**Spatio-Temporal Ecological Modeling of Water Hyacinth Environment on the Performance of a Biological Control Agent**

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To investigate the mechanisms of water hyacinth (*Eichhornia crassipes*) control, an efficient Baysian model system is required. Although deterministic models have been used to predict organism control, such models suffer from the inability to account for stochasticity in a system Entomologists and conservationists in related fields have offered multidisciplinary and multi-institutional computer modeling programs to optimize success of biological control agents. In view of the success of such models, it was decided to provide an up to date and comprehensive spatio-temporal ecological model of water hyacinth environment on the performance of a biological control agent. The first section of this presentation details the selection of the salient variables for spatio-temporal ecological models. The second section contains information dealing with biological control (*Coleoptera: Curculionidae Neochetina bruchi*) and weed interactions. The third section provides the results of a test of the model.

**Keywords:** Water Hyacinth, *Neochetina bruchi*, spatio-temporal modelling

**Poster Topic:** Modeling

## Planning Tools to Evaluate Salmonid Habitat Restoration in the Yolo Bypass

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Significant modifications have been made to the historic floodplains of California's Central Valley for water supply and flood damage reduction purposes. The resulting losses of rearing habitat, migration corridors, and food web production for fish have significantly hindered native fish species that rely on floodplain habitat during part or all of their life history. To support the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project, a collaboration between the California Department of Water Resources and US Bureau of Reclamation, previous evaluation efforts were improved with the development of a suite of planning tools to analyze benefits and impacts to agriculture, fish, waterfowl, and water quality in the Yolo Bypass. A calibrated two-dimensional hydrodynamic model was developed for the Yolo Bypass, which serves to characterize the effects of increased frequency, depth, and duration of floodplain inundation in the lower Sacramento River Basin and assess the improvements to fish passage throughout the Yolo Bypass. The two-dimensional model also provides the required hydrodynamic inputs into the other planning tools that include an agricultural economics model, a fish benefits model, and a mercury cycling model. Each of the planning tools are in various states of development and refinement as part of an ongoing evaluation process as managers continue to try and find sustainable and locally acceptable solutions for agriculture, fish, recreation, and terrestrial species in the Yolo Bypass. Preliminary results and lessons learned will be shared to include the importance of value engineering and stakeholder engagement.

**Keywords:** Yolo Bypass, Flood Control, Fish Passage, Fish Habitat, Ecology, Hydraulics

**Poster Topic:** Modeling

## Modeling the Effects of Varying Disturbance Frequency and Magnitude on Population Persistence in Predator-Prey Systems

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Human activities are rapidly and significantly transforming environments, altering historic ecosystem disturbance regimes. Estuaries are particularly vulnerable to disturbances due to resource use and other human activities. Anthropogenic disturbances can alter the physical environment and disrupt ecosystem function, leading to both direct and indirect population impacts. While the effects of disturbance frequency and magnitude on species diversity and competitive interactions have been studied, their effects on predator-prey interactions have not been investigated. To address this, we developed simple dynamic models to examine the effects of varying disturbance frequency and magnitude on prey population persistence in predator-prey systems. We then extended this analysis to a more realistic model of eastern oysters (*Crassostrea virginica*) and their predator, the southern oyster drill (*Stramonita haemastoma*), to assess how disturbances, characterized by changes in estuarine salinity and temperature, affect the predator-prey interaction. Initial results reveal that increasing the magnitude of disturbance increases the probability of prey population extinction more than increasing frequency. Additionally, effects differ depending on whether there are predator-prey cycles and whether the disturbance affects population abundance or demographic rates. The findings of this study will further understanding of the effects of varying disturbances on interacting populations and aid managers in improving long-term population outcomes. This work is relevant to San Francisco Bay-Delta management because these models can be used to aid management of local bivalves such as the Olympia oysters (*Ostrea lurida*). Currently, restoration and conservation efforts are threatened by the Atlantic oyster drill (*Urosalpinx cinerea*), an invasive predatory gastropod. These predators are limited by physical disturbances and gradients, and their impact on Olympia oyster populations will likely be exacerbated by climate change. These oysters provide habitat and invaluable ecosystem services, so it is critical to restoration and conservation management to examine how varying disturbances impact both short-term and long-term population outcomes.

**Keywords:** Modeling, predator-prey, disturbance, eastern oyster, oyster drill, climate change

**Poster Topic:** Modeling

## Advancing the Integration of Vegetation in Floodplain Modeling and Management to Achieve Multi-Objective Benefits for Flood Risk Reduction

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Past efforts at "flood control" were often made at the expense of the ecological integrity of rivers and streams by simplifying the systems, constraining key natural processes, and limiting habitat and ecological niches. Today, increasing scientific and public interest in the ecological, and economic, value of floodplains, and changing regulations, especially those related to the improved management of floodplains with consideration for endangered species, all advocate for restoring and sustaining floodplain functions and processes.

Numerical models can be a powerful tool to help achieve these multi-objective benefits in floodplain management; however, the representation of vegetation in models is often rudimentary. Plants play a key role in how processes and functions are expressed and hydraulic roughness is the principle model parameter describing how plants interact with flood water. Roughness is commonly over-simplified in models leading to missed opportunities for risk reduction and ecological enhancement. Aligning plant characteristics to variations in roughness is a key factor in integrative floodplain design.

We will describe recent engineering and ecological research, and explore design concepts and techniques, that advance the integration of vegetation in floodplain modeling and management. Vegetation on floodplains can be designed, modeled, and ultimately managed to achieve engineering and ecological objectives, such as maintaining flood conveyance while accommodating the establishment and growth of riparian plant communities. Case studies will show how placement of plants can direct overbank flows, improve flood storage, reduce scour and erosion, facilitate sediment transport, and alleviate other flood risk factors, while providing critical habitat.

**Keywords:** numerical modeling, vegetation, hydraulic roughness, multi-objective benefits, floodplain functions, habitat

**Poster Topic:** Modeling

### Interactions of Ending Overdraft and Delta Water Management

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Effects of ending long-term groundwater overdraft in the Central Valley and Delta water management operations are studied with several management cases using CALVIN, a statewide hydro-economic model for California's inter-tied water supply system. Four hypothetical “no overdraft” scenarios, besides base operations with overdraft, are evaluated under projected 2050 water demands using 82-year monthly historical hydrology .The cases include effects on Delta outflow and Delta exports from a “no overdraft” policy. Furthermore, Delta exports from Delta-Mendota Canal and California Aqueduct are prohibited with a no overdraft policy. Prohibiting Delta exports results in considerable water scarcities south of the Delta. Agricultural water scarcity costs and willingness-to-pay for additional water, and opportunity costs of environmental deliveries are evaluated. More Delta exports, groundwater banking, and water trades are useful adaptations when the long-term overdraft is ended.

**Keywords:** Overdraft; Delta Exports; Water Supply; Agriculture; Modeling

**Poster Topic:** Modeling

## Developing a High Resolution Bathymetric/Topographic DEM of the San Francisco Bay - Delta for use in CASCaDE II Models

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Climate change, sea level rise and human development all have had effects on the changing geomorphology of the San Francisco Bay – Delta system. The need to further predict scenarios of change led to the development of a high resolution bathymetric/topographic digital elevation model (DEM) of the San Francisco Bay – Delta that served as the foundation of CASCaDE II hydrodynamic and sediment transport models for use in predicting Delta change and better understanding the function of the Delta ecosystem (Fregoso, Wang, Ateljevich, and Jaffe, 2016). The 2016 USGS San Francisco Bay Delta high resolution DEM is the result of collaborative efforts of the USGS and the California Department of Water Resources (DWR). The DEM encompasses the entirety of Suisun Bay; beginning with the Carquinez Strait in the west, east to California Interstate 5, north following the path of the Yolo Bypass and the Sacramento River up to Knights Landing, and the American River northeast to the Nimbus Dam, and the San Joaquin River south to Tracy. The DEM is built on the 2005 USGS DEM comprised of single beam bathymetric surveys, updated to include newer single beam and multibeam bathymetric surveys, and topographic data in the form of lidar surveys. The DEM incorporates the newest available bathymetric survey data at the time of release as well as includes at minimum, 100 meters of available topographic data adjacent to most shorelines. This DEM is a crucial component of USGS's CASCaDE II and DWR's Bay-Delta SCHISM models for predicting change scenarios in the Bay-Delta and will aid decision making for managing the San Francisco Bay –Delta.

Fregoso, T.A., Wang, RF, Ateljevich, E., Jaffe, B.E., 2016, A Seamless, High-Resolution Digital Elevation Model (DEM) of the San Francisco Bay – Delta: U.S. Geological Survey Open-File Report 2016-XX., xx p.(in Review)

**Keywords:** Bathymetric, DEM, topographic, CASCaDE, model, Delta, GIS

**Poster Topic:** Modeling

**Cost-Effective Shallow Water Bathymetric Modeling**

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The high cost of shallow water bathymetric surveying has historically deprived many medium-to-smaller entities and organizations of critical data that could improve management and conservation decisions and help direct research. Additionally, hydrodynamic modeling is limited by the quality of underlying bathymetry. Using an inexpensive fishfinder in combination with commercial GPS equipment we were able to produce a high-quality bathymetric digital elevation model for the formerly poorly-characterized upper reaches of Cache-Lindsey Slough Complex, with uncertainty ranges suitable for research and conservation work. In four days of field work we navigated 36.2 linear km of tidal channels, a total of 2.12 sq. km of water surface at an average ensonification density of 2.78 soundings per 10 sq. m for a total cost less than $3,700. Our methods allow flexibility in increasing or decreasing data density as specific circumstances warrant, and data processing capability dictates. Our equipment setup achieved precision of 7 mm in horizontal positions with 6 mm in vertical elevations for the channel characteristics surveyed. Median total horizontal and vertical uncertainties of 0.813 m and 0.141 m were attained for survey points at the 95% confidence level for a mean depth of 2.69 m. These techniques could benefit a multitude of budget-limited projects in the Delta, and also permit rapid and inexpensive modeling for pilot research and serial hydromorphological dynamics studies.

**Keywords:** bathymetry, digital elevation, DEM, sonar, modeling, hydromorphology, hydrodynamics, GIS

**Poster Topic:** Modeling

## Biogeochemical Modeling for Nutrient Management in San Francisco Bay

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Ambient nutrient concentrations in San Francisco Bay are high relative to many urbanized estuaries, yet the classic symptoms of eutrophication are typically not observed in the Bay. The source of this resistance is hypothesized to be a combination of the light limiting effects of suspended sediments and the presence of benthic grazers, both of which exert strong controls on the phytoplankton population. However, observations in recent years suggest that this resistance may be declining.

As part of the San Francisco Bay Nutrient Management Strategy, we are developing a process-based, coupled physical-biogeochemical model of the Bay to characterize nutrient cycling and ecosystem response to nutrient management scenarios. The biogeochemical model successfully reproduces many features in the observed distributions of nitrogen species. Some discrepancies between the model and observations appear to be related to episodic blooms not captured by the model. Coast-sourced, upwelled nutrients present in Central Bay in the summer months may also be a source of discrepancies, highlighting the important, seasonal influence of the coastal ocean.

**Keywords:** nutrients, hydrodynamics, biogeochemistry, modeling, water quality, South Bay

**Poster Topic:** Modeling

## Riparian Forest Dynamics along the Sacramento River, California (USA): Constructing Tree Age Models to Illustrate Successional Patterns

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The riparian ecosystem along the Sacramento River (CA) has been greatly impacted by human activities, however the Middle Reach between Red Bluff and Colusa remains hydrogeomorphically active. This reach hosts young floodplain forests dominated by cottonwoods and willows, as well as later-successional species such as oak, ash and walnut. Despite a qualitative understanding of successional patterns, there remains considerable uncertainty in tree establishment timing relative to floodplain development and the potential impact of post-dam flow changes on that process.

To further our understanding of the Sacramento River's riparian forest dynamics, we: (1) cored >1000 riparian trees and determined ages for dominant species using a combination of standard dendroecological measurements and experimental mathematical corrections; (2) constructed a general pathway of forest community dynamics by comparing the relative species timing of tree ages to their associated floodplain ages; and (3) explored variation in ecological drivers over time, particularly in respect to river regulation following Shasta Dam's construction.

Tree cores showed that most cottonwoods and willows established within 15 years of floodplain creation, but cottonwood had a wider range of colonization times that expected. Box elder and walnuts similarly had short colonization times on floodplains <50 years old, indicating that currently they function as pioneers on recently created floodplains. In contrast, establishment of oak and ash trees occurred much later, at least ~15 to 25 years after the pioneers, respectively. In general, median colonization times for each species agree with the successional pattern suggested by previous research on the Sacramento River, but these new data illustrate variations in this pattern warranting further exploration. This research provides the most detailed view of forest succession within California's Central Valley riparian ecosystem, and can serve as a foundation for future work and to guide preservation and restoration efforts in this important and vulnerable ecosystem.

**Keywords:** riparian forest ecosystems, river restoration, succession, tree age models

**Poster Topic:** Modeling

## A New Public Domain Hydrodynamic Model for the Yolo Bypass

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Habitat reconciliation on Yolo Bypass proposed by the WaterFix necessitates a hydrodynamic model capable of simulating the full range of flow conditions experienced by the Sacramento River spilling into the Bypass. New bathymetry collected by the UC Davis Center for Watershed Sciences has been combined with existing spatial data to produce an updated digital elevation map (DEM). The model geometry was developed using the HEC-GeoRAS extension of ArcGIS and imported into HEC-RAS 5.0. The model consists of 1D river channels connected to 2D floodplains and is calibrated with available gage data. Irrigation canal details and control structures, important to a low flow model, have been included in the DEM and model geometry. Modifications such as the Fremont weir notch options specified by the California Department of Water Resources (DWR) and US Bureau of Reclamation (USBR) Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project have been modeled. While earlier studies of the Fremont Weir alternatives focused on gate operations and flow rates, this study focuses on area and duration of inundation. This public domain model was partially funded by Yolo County and the UC Davis Center for Watershed Sciences and is available for testing ongoing habitat reconciliation projects.

**Keywords:** Hydrodynamic Modeling; Reconciliation; Salmonids; Habitat; HEC-RAS; Fremont Weir; Yolo Bypass

**Poster Topic:** Modeling

## Downscaling Wind and Wave Fields for 21st Century Coastal Flood Hazard Projections in San Francisco Bay

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While Global Climate Models (GCMs) provide useful projections of near-surface wind vectors into the $21^{st}$ century, resolution is not sufficient enough for use in regional wave modeling. Statistically downscaled GCM projections from Multivariate Adaptive Constructed Analogues (MACA) provide daily averaged near-surface winds at an appropriate spatial resolution for wave modeling within the orographically-complex region of San Francisco Bay, but greater resolution in time is still needed. Short-duration high wind speeds, on the order of hours, are usually excluded in statistically-downscaled climate models and are of key importance in wave and subsequent coastal flood modeling. Here we present a temporal downscaling approach, similar to constructed analogues, for near-surface winds suitable for use in local wave models, and evaluate changes in wind and wave conditions for the $21^{st}$ century. Reconstructed hind-cast winds (1975-2004) using this methodology recreate important extreme wind values within the San Francisco Bay. A computationally-efficient method for simulating wave heights over long time periods was used to screen for extreme events during historical (1975-2004) and $21^{st}$ century (2010-2100) periods. Projections of extreme over-water wind speeds suggest contrasting trends within the different regions of San Francisco Bay, however, $21^{st}$ century projections show little change in the overall magnitude of extreme winds and waves.

**Keywords:** coastal storm modeling, storm wind, storm waves

**Poster Topic:** Modeling

# A Large-Scale, Infrared Quantitative Imaging System for Measuring the Instantaneous Surface Velocity Field in Natural Flows

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The design and implementation of an infrared, large-scale, Quantitative Imaging (QI) system is presented, along with results from an initial field test during the 2014 Georgiana Slough fish guidance study.

A Floating Fish Guidance Structure (FFGS) was constructed and tested in 2014 with the goal of guiding juvenile fish towards the Sacramento River and away from Georgiana Slough (e.g., Perry et al., 2014). This floating structure alters the near-surface flow field along, and downstream of, the FFGS. The effect of turbulence generated by the barrier on fish migration routes is largely unknown.

In order to study the mean and turbulent flow field in the vicinity of the FFGS we deployed a large-scale QI system comprised of a high-resolution (1344x784 pixel), high-sensitivity (NETD < 25 mK), MWIR (spectral range 3-5 µm) camera mounted at an elevation of approximately 20m above the surface of the water. The imaging field-of-view covered the river surface from shore-to-shore near the southern end of the FFGS. Once set up the system was remotely operated.

The QI algorithm tracks micro-gradients in the surface temperature of the water over time as captured in the infrared images, allowing us to construct the 2D flow field in high spatial and temporal resolution. This system has significant advantages over traditional (visible-wavelength) large-scale PIV systems in that temperature gradients are ubiquitous features of the water itself hence there is no need for seed particles or concerns regarding the validity of assuming seed particles passively follow the flow. Additionally there is no dependence on ambient light, so the system can run continuously 24 hours a day.

The results of the QI measurements show excellent agreement with mean flow velocities measured concurrently by ADCP. The turbulent flow field is characterized in order to correlate with fish migration tracks that were recorded by acoustic telemetry.

**Keywords:** PIV, Quantitative Imaging, LSPIV, turbulence, physical processes, hydrodynamics, infrared, flow

**Poster Topic:** Modeling

## Climate Change Effects on Optimal Bypass Capacity

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Large flood flows in a river can damage flood-prone areas, by overtopping river channels or structural failure. Flood bypasses can efficiently reduce flood risks, accommodating excessive river flow.

Climate change, with warmer temperatures and changes in patterns of precipitation, is compromising California's flood management efforts. Climate change is expected to worsen regional flooding problems, and at the same time, economic growth and urbanization of floodplains will increase potential damages. The long-term floodplain management challenge is to be able to balance increasing flood damages and benefits from using floodplains over periods.

This study develops a formulation to examine the effect of climate change on optimal bypass capacity using benefit-cost and risk analysis. The analysis should predict increasing flood risk due to climate change unless current flood management policies are changed. A simplified representation of the Sacramento River and the Yolo Bypass, near Sacramento, is considered. The problem is formulated as an economic optimization model solved using dynamic programming. This analysis examines, from an economic perspective, how flood management can adapt to flood frequency changes, and how bypass capacity changes can help reduce damages over time.

**Keywords:** Flood management, risk analysis, flood bypass, climate change, capacity optimization

**Poster Topic:** Modeling

## Central Valley Refuge Management under Non-stationary Climatic and Management Conditions

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Sustainable management of Central Valley refuges is critical to maintain the ecosystem balance. These refuges provide habitat for the more that 60% of the migrating waterfowl on Pacific Flyway and are home to nearly 50% of the threatened and endangered species in California. Uncertainties surrounding the future of water management coupled with the increasing cost of and diminishing opportunities for acquiring water threaten the long-term viability of refuge water supply. Global warming and regional hydro-climatic alterations are likely to further limit state's ability to manage water, reduce total volume of available water and intensify competition for surface water. Historically, reduction in surface water supplies is substituted with groundwater pumping. Long-term overdraft and Sustainable Groundwater Management Act (SGMA) provisions will, however, limit future pumping opportunities. This research examines impacts from warm-dry climate, peripheral tunnels, SGMA, and Delta regulations on water deliveries to Central Valley refuges. The study is conducted within a statewide framework using CALVIN – a hydro-economic optimization model of State of California – to capture the physical, environmental and policy constraints in the existing water management system. Sixteen scenarios are analyzed to capture and quantify the hydrologic and economic implications of climatic and management uncertainties on refuge deliveries including (1) climate vulnerability: historical and warm-dry climates; (2) Delta regulations: high and existing Delta Outflow requirements; (3) infrastructure: with and without isolated facility or peripheral tunnels; and (4) groundwater management: with and without long-term overdraft. A separate Spreadsheet Tool is also developed to explore the benefits and implications of inter-refuge trading and optimizing refuge land-use management practices. The research findings identify promising management schemes to buffer against the future uncertainty in refuge water supply, schemes such as expanding groundwater or surface water supplies, identifying potential water trading partners, optimizing land-use operations and collectively managing the Central Valley refuges.

**Keywords:** central valley, refuges, wetlands, water management, climate change, groundwater, SGMA

**Poster Topic:** Modeling

## Yolo Bypass Model: Providing a Public Model to Evaluate Future Options

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The Sacramento-San Joaquin Delta has been modified severely since initial settlement in the area. Efforts are being made to address the disparity between human suitability and native species' habitat suitability in the Delta. The Yolo Bypass, a ~60,000-acre floodplain in the North Delta that protects Sacramento against flooding, is a recent target for providing habitat to vital native Delta species.

To address this problem, alternatives have been proposed by making modifications to the existing hydraulic infrastructure on the Bypass. Numerical two-dimensional hydrodynamic and water-quality models can assist in evaluating the ecological and economic impact of alterations to the frequency, duration, and size of the flood footprint. A proprietary, commercial numerical model has been developed to evaluate the alternatives and their impacts in recent years. The information that the model is largely built upon is hydrologic gage data and many of the western tributaries to the Bypass are poorly monitored, implying added variability and uncertainty to the model results.

At UC Davis, we have developed a 2D hydrodynamic model using free and publicly available software, HEC-RAS, which can be used by others to evaluate the proposed alternatives to the flooding patterns. In addition to developing the model, we have quantified the potential variability that the lack of gage data introduces to the model results. Improvements to the model terrain have also been made using techniques developed by researchers at UCD.

The model will be an additional tool for stakeholders, landowners, and public interests to collaborate on the appropriate implementation of whichever alternative is deemed best. Additionally, the quantified variability and uncertainty of different missing or sparse data demonstrates the value that added monitoring will provide. The results of this research will provide insight on management practices on one of the largest floodplains in the Sacramento River system.

**Keywords:** Yolo Bypass, modeling, fish passage, stream monitoring, floodplain management, gages

**Poster Topic:** Modeling

## Quantifying Spatio-temporal Inundation Patterns for Floodplain Restoration on the Lower Cosumnes River, California

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Restoration of floodplain ecosystems within altered riverine landscapes is a global challenge, and one central to solving water management challenges of California broadly and the Delta specifically. Such restoration, intended to support ecological diversity, requires not only the rehabilitation of driving physical processes, but also improved understanding and quantification of the spatial distribution and temporal variability of floodplain inundation patterns. The research presented here formalizes the hydrospatial regime concept, presenting methods for better evaluation of specific physical conditions useful for floodplain management. This new spatio-temporally resolved approach quantifies a floodplain's hydrospatial regime using 2D hydrodynamic modeling (HEC-RAS) and spatial analysis. Pre- and post-restoration conditions are evaluated for the Oneto-Denier floodplain restoration site along the lower Cosumnes River, California. Modeling is performed for selected historical floods representing previously established flood types distinguished by ecologically-relevant variables such as magnitude, timing, and duration. Modeling output is analyzed and compared within and across flood events and restoration scenarios in space and time using metrics relating to depth, velocity, duration, connectivity, and spatial heterogeneity. Spatially-resolved flow-depth relationships allows for further assessment and comparison of conditions. The quantified and visualized hydrospatial metrics illustrate, for example, where and when different physical conditions are likely to be altered with restoration, and which flood types and where within the floodplain are associated with the greatest difference pre- versus post-restoration. They also demonstrate that physical conditions follow different spatial and temporal patterns across different floods and restoration scenarios. Implications include that variability of flow regimes and their interaction with heterogeneous floodplain topography should be considered in Delta restoration management and more broadly. This research advances floodplain hydroecology and restoration sciences and extends readily-applied methods using 2D modeling output to evaluate restoration scenarios, providing needed information and tools to better manage floodplains for variable conditions that benefit ecosystems.

**Keywords:** Cosumnes River, floodplain restoration, flow regime, hydrodynamic modeling, spatial analysis

**Poster Topic:** Modeling