U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 98-759
Version 1.0

Sedimentation and Bathymetric Change in San Pablo Bay: 1856–1983

by

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1998

ABSTRACT

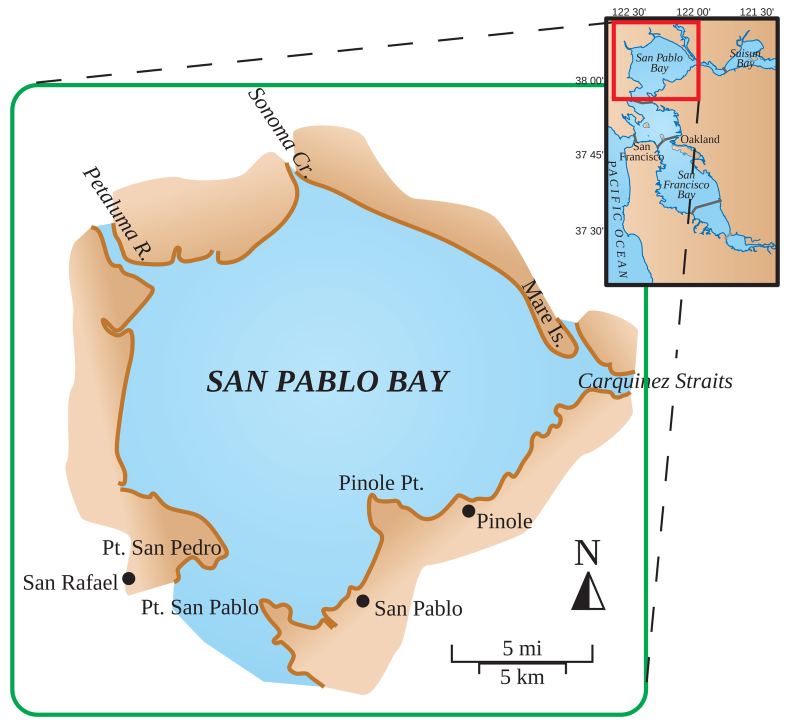
A long-term perspective of erosion and deposition in San Francisco Bay is vital to understanding and managing wetland change, harbor and channel siltation, and other sediment-related phenomena such as particle and particle-associated substance (pollutants, trace metals, etc.) transport and deposition. A quantitative comparison of historical hydrographic surveys provides this perspective. This report presents results of such a comparison for San Pablo Bay, California.

Six hydrographic surveys from 1856 to 1983 were analyzed to determine long-term changes in the sediment system of San Pablo Bay. Each survey was gridded using surface modeling software. Changes between survey periods were computed by differencing grids. Patterns and volumes of erosion and deposition in the Bay are derived from difference grids.

More than 350 million cubic meters of sediment was deposited in San Pablo Bay from 1856 to 1983. This is equivalent to a Bay-wide accumulation rate of approximately 1 cm/yr. However, sediment deposition was not constant over time or throughout the Bay. Over two-thirds of that sediment was debris from hydraulic mining that accumulated from 1856 to 1887. During this period, deposition occurred in nearly the entire Bay. In contrast, from 1951 to 1983 much of the Bay changed from being depositional to erosional as sediment supply diminished and currents and waves continued to remove sediment from the Bay. The decrease in sediment supply is likely the result of upstream flood-control and water-distribution projects that have reduced peak flows, which are responsible for the greatest sediment transport.

One consequence of the change in sedimentation was a loss of about half of the tidal flat areas from the late 1800's to the 1980's. Change in sedimentation must also have affected flow in the Bay, areas where polluted sediments were deposited, exchange of sediment between the nearshore and wetlands, and wave energy reaching the shoreline that was available to erode wetlands.

Further work is needed. Studies of historical wetland change and the relationship between change and man-made and natural influences would be valuable for developing sound wetland management plans. Additionally, extending the historical hydrographic and wetland change analyses eastward into Suisun Bay will improve the understanding of the North Bay sediment system.

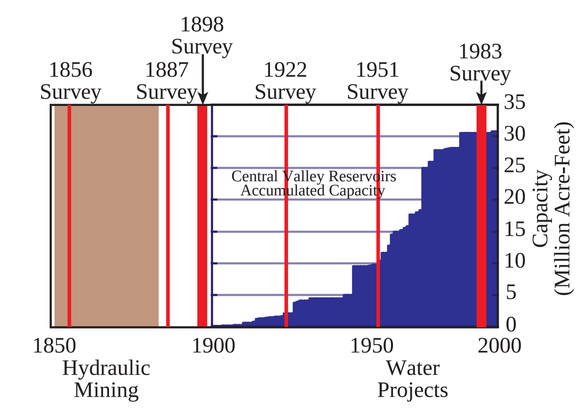


INTRODUCTION

Sedimentation in San Pablo Bay changed dramatically during the past 140 years. Two major factors, hydraulic gold mining in the foothills of the Sierra Nevada and Central Valley water projects, were largely responsible for this change. From 1856 (the earliest detailed hydrographic survey) until at least the late 1800's, debris from hydraulic mining was transported by rivers and the Delta and collected in San Pablo Bay. During the early 1900's sedimentation slowed and, in the late 1900's, San Pablo Bay was erosional as the supply of hydraulic mining debris decreased and Central Valley water projects diminished sediment supply to the Delta and Bay. This report presents a history of bathymetry and sedimentation in San Pablo Bay using computer analysis and display of historical hydrographic surveys made by the US Coast and Geodetic Survey (USCGS) and the National Ocean Survey (NOS).

A future step will be to apply this information to gain a better understanding of change in the San Francisco Bay ecosystem. Sedimentation is a basic control on many processes that affect the ecosystem including; (1) transport of sediment to wetlands (affecting wetland erosion and health), (2) flow patterns and tidal exchange if bathymetry, especially channels, are sufficiently altered (affecting habitat distribution), and (3) bioavailability of trace metals and toxic sediments (deposition of clean sediments will bury contaminated sediments or erosion can expose contaminated sediments).

SAN PABLO BAY SURVEY TIMELINE



METHODS

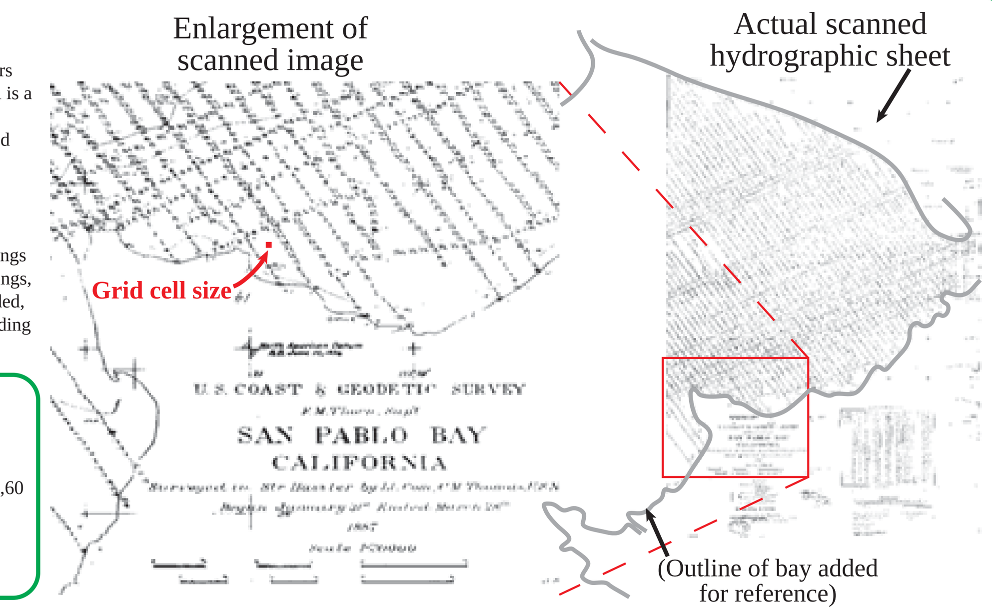
A continuous surface representation (surface grid) of each bathymetric survey was created using the Arc/Info Topogrid routine. Input data was a combination of point soundings and hand-drawn depth contours (see table below). Each historical bathymetric surface is defined by more than 300,000 grid cells (each cell is a 50-m square). Bathymetric change grids were generated by differencing bathymetric grids and applying vertical and horizontal corrections to bring surveys to a common datum. Creation of accurate grids involved several steps.

Starting with mylar copies of the original 1:20,000 scale NOS Hydrographic Sheets (H-Sheets, see the adjacent example), NOS contours were checked for accuracy and additional contours added in areas where point soundings were sparse. These annotated H-Sheets were scanned at 600 dpi and registered using Latitude/Longitude graticules and hard shoreline features in the National Wetlands Inventory. Point soundings and depth contours were digitized from the registered image. The existing NOAA/NOS database of soundings, supplemented by digitized depth contours, were used for the 1951 and 1983 surveys. Input data were gridded, and the grids compared to the input data to check for problem areas. The final step was regridding after adding point soundings and contours to force grids to accurately represent historical bathymetry.

The focus of this analysis was bathymetric change, not shoreline or marsh change. In most cases the H-Sheets have incomplete shoreline and marsh front information and were supplemented with shorelines from topographic sheets and from scanned, larger scale (1:40,000) navigation charts. Both the shoreline and marsh estimates could be improved by incorporating all available shoreline and marsh information from USCGS topographic sheets.

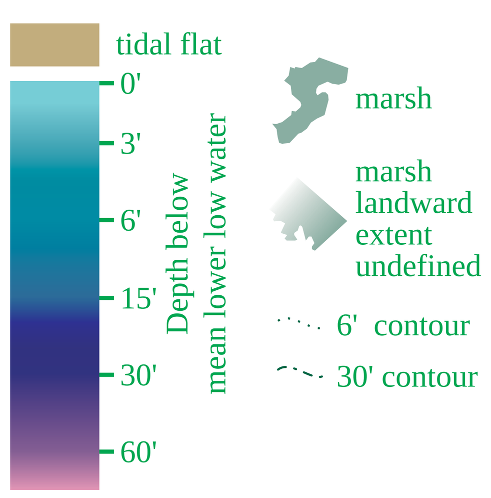
SUMMARY OF INPUT DATA

Year	# of soundings	Contour Depths (ft)
1856	4973	0,2,3,4,6,12,18,24,26,42,48,60
1887	3679	-1,0,1,2,3,4,5,6,7,9,12,24,30,36,48,60
1898	1994	0,3,6,12,18,24,30,36,60
1922	42764	-1,0,1,2,3,4,5,6,12,18,30,60
1951	62900	0,6,12,30,48
1983	65739	0,6,12,18,30,36,60

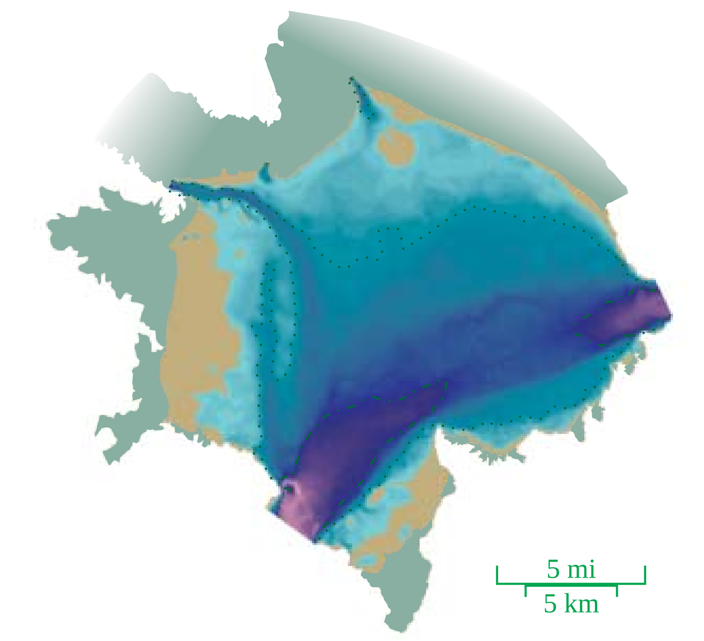


BATHYMETRY

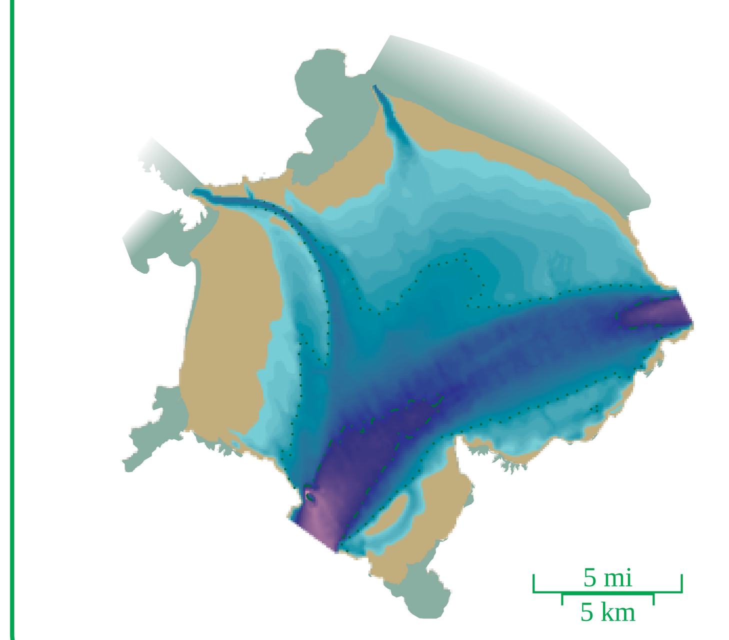
Explanation



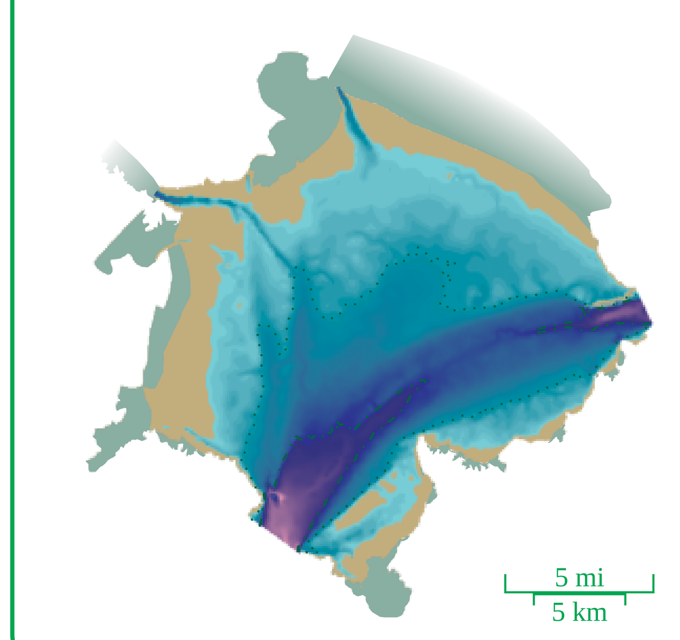
1856 SURVEY



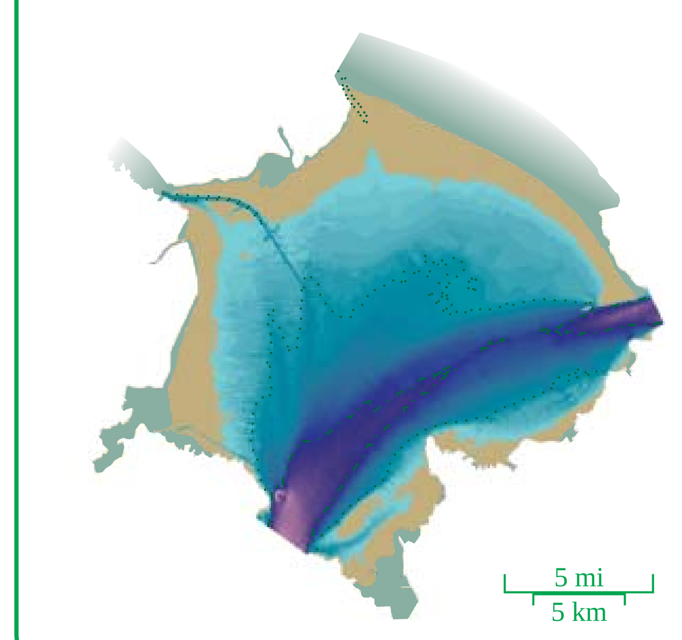
1887 SURVEY



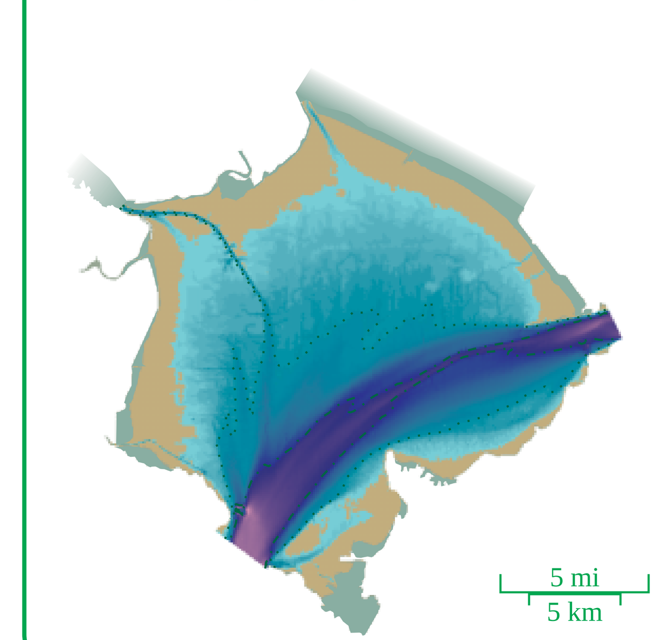
1898 SURVEY



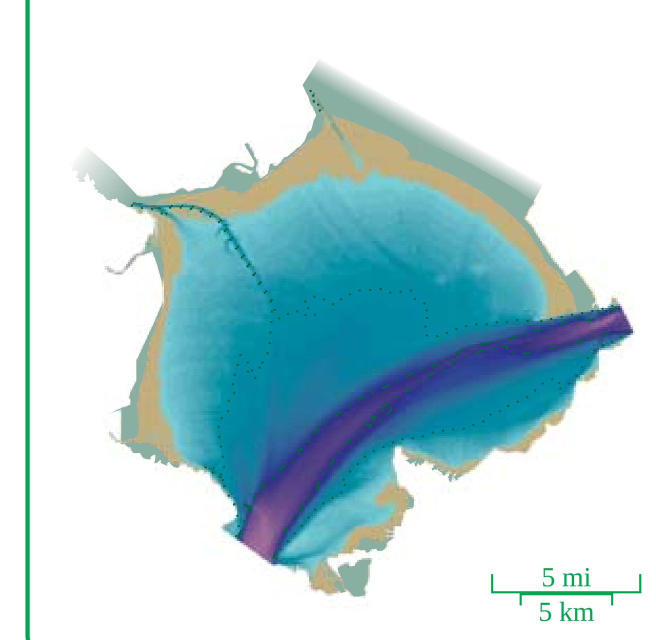
1922 SURVEY



1951 SURVEY

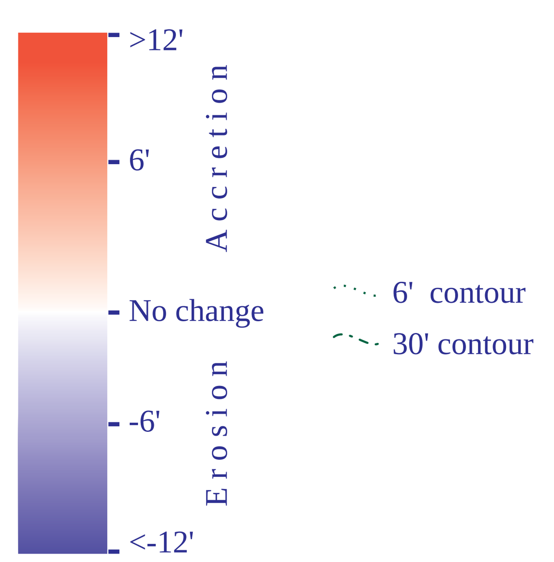


1983 SURVEY



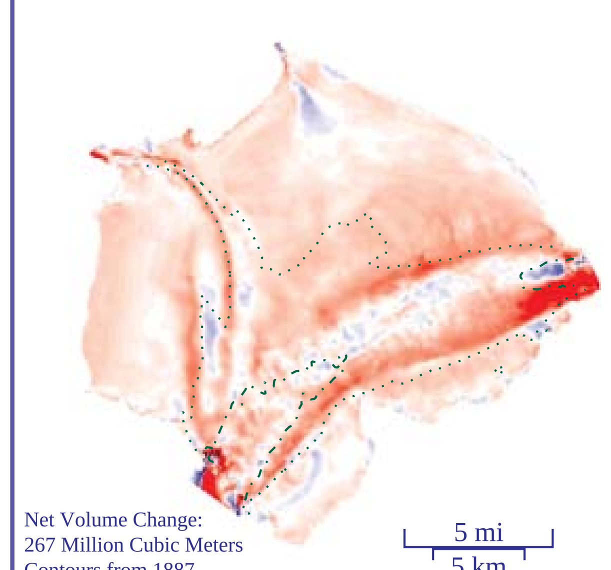
BATHYMETRIC CHANGE

Explanation



Net Volume Change, 1856 to 1983:
391 Million Cubic Meters

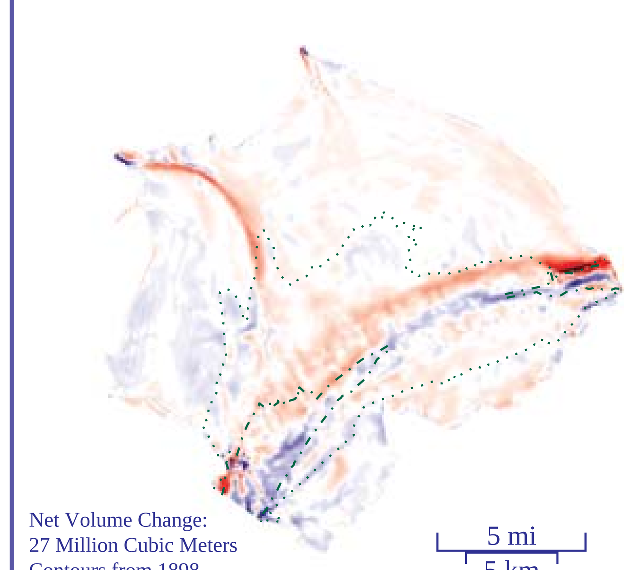
BATHYMETRIC CHANGE 1856 – 1887



Net Volume Change:
267 Million Cubic Meters
Contours from 1887

Massive quantities of sediment released by hydraulic gold mining in the Sierra Foothills entered San Pablo Bay. A volume of 267 million cubic meters (more than 8 million cubic meters a year on average) was deposited in San Pablo Bay. Some channel areas were filled with more than 4 meters (13 feet) of sediment. Isolated areas, primarily in the main channel, eroded (lost sediment). An abundant supply of sediment resulted in deposition in shallow areas and building of tidal flats. Tidal flat area doubled compared to pre-hydraulic mining times.

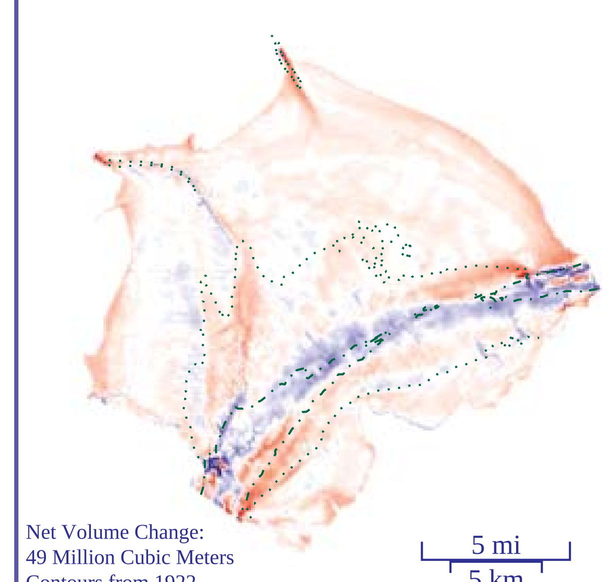
BATHYMETRIC CHANGE 1887 – 1898



Net Volume Change:
27 Million Cubic Meters
Contours from 1898

Hydraulic mining debris continued to fill San Pablo Bay, although the rate of filling decreased from the earlier period. A major factor in slowing deposition was the stoppage of hydraulic mining by Congress in 1884 that reduced the supply of sediment entering the Delta and San Francisco Bay. Even with stoppage of hydraulic mining, a volume of 27 million cubic meters (about 3 million cubic meters a year on average) was deposited in San Pablo Bay. Channels continued to fill, especially the Petaluma River channel in the northwest Bay. Much of the shallow area changed from depositional to either stable or erosional. Tidal flat area decreased by about 4,000 acres (about 330 acres lost each year on average). A large marsh formed on the shores of the west Bay.

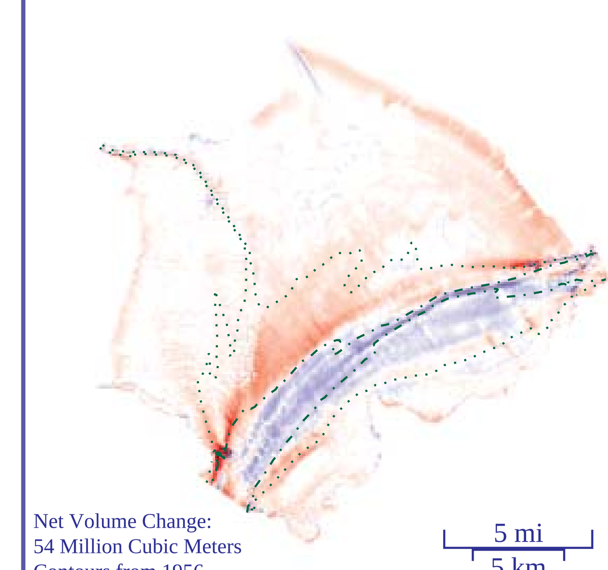
BATHYMETRIC CHANGE 1898 – 1922



Net Volume Change:
49 Million Cubic Meters
Contours from 1922

San Pablo Bay continued to fill with sediment. A volume of 49 million cubic meters (about 2 million cubic meters a year on average) was deposited in San Pablo Bay. Channel filling continued at a slower rate. The main channel deepened, and tidal flat area increased.

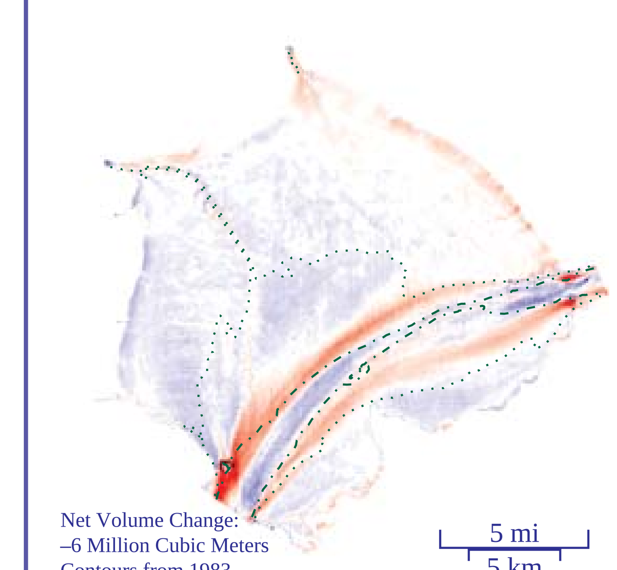
BATHYMETRIC CHANGE 1922 – 1951



Net Volume Change:
54 Million Cubic Meters
Contours from 1956

The rate of sedimentation was approximately the same as the preceding 20 years. A volume of 54 million cubic meters (about 2 million cubic meters a year on average) was deposited in San Pablo Bay. Channel filling primarily occurred on the northern portion of the main channel. The straight section of the 30' contour lines in the southeast delineates an area of dredging (less than one-quarter the length of the main channel). The main channel continued to deepen. Tidal flat area decreased slightly.

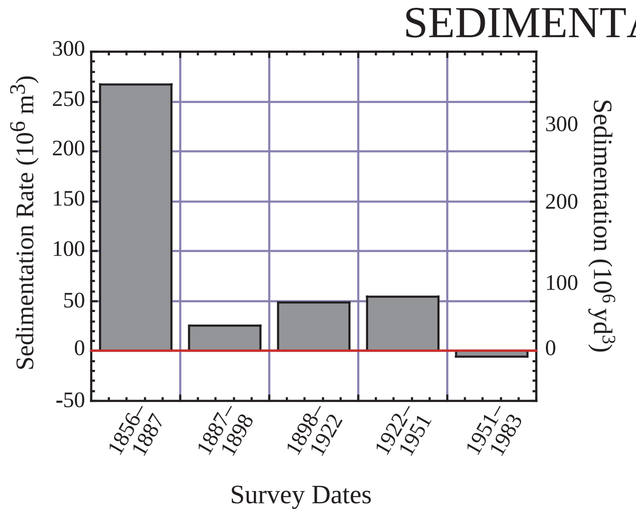
BATHYMETRIC CHANGE 1951 – 1983



Net Volume Change:
–6 Million Cubic Meters
Contours from 1983

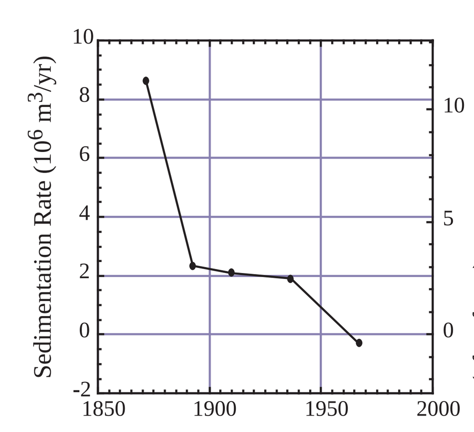
San Pablo Bay lost sediment during this period. This is in contrast to the previous 100 years when San Pablo Bay was filling with sediment. A volume of 6 million cubic meters (about one-quarter of a million cubic meters a year on average) eroded from San Pablo Bay. The Bay was erosional except for filling on the sides of the main channel and in the shallowest areas in the north and northeast Bay. The straight sections of the 30' contour lines in the southeast delineate an area of dredging (about one-quarter the length of the main channel). Tidal flat area decreased by about 4,200 acres (about 125 acres lost each year on average).

SEDIMENTATION



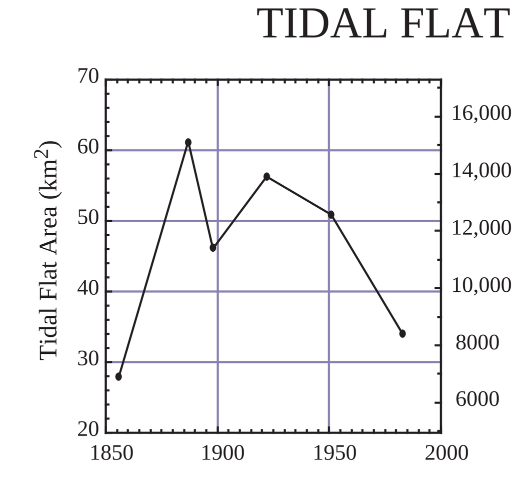
In the twenty-one years after the start of hydraulic mining of gold in the Sierra foothills massive quantities of sediment were washed down from the mountains to the Delta and San Francisco Bay. More than 250 million cubic meters of this sediment was deposited in San Pablo Bay. To give you a sense of how much material this is, it would take 10 dump trucks a second dumping their loads for 1 year to equal this volume. Sedimentation decreased in the following years and from 1951 to 1983, San Pablo Bay lost sediment. This was the first period we studied where San Pablo Bay lost sediment. One possible reason for the change from sediment accumulation to erosion is a decrease in sediment supply. The decrease in sediment supply is likely the result of upstream flood control and water distribution projects that have reduced peak flows, which are responsible for most of the sediment transport to the Bay. This possibility will be explored further in future work.

SEDIMENTATION RATES



Sedimentation, normalized by the time between surveys, gives the rate that San Pablo Bay is filling or losing sediment. The peak in sedimentation rate corresponds to the peak in hydraulic mining debris entering the Bay. By the early 1900's, sedimentation rates level off to about 2 million cubic meters per year. Sedimentation continues at the same rate until the 1950's. From 1951 to 1983, San Pablo Bay lost about one-quarter of a million cubic meters of sediment a year.

TIDAL FLAT CHANGE



Tidal flats grew in response to the great influx of hydraulic mining debris. The 1887 survey of San Pablo Bay showed the largest tidal flats (61 square kilometers, about 15,000 acres). Tidal flats eroded rapidly when the amount of mining debris washed into the Bay decreased. Tidal flat area was nearly constant in the early to mid-1900's. From 1951 to 1983, tidal flats eroded at a rate of about 125 acres a year. This latest episode of erosion could be the result of decreased sediment supply due to water projects reducing peak flows, which are responsible for most of the sediment transport to the Bay.

CONCLUSIONS

- Debris from hydraulic mining of gold in the Sierra foothills was washed into the Delta and San Francisco Bay in the latter part of last century. About 300 million cubic meters of this sediment was deposited in San Pablo Bay, filling it an average of 1 meter (3').
- San Pablo Bay lost 6 million cubic meters of sediment from 1951 to 1983. This could be caused by water projects decreasing peak flows, which in turn decrease sediment input into the Bay. Sediment input into the system was not great enough to overcome the erosive power of currents and waves.
- Changes in sedimentation in San Pablo Bay affect its ecosystem in many ways. For example, more than 7,100 acres of tidal flat, rich habitats, and sources of sediment to wetlands were lost from the fringes of San Pablo Bay as hydraulic mining debris deposited in the 1800's was eroded by currents and waves in the 1900's.