

Modelling estuarine sediment budget impacts: anthropogenic or natural?

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As is the case with many estuaries worldwide, the San Francisco Bay-Delta Estuary is heavily impacted by human activities. Human activities that change hydrodynamics including river damming and industrial and agricultural uses of water alter the sediment budget of the entire system. In addition, the hydrodynamics and sediment budget of the San Francisco Bay-Delta Estuary will be affected by climate change resulting in the acceleration sea level rise and there is the possibility of levee failures due to earthquakes. Applying a previously calibrated process based model (Dflow-FM), it is possible to quantify the contribution of anthropogenic activities and natural changes to the total sediment budget of the system, as well as assess changes in sediment dynamics within the rivers and creeks that composes the Delta system.

Introduction

Estuaries host industries, ports and endemic species and are the source of fresh water and sediment that prevent coastal erosion and maintain habitat conditions. The many stakeholders of the system have different water and/or space demands and often modify the estuary in many ways including building of dams, breakwaters, altering the geometry of river branches, and pumping water. In addition, estuaries are affected by sea level rise and earthquakes that damage levees.

Located landward of San Francisco Bay, the Delta is an inland channel network formed by the junction of the Sacramento and San Joaquin Rivers (Fig. 1a). The Delta collects more than 40% of the total fresh water from the entire state of California forming the largest estuary in the west coast of the United States (Kimmerer, 2004). Currently, fresh water is exported in a major pumping effort from the southern Delta to supply cities and agriculture to the south with fresh water (about 200 m³/s). Hydraulic mining in the mid-19th century supplied vast amounts of sediments to the Bay-Delta system. In the 20th century, reservoir construction in the watershed decreased sediment loads drastically. Water diversion works constructed in the 20th century in the Delta (such as gates and pumping stations) and a (possible) future extension of the pumping facilities further alter the flow regime, leading to significant impact in morphology (Jaffe *et al.*, 2007). Another important forcing for changes in sediment budget in estuaries is the increase of accommodation space by natural forcing like sea level rise. For the San Francisco Estuary, levee failure due to earthquakes would also drastically change the system. Ganju and Schoellhamer (2009) discuss how intertidal flats and wetlands may not be able to keep pace with sea level rise. The objective of this paper is to quantify changes in sediment dynamics and budget in the Delta system due to anthropogenic (dam construction, pumping) and natural (sea level rise and earthquake) changes.

Methodology

In order to meet the study objectives we applied a process-based numerical model, DFlow FM (finite volume model) covering the entire Bay-Delta System. The model domain is 150 by 180km and has a network of 80.000 node flexible mesh with spatial resolution varying from 10m to 400m. Since salinity does not enter the Delta we applied the 2D version. We calibrated the model using an extensive data set available for the Bay-Delta system to match observed water discharge, water level and suspended sediment concentration (SSC).

The anthropogenic impacts are assessed based on a multiple scenario analysis of reservoir construction and water diversion works. The natural impacts are based on 3 sea levels rise scenarios and island levee failure due to an earthquake. Covering the required range of spatial scales and time frames with a process-based approach is a unique and challenging aspect of this study.

Conclusions

This paper identifies flow pattern and sediment budget changes in the Delta caused by human intervention and natural variability. The model results are described in terms of sediment fluxes, such as the ones already determined for the existing system (Fig. 1), throughout the Delta and the spatial distribution of deposition and erosion from convergences and divergences in sediment

fluxes. Changes in sediment flux and budget for each stressor allow us to define the most and the least important of them to the San Francisco delta system. Insight is gained on past, as well as possible, future change to prepare and prevent major damage.

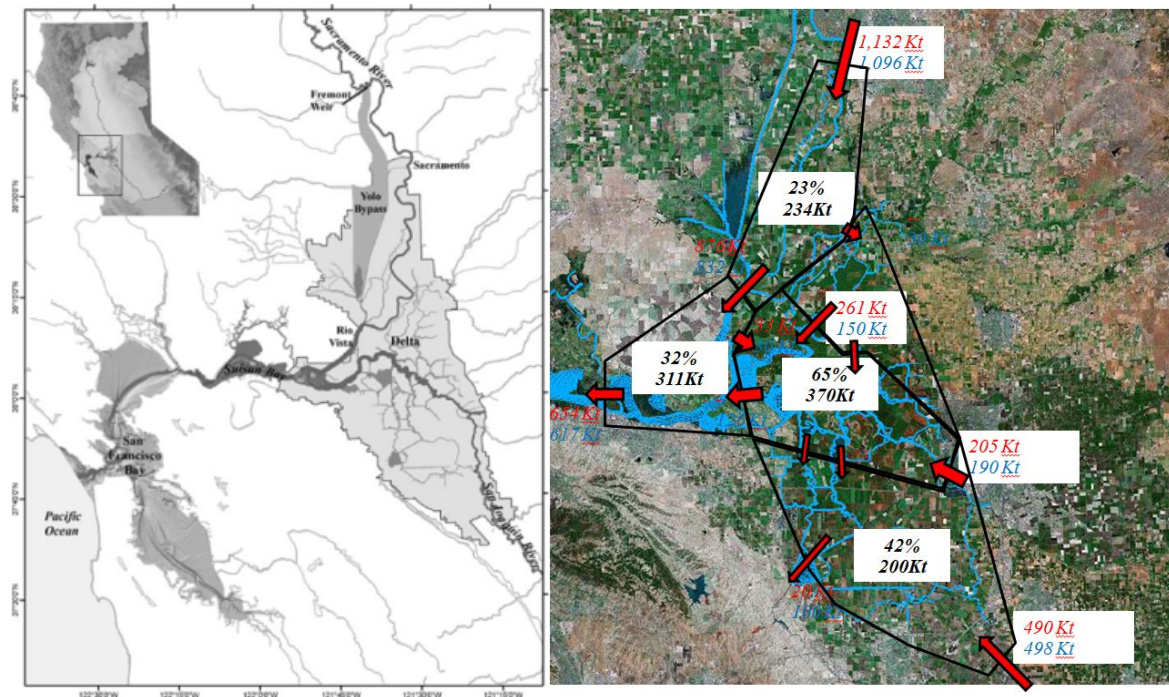


Fig. 1. a) Bay-Delta system map and location. b) Delta Sediment Budget for the year 2011. The arrows indicate the sediment flux direction and magnitude, which is also given by the numbers. The top (red) number is the data flux estimation and the bottom (blue) the model. The areas represent the net deposited sediment. In the background is the Delta unstructured mesh.

References

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