RMP

REGIONAL MONITORING PROGRAM FOR WATER QUALITY IN THE SAN FRANCISCO ESTUARY

Riverine Transport of Sediment and Mercury to North San Francisco Bay

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Abstract

Mercury is a potent neurotoxin of concern to humans and wildlife. Historic gold and mercury mining districts in the Sierra Nevada and Coast Range Mountains (California, USA), in addition to expanding urbanization in the Central Valley, are ongoing sources of mercury to San Francisco Bay. The large magnitude of runoff and associated sediment entering the Bay through the Sacramento-San Joaquin River Delta makes Delta outflow an important transport pathway for mercury and other particle-associated contaminants. From WY 2002 to WY 2006, water sampling and continuous monitoring of suspended sediment concentrations were performed at the landward boundary of the Bay to quantify mercury concentrations and loads associated with storm events. Mercury concentrations ranged from 3.2 to 25 ng/L and showed a strong correlation (r2 = 0.8) to suspended sediment concentrations. The collection of continuous turbidity measurements allowed for extrapolation of the suspended sediment record to estimate daily average total mercury loads. Daily mercury loads ranged from 3 to 13,530 g, while annual mercury loads varied from a minimum of 61 ± 21 kg in WY 2002 to a maximum of 131 ± 45 kg in WY 2004. In January of 2006, a series of large storms, with a return frequency of about eight years for the biggest storm, caused high flows and widespread flooding. This high flow year will result in an annual load much larger than previously estimated. Samples collected during these high flows make this one of the most valuable datasets on loads to the Bay. Combined with information on other significant transport pathways, the data collected will assist in understanding the long-term recovery of San Francisco Bay from mercury contamination and will influence implementation of the Bay mercury TMDL.

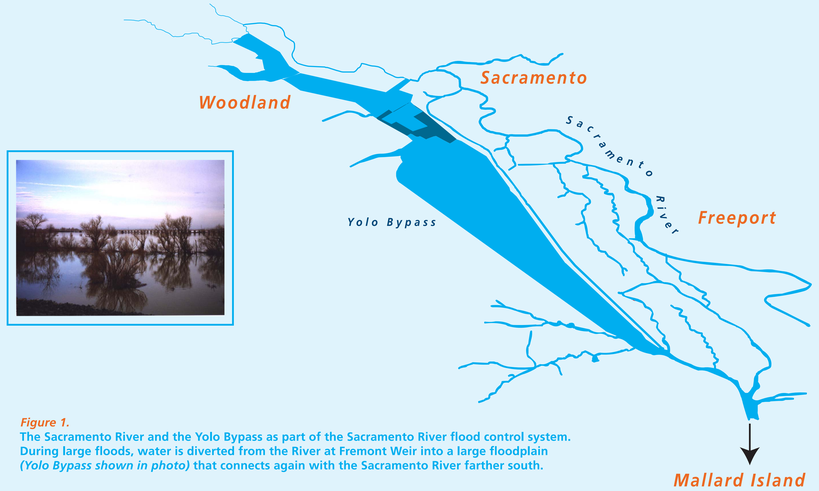


Figure 1.
The Sacramento River and the Yolo Bypass as part of the Sacramento River flood control system. During large floods, water is diverted from the River at Fremont Weir into a large floodplain *(Yolo Bypass shown in photo)* that connects again with the Sacramento River farther south.

Introduction

The Sacramento River is the largest source of freshwater to San Francisco Bay, contributing significant loads of sediment to the Estuary. Associated with an average annual sediment load of 1.08 Mt are particle-bound contaminants like mercury, PCBs, PAHs, PBDEs, and various pesticides. This makes the Sacramento-San Joaquin River Delta one of the major pathways for contaminants into San Francisco Bay, which is currently listed as impaired on the Clean Water Act 303(d) list for mercury. The concern for San Francisco Bay is due primarily to elevated concentrations in sport fish and associated fish consumption advisories.

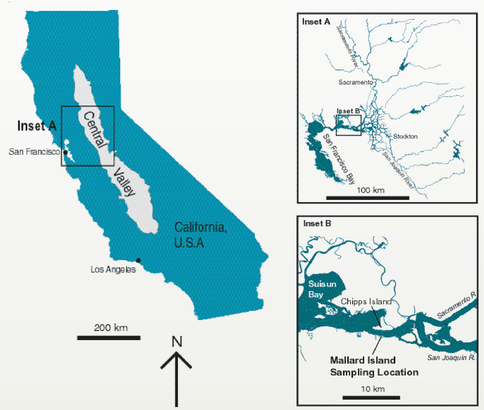
During large floods in the northern part of the Central Valley in California, water spills over a weir from the Sacramento River into the Yolo Bypass when flows are above 70,000 cubic feet per second (cfs) (*Figure 1* ↗). The Bypass serves as flood protection for the City of Sacramento and conveys the water through a flood plain and past the State capital. Before it flows back into the Sacramento River near Rio Vista, the Bypass collects water from several tributaries draining the Coast Range Mountains, an area known for historic mercury mining and environmental mercury contamination.

Due to a lack of long-term monitoring data, mercury loads from the Delta were previously underestimated (Leatherbarrow et al. 2005). Large storms, i.e., during the El Nino year of 1998, where much larger amounts of water were channeled through the Yolo Bypass, had not been described yet. To assess pollutant loads from the Delta more accurately, loads from the Sacramento watershed, including the contribution of flow from the Yolo Bypass, had to be studied during more unusual high-flow events.

Methods

The sample location, Mallard Island, is approximately eight kilometers downstream of the confluence of the Sacramento and the San Joaquin Rivers.

Mallard Island Sampling Location



Sampling was conducted focusing on high flows during the wet season from 2002 to 2006. One to three samples were taken per day to characterize trace contaminant variation in response to floods. Samples were collected about 1 m below the water surface at the end of a pier near a deep water ship channel. Filtered and unfiltered water samples were collected using established methods following trace metal clean protocols (Flegal et al. 1991).

Results and Discussion

Total mercury concentrations ranged from 3.2-25 ng/L. Despite dissolved concentrations contributing 11-24% of the total mercury concentrations, total mercury still showed a strong correlation (r2 = 0.8) to suspended sediment concentration (SSC).

Mercury data collected during this study formed different relationships with suspended sediment concentrations based on flow scenarios. Particles mobilized during larger flood events (above 150,000 cfs) had approximately twice the mercury concentrations of smaller floods (below 150,000 cfs). The estimated particulate mercury concentration during low flows was approximately 0.11 ng/kg, while the concentration for high flows was calculated at 0.22 ng/kg. The two regression lines describing the data (*Figure 2a and b*) are highly significantly different (p=0.0001).

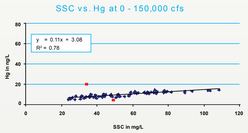


Figure 2a.
Relationship between suspended sediment concentration (SSC) and mercury during low flows (0 – 150,000 cfs).

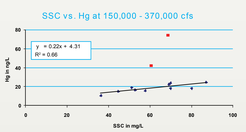


Figure 2b.
Relationship between suspended sediment concentration (SSC) and mercury during high flows (150,000 – 370,000 cfs).

Data outliers (red dots) were rejected for estimating mercury concentrations. Even though the extremely high mercury concentrations observed were not outside QA requirements, they do not relate to the relationship between SSC and mercury described with the rest of the data. To calculate a more conservative load estimate, the three data outliers will be rejected until a better understanding of these data points is achieved.

The hydrographs for the Sacramento River, the Yolo Bypass, and the calculated total Delta Outflow indicate that at a total Delta Outflow of 150,000 cfs, the Yolo Bypass contributes approximately equal volumes of water to Delta outflow as the Sacramento River. When flows from the Yolo Bypass exceeded flows in the Sacramento River, particles entering San Francisco Bay were more contaminated.

High mercury concentrations in the sediments of tributaries to the Yolo Bypass are the result of historic mining activities and deposition over the past 150 years. Mobilization of these sediments caused high mercury concentrations at the downstream end of the Sacramento River.

Using the model developed by McKee et al. (2006), which takes tidal processes at the sampling location into consideration, an average annual mercury load from the Delta was estimated at 242 kg (*Table1*). The revised annual mercury loads, calculated using the two different regression lines, are approximately 33% higher than the previously estimated load values based on only the regression of flows less than 150,000 cfs. In water years with low flows the change in estimated load was not very drastic but in years with high flows, the revised estimates are up to 65% higher than the values estimated without the 2006 flood data.

Water Year	Flow (Mm^3)	Sediment (Mt)	Hg (kg)	Hg (kg) revised	% Change
1995	51,559	2.58	399	599	50
1996	31,436	1.01	184	211	15
1997	42,307	2.24	351	579	65
1998	53,639	2.42	389	538	38
1999	27,805	0.84	156	163	5
2000	22,394	0.66	123	142	15
2001	8,565	0.26	52	53	2
2002	11,303	0.31	58	61	4
2003	17,330	0.55	97	101	4
2004	18,577	0.64	109	131	21
2005	18,588	0.42	81	86	6
2006*	50,020	-	-	-	-
Average	29,460	1.08	182	242	33

Table 1.
Annual sediment and mercury loads at Mallard Island, CA from 1995 to 2006. Mercury load estimates were revised after different concentrations were found during different flow scenarios.

Data collected during water year 2002-2006 have resulted in significantly higher estimated loads to San Francisco Bay. Combined with information on other significant transport pathways, concentrations described in this study will represent long-term load scenarios to the Bay with more certainty and will further influence Bay mercury TMDL decisions.

References

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