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SEDIMENTATION AND BATHYMETRY CHANGES IN SUISUN BAY: 1867-1990

by

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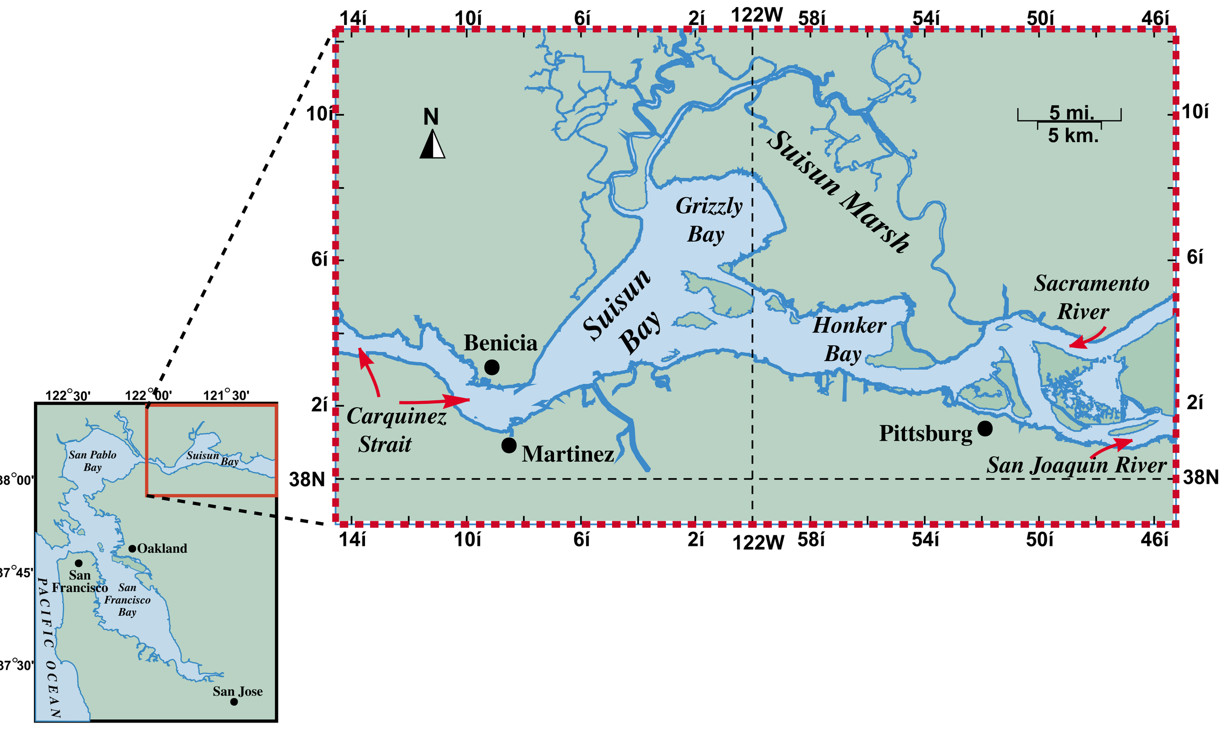
ABSTRACT

Understanding patterns of historical erosion and deposition in San Francisco Bay is crucial in managing such issues as locating deposits of sediment-associated contaminants, and the restoration of wetland areas. These problems were addressed by quantitatively examining historical hydrographic surveys.

The data from five hydrographic surveys, made from 1867 to 1990, were analyzed using surface modeling software to determine long-term changes in the sediment system of Suisun Bay and surrounding areas. A surface grid displaying the bathymetry was created for each survey period, and the bathymetric change between survey periods was computed by differencing these grids. Patterns and volumes of erosion and deposition, sedimentation rates, and shoreline changes were derived from the resulting change grids.

Approximately 115 million cubic meters of sediment were deposited in the Suisun Bay area from 1867 to 1887, the majority of which was debris from hydraulic gold mining in the Sierra Nevada. Just under two-thirds of the area of the study site was depositional during this time period, while less than one-third of it was erosional. However, over the entire study period, the Suisun Bay area lost sediment, indicating that a large amount of erosion occurred from1887 to 1990. In fact, this area lost sediment during each of the change periods between 1887 and 1990. Because erosion and deposition are processes that may vary over space and time, further analyses of more specific areas were done to examine spatial and temporal patterns.

The change in the Suisun Bay area from being a largely depositional environment to an erosional one is the result of a combination of several factors. These factors include the regulation and subsequent cessation of hydraulic mining practices, and the increase in flood control and water distribution projects that have decreased sediment supply to the bay by reducing the frequency and duration of peak flow conditions. Another pattern shown by the changing bathymetry is the substantial decrease in the area of tidal flat (defined in this study as the area between mean lower low water and the shoreline), particularly in Grizzly Bay and Honker Bay. These tidal flats are important to the bay ecosystem, providing stability and biologic diversity.

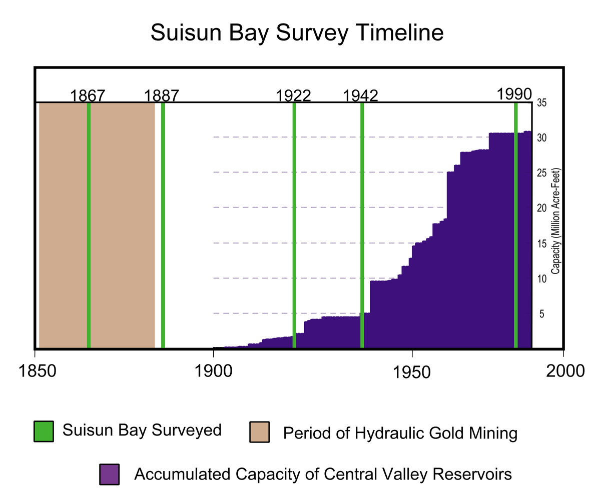


INTRODUCTION

Since the days of gold mining, sedimentation in San Francisco Bay has changed drastically. From 1853 until at least the late 1800's, debris from hydraulic mining in the Sierra Nevada was deposited in the bay (see adjacent time line). In 1884, the dumping of tailings from hydraulic gold mining was banned, which essentially killed the hydraulic mining industry. This act also greatly decreased the sediment supply to the bay. In the latter half of the 20th century, an increase in the implementation of flood control and water distribution projects in the Central Valley is what likely caused the bay to be erosional in nature due to the reduction of the frequency and duration of peak flow conditions, which in turn decreased sediment supply to the bay.

Suisun Bay, located in the northeast section of San Francisco Bay (see map at left), is part of the San Francisco Bay watershed and is the region of focus in this study. Because the study area includes not only Suisun Bay proper, but also Carquinez Strait, Grizzly Bay, Honker Bay, and the Sacramento and San Joaquin River mouths, for the purpose of this study the term Suisun Bay will refer collectively to these 5 areas.

Sedimentation is a basic control on many processes that affect the ecosystem including: (1) the transport of sediment to wetlands, which affects wetland health (2) erosion of wetlands (3) the redistribution of sediment, which may bury or expose trace metals and toxic sediments, thus affecting their bioavailability. Additionally, if sedimentation sufficiently alters topography, particularly in channels, flow patterns and tidal exchange can be affected, which in turn affects habitat distribution. This report details the change in sedimentation in Suisun Bay from 1867 to 1990 through the use of computer analysis, particularly Geographic Information Systems. These changes are based on historical hydrographic surveys (see adjacent time line) made by the U.S. Coast and Geodetic Survey (USCGS) and the National Ocean Survey (NOS).



METHODS

A continous surface representation (surface grid) of each bathymetric survey was created using Topogrid, an Arc/Info module that utilizes bathymetric sounding and contour information to create a hydrodynamically correct surface. Input data was a combination of point soundings and hand-drawn depth contours (see table below). Each historical bathymetric surface is defined by more than 200,000 grid cells (each cell is a 25 meter square). Bathymetric change grids showing erosion and deposition were generated by differencing bathymetric grids and applying vertical and horizontal corrections to bring surveys to a common datum (mean lower low water). Creation of accurate bathymetric grids involved several steps.

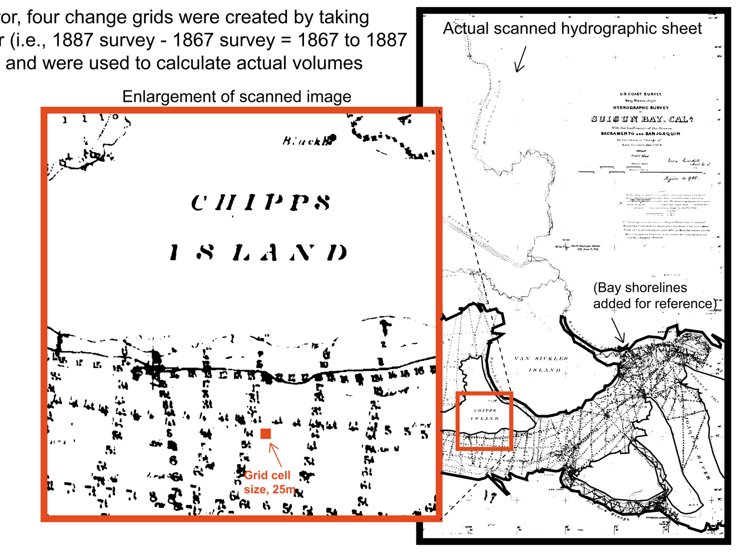
The data for the earlier survey years were taken from mylar copies of original 1:10,000 scale NOS Hydrographic Sheets (H-Sheets, see the example below). These annotated H-Sheets were scanned at 600 dpi and registered using Latitude/Longitude graticules and hard shoreline features shown in the National Wetlands Inventory. Point soundings and depth contours were digitized from the registered image. NOS contours were checked for accuracy and additional contours were added in areas where point soundings were sparse. For the 1942 survey, all of the sounding information was obtained digitally from the Geophysical Data System for Hydrographic Survey Data (GEODAS) compiled by NOS. The shoreline and contour information for the 1942 survey was obtained from hard copies of the H-Sheets. The sounding, shoreline, and contour information for the 1990 survey was obtained from GEODAS. Input data were gridded and the resulting surface compared to the input data to check for problem areas. The final step was re-gridding after modifying input data in areas where the interpolation process caused the grid to differ significantly from the original bathymetric data.

Once the bathymetric grids were revised to meet an acceptable level of error, four change grids were created by taking the difference between the bathymetric grids for each consecutive survey year (i.e., 1887 survey - 1867 survey = 1867 to 1887 change grid). These bathymetric change grids display erosion and deposition and were used to calculate actual volumes of sediment eroded or deposited once vertical and horizontal corrections were applied to bring surveys to a common datum (MLLW). The grids were used to identify patterns of change as well as to calculate sedimentation rates and net volume change for each time period.

The focus of this analysis was bathymetric change, not shoreline change. In some cases the H-Sheets have incomplete shoreline and marsh front information and were supplemented with shorelines from scanned USCGS Topographic Sheets (T-Sheets). Portions of the 1922 and 1942 Grizzly Bay shorelines are taken from the 1990 survey. In the future we plan to improve these estimates using additional marsh information from USCGS T-Sheets.

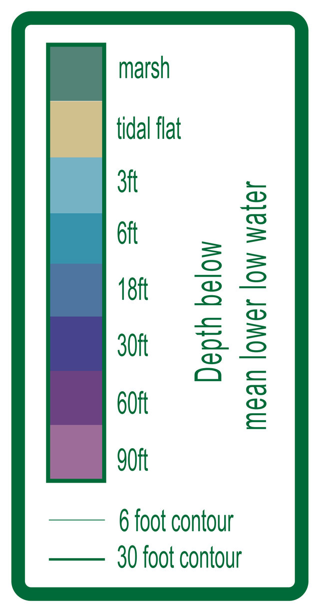
SUMMARY OF INPUT DATA

Year	# of soundings	Contour Depths (ft)
1867	18,202	-4, 0, 6, 12, 18, 30, 60, 90
1887	21,753	-4, 0, 6, 12, 18, 30, 60, 90
1922	17,303	-4, 0, 6, 12, 18, 30, 60, 90
1942	36,169	-4, 0, 6, 12, 18, 30, 60, 90
1990	93,303	-1, 2, 5, 10, 15, 20, 25, 30, 35, 45
		(1990 contours in meters)

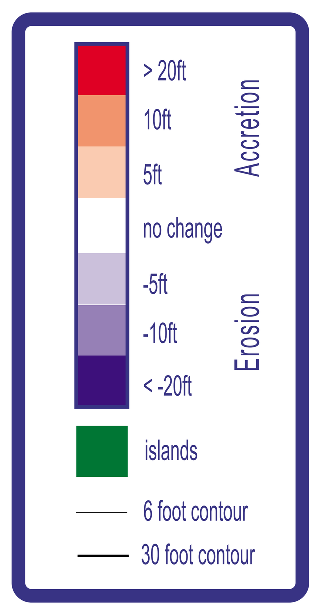


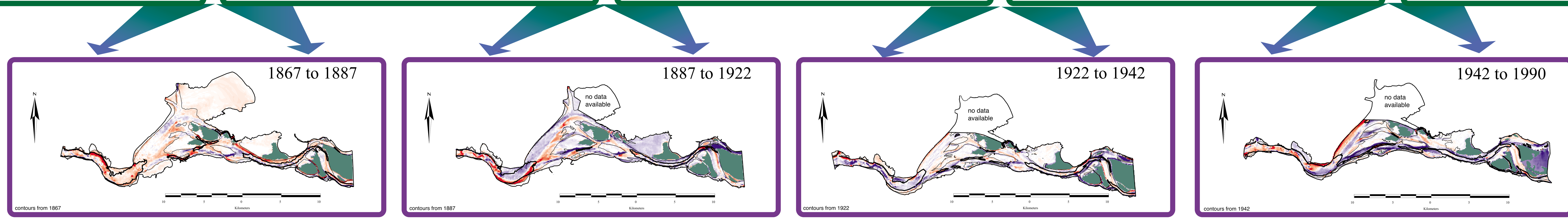
All hydrographic surveys conducted by U.S. Coast and Geodetic Survey

BATHYMETRY



BATHYMETRIC CHANGE





RESULTS

Sedimentation and Bathymetry Change

*Not including Grizzly Bay	1867-1887	1887-1922	1922-1942	1942-1990	1867-1990
Erosion (million cubic meters)	-42	-112	-92	-128	-219
Deposition (million cubic meters)	103	64	43	68	120
Net Volume Change (million cubic meters)	61	-48	-50	-61	-99
Change Rate (million cubic meters/year)	3	-1	-2	-1	-1
Sedimentation Rate (cm/square meters/year)	3.0	-1.4	-2.4	-1.2	-0.7
Area of Bay (square km)	102.51	102.58	102.82	107.75	109.21
% Erosional Area	30	63	55	60	63
% Depositional Area	58	32	35	33	34

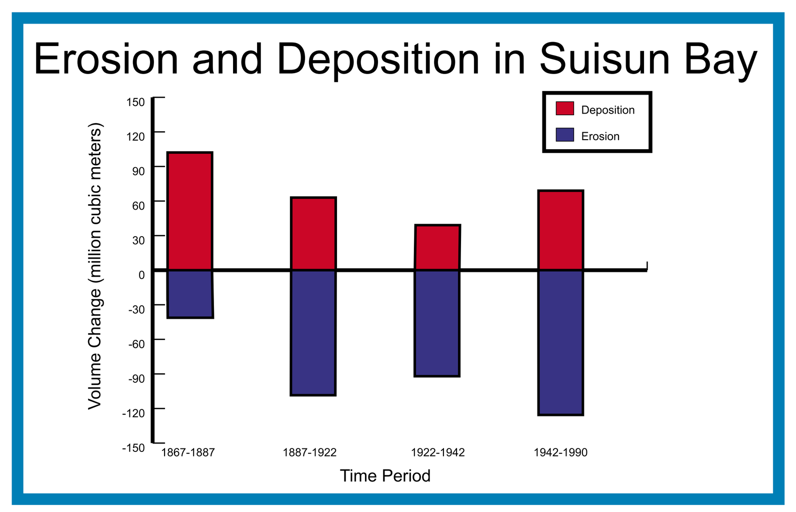
*Including Grizzly Bay	1867-1887	1887-1990	1867-1990
Erosion (million cubic meters)	-47	-262	-243
Deposition (million cubic meters)	115	87	135
Net Volume Change (million cubic meters)	68	-175	-108
Change Rate (million cubic meters/year)	3	-2	-1
Sedimentation Rate (cm/square meters/year)	2.5	-1.2	-0.6
Area of Bay (square km)	134.84	141.58	142.05
% Erosional Area	27	71	64
% Depositional Area	60	26	32

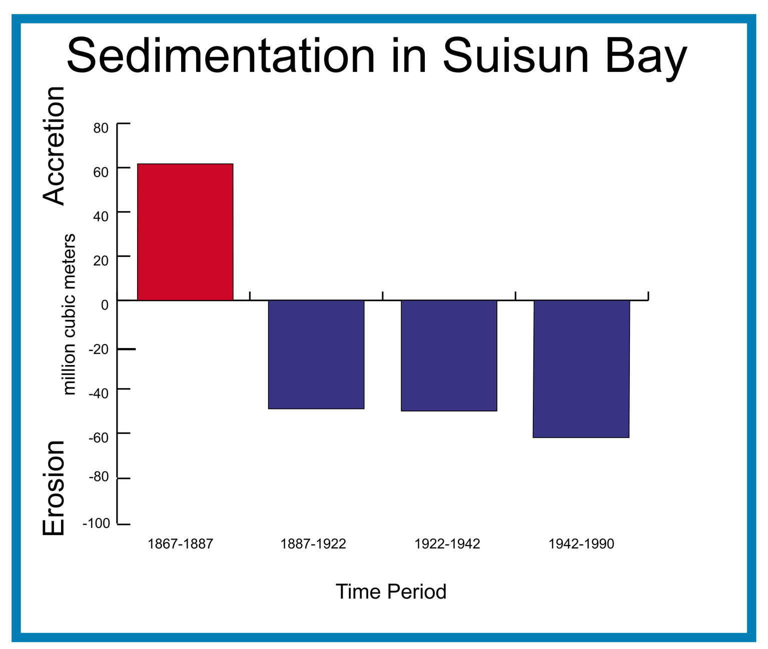
Tidal Flat Change

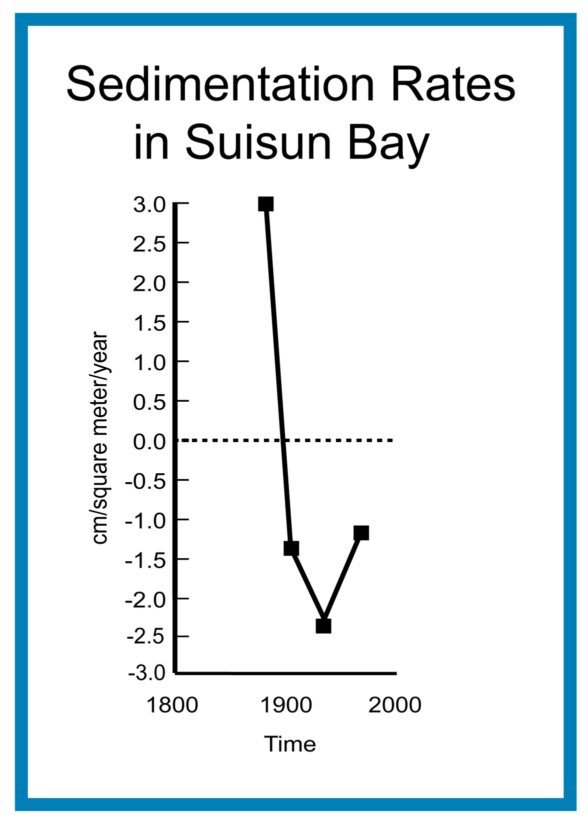
	1867	1887	1990
Area of Tidal Flat (square km)	41.00	52.16	12.08

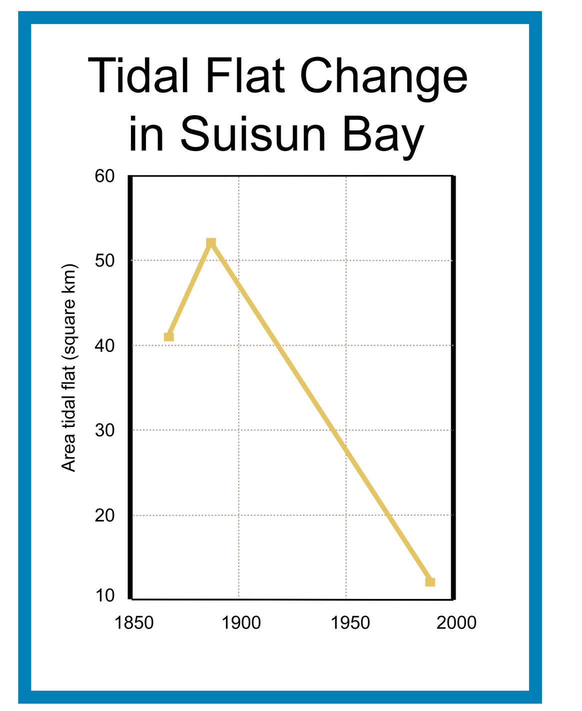
Island Change

	1867	1887	1922	1942	1990
Island Area (square km)	24.41	24.52	25.18	23.86	18.70
	1867-1887	1887-1922	1922-1942	1942-1990	1867-1990
Area Change Rate (square km/year)	0.005	0.019	-0.066	-0.108	-0.046









DISCUSSION

From 1867 (the year of the earliest detailed hydrographic survey of the area) until at least 1887, Suisun Bay was depositional in nature, and much of the sediment deposited was hydraulic mining debris. During this time period, approximately 115 million cubic meters of sediment was deposited in the study area. This is equivalent to about 2.5 cm/yr accumulation over all of Suisun Bay. Just under two-thirds of the area of Suisun Bay was depositional from 1867 to 1887, while less than one-third of it was erosional. From 1887 to 1990, Suisun Bay was erosional in nature, due to a decrease in sediment supply to the bay. This decrease was a result of factors such as the ban on dumping tailings from hydraulic mining that was passed in 1884, and the increase in water distribution and flood control projects during the 20th century. The actual volume of erosion increased slightly during each change period from 1887 to 1990. From 1887 to 1990, approximately 262 million cubic meters of sediment were eroded from the bay, which is equivalent to 1.2 cm/yr over the entire study area. Over the entire study period, Suisun Bay had a net loss of over 100 million cubic meters of sediment, which is equivalent to a loss of 73.8 cm over the entire Suisun Bay area. These changes in sedimentation in Suisun Bay affected its ecosystem in many ways. For example, the area of tidal flat, rich habitats and a source of sediment to the wetlands, increased by approximately 10 square km from 1867 to 1887 due largely to the input of hydraulic mining debris. From 1887 to 1990, the area decreased from 52 square km to 12 square km.

Future goals for this project include using historical bathymetry to identify which portions of the bay may contain contaminants from hydraulic mining debris near the surface of the bay floor. This has implications for the health of the bay because the elemental mercury associated with the mining debris will add to the existing mercury contamination problems of the bay (Jaffe, et al, 1999; Bouse, et. al, 1999). Future work will include the integration of this study with the data from San Pablo Bay (Jaffe, et. al, 1998) for a better understanding of sediment transport throughout Northern San Francisco Bay ecosystem.

CONCLUSIONS

From 1867 to 1887, Suisun Bay was depositional in nature due to the input of hydraulic mining debrIs. Approximately 115 million cubic meters of sediment were deposited in the bay during this time, which is equivalent to 2.5 cm/yr over all of Suisun Bay.

After 1887, Suisun Bay became erosional in nature, and the volume of erosion increased until 1990, the final year of this study. From 1887 to 1990, approximately 262 million cubic meters of sediment were eroded from the bay, which is equivalent to a loss of 1.2 cm/yr over the entire study area.

Over the entire study period, Suisun Bay had a net loss of over 100 million cubic meters, which is equivalent to a loss of 73.8 cm over the entire study area.

The area of tidal flat increased by approximately 10 square km from 1867 to 1887, and decreased from 52 square km to 12 square km from 1887 to 1990.

REFERENCES

Bouse, Robin, Luoma, Sam, Hornberger, Michelle, Jaffe, Bruce, and Smith, Richard. 1999. *Remobilization of Historical Metal Contaminants in San Francisco Bay Sediments.* Poster, 4th Biennial State of the Estuary Conference, San Francisco, CA.

Jaffe, Bruce, Smith, Richard, Cappiella, Karen, Bouse, Robin, Luoma, Sam, and Hornberger, Michelle. 1999. *Mercury-Contaminated Hydraulic Gold Mining Debris in North San Francisco Bay.* Poster, 4th Biennial State of the Estuary Conference, San Francisco, CA.

Jaffe, Bruce, Smith, Richard, and Torresan, Laura Zink. 1998. *Sedimentation and Bathymetric Change in San Pablo Bay: 1856-1983.* USGS Open-File Report #98-759.

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