SUSPENDED SEDIMENT IN SAN FRANCISCO BAY ESTUARY, CALIFORNIA -- RECENT HISTORY AND AVAILABLE DATA SETS

By David H. Peterson, Marlene Noble, and Richard E. Smith

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ILLUSTRATIONS

CONVERSION FACTORS

Multiply	By	To obtain
cm (centimeter)	0.3937	inch
km (kilometer)	0.6214	mile
m (meter)	3.281	foot
m^2 (square meter)	10.76	square foot
mm (millimeter)	0.03937	inch

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ABSTRACT

On interannual, seasonal, and tidal time scales, little is known of how sediment dynamics in the bay are influenced by fluctuations in riverine emissions. This report describes and refers to the available data (on personal computer disks) on the suspended sediment (turbidity) and related oceanographic measurements of the bay for 1979 (low riverine emissions) and 1980 (high riverine emissions). These observations provide a basis for subsequent analyses.

INTRODUCTION

On a time scale of decades and centuries, riverine sediment emissions clearly have been a major control on sedimentary processes in San Francisco Bay. Up to the time of early European settlement of California, natural sources of riverine sediment could not keep pace with rising sea level. After the mid - 1800s gold rush, however, effects of hydraulic mining and reclamation activities such as diking, draining, and land filling offset the effects of rising sea level, and in less than 140 years the bay's surface area has shrunk back to where it was about 5,000 years ago.

Although hydraulic mining ceased a century ago, the need to better understand the balance or imbalance between rising sea level and natural and artificial emissions of riverine sediment remains. This interest is motivated largely by the chronic shoaling of ship channels and the subsequent maintenance-dredging problems. Not all human activities cause an increase riverine emissions of sediment. Concentrations of suspended sediment in the Sacramento River downstream of the American River appear to have decreased after completion of Oroville Dam on the Feather River (1967).

This is the first in a planned series of reports on the nature of suspended sediment and its variability in San Francisco Bay estuary. This report provides a broad geologic perspective of the regional setting of the bay and its recent history regarding sediments and references the "raw" data available for the study (Appendix I). Subsequent planned reports will provide a hydroclimatic perspective, methods of analysis, and documentation of supportive data not provided in this report; describe results of field observations of suspended sediment concentrations in the bay (turbidity) and associated atmospheric, hydrologic and oceanographic observations; and provide a broad overview and summary of our findings of suspended sediment dynamics in the bay.

Background

A quantitative knowledge of the dynamics of suspended sediments in San Francisco Bay is critical to advancing our knowledge of several major processes that relate to both the dynamics of and the management policies affecting San Francisco Bay. Some of these processes/policies include:

1). the need to develop a long-term strategy for resolving chronic shoaling in ship channels (San Francisco Bay Conservation and Development Commission, 1966),

2). the ultimate fate of disposed dredged material,

3). the characterization of the nature and origin of water column turbidity over a range of time and spatial scales. The turbidity of the water column is a control through light limitation on the productivity of phytoplankton. Turbidity data are also needed for defining the transport and disposition of hydrophobic and other toxic substances in the bay, 4). the effects of a long-term rise in sea level (San Francisco Bay Conservation and Development Commission, 1987 and 1988).

Objectives and Approach of This Study

Most studies of the physics of sediment transport in San Francisco Bay have been done over short periods of time at a specific location, where the increase and decrease of suspended sediment concentrations are monitored over several tidal cycles. These studies largely trace a resuspension/deposition process. Deposition is enhanced during slack water and resuspension occurs during peak tidal flows. The resuspended sediments move seaward on the ebb tide and landward on the flood. Net movement of sediment occurs when the ebb and flood movements are not symmetric, because of either asymmetric tidal currents or net non-tidal currents moving either up or down the river. The amount of asymmetry at any one location is site specific and can vary over seasonal time scales. This is one reason why the details of sediment transport over an entire estuary are very difficult to model.

The primary objective of this study is to analyze a set of tidal current data and resuspended sediment data that were collected over a broad region of the northern Bay for periods of as much as a year (fig. 1). An objective is to look for the hypothesized seaward transport of suspended material between Suisun Bay and San Pablo Bay during the winter, when the flow down the river reaches a peak, and the hypothesized landward transport in summer, when river flow is low (fig. 2). The primary riverine suspended sediment source is considered to be the Sacramento River; local stream sources were not considered but can be very important on a local scale (Porterfield, 1980). A secondary, but related objective is to quantify the space/time variability of the suspended sediment concentrations as a function both of tidal current amplitude and storms. Of main interest is how these concentrations vary among the measurement sites.

The primary data set used in this study was collected by the Kinnetics Laboratory Incorporated (1981) Santa Cruz, Calif., under contract to the U.S. Army Corps of Engineers. Records of water clarity, currents, salinity, temperature, and sea level were collected at six locations during 1979 and 1980 (fig. 1). We also used wind, sea level, and river flow data collected in the region for the same time period.

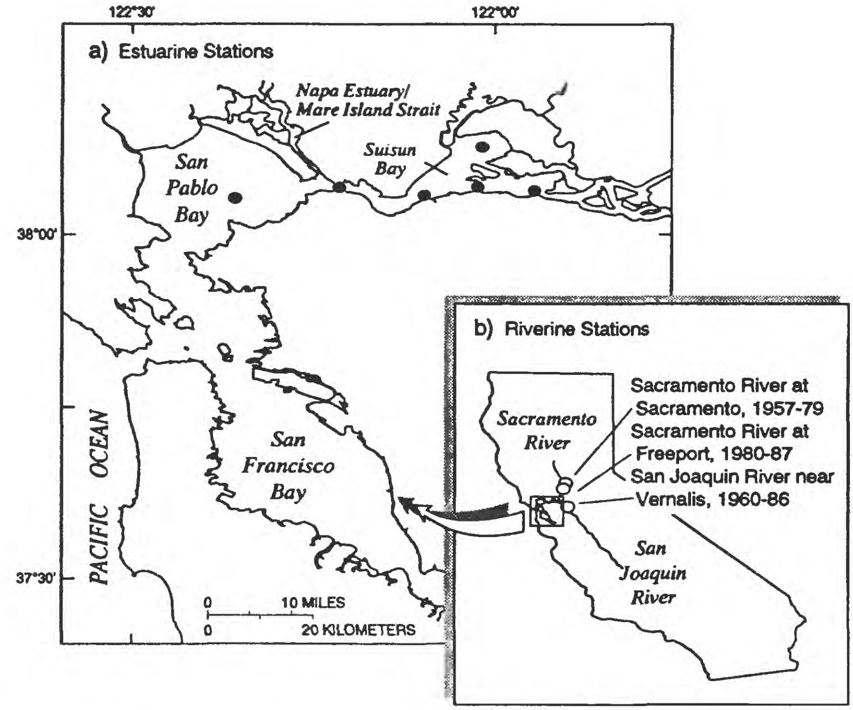

***Figure 1.-** Study area and locations of a) estuarine and b) riverine stations.*

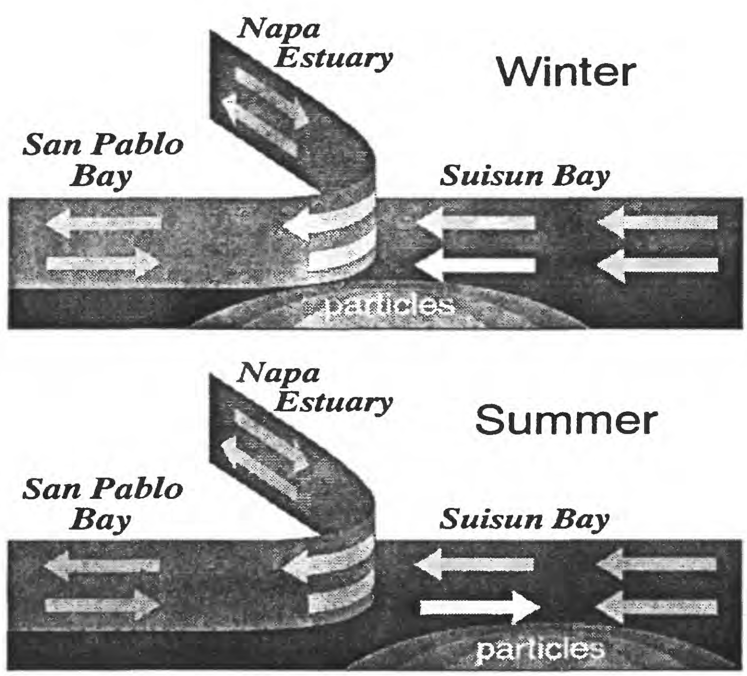

Figure 2.- *Idealized diagram of winter-summer shift in circulation and suspended sediment particles in Northern San Francisco Bay.*

Acknowledgments

The cover illustration is adapted from Edwards and Batson (1990). Assistance from Patrick Kinney, Kinnetic Laboratories regarding data documentation is appreciated.

AN OVERVIEW OF THE HISTORY OF SEDIMENTS IN THE SAN FRANCISCO BAY

About three decades ago a "save the bay" movement originated largely because it was visibly evident that the estuary was losing area either because of the development of marshes and other nearshore regions or because of sedimentation. For this reason, it seems instructive to discuss the bay's sediment history from the perspective of a longer time frame, perhaps even a geologic-time scale.

A Geologic Perspective

Before European settlement, riverine sediment sources did not keep pace with the rise in sea level and the bay shoreline expanded. In about the last 5,000 years, sea level in the San Francisco Bay rose 8 meters and simultaneously the Bay shoreline retreated about 2,000 meters, but the retreat varied widely with location (Atwater, 1979, p.41, fig. 6). To consider the effects of such a large sea level rise on shoreline retreat, we will simplify the changes in the sea level, shoreline, riverine sediment sources, and the bottom sediment (figs. 3 and 4). Over about the last 5,000 years, sea level rose 8 meters and about 6.5 meters of bottom sediment accumulated . Consequently the water depth increased about 1.5 meters. The relative rate of sea level rise, approximately 0.16 cm per year over the last 5,000 years (fig. 3), is virtually the same as the rate observed with instruments over the last century (Krone, 1979). Note also that today's shoreline is very close to its position about 5,000 years ago (Atwater, 1979). Human actions, principally diking, reclamation of marsh and intertidal land, and hydraulic mining, have pushed back the shoreline in 140 years to where it was 5,000 years ago. An exception is a large area in the northern part of South San Francisco Bay, suggesting erosion or nonaccumulation (or a tectonic history that differs from that of the rest of the Bay). Until high resolution seismic profiling records of bottom sediments are available, we are limited to broad generalizations regarding the bay's sedimentary history.

Gross assumptions regarding retreating shoreline (fig. 4) include: 1) the slope for present shoals is approximately 2,000 meters per 1.5 meters rise (Conomos, 1979, fig. 3, p. 51); 2) the natural sediment supply to the Bay is 2 million cubic yards of bottom sediment equivalent (Gilbert, 1917, cited by Porterfield, 1980), for an area of the bay of 343 square miles, (U.S. Geological Survey, 1962, p. 35), which implies a uniform rate of sediment accumulation of about 0.13 centimeters per year; and 3) a relative rate of sea level rise of about 8 meters over the last 5,000 years (Atwater, 1979 fig. 6, p. 41). Also, the shoreline retreat was not uniform: the shoreline retreat for steep-sided narrows was generally small, whereas it was large for low-lying broad valley/shoals (Atwater and others, 1979). Gross assumptions regarding advancing shoreline (fig. 4) include a sediment accumulation rate of about 1 centimeter per year [350 milligrams per square centimeter per year (Conomos and Peterson, 1977 Table 1, p. 85)] and a water content of bottom sediment of about 70 percent by weight, or about 15 million cubic yards of bottom sediment equivalent per year.

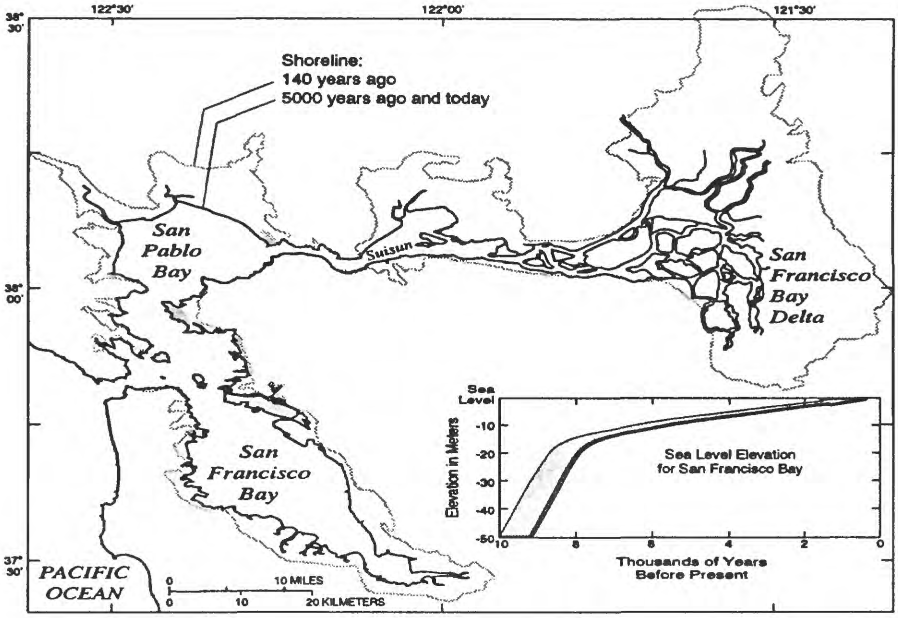

Figure 3.- The present (solid line) and 1850 (hatched patterns) shorelines of the San Francisco Bay (Modified from Nichols and Pamatmat, 1988). Inset is sea level rise based on carbon 14 dates of peat (Modified from Atwater, 1979).

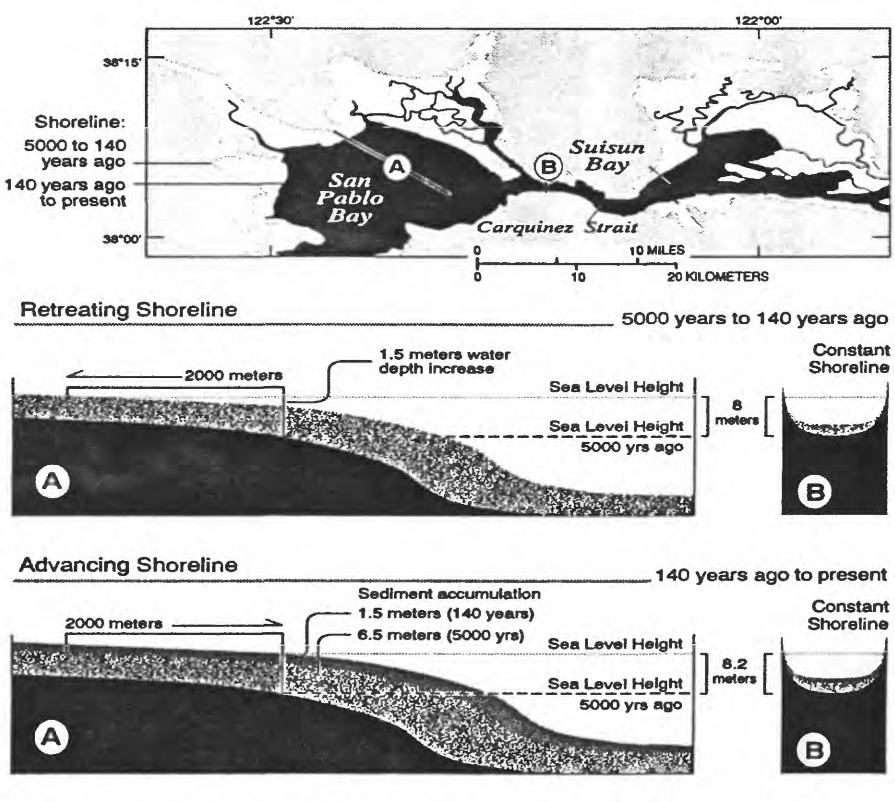

***Figure 4.-** Idealized scenario of retreating (5000 years to 140 years ago) shoreline and advancing (140 years ago to present) shoreline.*

Effects of Hydraulic Mining

Human-caused increases in riverine sediment emissions, principally the result of hydraulic mining, overwhelmed effects of rising sea level and resulted in contraction of the shoreline of San Francisco Bay. The shoreline position of 5,000 years ago is considered close to today's shoreline position (Nichols and Pamatmat, 1988, p.5, fig. 3, panels A and B). Thus, to change the shoreline back to where it was 5,000 years ago, about 1.5 meters of sediment must have accumulated in the shallow marshes created when sea level rose. This 1.5 meters of sediment accumulated in about 140 years, which is remarkable considering that it took more than 1,000 years to accumulate an equivalent amount before 1850. The rate of sediment accumulation thus increased by almost an order of magnitude.

As Nordhoff (1874, p. 112) describes:

"Already, however, the Yuba, the Feather, and the American rivers, tributaries of the Sacramento, have been leveed at different points for quite another reason. These rivers, once clear and rapidly flowing within deep banks, are now turbid, in many places shallow, and their bottoms have been raised from twenty to thirty feet by the accumulation of the washings from the gold mines in the foothills. It is almost incredible the change the miners have thus produced in the short space of a quarter of a century. The bed of the Yuba has been raised thirty feet in that time; and seeing what but a handful of men have effected in so short a period, the work of water in the denudation of mountains, and the scouring out or filling up of valleys during geological periods becomes easily comprehensible."

Van Winkle and Eaton (1910) describe a similar phenomenon on the Yuba River:

"For the lower 10 miles of its course in the foothills the bed of the (Yuba) river is badly clogged with debris from hydraulic mining camps and is held between levees which have been raised from year to year to meet the overflow caused by the filling up of the area between them. The channel of the river in the lower foothills has been filled with cobbles and bowlders to a depth of more than 100 feet."

The above effects are widely known (and qualitatively shown in fig. 5). Further, it is well understood that the effects of hydraulic mining were seen for many years after the mining ended. Gilbert (1917) estimated that an average of 18 million cubic yards of sediment was transported annually to the San Francisco Bay during 1849-1914. In fact Gilbert estimated that the effects of hydraulic mining would continue for 50 years after 1914, with an average annual sediment transport of 8 million cubic yards. It is interesting that Gilbert's sediment transport estimate was close to some estimates from field observations that were made 50 years later (Porterfield, 1980).

To summarize, in less than 140 years this extraordinary release of sediment volume counteracted the shoreline retreat from 5,000 years of rising sea level by moving the shorelines back to their position of 5,000 years ago and in some places even further (figs. 1 and 2).

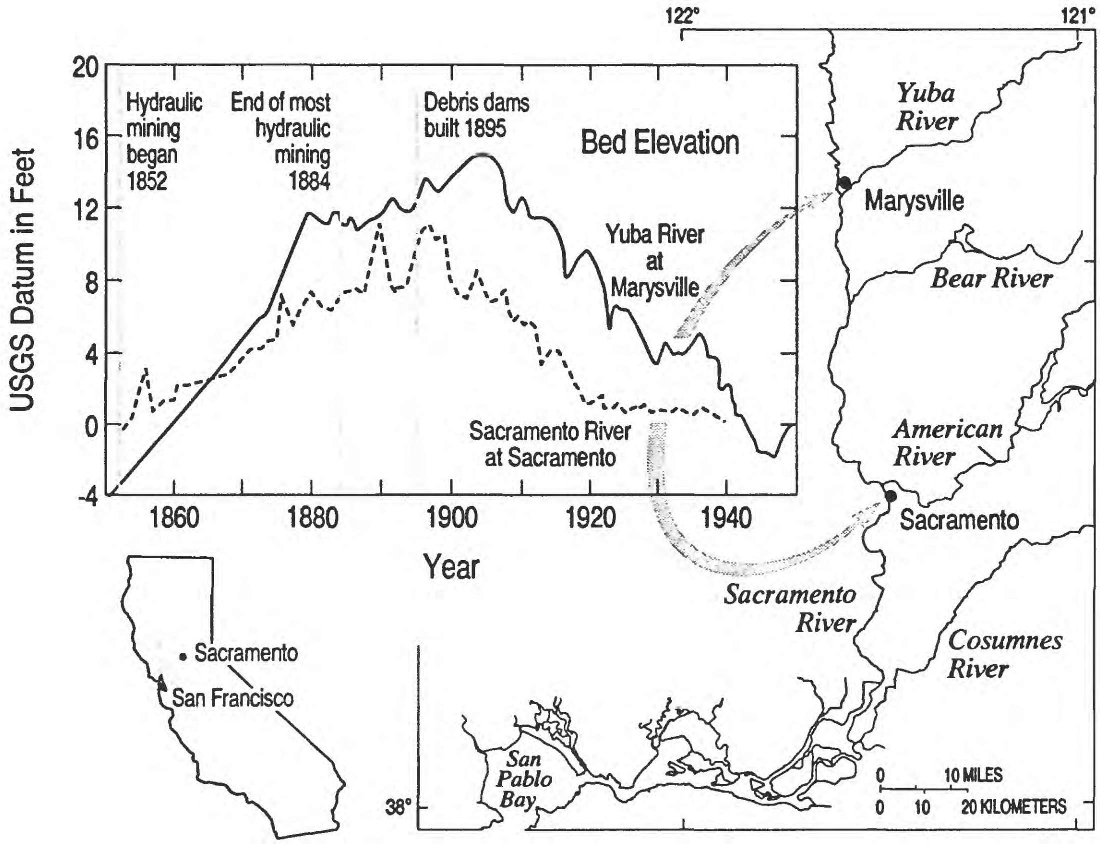

Figure 5.- Changes in bed elevation of the Yuba and Sacramento Rivers (Modified from Bureau of Reclamation, 1987, fig. 5, p. 17).

Effects of Dams

At least on a time scale of decades and centuries, the mass emissions of riverine sediments are a major control on sediment dynamics in the bay. Although century-old effects of hydraulic mining have presumably attenuated with time, new sources of sediments have been released into the river systems as a result of urbanization, agricultural activity, and deforestation. New sinks for sediments have also been created. Dams have caused downstream reductions in sediment mass emissions by trapping river borne sediments (fig. 6). Time series observations of suspended sediments in the Sacramento River appear to follow a step function change since construction of the large Oroville Dam (fig. 6); although the probable reduction appears less clear in observations (fig. 7) than in noise-free simulations (fig. 8; note details of the simulations are in Appendix 2).

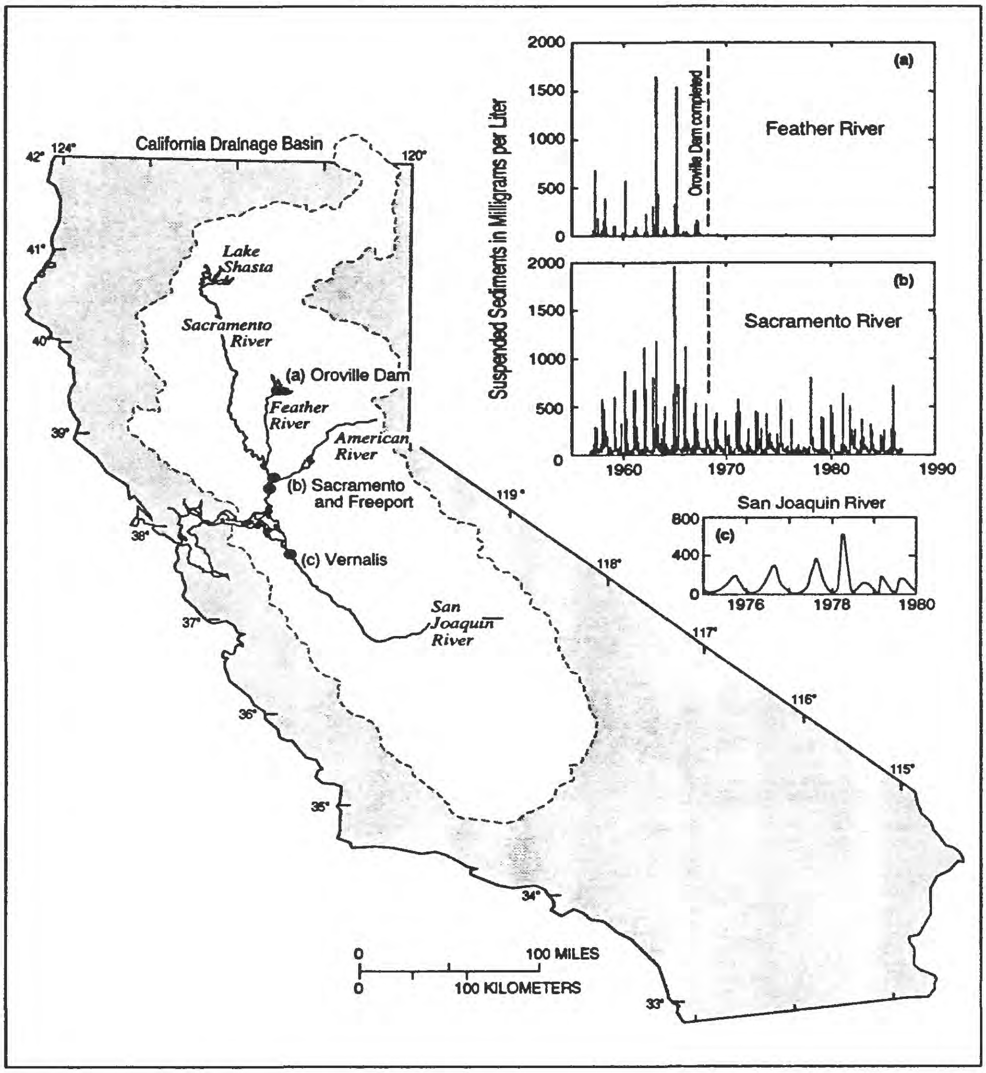

Figure 6. - Sacramento/San Joaquin River basin and time series of suspended sediment concentrations for the (a) Feather River (note effects of the Oroville Dam construction); (b) Sacramento River; and (c) San Joaquin River.

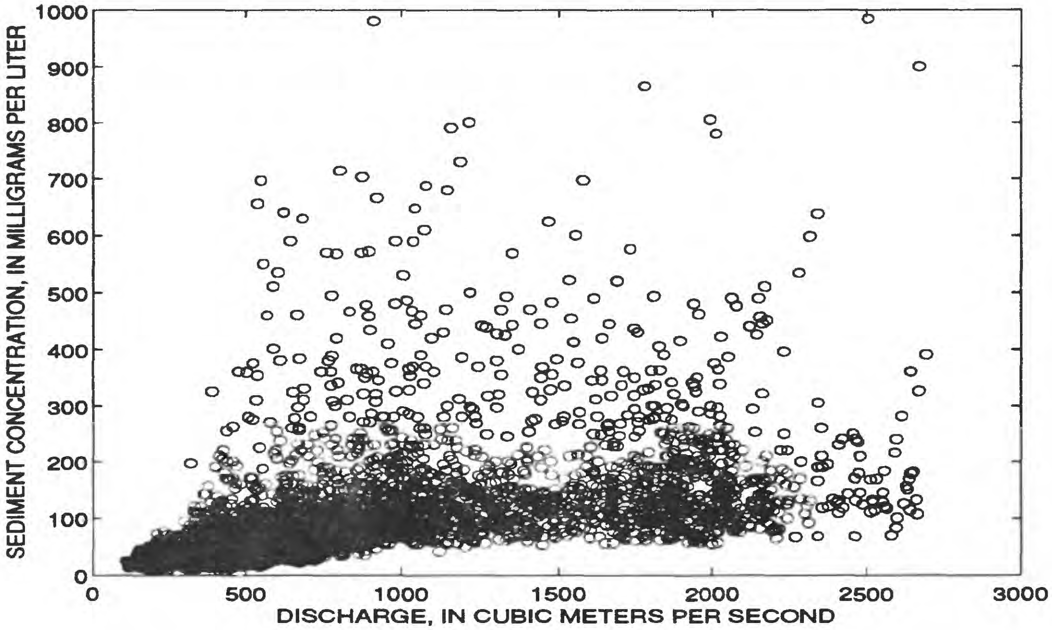

Figure 7.- Relation of daily suspended sediment concentrations for the Sacramento River at Sacramento to actual river discharge, water years 1957-1979. Red is pre-Oroville; Black is post-Oroville.

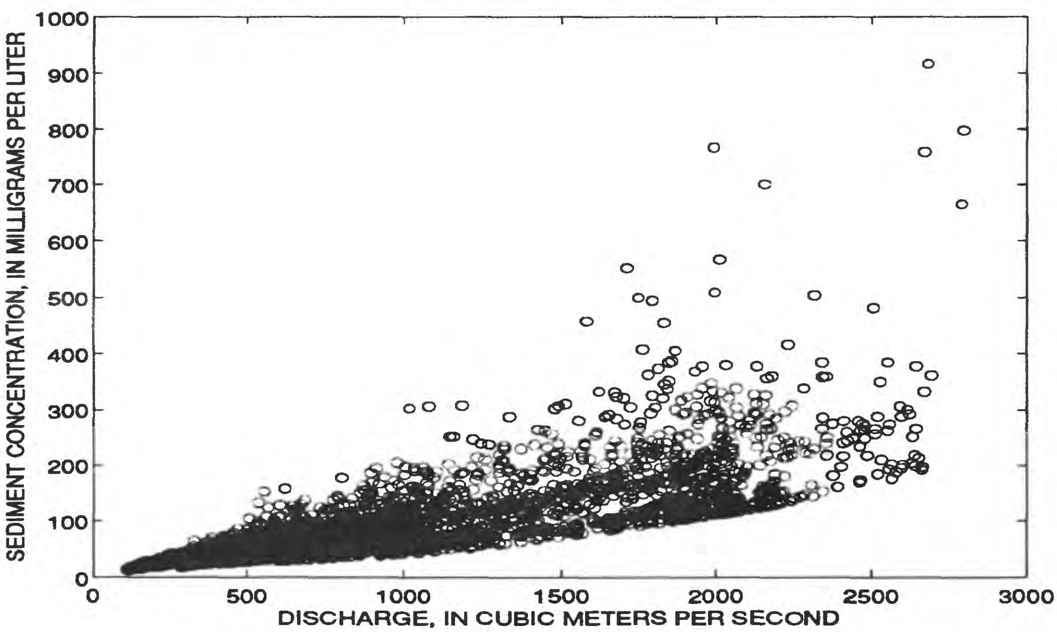

Figure 8.- Relation of simulated daily suspended sediment concentrations for the Sacramento River at Sacramento to actual river discharge, water years 1957-1979. Red is pre-Oroville; Black is post-Oroville.

Effects of Agriculture

The effects of agriculture on annual sediment concentrations and emissions is more obscure for the Sacramento River than for the San Joaquin River because of the large dilution effects in the Sacramento River and complications caused by the Yolo Bypass (the Yolo Bypass is used as an additional river channel during peak river flows to control floods). In fact, the San Joaquin River shows nearly an inverse in expected response of sediment concentrations with flow. Highest concentrations occur in dry years during the summer period of maximum agricultural return flow (with the exception of the first winter storm). Note, for instance, panel (C) in fig 6. The summers of 1976 and 1977 (dry) show higher sediment concentrations than 1978 (wet), with the exception of the early winter storm for 1978.

SUMMARY

The brief sketch of sediment history in this report provides a perspective for analyzing and interpreting the observations of Kinnetics Laboratory for 1979 (low Sacramento River flow) and 1980 (high Sacramento River flow). Sediment emissions from the Sacramento - San Joaquin River, influenced by hydraulic mining, dams and agriculture are a major control on long-term variations in San Francisco Bay's sediment history. It is also recognized that the small highly -urbanized streams that surround the bay are important sources of sediment, but on a more local scale. Therefore, the importance of local sources were not included in this brief overview.

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APPENDIX I

DATA COLLECTED BY KINNETICS LABORATORY

Documentation of personal computer floppy disc copies of the Data collected by Kinnetics Laboratory 1979/1980 at stations 1-6 (Fig. 1) in San Francisco Bay.

Records identified in this appendix are on file discs as IBM-compatible 5 1/4" floppy : c/o Michael Carlin, San Francisco Regional Water Quality Control Board, 1111 Jackson Street, Room 6040, Oakland, California 94607.

TAPE NAME KL10 2
APPROX. SAMPLING DATES 39-79, 1979 (JULIAN DAYS)

STATION 1 SAN PABLO		
PC FILE NAME:	KLI0 2 1.LOG	SIZE: 464233
STATION 2 CARQUINEZ		
PC FILE NAME:	KLI0 2 2.LOG	SIZE: 367473
STATION 3 BENICIA		
PC FILE NAME:	KLI0 2 3.LOG	SIZE: 388793
STATION 4 PORT CHICAGO		
PC FILE NAME:	KLI0 2 4.LOG	SIZE: 403461
STATION 5 CHIPPS ISLAND		
PC FILE NAME:	KLI0 2 5.LOG	SIZE: 405101
STATION 6 GRIZZLEY BAY		
PC FILE NAME:	KLI0 2 6.LOG	SIZE: 152604

NO. OF 1.2 MB FLOPPIES 2; NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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APPROX. SAMPLING DATES 78-109, 1979
TAPE DENSITY 800 (JULIAN DAYS)

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STATION 2 CARQUINEZ
PC FILE NAME: KLLI0 3 2.LOG SIZE: 184449

STATION 3 BENICIA
PC FILE NAME: KLI0 _ 3.LOG SIZE:

STATION 4 PORT CHICAGO
PC FILE NAME: KLI0 _ 4.LOG SIZE:

STATION 5 CHIPPS ISLAND
PC FILE NAME: KLI0 _ 5.LOG SIZE:

STATION 6 GRIZZLEY BAY
PC FILE NAME: KLLI0 _ 6.LOG SIZE:

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 1 NO. OF FILES: 2

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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STATION 3 BENICIA		
PC FILE NAME:	KLI0 4 3.LOG	SIZE: 324741
STATION 4 PORT CHICAGO		
PC FILE NAME:	KLI0 4 4.LOG	SIZE: 321461
STATION 5 CHIPPS ISLAND		
PC FILE NAME:	KLI0 4 5.LOG	SIZE: 328275
STATION 6 GRIZZLEY BAY		
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DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 2 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

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1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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STATION 3 BENICIA		
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STATION 4 PORT CHICAGO		
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STATION 5 CHIPPS ISLAND		
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STATION 6 GRIZZLEY BAY		
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DATE AND NUMBER OF 1.2 MB FLOPPIES		
NO. OF FLOPPIES 2 NO. OF FILES: 6		

Thirteen Columns of Data on the Floppy Disks:

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2	Water Depth	9	Salinity
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4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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Thirteen Columns of Data on the Floppy Disks:

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3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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STATION 5 CHIPPS ISLAND
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STATION 6 GRIZZLEY BAY
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DATE AND NUMBER OF 1.2 MB FLOPPIES
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6	Year	13	Sample
7	Current Speed		

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Column	Content	Column	Content
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3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

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PC FILE NAME: KLI1 1 2.LOG SIZE: 19701

STATION 3 BENICIA
PC FILE NAME: KLI1 1 3.LOG SIZE: 14961

STATION 4 PORT CHICAGO
PC FILE NAME: KLI1 1 4.LOG SIZE: 147730

STATION 5 CHIPPS ISLAND
PC FILE NAME: KLI1 1 5.LOG SIZE: 144342

STATION 6 GRIZZLEY BAY
PC FILE NAME: KLLI1 1 6.LOG SIZE: 45989

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 1 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 12
APPROX. SAMPLING DATES 332-365, 1979 (JULIAN DAYS)

STATION 1 SAN PABLO
PC FILE NAME: KLI1 2 1.LOG SIZE: 202559

STATION 2 CARQUINEZ
PC FILE NAME: KLI1 2 2.LOG SIZE: 162379

STATION 3 BENICIA
PC FILE NAME: KLI1 2 3.LOG SIZE: 203379

STATION 4 PORT CHICAGO
PC FILE NAME: KLI1 2 4.LOG SIZE: 196821

STATION 5 CHIPPS ISLAND
PC FILE NAME: KLI1 2 5.LOG SIZE: 203429

STATION 6 GRIZZLEY BAY
PC FILE NAME: KLLI1 2 6.LOG SIZE: 67259

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 1 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 13
APPROX. SAMPLING DATES 1-15, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO		
PC FILE NAME:	KLI1 3 1.LOG	SIZE: 90219
STATION 2 CARQUINEZ		
PC FILE NAME:	KLI1 3 2.LOG	SIZE: 73871
STATION 3 BENICIA		
PC FILE NAME:	KLI1 3 3.LOG	SIZE: 173039
STATION 4 PORT CHICAGO		
PC FILE NAME:	KLI1 3 4.LOG	SIZE: 178826
STATION 5 CHIPPS ISLAND		
PC FILE NAME:	KLI1 3 5.LOG	SIZE: 177959
STATION 6 GRIZZLEY BAY		
PC FILE NAME:	KLLI1 3 6.LOG	SIZE: 60699

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 1 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 14
APPROX. SAMPLING DATES 29-58, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO	
PC FILE NAME: KLI1 4 1.LOG	SIZE: 4941
STATION 2 CARQUINEZ	
PC FILE NAME: KLI1 4 2.LOG	SIZE: 334581
STATION 3 BENICIA	
PC FILE NAME: KLI1 4 3.LOG	SIZE: 346061
STATION 4 PORT CHICAGO	
PC FILE NAME: KLI1 4 4.LOG	SIZE: 273951
STATION 5 CHIPPS ISLAND	
PC FILE NAME: KLI1 4 5.LOG	SIZE: 334581
STATION 6 GRIZZLEY BAY	
PC FILE NAME: KLLI1 4 6.LOG	SIZE 114821
DATE AND NUMBER OF 1.2 MB FLOPPIES	
NO. OF FLOPPIES 2 NO. OF FILES: 6	

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 15A
APPROX. SAMPLING DATES 58-85, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO
PC FILE NAME: KL1 5A 1.LOG SIZE: 2479

STATION 2 CARQUINEZ
PC FILE NAME: KL1 5A4 2.LOG SIZE: 167340

STATION 3 BENICIA
PC FILE NAME: KL1 5A 3.LOG SIZE: 160739

STATION 4 PORT CHICAGO
PC FILE NAME: KL1 5A 4.LOG SIZE: 78739

STATION 5 CHIPPS ISLAND
PC FILE NAME: KL1 5A 5.LOG SIZE: 162379

STATION 6 GRIZZLEY BAY
PC FILE NAME: KLL1 5A 6.LOG SIZE: 54959

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 1 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 16
APPROX. SAMPLING DATES ___, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO
PC FILE NAME: KLI1 6 1.LOG SIZE: 483821

STATION 2 CARQUINEZ
PC FILE NAME: KLI1 6 2.LOG SIZE: 359181

STATION 3 BENICIA
PC FILE NAME: KLI1 6 3.LOG SIZE: 403507

STATION 4 PORT CHICAGO
PC FILE NAME: KL1 6 4.LOG SIZE: 134554

STATION 5 CHIPPS ISLAND
PC FILE NAME: KL1 6 5.LOG SIZE: 429701

STATION 6 GRIZZLEY BAY
PC FILE NAME: KLI1 6 6.LOG SIZE 147621

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 2 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 17
APPROX. SAMPLING DATES 119-158, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO		
PC FILE NAME:	KLI1 7 1.LOG	SIZE: 16421
STATION 2 CARQUINEZ		
PC FILE NAME:	KLI1 7 2.LOG	SIZE: 415113
STATION 3 BENICIA		
PC FILE NAME:	KLI1 7 3.LOG	SIZE: 392030
STATION 4 PORT CHICAGO		
PC FILE NAME:	KL1 7 4.LOG	SIZE: 200156
STATION 5 CHIPPS ISLAND		
PC FILE NAME:	KL1 7 5.LOG	SIZE: 298560
STATION 6 GRIZZLEY BAY		
PC FILE NAME:	KLI1 7 6.LOG	SIZE: 132861
DATE AND NUMBER OF 1.2 MB FLOPPIES		
NO. OF FLOPPIES 2 NO. OF FILES: 6		

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

TAPE NAME KL10 18
APPROX. SAMPLING DATES ___, 1980 (JULIAN DAYS)

STATION 1 SAN PABLO
PC FILE NAME: KLI1 8 1.LOG SIZE: 5028

STATION 2 CARQUINEZ
PC FILE NAME: KLI1 8 2.LOG SIZE: 360821

STATION 3 BENICIA
PC FILE NAME: KLI1 8 3.LOG SIZE: 362461

STATION 4 PORT CHICAGO
PC FILE NAME: KL1 8 4.LOG SIZE: 371554

STATION 5 CHIPPS ISLAND
PC FILE NAME: KL1 8 5.LOG SIZE: 360192

STATION 6 GRIZZLEY BAY
PC FILE NAME: KL1 8 6.LOG SIZE: 122622

DATE AND NUMBER OF 1.2 MB FLOPPIES
NO. OF FLOPPIES 2 NO. OF FILES: 6

Thirteen Columns of Data on the Floppy Disks:

Column	Content	Column	Content
1	Station	8	Current direction
2	Water Depth	9	Salinity
3	Water Depth From Bottom	10	Temperature
4	Time of Day	11	Turbidity
5	Julian Day	12	Sea level height
6	Year	13	Sample
7	Current Speed		

APPENDIX II

STATISTICAL MODEL OF SACRAMENTO RIVER SUSPENDED SEDIMENT CONCENTRATION

Suspended sediment concentrations appear to be lower in the Sacramento River after construction of the Oroville Dam (fig. 6, panels a and b). To examine this hypothesis a time series model was used to estimate deviations in daily Sacramento River suspended sediment concentrations (ss) from the long-term mean:

$$ss(1)=b(1)\ Flow(1) + a(2)\ ss(2) - a(3)\ ss(3) + Noise\ (1), \qquad (1)$$

where river flow is the deviation from long-term mean and the ss parameters are for the present day (1) flow and past day (2) and past two days (3) ss. Parameters were estimated using an instrumental variables method (Ljung, 1987; Ljung, 1988). These parameters and statistical properties of river flow and suspended sediment concentrations are in Table 1 (note: the coefficients are for log(e) transformed suspended sediment concentrations and flow).

The model used herein is not intended as an in-depth analysis but simply a compact way to describe more than 50% of the observed variance before and after the construction of Oroville Dam (Table 1). Time series of daily suspended sediment concentrations are exceedingly complex and numerous observations are needed for reliable estimates of suspended sediment concentrations and mass emissions (Goodwin and Denton, 1991). Equation (1) above, for example, does not capture the high suspended sediment concentrations associated with the first major storms of the winter season.

TABLE 1- - Model parameters and statistics

PROPERTIES/PARAMETERS[a]	PRE-OROVILLE (1957 - 1967)	POST-OROVILLE (1968 - 1979)
Mean flow (cubic meters per second)	592	686
Mean suspended sediment concentration (milligrams per liter)	81	64
a (2)	-1.26	-1.39
a (3)	0.67	0.71
b (1)	0.37	0.26
Modeled variance (percent of observed)	60	55

(a) Based on log(e) transform of sediment concentration and flow.