# San Francisco Bay Sediment Dynamics in Low Energy Turbulence

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Sediment dynamics in San Francisco Bay control whether the Bay floor and surrounding marshes are growing or eroding, dictate how sediment-associated contaminants spread, and determine the amount of light available for primary production through turbidity levels. In San Francisco Bay, much of the actively transported sediment is cohesive, and can flocculate when suspended. Changes to the composition of the sediment and waters, the suspended sediment concentration, and the turbulence can all affect the flocculation of suspended sediment. In turn, flocculation controls the particle diameter, settling velocity, density, and particle inertia. These sediment properties have a large impact on the vertical distribution of sediment in the water column, which strongly affect the way sediment is transported through the estuary by fluid flow.

We isolated the effect of turbulence on particle characteristics by measuring the concentration gradient, settling velocity, and turbulent diffusivity in homogeneous, isotropic turbulence in a controlled laboratory setting. We compared the behavior of well-defined particles: a) sorted, fine-grained, non-flocculating sediment and b) synthetic flocs produced in the laboratory, with c) real mud from San Francisco Bay.

These results will make numerical models of sediment transport in San Francisco Bay more accurate, enabling managers to make better predictions of contaminant transport and sediment accumulation or erosion within the Bay. The Bay Margins are considered a management priority, since they have some of the highest concentrations of contaminated sediments in the Bay and are affected by current discharges. Increasing our mechanistic understanding of sediment transport directly improves our ability to make effective management decisions.

**Keywords:** suspended sediment, settling velocity, turbulence, diffusivity

**Poster topic:** Physical Processes

# Daily Tracking and Evaluation of Effective Delta Outflow and Delta Salinity (EC) During the 2014 Drought

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The 2014 Drought Management Plan (DWR and Reclamation) described several possible changes in the D-1641 objectives to reduce the minimum required Delta outflow so that upstream reservoir releases could be reduced and to allow Delta exports for minimum "health and safety" water supply needs. The effects of relatively low Delta outflow on seawater intrusion were tracked and evaluated using daily Delta operations data from Central Valley Operations (CVO) and daily EC data from USGS, DWR and Reclamation monitoring stations (from CDEC). A daily model was developed to allow forecasted and measured Delta outflow and EC conditions to be compared and evaluated. The daily average salinity at Suisun Bay and western Delta stations was calculated using the "effective Delta outflow", based on the G-model formulation (volumetric moving-average) developed by CCWD. One challenge for tracking Delta salinity is that the daily Delta outflow must be estimated from the Delta inflows with assumed channel depletions, or from the USGS tidal flow measurements with assumed "tidal filling" effects. Once the effective outflow was calculated, the effects on salinity at each station were well-described with a unique outflow-EC relationship (e.g., negative exponential). The calculated EC generally matched the measured EC for the historical conditions. The increased runoff from moderate storms in February, March, and April had a dramatic effect on EC that extended into May and June. The daily model was used to evaluate future conditions with alternative Delta operations (outflows). For example, the projected effects of D-1641 outflow objectives and reduced outflow objectives (3,000 cfs) were compared. The benefits from the proposed drought barriers on south Delta EC conditions were also evaluated, although the drought barriers were not installed. The daily model provided an accurate evaluation of alternative Delta operations effects on salinity.

**Keywords:** Delta outflow, Salinity, Seawater Intrusion, Drought Barriers, EC measurements

**Poster topic:** Physical Processes

## Blacklock Restoration Project in Suisun Marsh - Changes to Marsh Plain Elevations and Channel Network Evolution Over Five Years

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The Blacklock Restoration Project in Suisun Marsh is a 70 acre site in which tidal flow was restored to managed wetlands by the Department of Water Resources. The objectives of this project are to increase the amount of tidal brackish wetlands to aid in the recovery of listed species and to improve the understanding of tidal marsh restoration through collaborative science. There is a 10 year monitoring period following breaching of the levee in 2006. Data on 15 parameters was collected and analyzed to evaluate progress towards meeting these objectives. This poster will focus on 4 interrelated parameters: channel network evolution and accretion measurements through surface elevation tables (SET), cryogenic core samples, and topographic surveys. Channel network evolution results include: total channel length increased by 26%; channels in the 5 to 10 ft wide classification increased by 112%; and there is not a need to conduct actions to foster channel development. Elevation change results include: accretion was not uniform across the site; topographic survey transects showed an average elevation increase of 0.3 ft; SET and cryogenic core sampling were found to be ineffective ways to measure accretion in highly subsided unvegetated areas due to scour. Overall, geomorphology of the site is progressing toward a complex dendritic channel system in a high intertidal marsh plain.

**Keywords:** Suisun Marsh, Blacklock, tidal restoration, subsided, accretion, sedimentation, channel formation

**Poster topic:** Physical Processes

# Evaluating the Measured Effects of Delta Outflow on San Francisco Estuary Salinity in WY 2011

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Data collected by the USGS, DWR, and USBR in the Delta and San Francisco Bay during water year 2011 were evaluated to better understand the effects of outflow on seawater intrusion in the Delta and on the longitudinal salinity gradient, vertical salinity stratification, and the upstream edge of the salinity gradient (X2). Water year 2011 was selected because Delta outflow varied widely from approximately 2,500 cfs to 225,000 cfs. Electrical conductivity (EC), tidal elevation, flow and velocity data collected every 15 minutes at multiple locations, as well as USGS boat survey data were integrated and evaluated. The data show how salinity varies longitudinally and vertically through the SF Estuary as well as how the salinity gradients vary in response to tidal flow and net Delta outflow. At any given location, the daily range of EC values (caused by tidal excursion) is much greater than vertical EC stratification. Delta outflow is the primary control for seawater intrusion. Other factors such as tidal strength and gravitational circulation play a secondary role. Effective outflow (described with the G-model by CCWD) was used to estimate the daily EC at each monitoring location and to estimate the daily X2 position more accurately than the daily X2 equation. Adding a term representing the variation in high tides (caused by the spring-neap tidal cycle) improved the daily EC and daily X2 estimates. Although outflow, X2 and daily average EC values provide an accurate summary of the SF Estuary salinity gradients, the 15-minute data reveal many more interesting hydrodynamic events and processes. The integration of the salinity data from the entire SF Estuary provides a more complete understanding of the outflow-salinity relationships.

**Keywords:** Delta outflow, salinity gradients, seawater intrusion, EC monitoring, X2

**Poster topic:** Physical Processes

# Floc Depositional Characteristics within the Sacramento–San Joaquin River Delta, Northern California, USA

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Deposited sediment helps create and sustain the landscape in the Sacramento–San Joaquin River Delta (Delta), including desirable habitats such as tidal marsh, shoals, and floodplains. A key management question is whether the existing Delta landscape can be sustained as sea level rises. The erosion and deposition processes are strongly dependent on the local sediment properties, particularly when cohesion and flocculation are important, as they are in the Delta.
The U.S. Geological Survey collects data that support the development, calibration, and validation of numerical models of sediment transport and turbidity in the Delta. Research questions include: How much flocculation of sediment particles occurs in the Delta, and what are the settling velocities of the flocs? How do floc settling properties vary spatially and temporally? To address these questions, a Co-operative Agreement was established between the USGS and HR Wallingford (UK).
This abstract presents preliminary findings from measurements of floc depositional properties throughout the Delta, 2010-2011. Individual floc properties and dynamics were measured with the LabSFLOC-1 instrument; a high resolution video-based device. Thirty-one floc population samples were obtained from 21 sites within the Delta. Flocculated particles were observed throughout the Delta including in freshwater. Suspended-sediment concentrations in the near-bed region ranged from 4-52 $mg.l^{-1}$. A combined total of more than 2,200 individual flocs were measured. Floc sizes (D) ranged from 27 micron microflocs (D < 160 microns) to macroflocs of 500 microns. Macrofloc settling velocities (Ws) were 0.7-5 mm/s (mean 2.25 mm/s) and macroflocs comprised 1-56% (mean 24%) of the suspended mass. Microfloc Ws was smaller (0.3-4.0 mm/s, mean 1.63 mm/s), but comprised more (44-99%, mean 76%) of the suspended mass and thus, mass settling fluxes (spanning 0.1-80 $mg.m^{-2}s^{-1}$) were dominated by microflocs, albeit an order of magnitude less than depositional fluxes within San Francisco Bay.

**Keywords:** Flocculation, Flocs, Settling Velocity, Depositional Flux, River Delta, Suspended Sediment

**Poster topic:** Physical Processes

# Comparison of Downscaled CMIP5 Precipitation Datasets for Projecting Changes in Extreme Precipitation in the San Francisco Bay Area

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Water resource managers planning for the adaptation to future events of extreme precipitation now have access to high resolution downscaled daily projections derived from statistical bias correction and constructed analogs. We also show that along the Pacific Coast the Northern Oscillation Index (NOI) is a reliable predictor of storm likelihood, and therefore a predictor of seasonal precipitation totals and likelihood of extremely intense precipitation. Such time series can be used to project intensity duration curves into the future or input into stormwater models. However, few climate projection studies have explored the impact of the type of downscaling method used on the range and uncertainty of predictions for local flood protection studies.

Here we present a study of the future climate flood risk at NASA Ames Research Center, located in South Bay Area, by comparing the range of predictions in extreme precipitation events calculated from three sets of time series downscaled from CMIP5 data: 1) the Bias Correction Constructed Analogs method dataset downscaled to a 1/8 degree grid (12km); 2) the Bias Correction Spatial Disaggregation method downscaled to a 1km grid; 3) a statistical model of extreme daily precipitation events and projected NOI from CMIP5 models. In addition, predicted years of extreme precipitation are used to estimate the risk of overtopping of the retention pond located on the site through simulations of the EPA SWMM hydrologic model.

Preliminary results indicate that the intensity of extreme precipitation events is expected to increase and flood the NASA Ames retention pond. The results from these estimations will assist flood protection managers in planning for infrastructure adaptations.

**Keywords:** Precipitation extremes, statistical downscaling, empirical downscaling, NOI, flooding, stormwater

**Poster topic:** Physical Processes

# Influence of Wind, Wind Waves, and Tidal Forcing on Sediment Resuspension, Liberty Island, CA

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Liberty Island is an abandoned agricultural land in the Northern Sacramento-San Joaquin Delta at the south end of the Yolo Bypass. The North Delta around Liberty Island is a region known to have elevated turbidity compared to other Delta regions and currently sustains a functioning Delta smelt habitat. The island flooded when the south levee failed in 1998 due to a large winter flood and was not repaired. It is now a shallow, tidally forced embayment, approximately 2.5 by 8.5 km, surrounded by levees with multiple breaches, especially on the east side, and hydrodynamic interaction with the surrounding sloughs. Since 2010, USGS researchers have measured turbidity, water temperature, salt and wind waves within the embayment, flow, turbidity, suspended-sediment concentrations (SSC), salt, water temperature, and SSC flux at the south breach. The focus of this poster is the relationship between wind-driven and tidally-driven hydrodynamics, turbidity, suspended-sediment concentrations, and how the sediment exchanges with the Liberty Island/Cache Slough complex. The spatial and temporal turbidity distributions are a critical aspect of Delta smelt habitat.

The bed sediments within the Cache Slough complex are finer than elsewhere in the delta with median diameter less than 0.1 mm. These fine sediments are easily re-suspended by tidal currents and wind-driven near-bed orbital motions, enhancing turbidity throughout the area. Preliminary results demonstrate a large seaward sediment flux through the breach when the Yolo Bypass floods, a landward sediment flux during low flows and elevated turbidity during spring and summer winds. The majority of the winds are from the southwest, however, at similar wind speeds, significantly higher wave heights occur during northwesterly winds. This information will help resource managers plan future habitat restoration efforts throughout the Delta.

**Keywords:** wind induced turbidity, wind-waves, sediment resuspension, turbidity, Liberty Island

**Poster topic:** Physical Processes

# Beyond the 10% Rule: A New Method for Predicting Salmon Spawning Potential from Substrate Grain Size and Fish Length

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We describe a new approach to assessing the amount of salmon spawning habitat in coarse-bedded rivers. The approach is based on a recently developed model that predicts the reproductive potential of coarse-bedded rivers as a continuous function of grain size and salmon length. It incorporates empirical relationships between fish length, redd area, and the size of the largest particles that female fish can move when building redds. Estimates of this threshold particle size are incorporated into a mechanistic model for the amount of spawning habitat in riverbeds where grain-size distributions have been measured. Model inputs are the grain size indices D50 and D84 and an estimate of fish length. Outputs include predictions of the fraction of the bed that the fish can use for redd building and also the number of redds that they can build within the useable area. We cast the model into a variety of easy-to-use tools, including look-up tables, charts, an Excel worksheet, a MatLab user interface, and a Java web applet. We discuss how these tools can be used as part of a new, mechanistic approach to assessing spawning substrates and optimizing gravel augmentation in coarse-bedded rivers.

**Keywords:** Pacific salmon, gravel augmentation, grain-size distributions, population diversity, river restoration

**Poster topic:** Physical Processes

# Evaluation of Junction Hydrodynamics in the Sacramento-San Joaquin Delta

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The understanding of junction hydrodynamics in the Delta is critical to determine survival pathways of out-migrating salmon. This is the first in a series of four presentations that collectively investigate the relationship between water velocities and fish entrainment in these junctions. Specifically, we investigated methods to quantify junction scale hydrodynamics focusing on accurately describing the surface currents with two-dimensional (2D) velocity interpolation, and simplified metrics such as discharge ratio and critical streakline. Continuous measurements with side-looking acoustic Doppler current profilers (SL-ADCP's) were collected at six junctions in the Delta over a period of two to five months to provide baseline detailed hydrodynamic information. The SL-ADCP profile data at the junctions were used to provide accurate velocity field interpolations using a mass balance Lagrangian particle tracking and inverse path-length weighted algorithms. The profile data was extrapolated in the horizontal and vertical, and cross-sectional area were integrated to determine accurate discharge estimations with the Velocity Profile Method. These results are validated with down-looking (DL)-ADCP measurements and Lagrangian drifter tracks.

Our preliminary results show, junction scale hydrodynamics vary considerably depending on the phase of the tide and river inflows. The time scale of entrainment and the amount of water entrainment is dependent on location. Since these investigations occur over a short time scale, we compared the 2D velocity and discharge measurements to long term discharge monitoring stations in order to evaluate water entrainment on longer time scales. These results show that site specific studies are needed to effectively understand junction hydrodynamics for the design and placement of fish diversion structures.

**Keywords:** Junction Hydrodynamics, ADCP. Velocity Interpolation, Ecohydraulics

**Poster topic:** Physical Processes

## Central Valley Outflow over Time: Water Budgets and Other Estimates

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The Bay Institute's 1998 publication, From the Sierra to the Sea: the Ecological History of the San Francisco Bay-Delta Watershed (STS) (http://bay.org/publications/from-the-sierra-to-the-sea-the-ecological-history-of-the-san-francisco-baydelta-watershed), examined multiple estimates of Central Valley outflow prior to large-scale water development. STS was a consensus effort with public water agencies to develop a common understanding of the natural functioning of the Bay-Delta-River ecosystem.

These previous estimates used a variety of approaches:

- sediment cores and correlations by academic researchers

- Gaging and correlations from 1879-1885 by the State Engineer

- Gaging and correlations in early 20th century by State Public Works Department

- Water budget calculations of average annual "natural" outflow with the 20th century unimpaired hydrology and precipitation as inflow and estimated natural vegetation acreage and evapotranspiration (ET) rates for outflow, developed by competing parties to the 1987 Water Board hearings. USGS developed an annual natural groundwater budget for its 1989 Central Valley groundwater study.

STS also developed an average annual "natural" outflow using a water budget approach. Although these water budget estimates were formulated similarly and used the same unimpaired runoff data sets, their results vary from 11 MAF to 24 MAF per year. The variation in these estimates is attributable to differences in the reconstructions of natural vegetation types, acreage and ET rates, as well differences in the extent of the inflow watersheds. The monthly outflow estimates derived in the 19th century and early 20th century are closer to or exceed the higher end of the 20th century water budget estimates.

To gain further insight into how the Central Valley pre-disturbance landscape may have functioned hydrologically and ecologically STS also began development of a monthly natural water budget, which required monthly estimates of groundwater inflow, groundwater storage changes and surface water storage changes in the Sacramento Valley flood basins.

**Keywords:** Natural Outflow, Unimpaired Runoff, Evapotranspiration, Landscape History

**Poster topic:** Physical Processes