Sediment 101

The San Francisco Bay Area is facing rising sea levels, the rate of which will accelerate in the coming century. Sea level rise threatens public safety and recreation, regional economic productivity, and wildlife that live in and adjacent to the Bay. Restoring and enhancing the Bay's wetlands will help the region adapt to sea level rise, increase flood water absorption, protect critical infrastructure, and create habitat for wildlife.

Restoring and enhancing wetlands and keeping them healthy and elevated as sea level rises will require human intervention to ensure the required amount of sediment and soil reaches them. From 2023-2024, the Sediment and Beneficial Reuse Commissioner Working Group of the San Francisco Bay Conservation and Development Commission held a series of meetings at which local industry experts presented about how best to accomplish this task. Attendees heard from scientists, engineers, agencies, and restoration practitioners about the processes controlling the natural movement of sediment in the estuary, the historic impacts of human activities on sediment flows, and the methods and opportunities available to restore regional wetlands.

This document provides a short summary of what we learned.

The sediment in the estuary has varying characteristics that, along with the bathymetry and morphology of the Bay, influence its distribution.

Different types of sediment are found all throughout the Bay system, with the majority being fine-grained (clay, silt, and mud) and a smaller portion being coarse-grained.[1-3]

These sediments come from the Sacramento-San Joaquin River Delta, the San Francisco Bay, exchange with the Pacific Ocean at the Golden Gate, upland construction, and local flood and stormwater control systems.[4]

The geomorphology and bathymetry of San Francisco Bay varies and includes deep water channels, embayments, shallow shoals, headland "pinch points" that constrain water and sediment flow, intertidal mudflats, tidal wetlands, and sandy beaches.[3]

Different embayments in the Bay have different conditions and ranges of salinity.[3] Sediment is transported in and out of embayments[3,4] and can reverse directions depending on conditions.[5] Wind, tides, currents, salinity, and sediment size and weight also influence how and where sediment will move.[1,6-8]

Finer sediments cycle between the sediment bed and the water column and are easily moved through water movement. Coarser particles require more energy and move along the bottom of the Bay and tributaries. Both fine-grained and coarse-grained sediments travel further distances during high water flows.[9] In tributaries, coarser-grained sediment is often trapped.

Sediment flows through the estuary to establish and maintain estuarine wetlands.

Suspended sediment is naturally transported onto marshes through tidal creeks and across the Bay-marsh edge.[11,12]

Winter storms bring sediment towards marshes where it accumulates near the marsh edge until gentler summer waves transport it up and onto the marsh.[13]

Sediment-laden water is carried onto marshes during flood tide, the sediment then settles out, and water with lower suspended sediment concentration exits marshes during ebb tide. Depending on the strength of the ebb tide, sediment is drawn back out of the marsh or remains in place.[11,13]

Human activity since the Gold Rush has altered these sediment flows.

Human activity has impacted the sediment transport system in the Bay starting with the increase in hydraulic mining during the California Gold Rush of the 1850's which flushed a significant amount of sediment from the Sierra Mountains into the Delta and Bay.[2] That sediment has largely moved through and out of the Bay system.[2]

In the modern era, the development of dams, reservoirs, flood protection projects, and stormwater retention systems disrupted the Bay's natural water flow and sediment system, reducing the amount of sediment entering the Bay.[1,2,9,14-18]

Most of the suspended sediment supply now comes from local tributaries.[14,19,20]

Wetlands provide many benefits to the region.

Healthy tidal marshes offer sea level rise resilience and essential wildlife habitat.[21,22] Tidal marshes protect shorelines by absorbing flood waters, reducing wave impacts,[23] and mitigating greenhouse gases through carbon sequestration.[24] Healthy marshes also provide sense of place, recreational and educational opportunities, and connect Native Americans to their traditional land.

The estuary once had large wetlands that have mostly been destroyed by postcolonial human activity.

The Bay has deeply subsided baylands (areas of marshes that were historically diked off from the Bay) that require large volumes of sediment to restore elevations necessary for marshes to revegetate.[25] Existing and restored tidal marshes depend on a robust sediment supply to adapt to sea level rise.[26] Due to the aforementioned human interventions, very few Bay marshes are still connected to local tributaries.[10]

Wetland restoration is accomplished through the beneficial reuse of sediment.

Sediment is removed from the Bay primarily through dredging to maintain navigational channels, mining sand for the construction industry, and maintaining floodwater flows in the lower portions of flood control channels.[2,3,27-30]

Beneficial reuse, a human intervention, is the application of dredged sediment and upland construction soil to restore subsided baylands and maintain wetlands' resilience to sea level rise.[27,34-36]

Between 1.5 and 3 million cubic yards of sediment is dredged for navigation purposes annually from the Bay[30,31] and most is available for marsh restoration through beneficial reuse.

Between 2000 and 2020, 60% of sediment dredged from the Bay was disposed of as waste at regulated disposals sites in the Bay and in the deep ocean.[4]

The method by which sediment and soil are transported to restoration sites depends on the material's characterization, the shallowness of the Bay, and proximity to the sites.[27]

Sediment dredged from navigation channels can be transported in barges that hold between 300 to 6,000 cubic yards. Barges can carry sediment long distances, where the sediment can be offloaded at restoration sites.[32] Trucks bring soil directly from the construction site to the restoration site with loads of 10 to 20 cubic yards per truck. Excess construction soil is used in restoration sites for structural needs or as general fill to raise elevations.[33]

Different types of sediment and soil are required for different types of projects depending on conservation and restoration needs. For example, fine-grained sediment is ideal for mudflats and marsh development, while a mix of fine and coarse grained is ideal for beaches and levees.[16]

To be used at a restoration site, sediment and soil need to be tested to ensure they do not have elevated levels of contamination that would harm wildlife. Dredged sediment and upland construction soil have an established testing program.[33]

Sea level rise will drown wetlands unless sediment is provided.

Recent climate modeling indicates that there are generally two likely climate scenarios in which there are longer periods of dryness, or longer periods of wetness.[27] The smallest sediment flows, both into and out of the Bay, occur during the dry seasons of wet years. Currently, the Bay experiences the most sediment flow during the wet seasons of wet years, when the most sediment is deposited by tributaries.[3,19]

Current climate models estimate that between now and 2100, the total amount of sediment removed from the Bay system will exceed the amount entering the system.[27]

Without a consistent and robust sediment supply, rising sea levels will inundate marshes over time, threatening their health and the wildlife that they support.[13,24,37-39]

The Bay will need up to 550 million metric tonnes of sediment and soil to preserve, restore, and sustain wetland habitat, and adapt to rising sea levels through 2100.[27]

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