colo. In addition to the weekly grab samples, Alameda County Water District collected daily composite samples, and the U.S. Geological Survey collected monthly and semiannual grab samples at Alameda Creek near Niles. The Alameda County Water District sampled wells in the Niles Cone recharge area weekly and annually. Each wastewater discharge site was sampled on a 24-hour, 7-day composite, and weekly basis by the wastewater treatment plant.

TABLE 1. - Sampling program, October 1974-June 1979

Frequency: A, annually; D, daily; M, monthly; S, semiannually; W, weekly; 7, 7-day; 24, 24-hour

Group: 1: Specific conductance, dissolved solids, chloride, hardness as $CaCO_3$, total nitrate as N, turbidity

2: Ammonia nitrogen, total coliform bacteria, methylene blue active substances

MI, major ions (dissolved): Calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, silica, nitrite plus nitrate, boron, iron

N, nutrients: Dissolved nitrite plus nitrate as N, dissolved ammonia nitrogen as N, dissolved ammonia nitrogen as NH_4, total organic nitrogen as N, dissolved organic nitrogen as N, dissolved ammonia plus organic nitrogen, dissolved orthophosphate as P, total phosphorus as P

TM, trace metals (dissolved): Arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, zinc

Other: B, boron; Q, water discharge; RC, residual chlorine; BOD, biochemical oxygen demand.

Type of sample: C, composite; G, grab

Type of recorder: S, stage; SC, specific conductance; T, temperature

Collecting and analyzing agency: ACWD, Alameda County Water District; D-SR, Dublin-San Ramon Services District; LWTP, Livermore Wastewater Treatment Plant; USGS, U.S. Geological Survey

Station number and name		Frequency	Group	Type of sample	Type of recorder	Collecting and analyzing agency[1]	Reason
11174200	Alameda Creek at Sunol.	W	1,2	G		ACWD	Import water.
11174600	Alamo Canal near Pleasanton.	W	1,2	G		ACWD	Upstream of wastewater discharge.
			BOD	G		D-SR	
11174610	Dublin-San Ramon Services District Wasteway.	7	1	C		ACWD	Wastewater discharges.
		24	1	C		D-SR	
		W	2	G			
			RC	G			
			BOD	G			

11176150	Arroyo Las Positas	W	1,2	G		ACWD	Upstream of wastewater
	near Livermore.		BOD	G		LWTP	discharge.
11176160	Livermore Treatment	7	1	C		ACWD	Wastewater discharges.
	Plant Wasteway.	24	1	C		LWTP	
		W	2	G			
			RC	G			
			BOD	G			
11176350	Arroyo de la Laguna	W	1,2	G	S	ACWD	Downstream of wastewater
	above Arroyo Valle.				SC		discharge.
					T		
11176600	Arroyo Valle at	W	1,2	G	S	ACWD	Import water.
	Pleasanton.				SC		
					T		
11177200	Vallecitos Creek	W	1,2	G	SC	ACWD	Import water and
	at Sunol.				T		wastewater discharge.
11177300	Sinbad Creek	W	1,2	G		ACWD	Natural flow.
	at Sunol.						
11178400	Stonybrook Creek	W	1,2	G		ACWD	Natural flow.
	near Niles.						
11179000	Alameda Creek near	D	1	C	S	ACWD	Recharge potential.
	Niles.	W	2	G	SC		
		M	N,Q,B	G	T	USGS	Lead agency.
		S	TM	G			
			MI				
11179010	Niles Reservoir	W	1,2	G		ACWD	Recharge potential.
	at Niles.						
11179040	Kaiser Pit at Niles	W	1,2	G		ACWD	Recharge potential.
11179050	Shinn Pit at Niles	W	1,2	G		ACWD	Recharge potential.
Niles Cone wells:							
373349121585701	4S/1W-28D9	W	1	G		ACWD	Recharge ground water.
373355121583801	4S/1W-21P6	A	MI,TM				
373357121591401	4S/1W-20R2						
373424121584501	4S/1W-21F2						

[1]Duplicate samples for group 1 analyses at all sites were analyzed quarterly, and samples for trace metals and major ions at Alameda Creek and Niles Cone wells were analyzed annually at the U.S. Geological Survey Central Laboratory, Arvada, Colo.

Breaks in sampling occurred at some surface water sites due to no-flow periods, especially during the 1976-77 drought. Sampling was intermittent at several other locations because of unforeseen difficulties with equipment and well conditions.

The procedures used by local agency laboratories to analyze samples were those outlined in Standard Methods (American Public Health Association and others, 1976). The field and laboratory procedures for quality-control samples sent to the Survey Central Laboratory in Arvada, Colo., were those described by Skougstad and others (1979). Ground-water samples were collected after pumping wells for 15 minutes to assure sampling of aquifer water.

RESULTS AND DISCUSSION

Areal Variations in Water Quality

Areal variation in water quality was assessed by comparing mean values of physical properties and chemical constituents among stations. Means were compared for only normally distributed data collected under similar climatic and hydrologic conditions. A statistical procedure, Analysis of Variance (ANOVA)-Model II - single classification 0.05 significance level (Dixon and Massey, 1969), was used to compare physical properties and constituents between stations. The data were processed by the ANOVA and UNIVARIATE procedures using the Statistical Analysis System (SAS) (Hellwig and Council, 1979). The results of the ANOVA procedure are shown in table 2.

The three stations where data were sufficient to assess areal variation by analysis of variance (ANOVA) are Arroyo de la Laguna above Arroyo Valle (11176350), Vallecitos Creek at Sunol (11177200), and Alameda Creek near Niles (11179000). The means were determined from a sample size of 47 values. The period of record included in the sample mean was from October 10, 1974, to May 30, 1979. The data collected during this period represented regulated streamflow during all seasons.

Flow in Arroyo de la Laguna above Arroyo Valle is composed of wastewater discharges and a small amount of natural flow; the station is upstream from both sites where significant imported water is released. Water in Vallecitos Creek is principally imported water from the South Bay Aqueduct. Water in the main stem of Alameda Creek near Niles is a composite of water from all sources in the entire Alameda Creek basin, including imported water, seasonal natural flow, and wastewater discharges.

TABLE 2. - Comparison of mean values of water-quality properties and constituents among three stations in the Alameda Creek basin

[Analysis of variance significance level is 0.05. A plus (+) or minus (-) indicates that property or constituent mean at first station listed in column heading is significantly greater than or less than mean at second station listed. A zero (0) indicates that property or constituent means at stations compared are not significantly different. Columns having mostly zeros indicate that stations compared are similar in water quality. Columns having mostly plus or minus signs indicate that stations compared are dissimilar in water quality. Numbers in parentheses are mean values. First number corresponds to upper station in column heading; second number corresponds to lower station]

Properties and constituents	Stations					
	Arroyo de la Laguna above Arroyo Valle (11176350) and Alameda Creek near Niles (11179000)		Arroyo de la Laguna above Arroyo Valle (11176350) and Vallecitos Creek at Sunol (11177200)		Vallecitos Creek at Sunol (11177200) and Alameda Creek near Niles (11179000)	
Turbidity ------------- NTU --	0	(16/16)	0	(16/10)	0	(10/16)
Hardness-------------- mg/L--	+	(260/200)	+	(260/140)	-	(140/200)
Chloride, dissolved---- mg/L--	+	(200/150)	+	(200/140)	0	(140/150)
Dissolved solids ------- mg/L--	+	(782/529)	+	(782/388)	-	(388/529)
Nitrate, total, as N --- mg/L--	+	(19/6.4)	+	(19/2.2)	-	(2.2/6.4)

Comparisons in table 2 show that at the 0.05 significance level Arroyo de la Laguna (where the flow consists mostly of wastewater discharges) has significantly greater concentrations of total nitrate, dissolved solids, hardness, and dissolved chloride than either Vallecitos Creek (mostly imported water) or Alameda Creek near Niles (combination of wastewater, imported water, and reservoir release of impounded surface-water runoff). At the 0.05 significance level, Vallecitos Creek has significantly lower concentrations of total nitrate, dissolved solids, and hardness than Alameda Creek, but the dissolved-chloride concentrations of the two stations are not significantly different. Water from Vallecitos Creek mixed with water from Arroyo de la Laguna composes the water at Alameda Creek at Niles, with a chemical quality different from that of either tributary. Water lower in dissolved-solids concentration and total nitrate contributed by Vallecitos Creek diluted the water of higher dissolved-solids concentration and total nitrate contributed by Arroyo de la Laguna.

Temporal Variations in Water Quality

Seasonal Variation

Two stations were selected to illustrate seasonal variations in water quality in the Alameda Creek drainage basin. Alameda Creek near Niles (11179000), selected because the water quality there is representative of the entire basin, is downstream of the major tributaries to Alameda Creek, wastewater discharges, and imported-water releases. In addition, the water at this station is used for ground-water recharge in the Niles Cone area. Arroyo de la Laguna above Arroyo Valle (11176350), downstream of most wastewater discharges but upstream of major imported-water releases, was selected to represent the quality of surface waters receiving wastewater effluent.

The bar graphs of water discharge (fig. 3) show the quantity of water flowing by the gaging stations, Alameda Creek near Niles (11179000), and Arroyo de la Laguna (11176350). The bar graph of imported water (fig. 4) shows the quantity purchased by Alameda County Water District and released to Vallecitos Creek (11177200) and Arroyo Valle (11176600) upstream of Alameda Creek near Niles (11179000) for the Niles Cone ground-water recharge facility. Figures 5 through 9 are bar graphs showing seasonal variations in water quality.

This discussion of seasonal variations of mean specific conductance, turbidity, dissolved chloride, dissolved solids, and total nitrate focuses on the drought period, 1976-77, when the greatest change in values of physical properties and chemical constituents occurred at Alameda Creek near Niles (figs. 5-9). From the autumn of 1975 through the autumn of 1977, precipitation and natural runoff were low enough to be considered drought conditions (fig. 3). In the Alameda Creek drainage basin, streamflow ranging from reduced to nonexistent in some channels created a need for an increase in imported water to dilute the wastewater effluent released upstream of Alameda Creek near Niles and the Niles Cone ground-water recharge facility. South Bay Aqueduct releases were greatest during the spring and summer of 1976 and decreased during 1977 (fig. 4). During the drought the quantity of effluent released from wastewater treatment plants changed little in comparison with South Bay Aqueduct releases (table 3).

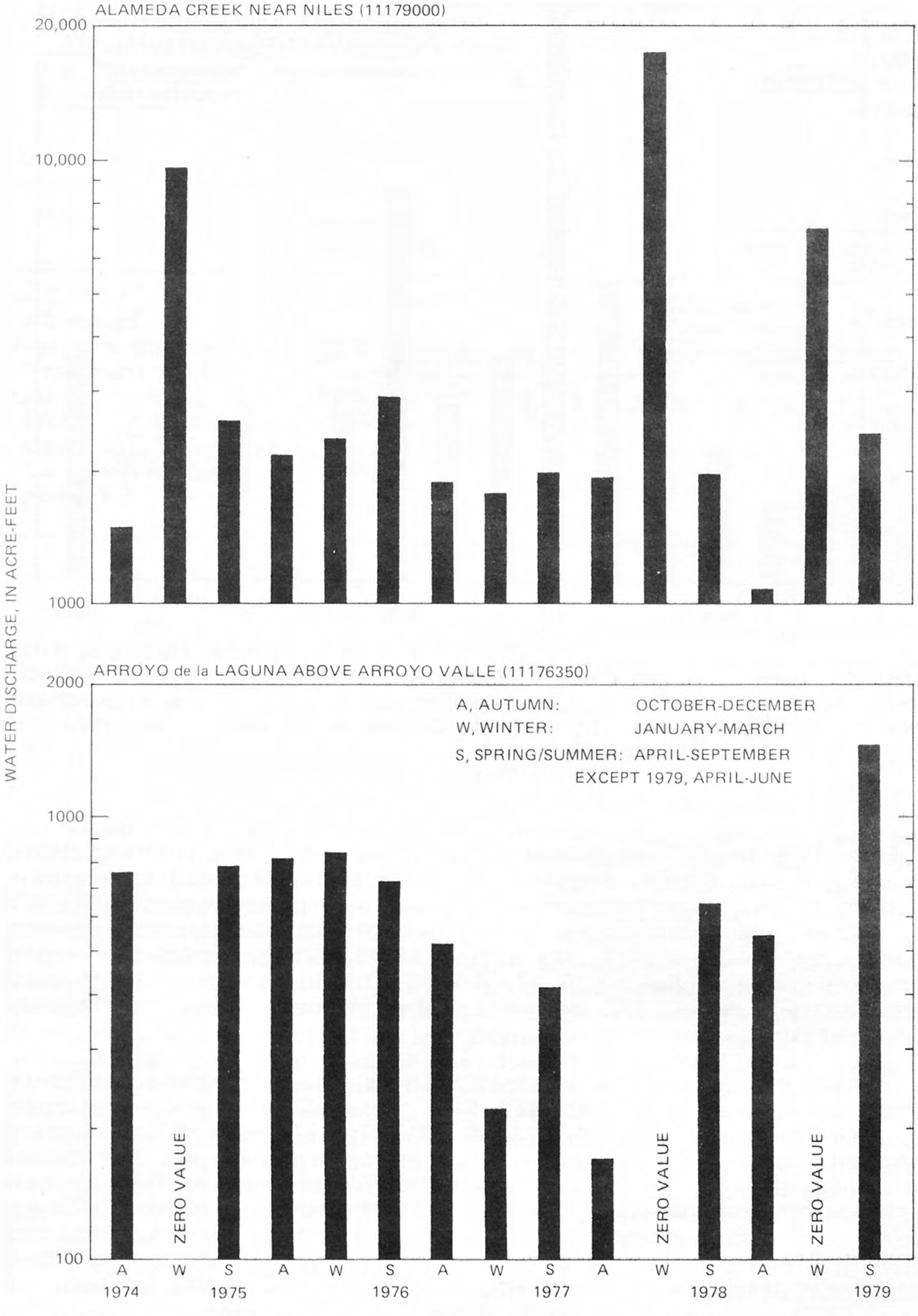

FIGURE 3.--Seasonal mean water discharge.

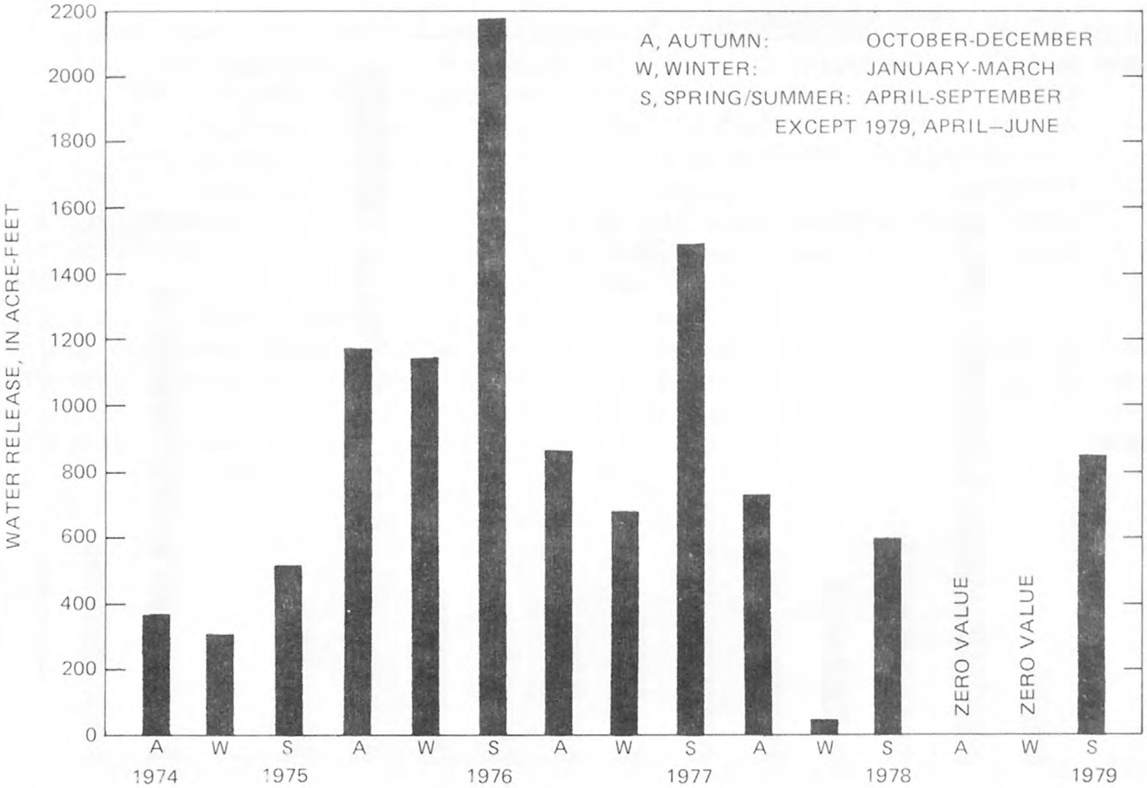

FIGURE 4.--Seasonal mean releases of South Bay Aqueduct water to Vallecitos Creek and Arroyo Valle. (Amounts shown are representative of purchase amounts of imported water by Alameda County Water District and do not reflect channel conveyance losses.)

From 1976 to 1977 at Alameda Creek near Niles, seasonal variations of mean specific conductance, dissolved solids, chloride, and total nitrate may be related to the seasonal variation in releases of imported water (figs. 5 and 7-9). When mean concentrations of chemical constituents were lowest at Alameda Creek near Niles in the spring of 1976, mean releases of imported water were greatest (figs. 4, 5, 7, 8, and 9). In contrast, during winter, spring, and autumn of 1976, mean chemical-constituent values at Arroyo de la Laguna increased.

In 1977 during all three seasons, mean values of chemical constituents at Alameda Creek near Niles increased over those of 1976, while the imported water mean decreased (figs. 4, 5, and 7-9). In 1977 mean values of chemical constituents upstream at Arroyo de la Laguna again increased. The increased mean values in 1977 at Alameda Creek near Niles resulted from decreased imported water and increased concentrations of chemical constituents in water entering upstream. Increased mean values at Arroyo de la Laguna during 1976 and 1977 reflect decreased natural runoff, hence a greater contribution of wastewater treatment-plant effluent to the streamflow at this location.

TABLE 3. - South Bay Aqueduct releases to Vallecitos Creek and Arroyo Valle, Livermore Wastewater Treatment Plant effluent releases to Arroyo Las Positas, and Dublin-San Ramon Services District Treatment Plant effluent releases to Alamo Canal

[Releases in acre-feet]

	Calendar year					
	1974[1]	1975	1976	1977	1978	1979[2]
South Bay Aqueduct.[3]	1,120	7,470	19,100	13,100	3,710	1,340
Livermore Wastewater Treatment Plant.[4]	1,270	4,710	4,260	4,030	4,150	2,200
Dublin-San Ramon (formerly Valley Community) Services District Treatment Plant.[4]	1,120	4,480	4,370	3,700	4,150	1,940

[1]October-December.
[2]January-June.
[3]Allocated to Alameda County Water District for ground-water recharge. Data from records at the Alameda County Water District.
[4]Average daily effluent flow, in millions of gallons per day, converted to average yearly flow, in acre-feet, from treatment plant effluent-release records.

Increased mean values of chemical constituents at Alameda Creek near Niles during 1977 may also be related to another factor. South Bay Aqueduct water entered Alameda Creek by two methods: directly as releases to Arroyo Valle and Vallecitos Creeks, and indirectly as treated wastewater. Zone 7 of the Alameda County Flood Control and Water Conservation District purchases South Bay Aqueduct water and distributes it to the Livermore-Amador Valley. This water eventually becomes wastewater to be treated at the Livermore Wastewater Treatment Plant and Dublin-San Ramon Services District Water Treatment Plant and is released as wastewater effluent to Arroyo Las Positas and Alamo Canal to become part of the flow of Arroyo de la Laguna above Arroyo Valle. By 1977, the second year of the drought, water from the San Francisco Bay was mixing farther upstream with Sacramento-San Joaquin Delta inflow due to a decrease in freshwater from northeastern California. Sacramento-San Joaquin delta water, the source of South Bay Aqueduct water imported to the Alameda Creek drainage basin, may have changed sufficiently in chemical composition to affect South Bay Aqueduct water, which in turn affected imported water and wastewater released to the Alameda Creek drainage basin (Ralph Johnson, Zone-7, Alameda County Flood Control and Water Conservation District, oral commun., 1980). In 1977 South Bay Aqueduct water, with an increase in concentrations of chemical constituents, may not have diluted the wastewater as effectively as in 1976 and may even have increased chemical-constituent concentrations.

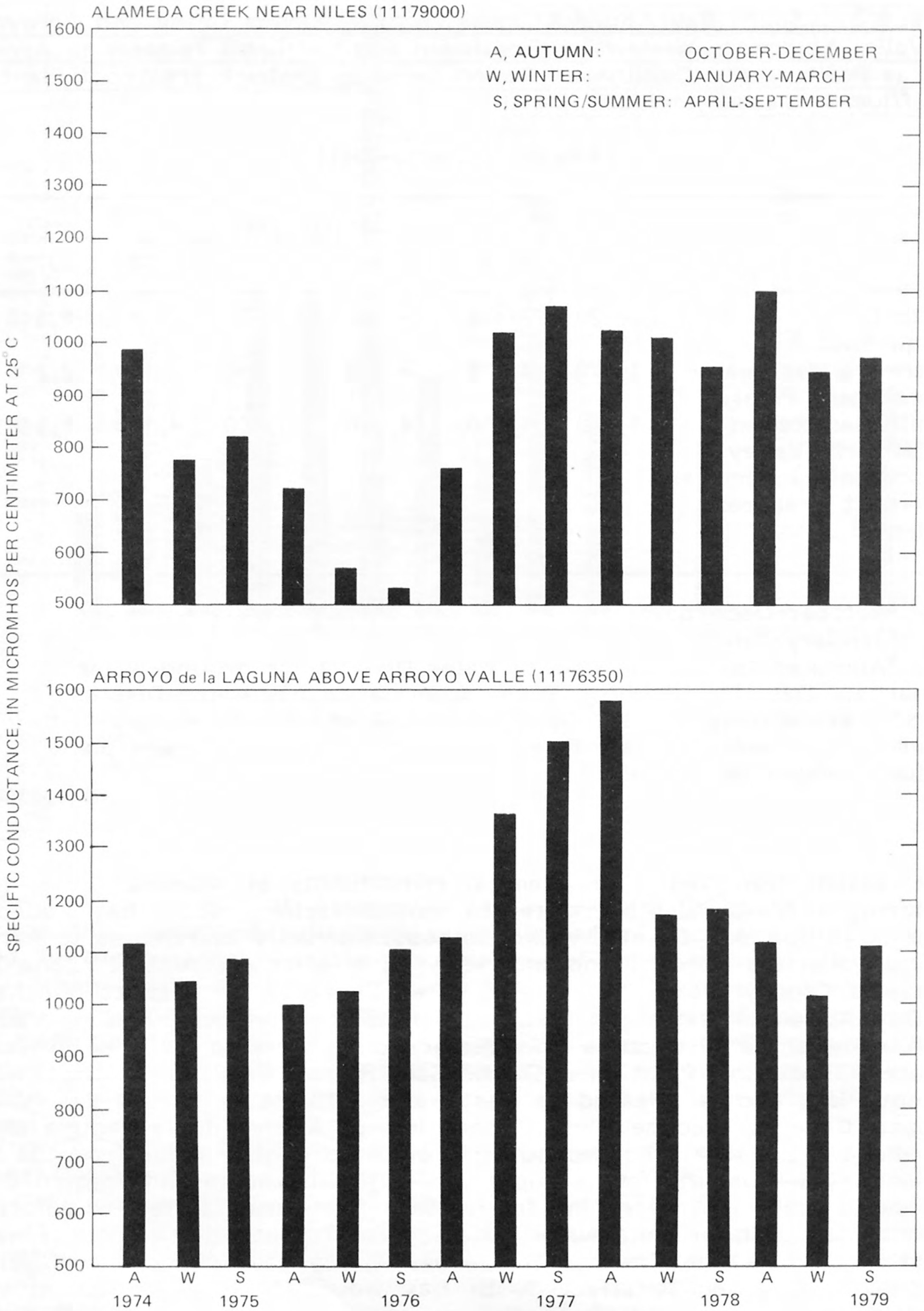

FIGURE 5.--Seasonal mean values of specific conductance.

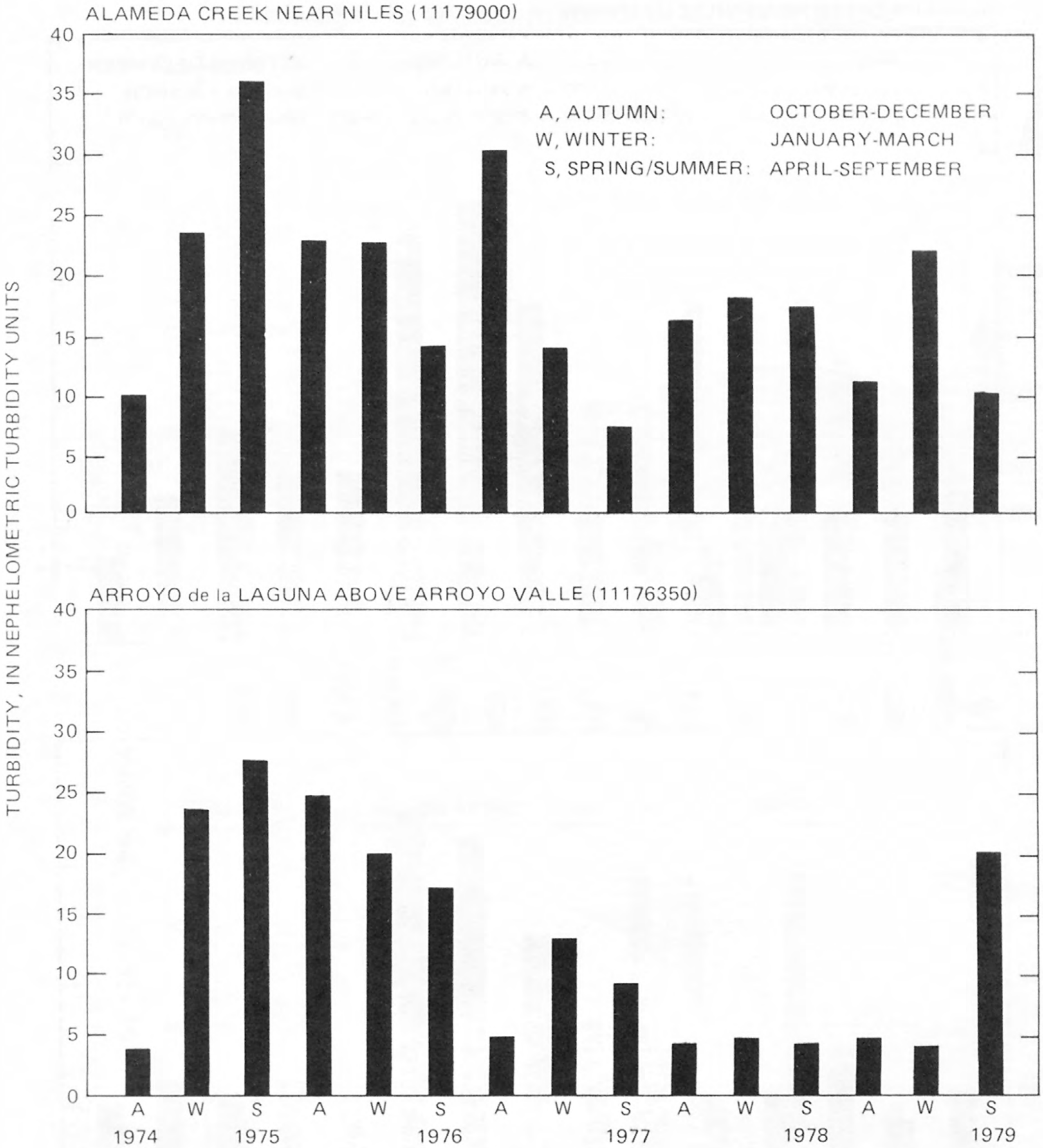

FIGURE 6.--Seasonal mean values of turbidity.

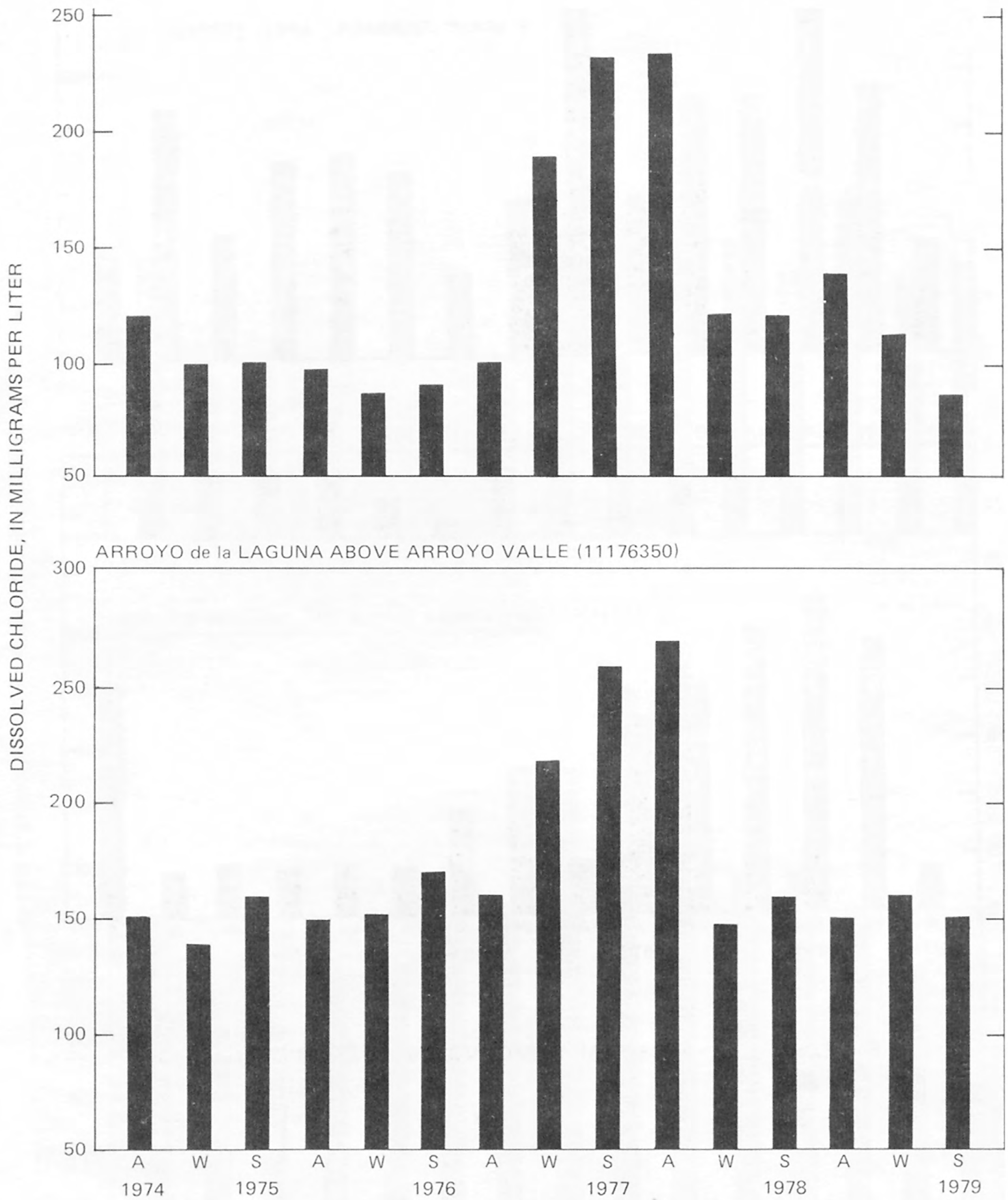

FIGURE 7.--Seasonal mean concentrations of dissolved chloride.

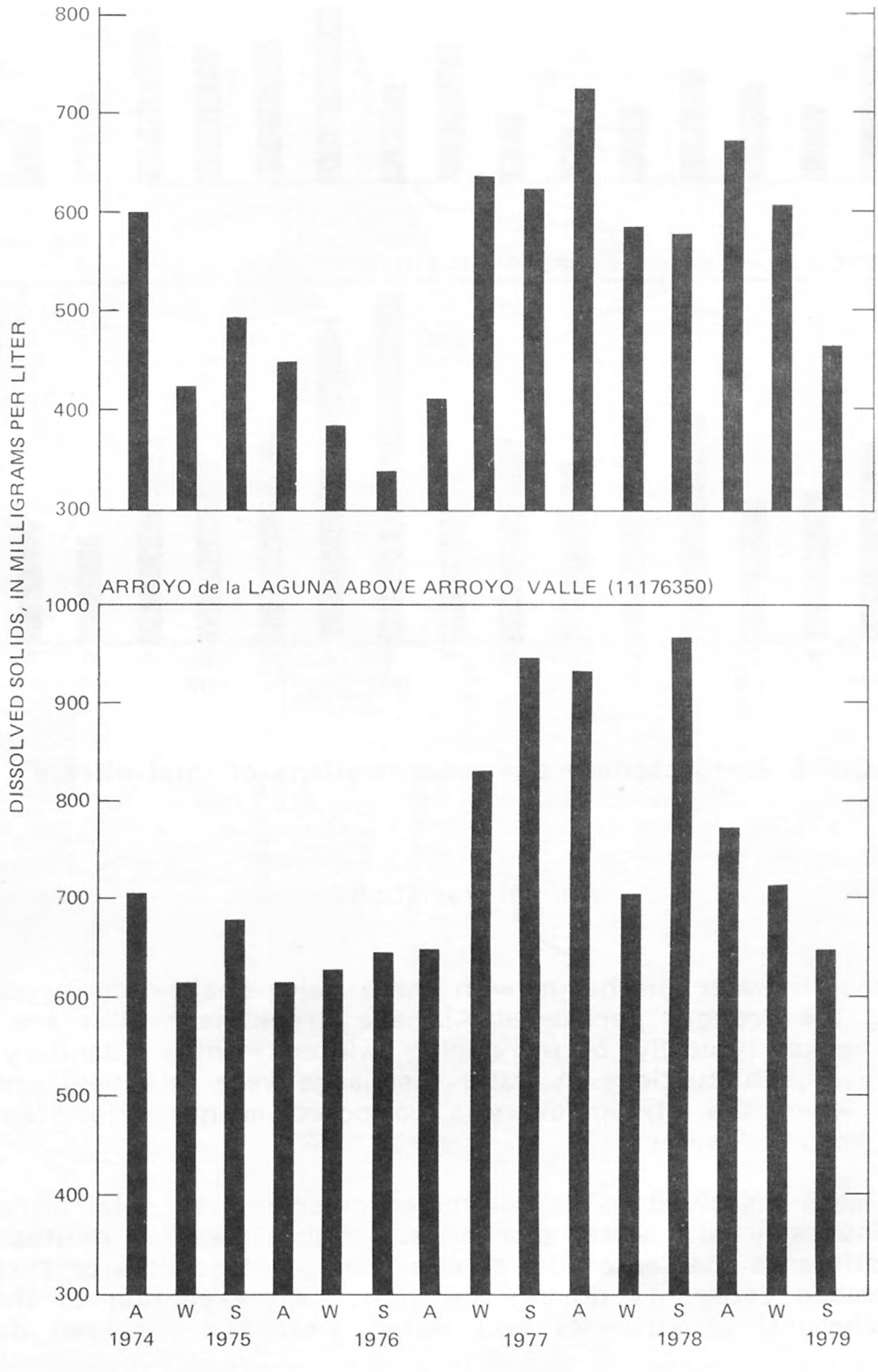

FIGURE 8.--Seasonal mean concentrations of dissolved solids.

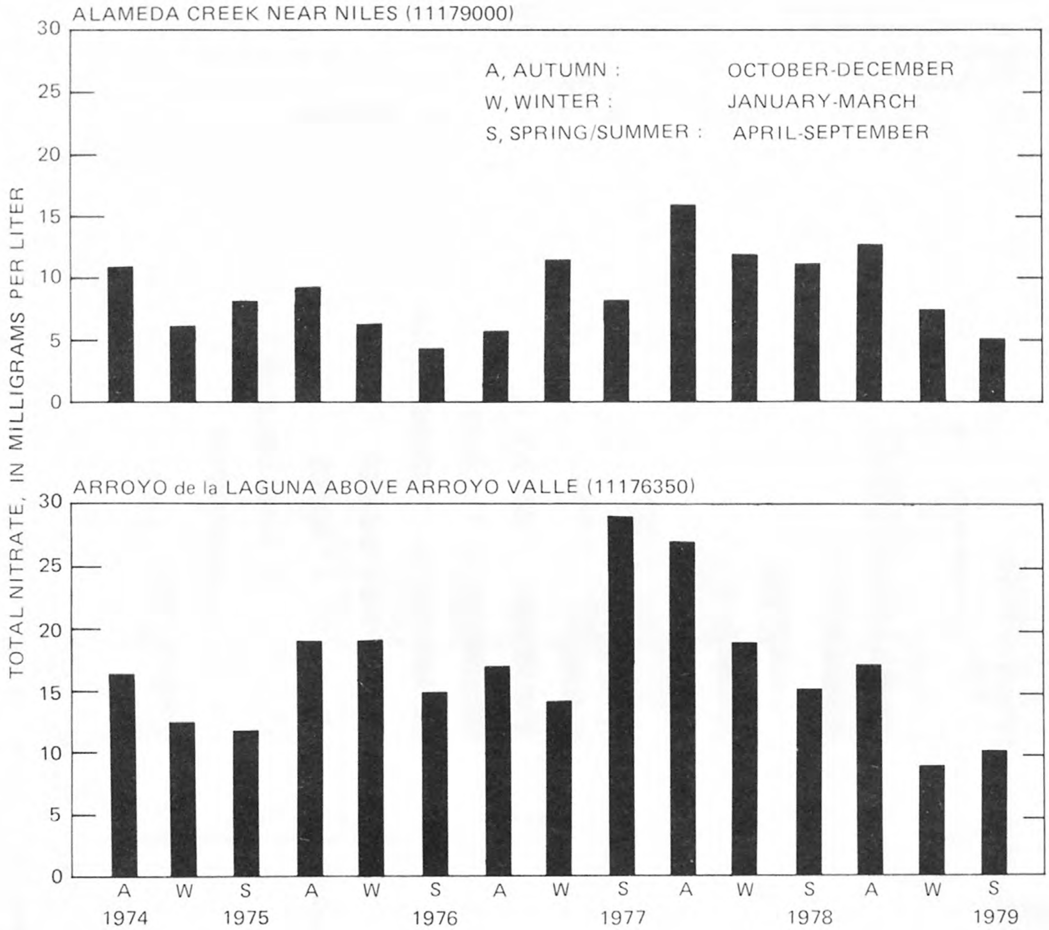

FIGURE 9.--Seasonal mean concentrations of total nitrate.

Annual Variation

Variations in water discharge with three major peaks--one preceding and two following the drought period--at Alameda Creek near Niles are shown in figure 10. Peaks typically occur during winter months (January through March); however, fluctuations in water discharge were relatively small during the drought when the streamflow was composed mainly of wastewater discharges and imported water.

Annual mean dissolved solids, dissolved chloride, and total nitrate generally varied inversely with water discharge. High streamflow dilutes dissolved chemical constituents that enter the stream from point sources or that accumulate in streambed sediments during low flow. An exception to the inverse relation of chemical constituents and water discharge occurred during the drought.

FIGURE 10.--Annual variation in monthly mean values of dissolved solids, dissolved chloride, total nitrate as N, water discharge, and total coliform bacteria at Alameda Creek near Niles (11179000).

Mean values of dissolved solids, including chloride, increased from mid-1976 to the end of 1977 while mean water discharge changed little. Mean total nitrate decreased sharply in mid-1976, then increased in early 1977 coinciding with an increase in mid-1976 and a decrease in early 1977 in imported water releases (fig. 4). During the drought, imported water maintained the water discharge but did not effectively prevent a gradual increase in mean concentrations of dissolved solids (fig. 10).

From 1976, the first year of the drought when nutrient concentration means were the lowest, to 1977 when the means increased, mean water discharge decreased (figs. 10 and 11). In 1978 when most nutrient concentration means increased again, mean water discharge peaked (fig. 11) but imported water decreased (fig. 4 and table 3). From 1978 to 1979 natural runoff became a larger component of the water discharge of Alameda Creek at Niles. Of the nutrient means plotted in figure 11, dissolved $NO_3 + NO_2$ (nitrate plus nitrite as N) shows the greatest fluctuations in mean values. Mean dissolved $NO_3 + NO_2$ decreased from 1974 to 1976, increased more than the other nitrogen species in 1977, and decreased to a low mean value in 1978. These decreases in mean dissolved $NO_3 + NO_2$ and other nutrients from 1974 to 1976 may be explained by the increases in imported water during this period. There was an increase in imported water from South Bay Aqueduct to Vallecitos Creek and Arroyo Valle; from 1976 to 1978 water imported to the tributaries of Alameda Creek generally decreased.

Annual variations in water quality are seen when examining changing water types. The Stiff method for examining water composition displays the pattern of cation and anion concentrations (Hem, 1970). A computer program, Stiff diagram, was used to plot data from complete major ion analyses for this study (Morgan and McNellis, 1969).

At Alameda Creek near Niles, three samples were collected during the period March 1976 to October 1977 for complete major ion analysis. The Stiff diagrams of these analyses in figure 12 indicate that sodium and chloride ions were predominant in all three samples and increased in the October 1977 sample. The decreased water discharge and decreased contribution of imported water releases in October 1977 probably account for the increase in sodium and chloride ion concentrations from the earlier samples. The samples analyzed for major ions were taken at the beginning and end of the drought period.

Water-Quality Objectives of the California Regional Water Quality Control Board

The California Regional Water Quality Control Board, San Francisco Bay Region, outlined water-quality objectives applicable to surface water in the bay region and set receiving-water requirements for major wastewater discharges in the basin. The basin plan applies to surface waters of the Alameda Creek drainage basin upstream of Niles Cone. According to the plan, beneficial uses of the water in the Alameda Creek watershed include groundwater recharge, municipal, recreational, and agricultural. The chemical-quality limits of Alameda Creek watershed are set by the basin Plan-Section Objectives For Inland Surface Waters, Enclosed Bays, and Estuaries, and Section-Alameda Creek Watershed (California State Water Resources Control Board, 1975).

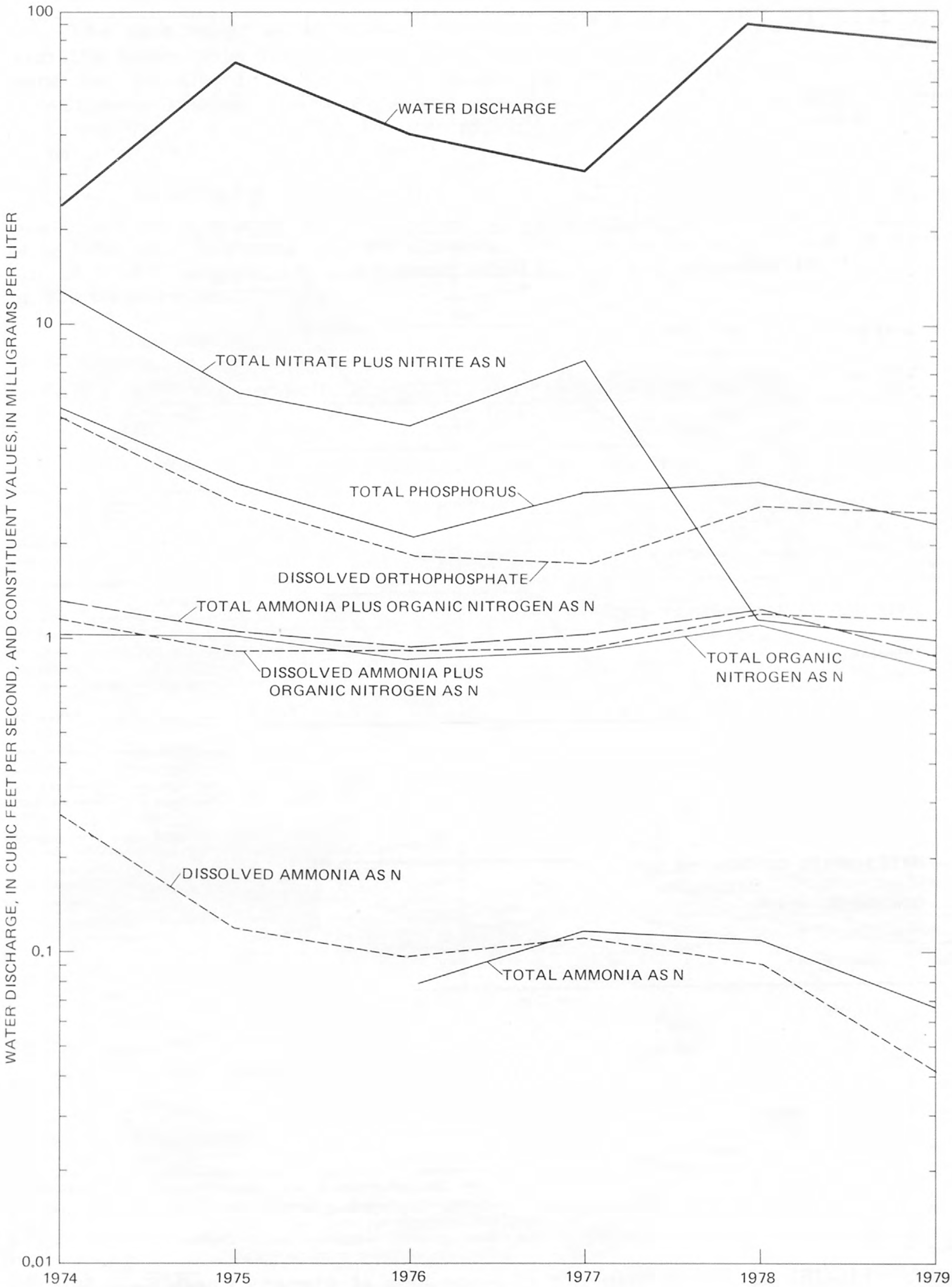

FIGURE 11.--Yearly mean values of nutrients and water discharge at Alameda Creek near Niles (11179000).

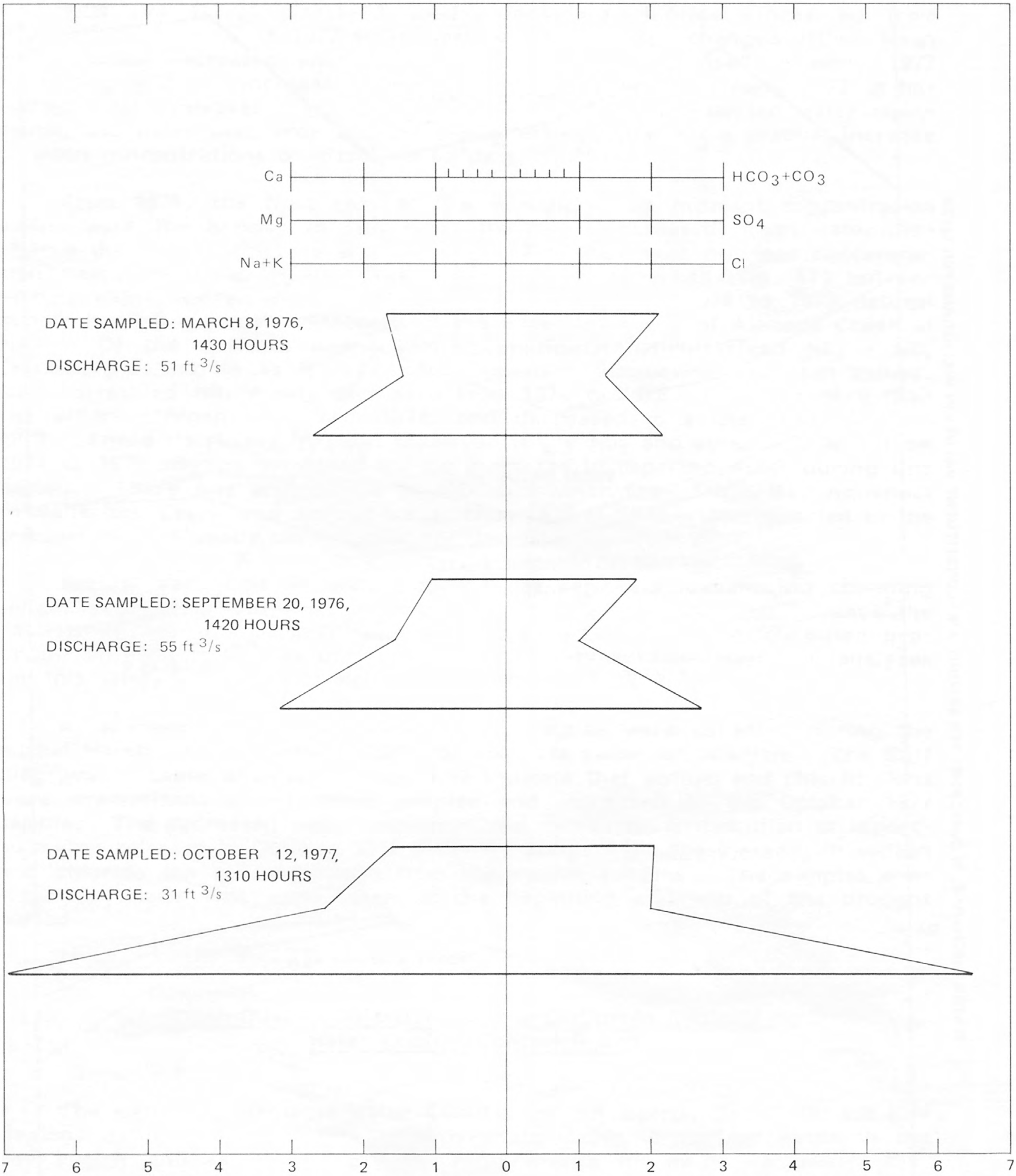

FIGURE 12.--Stiff diagrams of major ions at Alameda Creek near Niles, March 1976, September 1976, and October 1977.

The data collected at Alameda Creek near Niles (table 4) were compared with the basin objectives. Limits for concentrations of inorganic constituents were set by the State Board for municipal and agricultural use. Of the constituents sampled, lead exceeded the limit 5 times in 6 samples; boron exceeded the limit 2 times in 16 samples; and nitrate plus nitrite as N exceeded the limit 11 times in a total of 71 samples.

The limits of dissolved solids and dissolved chloride set by the State Board are daily maximums. Dissolved solids exceeded the limit 695 times out of a total of 1,678 samples, and dissolved chloride exceeded the limit 33 times out of 1,683 samples. The maximum value for pH was exceeded 150 times out of 815 measurements.

TABLE 4. - Water-quality objectives and noncompliance for Alameda Creek near Niles

[Objectives from California State Water Resources Control Board, 1975]

Properties and constituents	Objectives					Noncompliance	
	Minimum	Maximum	Annual median	Threshold concentration	Limiting concentration[1]	Total samples	Number of times objective exceeded
Turbidity ------------ NTU --	--	[2]10	--	--	--	883	([3])
pH ------------------ units --	6.5	8.5	--	--	--	815	150
Total coliform bacteria[2] ----- col/100 mL --	--	[4]100	--	--	--	1,144	([3])
Ammonia nitrogen as N (un-ionized) -- mg/L --	--	0.4	--	--	--	73	([3])
	--	--	0.025	--	--	5	([3])
Fluoride ------------ mg/L --	--	--	--	--	0.8-1.7 mun		
	--	--	--	--	15 agr		
Arsenic ------------- mg/L --	--	--	--	--	2.0 agr		
Barium -------------- mg/L --	--	--	--	--	1.0 mun	5	0
Cadmium ------------ mg/L --	--	--	--	--	0.05 agr	4	0
Chromium ----------- mg/L --	--	--	--	--	0.05 mun		0
	--	--	--	--	1.0 agr	5	0
Cyanide ------------- mg/L --	--	--	--	--	0.2 mun		
Lead ---------------- mg/L --	--	--	--	--	0.05 mun	6	5
	--	--	--	--	10 agr		0
Mercury ------------- mg/L --	--	--	--	--	0.005 mun	5	0
Nitrate plus nitrite as N -------------- mg/L --	--	--	--	--	10 mun	71	11
Selenium ------------ mg/L --	--	--	--	--	0.01 mun	5	0
	--	--	--	--	0.02 agr		
Boron --------------- mg/L --	--	--	--	--	1.0 mun	16	2
					2-10 agr		
Zinc ---------------- mg/L --	--	--	--	5.0 mun	--		0
	--	--	--	--	10.0 agr	5	0
Copper -------------- mg/L --	--	--	--	1.0 mun	--		0
	--	--	--	--	5.0 agr	5	0
Silver --------------- mg/L --	--	--	--	--	0.05 mun		
Methylene blue active substance --- mg/L --	--	--	--	--	0.5 mun		
Dissolved solids ------ mg/L --	--	[5]500	--	--	--	1,678	695
Chloride ------------ mg/L --	--	[5]250	--	--	--	1,683	33

[1]Suggested as 90th-percentile limits. Abbreviations: mun, municipal; agr, agricultural.
[2]Increases relatable to waste discharge shall not be greater than 10 percent in areas of 10 NTU or more.
[3]Not possible to evaluate because appropriate data not collected.
[4]In nontidal waters designated for municipal drinking water supply, the total coliform bacteria, based on an arithmetic average of at least five consecutive samples collected over a 30-day interval, should not exceed maximum concentration of 100 col/100 mL.
[5]Daily maximum.

FUTURE STUDIES

Two major modifications for any future studies might include: (1) Sampling all stations established above and below existing and potential sources of water quality impairment, and (2) sampling all stations for the entire time of the study. Knowledge of areal and temporal variation of water quality in the upstream tributaries is necessary to evaluate properly the water quality of Alameda Creek. Random sampling at all stations under all climatic and hydrologic conditions would be desirable. Random sampling for areal and temporal variations provides more complete data for comparative evaluation of water quality. In this study random sampling at all stations under all climatic and hydrologic conditions was not accomplished. Major ion analysis of water in the drainage basin facilitates a comparison of water types and a description of sources of streamflow. As a result of incomplete data during and after the drought, the total effects of the drought on Alameda Creek cannot be assessed.

Future studies could also include (1) a more flexible sampling schedule to allow for sampling during significant hydrologic events, (2) a randomly equal sampling at all stations, (3) use of an EWI (equal width interval) method of sampling surface water (Skougstad and others, 1979), and (4) analysis for major ions and total nutrients (organic and inorganic) at all established stations.

SUMMARY

The results of this study indicate that in Alameda Creek the water quality, as represented by mean values of physical properties and chemical constituents, improved from the upstream tributary Arroyo de la Laguna to Alameda Creek near Niles and the Niles Cone Ground Water Recharge Facility. The mean values of physical properties and chemical constituents are greater at Arroyo de la Laguna, which is downstream of most wastewater discharges but upstream of major imported water releases, than at other sites in the Alameda Creek drainage basin. Imported water of a better quality than that found in the Alameda Creek basin is released to Arroyo Valle, Vallecitos Creek, and occasionally to Alameda Creek at Sunol. The imported water mixes with water from Arroyo de la Laguna and dilutes the concentrations of chemical constituents.

The drought of 1976-77 brought about the most noticeable temporal change in the water quality of Alameda Creek. At Alameda Creek near Niles specific conductance and concentrations of dissolved solids, dissolved chloride, and total nitrate decreased acutely during the spring and summer of 1976 when imported water releases were greatest and increased dramatically during 1977 (the second year of the drought) when imported water releases decreased. Increased physical-property and chemical-constituent values during 1976 and 1977 at Arroyo de la Laguna are most likely attributed to decreased natural runoff and hence a greater contribution of wastewater treatment plant effluent to streamflow at this location. With the return of normal flows during 1978-79, some concentrations returned to predrought levels. Water-quality degradation in Alameda Creek was assessed by comparing concentrations of constituents with State water-quality objectives. Several constituents, including dissolved solids, chloride, and nitrate, did not meet the objectives.

SELECTED REFERENCES

American Public Health Association and others, 1976, Standard methods for the examination of water and wastewater (14th ed.): New York, American Public Health Association, 1151 p.

Brown and Caldwell, 1972, Water quality management plan for the Alameda Creek watershed above Niles: Consultant's final report to a group of water and sewerage agencies in the Alameda Creek basin, 205 p.

California Department of Water Resources, 1964, Alameda Creek watershed above Niles: Chemical quality of surface water, waste discharges, and ground water: Federal-State Cooperative Water Quality Investigation, 122 p., and appendixes.

California State Water Resources Control Board, 1975, Water quality control plan, San Francisco Bay basin: California Regional Water Quality Control Board, San Francisco Bay Region, May 1975. 2 parts.

Consoer-Bechtel, 1972, Water quality management plan for south San Francisco Bay: Consultant's final report to the Association of South Bay Dischargers, 13 chapters and appendixes.

Dixon, W. J., and Massey, F. J., 1969, Introduction to statistical analysis: New York, McGraw-Hill Inc., 638 p.

Helwig, J. T., and Council, K. A., eds., 1979, SAS user's guide: Raleigh, N.C., SAS Institute, Inc., 475 p.

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

Morgan, C. O., and McNellis, J.M., 1969, Stiff diagram of water-quality data programmed for the digital computer: Kansas Geological Survey Specially Distributed Publication 43, 27 p.

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

U.S. Geological Survey, 1976-81, Water resources data for California, water years 1975-79, Volume 2, Pacific slope basins from Arroyo Grande to Oregon state line except Central Valley: U.S. Geological Survey Water-Data Reports CA 75-2, 515 p.; CA 76-2, 499 p.; CA 77-2, 544 p.; CA 78-2, 566 p.; CA 79-2, 509 p.

SUPPLEMENTAL DATA

SUPPLEMENTAL DATA--WATER-QUALITY DATA SUMMARY BY STATION, OCTOBER 1974-JUNE 1979

		Properties and constituents								
		Streamflow (ft^3/s)			Specific conductance (μmho/cm at 25°C)			pH (units)		
Station No.	Water-quality station	Number of measurements	Mean	Range	Number of samples	Mean	Range	Number of samples	Mean	Range
				Surface Water						
11174200	Alameda Creek at Sunol	4	56.5	24-96	39	414	222-1,040	38	8.2	7.4-9.0
11174600	Alamo Canal near Pleasanton.	184	3.32	0.01-44	241	1,330	255-2,900	13	7.4	7.0-8.3
11174610	Dublin-San Ramon Services District Wasteway.	58	6.54	3.4-65	1,242	1,400	800-2,000	33	7.2	5.8-9.7
11176150	Arroyo Las Positas near Livermore.	18	8.64	2.5-26	48	1,670	160-6,040	7	7.6	7.2-8.0
11176160	Livermore Treatment Plant Wasteway.	--	--	--	706	1,310	830-1,960	219	6.7	3.0-9.8
11176350	Arroyo de la Laguna above Arroyo Valle.	205	14.7	0.3-190	231	1,190	230-1,690	221	7.6	6.7-8.5
11176600	Arroyo Valle at Pleasanton.	76	14.4	[1]0.1-41	87	448	197-707	82	7.9	7.0-8.6
11177200	Vallecitos Creek at Sunol	167	17.4	0.02-72	242	587	195-1,240	231	8.1	6.2-9.0
11177300	Sinbad Creek at Sunol	29	6.69	0.2-56	50	519	207-735	49	8.2	7.0-9.0
11178400	Stonybrook Creek near Niles.	63	5.06	0.1-58	66	650	233-968	64	8	7.0-9.0
11179000	Alameda Creek near Niles	1,252	40.4	4.8-900	940	841	248-1,710	815	8.2	6.0-10.0
11179010	Niles Reservoir at Niles	--	--	--	174	534	333-710	166	8.1	6.6-9.3
11179040	Kaiser Pit at Niles	--	--	--	235	798	179-1,120	224	8.6	6.4-11.0
11179050	Shinn Pit at Niles	--	--	--	230	811	451-1,240	227	9	6.7-11.0
				Niles Cone Wells						
373349121585701	4S/1W-28D9	--	--	--	145	721	529-924	142	7.6	6.2-9.5
373355121583801	4S/1W-21P6	--	--	--	119	722	553-968	114	7.8	6.4-8.8
373357121591401	4S/1W-20R2	--	--	--	218	798	562-1,500	210	7.5	5.6-8.5
373424121584501	4S/1W-21F2	--	--	--	145	841	600-1,120	137	7.4	6.2-8.5

[1]One extreme value of 365 ft^3/s not included.

Station No.	Temperature (°C)			Turbidity (NTU)			Biochemical oxygen demand (mg/L)			Total coliform bacteria (col/100mL)			
	Number of samples	Mean	Range	Number of samples	Mean	Range	Number of samples	Mean	Range	Number of samples	Mean: Arith-metic	Mean: Geo-metric	Range
Surface Water													
11174200	39	15.8	6-29	39	18	1.6-150	--	--	--	34	2,200	870	40-24,000
11174600	12	19	10-25	236	9.7	1-160	195	4	1-56	162	10,300	1,900	2-720,000
11174610	25	20.8	14-25	1,274	1.3	0.1-25	126	4	2-7	114	4	2	2-110
11176150	5	16.3	9-25	38	55	1-450	19	4	0-11	35	31,200	7,400	62-240,000
11176160	236	22.2	14-29	713	5.0	0.4-140	72	5	0-13	269	41	4	2-2,400
11176350	209	18.3	7-30	212	19	1-100	--	--	--	216	23,100	6,900	21-240,000
11176600	84	16.8	5-25	83	12	0.5-55	--	--	--	77	3,000	1,400	17-46,000
11177200	183	14.8	3-25	188	15	0.5-580	--	--	--	178	4,300	1,700	20-110,000
11177300	47	13.1	6-23	48	22	0.3-340	--	--	--	45	2,500	1,100	200-24,000
11178400	63	12.4	6-17	63	16	0.3-300	--	--	--	61	2,200	910	150-35,000
11179000	984	15.6	6-28	883	15	1-650	1	3	--	1,144	5,900	2,100	0-240,000
11179010	171	15.6	9-24	177	9.4	0-70	--	--	--	166	190	17	2-4,300
11179040	226	18.4	6-27	230	9.3	1-35	--	--	--	218	120	20	2-2,400
11179050	228	18.7	10-29	231	9.5	1-60	--	--	--	218	190	30	2-3,300
Niles Cone Wells													
373349121585701	147	17.8	12.5-24	63	1.1	0.4-7	--	--	--	61	3	2	2-22
373355121583801	122	18.4	15.5-22	21	1.2	0.2-6.4	--	--	--	25	2	2	2-2
373357121591401	223	18.3	14-24	102	1.2	0.3-10	--	--	--	106	390	21	2-3,300
373424121584501	146	18.1	15-21	62	1.2	0.4-6.4	--	--	--	67	3	2	2-22

Station No.	Hardness (mg/L) Number of samples	Hardness (mg/L) Mean	Hardness (mg/L) Range	Dissolved chloride (mg/L) Number of samples	Dissolved chloride (mg/L) Mean	Dissolved chloride (mg/L) Range	Dissolved solids (mg/L) Number of samples	Dissolved solids (mg/L) Mean	Dissolved solids (mg/L) Range
				Surface Water					
11174200	39	186	100-260	38	27	12-150	39	270	193-662
11174600	243	416	70-670	247	180	13-630	247	827	135-1,480
11174610	1,283	248	160-450	1,282	190	120-260	1,274	881	550-1,180
11176150	40	300	76-790	49	290	26-1,400	50	1,050	84-3,180
11176160	615	196	110-420	687	190	110-370	713	762	164-1,140
11176350	239	256	110-390	237	180	48-370	235	731	202-1,080
11176600	88	163	76-280	88	47	6-82	88	276	139-419
11177200	244	140	60-260	245	100	16-320	236	337	126-758
11177300	50	237	92-340	50	30	12-100	50	355	210-497
11178400	66	294	110-470	66	25	3-42	66	453	240-714
11179000	1,680	199	60-350	1,683	120	30-1,100	1,678	481	125-855
11179010	180	240	140-350	180	35	14-84	178	347	210-927
11179040	238	206	130-320	239	130	11-280	233	486	205-776
11179050	239	205	120-290	241	130	7-270	234	485	236-660
				Niles Cone Wells					
373349121585701	153	237	190-330	152	107	60-180	149	444	247-712
373355121583801	131	260	210-410	130	80	46-170	126	419	291-609
373357121591401	227	234	100-300	228	125	72-230	223	477	303-659
373424121584501	149	267	180-360	149	121	72-220	144	504	335-713

Station No.	Nitrate, total as N (mg/L)			Ammonia nitrogen, dissolved as N (mg/L)		
	Number of samples	Mean	Range	Number of samples	Mean	Range
Surface Water						
11174200	39	1.4	0-7.7	5	0	0-0.10
11174600	233	1.1	0.1-29	139	0.20	0-1.0
11174610	1,204	25	0.2-39	145	0.20	0-4.2
11176150	21	2.1	0.8	20	0.90	0-4.2
11176160	278	23	2.1-45	69	1.2	0-9.2
11176350	230	17	1.4-35	18	0.90	0-5.6
11176600	84	1.5	0-10	6	0	0-0.10
11177200	235	1.9	0-14	16	0	0-0.20
11177300	50	1.6	0.2-6.3	5	0	0-0
11178400	66	1.5	0.1-6.3	5	0	0-0.10
11179000	1,641	7.1	0.7-22	73	0.10	0-1.2
11179010	173	3.7	0.7-7.9	14	0	0-0.10
11179040	232	4.3	0.2-15	17	0.10	0-1.8
11179050	233	3.7	0-16	14	0	0-0.20
Niles Cone Wells						
373349121585701	145	2.6	1-6.5	--	--	--
373355121583801	125	2.5	1-5.2	--	--	--
373357121591401	216	3.0	0.2-10	--	--	--
373424121584501	145	4.3	0.3-9.1	--	--	--

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