Natural Delta Hydrodynamic Model Development

John DeGeorge, Resource Management Associates, Inc., jfdegeorge@rmanet.com
Stephen Andrews, Resource Management Associates, Inc., steve@rmanet.com
Edward Gross, Resource Management Associates, Inc., ed@rmanet.com
Stacie Grinbergs, Resource Management Associates, Inc., stacie@rmanet.com

A new three dimensional, stratified flow model is being created to better understand the hydrodynamic and salinity regime of the Sacramento-San Joaquin Delta prior to agricultural development of the 1800's. Geometry of the new model is based on the San Francisco Estuary Institute (SFEI) Sacramento-San Joaquin Delta Historical Ecology Study[i]. The first use of this model will be to establish a draft relationship between isohaline positions and Bay-Delta outflow under "natural" and current conditions. This work is being performed by Resource Management Associates, Inc., (RMA) with support of the Metropolitan Water District of Southern California and in collaboration with the UC Davis Watershed Science Center (UCD) and SFEI. UCD and SFEI are developing detailed plan view channel networks and a digital elevation model to serve as the bathymetric data set for the flow model.

Utilizing a three dimensional, stratified flow model for this study is essential because it is not known at the outset how different the level of salinity stratification might be under the historic condition relative to today, and so there is no way to calibrate empirical mixing coefficients required by lower dimensional models. Representing the complex natural Delta channel network in a 3D model that must also represent the San Francisco Bay is a significant challenge. The UnTRIM3D engine was selected for this application because it is computationally very efficient and because it supports the use of sub-grid scale bathymetry in determining the volumetric and conveyance attributes of computational elements. Using sub-grid bathymetry it is possible to perform reasonably accurate hydrodynamic calculations for detailed tidal marsh channel networks without the extreme grid resolution and very long run times.

http://sfei.org/DeltaHEStudy

Keywords: Natural Delta, Multidimensional Modeling, Hydrodynamics, Salinity
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Reducing Hydrodynamic Complexity in Junctions and the Challenge of Producing Accurate Lagrangian Simulations

Jon Burau, US Geological Survey, jrburau@usgs.gov

We present simplified metrics to capture the hydrodynamic complexity at junctions based on the bulk discharge measured at flow stations. Making detailed measurements of velocity fields in junctions involves deployment, calibration, and interpolation of data from numerous Side-Looking Acoustic Doppler Current Profilers. These efforts are equipment and man-power intensive and therefore expensive. It is important to make these measurements in the context of process oriented studies where the details help to gain a mechanistic understanding; however, this level of effort is not practical for day-to-day management of the system. The metrics discussed in this talk include tidal averages of: (1) the discharge ratio, (2) critical streakline and, (3) the partitioning of discharge based on canonical flow distributions such as the flow entering the side-channel from upstream, downstream, converging and reversing flow conditions.

We examine time series of these metrics to: (1) document the temporal evolution of a single junction in response to the net flow, (2) compare and contrast the hydrodynamic/entrainment characteristics between junctions, (3) quantify how Delta Cross Channel operations affect velocity distributions in junctions throughout the north delta, and (4) use these metrics to explain tidally-averaged entrainment rates of acoustically-tagged salmon in junctions.

Finally, we discuss the extraordinarily rigorous demands the transport of constituents and particles place on numerical hydrodynamic models. Because transport and particle tracking involves the time integral of the temporal evolution of velocity field throughout the domain, model inaccuracies accumulate. The accuracy/treatment of the velocities fields in junctions is particularly important because the temporal distribution of the entrainment rates of constituents/particles at junctions can lead to vastly different outcomes. Accuracy demands increase the longer and farther constituents are advected, and particles are tracked.

Keywords: Hydrodynamics, Lagrangian
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Reducing Uncertainty in Design of in-Delta Sampling Experiments Using Particle-Tracking Models

Marianne Guerin, Resource Management Associates, maguerin@rmanet.com
Tamara Kraus, USGS California Water Science Center, tkraus@usgs.gov

Hydrodynamic modeling and particle tracking animations were used to inform and optimize field experiments designed to evaluate the effects of wastewater derived nutrients on Delta food web dynamics. Using a Lagrangian-based sampling approach, the study involved tracking parcels of water that traveled down the Sacramento River and into the Delta under normal conditions of wastewater effluent release and when effluent flows from the Sacramento Regional Wastewater Treatment Plant were halted for 15 to 20 hours. The two distinct water parcels were monitored for changes in water quality over a 5-day period as they traveled 45 miles down the mainstem of the Sacramento River from the I80 Bridge to Isleton, with tidal forcings increasing with downstream movement. In order to plan for the study, hydrodynamic and particle tracking models were run using different hydrologic scenarios. The modeling objectives were: (1) to test different scenarios relating to the time and duration of the wastewater hold period in order to maximize the length of the wastewater-free stretch of river; (2) to help position the sampling boats over the multi-day sampling campaign to capture wastewater-free and wastewater-containing water samples by using animations to identify areas where the water parcels likely remained intact versus where tidal mixing was most likely to occur, and (3) to generate quantitative results from the predictive models to reduce uncertainty in the experimental design related to Delta operations. We found that the hydrodynamic scenarios and particle tracking simulations provided key information regarding Delta Cross Channel operation, changes in Net Delta Outflow and Sacramento River inflow, and the effect of agricultural diversions. The modeling results were particularly important for the May/June 2014 experiment which occurred during a period of unusually high uncertainty in Delta conditions due to extreme drought conditions.

Keywords: particle tracking lagrangian sampling Delta operations animations forecast modeling wastewater
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Temperature Dynamics in the Sacramento-San Joaquin Delta, CA

Karla Gleichauf*, Environmental Fluid Mechanics Laboratory, Stanford University, kgleich@stanford.edu
Stephen Monismith, Environmental Fluid Mechanics Laboratory, Stanford University, monismith@stanford.edu

We examine the spatio-temporal dynamics of water temperatures in the Sacramento-San Joaquin River Delta in response to tides, atmospheric forcing, river inflows, diversions, and inflow temperatures. Warm temperatures critically stress the Delta environment and are likely to increase in frequency with global warming, which can lead to degradation of water quality and mortality of endangered species of fish such as the Delta Smelt and Chinook salmon. Thus, we aim to understand what determines water temperatures in the Delta and whether water managers can alleviate elevated water temperatures in the face of climate change. We study the subtidal temperature field, which is determined by surface heat exchanges, solar heating, and entering water temperature. We performed a heat balance at various parts of the Delta by calculating the heat content of the water column and the atmospheric heat fluxes, which are the latent and sensible fluxes and the longwave and shortwave radiation. We find that the most important meteorological factors are air temperature, wind, and relative humidity, which can create large latent heat fluxes that warm the water. While global warming will increase air temperature, we conclude that river inflows can significantly assuage thermal stresses. In particular, barrier and gate operations were found to greatly change water temperatures even during warm atmospheric conditions. Thus, the movement of heat in the water column can have a major effect on temperatures in the Delta. We calculated the amount of heat moved within the water, defined as the downstream heat flux, by finding the difference between the atmospheric and water heat fluxes. By analyzing the spatial and temporal variability of the downstream flux, we see that downstream heat fluxes are greatest in the western Delta close to the Bay, indicating that heat is being advected downstream and enhanced by dispersion at junctions.

Keywords: Temperature, Global Warming, Junctions, Fluxes, Heat Content, Dynamics, Dispersion
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Multi-Species Effects Analysis & Ecological Flow Criteria: Lessons from Application of the Ecological Flows Tool (EFT) to Water Planning Efforts in the Delta & Sacramento River

Ryan Luster, The Nature Conservancy, rluster@tnc.org
Clint Alexander, ESSA Technologies Ltd, calexander@essa.com

Since its launch in 2004 the EFT project has had the goal of improving water planning by explicitly linking ecosystem needs with physical models in the Sacramento River and the San Joaquin-Sacramento Delta. Aided by over 70 scientists and managers, we have developed an integrated bio-physical decision support tool that characterizes how a suite of 13 Delta and Sacramento River focal species (and habitats) are expected to respond to alternative flow, river bank, and gravel management scenarios. EFT species submodels are made up of 25 key life-history indicators, each of which is driven by relevant measures of flow, water temperature, channel migration, salinity and/or stage at a daily timescale. Our research has clearly demonstrated that there is a pressing need to develop greater awareness of the value of flexibility to manage ecosystem trade-offs over time within and among objectives. The detailed applications of EFT crystallize the fact that it is impossible to achieve all ecosystem objectives – let alone the co-equal goals of meeting human, agricultural and environmental needs – each and every year. We review these and other findings and describe a paradigm shift involving seeing balance as a condition which does not involve the same species or objectives losing (or winning) unnecessarily often. Other effects analysis findings highlight the need for a stronger focus on climate change mitigation itself (and the general difficulty of comparing future scenarios to a progressively deteriorating baseline). The presentation also summarizes promising results from an initial pilot study using EFT flow criteria to create new rules for CALSIM to improve outcomes for winter-run chinook and Delta smelt. With its emphasis on specific cause-effect linkages based on functional flow needs, EFT provides a solid framework that remains open to testing, enhancement and adaptation over time.

Keywords: Ecological flow, decision support, effects analysis, flow criteria, EFT, modelling
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

What if We Could Start Over: Large Landscape Scale, 2D Hydrodynamic Modeling of Sacramento Valley "What if" Floodway Scenarios

Chris Bowles, cbec eco engineering, c.bowles@cbecoeng.com
Chris Campbell, cbec eco engineering, c.campbell@cbecoeng.com
Kevin Coulton, cbec eco engineering, k.coulton@cbecoeng.com
Kristin Brainerd, Resources Law Group, LLP, KBrainerd@resourceslawgroup.com

Floodplain management planning efforts in the Central Valley of California are moving at an accelerated pace. In the next few years, critical decisions will be made regarding how to modify the current complex flood management system that protects major urban and agricultural areas in the Central Valley, based on holistic and multi-objective criteria aimed not solely for flood management, but also for ecosystem enhancement and agricultural sustainability.

To help inform these critical decisions, an innovative new tool has been developed and tested that will facilitate prediction of floodplain flows over vast areas of the Central Valley under existing conditions and a range of different potential management scenarios. This tool is a new, rapid 2-dimensional hydrodynamic model that is based on novel approaches to approximating the equations of water flow using latest computational hardware. The tool is ideal for testing multiple large-scale planning scenarios in a computationally efficient manner, and is being calibrated and validated for the Sacramento Valley from Ord Ferry to Sacramento, including the major tributaries to the Sacramento River. A range of “What if” scenarios for multi-objective floodplain management were developed and tested using the model. The results are presented in terms of hydrodynamic parameters and ecological indicators. Other current and potential future uses of the tool for planning purposes are discussed.

Keywords: Hydrodynamic, modeling, ecology, Sacramento Valley, Floodplains, multi-objective
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

Numerical Modeling of Sediment Dispersal Following Dredged Material Placements to Examine Possible Augmentation of the Sediment Supply to Marshes and Mudflats in Far South San Francisco Bay

Craig Conner, U.S. Army Corps of Engineers, SF District, Craig.S.Conner@usace.army.mil
Aaron Bever, Delta Modeling Associates, Inc., aaron@deltamodeling.com
Michael MacWilliams, Delta Modeling Associates, Inc., michael@deltamodeling.com
Frank Wu, U.S. Army Corps of Engineers, SF District (retired), frank.h.wu@gmail.com
Lisa Andes, U.S. Army Corps of Engineers, SF District (formerly), sednaasil@gmail.com
Tom Kendall, U.S. Army Corps of Engineers, SF District, Thomas.R.Kendall@usace.army.mil

Recent studies of sea level rise in the San Francisco Estuary have indicated that the majority of tidal marshes surrounding the Bay are likely to lose marsh plant communities by 2100 because natural accretion rates will not keep pace with sea level rise. The Baylands Ecosystem Habitat Goals Update (BEHGU) has identified the need to establish cost-effective strategies to minimize this potential loss of tidal marsh habitat. The beneficial re-use of dredged material may provide a valuable resource to augment sediment supply to mudflats and marshes in the San Francisco Estuary. However, little information currently exists on where waves and currents transport sediment within San Francisco Bay following an in-bay dredged material placement. A three-dimensional hydrodynamic, wave, and sediment transport model was applied to examine sediment dispersal throughout the San Francisco Bay and the Sacramento-San Joaquin Delta. One focus of the sediment transport modeling effort was to examine the sediment dispersal following dredged material placements. The model was applied to evaluate whether smaller shallow-water dredged material placements in Far South San Francisco Bay adjacent to existing marshes or breached salt ponds would result in an increase in deposition rates within these areas through natural dispersal of the placed sediment. In the Far South Bay, dredged material placements were effective at supplying sediment to the surrounding mudflats and breached salt ponds and resulted in increased accretion rates. These model results highlight the usefulness of three-dimensional sediment transport modeling for managing dredged material placements and suggest dredged material placements in strategic locations may be used to augment sediment supply to mudflats, marshes, and breached salt ponds surrounding San Francisco Bay.

Keywords: Baylands Ecosystem Habitat Goals Update, Sediment Modeling, Mudflats, Restoration, UnTRIM
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

Modeling the Benefits of Yolo Bypass Restoration Actions on Chinook Salmon

Paul Bergman, Cramer Fish Sciences, pbergman@fishsciences.net
Travis Hinkelman, Cramer Fish Sciences, travis.hinkelman@fishsciences.net
Joseph Merz, Cramer Fish Sciences, jmerz@fishsciences.net

In recent years the Yolo Bypass has been recognized as important rearing, spawning, and migratory habitat for numerous native fish species, including Chinook salmon. The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Draft Implementation Plan (Implementation Plan) was developed to restore Yolo Bypass rearing and migratory habitat through increase of seasonal inundation and modification of water control structures of the Yolo Bypass. Prior to execution of the Implementation Plan, a modeling effort is being undertaken to evaluate potential benefits to all four Central Valley (CV) Chinook salmon runs, particularly Sacramento River spring-run and winter-run, both federally listed under the Endangered Species Act. A model was built that simulates key Chinook salmon life history stages from freshwater emigration (just upstream of the entrance to the Bypass) to adults returning from the Pacific Ocean (escapement) and quantifies the potential impacts of restoration actions on juvenile growth, emigration success, and ultimately survival to adult escapement. This model configuration allows for a direct quantitative comparison of competing management alternatives by comparing the relative abundance of returning adults from juvenile salmon that reared in the Yolo Bypass versus the mainstem Sacramento River. Additionally, the intermediate abundance levels at ocean entry are provided along with fish demographics (% entrainment, survival during rearing, fish size at ocean entry, and ocean survival) for each alternative. Initial modeling results have helped identify management alternatives that provide the greatest growth and survival benefit for CV Chinook salmon runs, allowing managers to focus on a smaller sub-set of alternatives for further evaluation. Future modeling work will help optimize the identified sub-set of management alternatives by evaluating the effects of specific management actions on Chinook salmon, including additional modifications to water control structures, grading of floodplain habitat, and changes to Bypass drainage canals.

Keywords: Chinook salmon, Yolo Bypass, Modeling, Floodplain, Restoration
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

Use of Daily Historical Data and a Daily Reservoir Model to Evaluate Adaptive Implementation of Alternative Reservoir Operations

Russ Brown, ICF International, russell.brown@icfi.com
Lucas Sharkey, SWRCB, Lucas.Sharkey@waterboards.ca.gov

Historical reservoir and river data can be used in a daily model to evaluate multi-purpose reservoir operations that may include adjustments in the flood control rules, alternative water quality objectives to support fish and wildlife (i.e., fish flows based on unimpaired runoff), and conjunctive water supply. A daily model can demonstrate the potential for adaptive implementation of alternative reservoir operations that could improve downstream fish habitat conditions without substantially reducing water available for other beneficial uses (i.e., water supply, flood control, hydropower). Monthly models provide an accurate characterization and allocation of water among beneficial uses for planning purposes; however, historical daily data and a daily model can provide a more resolved evaluation of the effects of alternative reservoir operations and downstream fish habitat conditions (e.g., inundation and water temperature) as needed for implementation. The daily reservoir inflows may be the historical unimpaired runoff or may be modified by upstream storage and diversions. Water supply delivery targets, including increased deliveries in wet years (i.e., conjunctive use) may be determined from the available storage, forecast runoff and specified fish flows. Daily flood control operations may be determined from the daily storage, inflow, and maximum allowable downstream flows. The effects of reservoir release flows on downstream fish habitat conditions can be evaluated and compared with identified or assumed relationships. Using the Merced River as an example, a daily model was developed to adjust flood control operations to provide more sustained reservoir releases for riparian inundation and water temperature control. Reduced flood control releases during moderate storm events could provide more sustained inundation of riparian habitat. The daily model can also be used to evaluate increased spring-time flows (e.g., percent of unimpaired flow). These moderate increases in spring-time flow could improve fish habitat conditions in many years without reducing water supply.

Keywords: Daily data, Flow objectives, Reservoir Operations, flow benefits, riparian inundation
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

The Delta Salinity Gradient (DSG) Model

Paul Hutton, Metropolitan Water District of Southern California, phutton@mwdh2o.com

A new empirical sub-tidal model of daily averaged salinity in Suisun Bay and the western Delta was developed. Called the Delta Salinity Gradient (DSG) model, this new tool integrates and expands upon the functionalities of Denton's G-Model and the Kimmerer-Monismith (K-M) X2 equation. The new model predicts specific conductance at user-specified longitudinal distances along the Bay-Delta estuary. The new model also predicts the location of the X2 isohaline, as well as the location of other user-specified isohalines.

The model was calibrated with daily averaged salinity and X2 isohaline observations for calendar years 2000 through 2009. The model was also calibrated with simulated data from the DSM2 model for purposes of demonstration. Model validation was accomplished using the entire period of record that was available at the time of development, i.e. October 1921 through September 2012. Model results were compared with predictions provided by the G-Model as well as the K-M X2 equation.

This new tool will allow scientists and engineers a simple method for evaluating the salinity structure of the Bay-Delta estuary under extremely low outflow conditions such as those experienced prior to Shasta Dam and those that would occur under "without-Project" conditions, i.e. scenarios that assume SWP-CVP project reservoirs are not in place. The ability to model these low outflow conditions is necessary in order to evaluate how and why the salinity structure of the estuary has changed over time. Currently available empirical and mechanistic models are not sufficiently formulated or calibrated to evaluate these extreme conditions.

Keywords: salinity model; X2 position; estuarine salinity gradient; Delta salinity
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314