Thermal Implications of an Unimpaired Hydrograph on Managing Declining Salmonid Populations in a Delta Tributary

Chris Hammersmark, CBEC Eco Engineering, Inc., c.hammersmark@cbecoeng.com
Chris Bowles, CBEC Eco Engineering, Inc., c.bowles@cbecoeng.com
Chris Campbell, CBEC Eco Engineering, Inc., c.campbell@cbecoeng.com
Tom Gohring, Water Forum, tgohring@waterforum.org

Current efforts to rehabilitate the Bay-Delta Ecosystem have identified the ecological importance of the natural flow regime, and this recognition has led to the consideration of a prescription of some proportion of unimpaired inflow for the delta. However, this framework may yield unintended impacts to declining anadromous salmonid species. In most major Central Valley Rivers, these cold-water dependent populations are relegated to the valley floor by rim dams, and as such are required to complete some of their freshwater life stages in environments that differ from those in which they evolved (i.e., on the valley floor rather than higher in the watershed). The understanding that we are trying to promote and improve a cold-water fishery in an environment that is not thermally suitable needs to be considered when scenarios prescribing some proportion of the unimpaired flow are evaluated. To quantify the potential impact to the cold-water fisheries components of the ecosystem, a suite of water supply, hydrodynamic and water quality models are used in concert to simulate long term series of water temperature in the lower American River. In this effort, existing water supply and water quality models (CALSIM II and USBR Temperature Model) are used to develop flow and temperature boundary conditions for a sub-daily hydrodynamic and water quality model (HEC-RAS). These models are used to simulate water temperatures for current and proposed flow management scenarios, allowing a quantitative assessment of potential differences. The results show that a flow prescription which uses a proportion of unimpaired runoff results in elevated temperature conditions particularly in the late summer and early fall, exposing salmonids to less-tolerable and in many cases unsuitable thermal conditions. Using this knowledge, the impacts to cold-water dependent fisheries in delta tributaries must be considered simultaneously and not serially when determining the flow needs for the delta.

Keywords: salmon, water temperature, flow objective, American River, flow management

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 1

Analyzing Spatial Patterns of Groundwater-Surface Water Interactions at the Meander-Bend Scale in a Gravel-Bed Lowland River during a Large-Scale Flow Experiment

Erin Bray*, Bren School of Environmental Science and Management, University of California, Santa Barbara, California, USA, ebray@bren.ucsb.edu
Thomas Dunne, Bren School of Environmental Science and Management, University of California, Santa Barbara, California, USA, tdunne@bren.ucsb.edu

We measured the effects of a large-scale flow experiment on near-bed and subsurface temperature throughout three meander bends using fiber optic distributed temperature sensing (DTS) as a means to investigate groundwater-surface water exchange in a gravel-bed lowland river. We deployed 2 km of fiber-optic cable directly on top of the riverbed over three pool-riffle sequences each with a different degree of bed mobility. DTS data were collected in Reach 1A of the San Joaquin River, CA (1.5 days at 10 cms, 10 days at 20 cms, 16 days at 10 cms, and 4.5 days at 2-4 cms). Three installations of six hyporheic zone sensors recorded interstitial pore water temperature at depths of 46 cm. Measured channel bed elevation, flow depth, velocity, and bed-material grain size were used to develop a two-dimensional numerical model of the flow field as boundary conditions for a model of the hyporheic flow field.

The initial flow of 10 cms showed relatively uniform temperature over the 2-km reach. Near-bed temperatures averaged 15.6°C while pore water temperatures at 46 cm averaged 15.4°C. The 20 cms flow decreased average near-bed temperatures to 14.9°C and pore water temperatures to 14.7°C. During the 20 cms flow, the bed became mobile causing local scour and deposition at three locations and buried the DTS cable with sand/gravel. Our DTS results allowed us to record the transition from near-bed temperatures to shallow subsurface temperatures during a sediment-mobilizing flow. Shallow pore water temperatures were increasingly buffered and lagged with 1) distance downstream over the length of a point bar and 2) duration of the high flow event. We aim to generalize spatial patterns of groundwater exchange, intra-gravel, and near-bed temperatures at the meander-bend scale over a range of restoration flow releases in determination of suitable salmonid spawning habitat below Friant Dam.

Keywords: groundwater, surface water, river, hydrology, geomorphology, instream flow

Thursday, October 18, 2012: Room 306, Modeling (I)– Order 2

Forecasting Delta Turbidity Conditions with Artificial Neural Networks

Paul Hutton, Metropolitan Water District of Southern California, phutton@mwdh2o.com
Sujoy Roy, Tetra Tech, Sujoy.Roy@tetratech.com
Limin Chen, Tetra Tech, limin.chen@tetratech.com

Significant salvage of adult Delta smelt at the south Delta export facilities has been observed to coincide with the formation of a turbidity “bridge” between the central and south Delta. The remanded 2008 USFWS biological opinion restricts reverse flows from the central to south Delta along Old and Middle Rivers when turbidity conditions reach pre-defined threshold levels. Understanding the influence of export operations on prevailing turbidity conditions is necessary to develop management strategies that promote cost-effective protection of adult Delta smelt.

Metropolitan Water District, in collaboration with its consulting team, has developed and piloted a decision support system over the past three years to forecast turbidity conditions in the Delta. The system integrates hydrology and operations forecasts, computer simulation models, and real-time data to generate Delta turbidity forecasts on a weekly basis during the winter when Delta smelt are preparing to spawn. To compliment this decision support system, a fast and easy-to-use tool with a spreadsheet-based interface was developed for scenario analysis as well as for long-term water supply planning. Employing artificial neural network technology, this tool was successfully designed and calibrated to mimic flow-turbidity relationships as modeled in DSM2, the Department of Water Resources’ Delta hydrodynamic and water quality transport model. This tool, by allowing for rapid evaluation of turbidity response under alternative export and watershed loading scenarios, can provide scientists, regulators and operators insights for developing cost-effective management strategies for fishery protection.

Keywords: Delta smelt, biological opinion, turbidity, modeling, management strategies, hydrodynamics

Thursday, October 18, 2012: Room 306, Modeling (I)– Order 3

The Devil is in the Details: Why the Representation of the Flow Field, Especially at Junctions, Matters in Order to Simulate Dispersion in the Delta

Nancy Monsen, Stanford University; Dept. of Civil and Environmental Engineering; Environmental Fluid Mechanics Laboratory, winter@stanford.edu
Phillip Wolfram, Stanford University; Dept. of Civil and Environmental Engineering; Environmental Fluid Mechanics Laboratory, pwolfram@stanford.edu
Karla Gleichauf, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, kgleich@stanford.edu
Oliver Fringer, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, fringer@stanford.edu
Stephen Monismith, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, monismith@stanford.edu

The Bay Delta Conservation Plan Effects Analysis in many cases represents the hydrodynamic flow field as an Eulerian tidally-averaged flow as the basis for many other ecological models. In addition, the Effects Analysis includes particle tracking to simulate migration patterns and entrainment of fish using a 1-dimensional hydrodynamic representation the Delta.We will present results from hydrodynamic simulations utilizing the newly developed SUNTANS multi-dimensional hydrodynamic model of the Delta to discuss why tidal flow and physical representation of junctions are essential to represent dispersion in the Delta.

We are extending the SUNTANS Bay hydrodynamic model to include the Sacramento- San Joaquin Delta region. This development includes the addition of river inflows as well as gate, pump, and temporary barrier operations. Using a particle tracking method, we will discuss circulation patterns and dispersion at key junctions in the Western and Central Delta. We will also identify regions where the length of tidal excursion is longer than the distance between junctions.

In the Delta, the characteristics of the channel junctions and a Lagrangian framework are important to understand mixing. The representation of mixing at junctions in hydrodynamic models is critical in order to use these foundational models to assess ecosystem stability in the near and long term.

Keywords: hydrodynamic models; dispersion; junctions; Lagrangian transport; circulation patterns; tidal flow

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 4

Investigating the Retention of Planktonic Organisms in the Low-Salinity Zone Using a Particle Tracking Model

Edward Gross, Resource Management Associates, ed@rmanet.com
Wim Kimmerer, Romberg Tiburon Center, San Francisco State University, kimmerer@sfsu.edu
Michael MacWilliams, Delta Modeling Associates, michael@deltamodeling.com

A major challenge for estuarine plankton is to maintain populations within an estuary against tidal mixing and continuous seaward movement due to river flow. The Entrapment Zone study in 1994-1996 examined how vertical movements of plankton might result in retention in the Low-Salinity Zone of the San Francisco Estuary, generally in Suisun Bay. Copepods and larval fish appeared to move vertically in synchrony with the tidal currents, a pattern that should aid in retention of these organisms. However, retention calculated with observed vertical velocity profiles in the Suisun Bay channel was negligible, implying a need to represent the three-dimensional flow field. We have examined the influence of vertical movement on retention using the UnTRIM three-dimensional hydrodynamic model and the Fish-PTM particle tracking model. Particles were assigned various behaviors including passive drifting, tidal vertical migration, and constant downward swimming. We first determined the tidal patterns of vertical distribution of particles that resulted from each behavior, then selected behaviors that gave similar vertical profiles of abundance to those observed. We released particles distributed in salinity space similar to the distribution of *Eurytemora affinis* and compared retention of vertically migrating particles to retention of passive particles. Passive particles shifted seaward with the net flow. Downward movement, either tidally synchronized or continuous, reduced or eliminated seaward movement. Thus, the time-varying three-dimensional flow field determines how behaviors influence retention. By inference, the horizontal spatial distributions of organisms that move vertically would be difficult to predict without a particle tracking model operating at a suitably fine spatial scale.

This work is part of a project whose goal is to develop an understanding of the pelagic food web that accounts for hydrodynamic influences. We will incorporate this understanding into an individual-based model to explore the influence of management actions on the food web supporting pelagic fish species.

Keywords: modeling, hydrodynamic,s three-dimensional particle, copepod, pelagic, salinity, Suisun

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 5

Water Quality Model Framework to Support Resource Management Planning for the Sacramento San Joaquin Delta

Silong Lu, Dynamic Solutions LLC, slu@dsllc.com
Paul Craig, Dynamic Solutions-International, pmcraig@ds-intl.biz
Christopher Wallen, Dynamic Solutions LLC, cmwallen@dsllc.com
Zhijun Liu, Dynamic Solutions LLC, zliu@dsllc.com
Andrew Stoddard, Dynamic Solutions LLC, astoddard@dsllc.com
William McAnally, Dynamic Solutions LLC, whmcanally@dsllc.com
Eugene Maak, US Army Corps of Engineers, Sacramento District,
Eugene.C.Maak@usace.army.mil

The Sacramento San Joaquin Delta is a unique estuarine resource that supports water supply, navigation, and recreation while maintaining a complex but fragile ecosystem. Ecosystem restoration and maintenance of an abundant supply of clean water to support agricultural and public needs have been deemed co-equal goals for planning efforts in the Delta. Long-term trends in nutrient availability have triggered questions about the sources and effects of nutrients on algal production and other ecological processes. Ecosystem models are needed to provide a scientifically credible framework to understand the complex interactions of natural conditions, regulatory controls, and resource management efforts on water quality and ecological resources. A three-dimensional water quality model – from Carquinez Strait, through Suisun Bay and the Delta to Verona on the Sacramento River and Vernalis on the San Joaquin River – has been developed by the USACE, Sacramento District using the Environmental Fluid Dynamics Code (EFDC). The model is a fully-coupled representation of Delta hydrodynamics, sediment transport, water quality and sediment diagenesis calibrated and validated to data from 2003 and 2004. Selected model results for nutrients, algae biomass (chlorophyll), and dissolved oxygen will be presented as (a) station time series and (b) for specific times along profiles running from Suisun Bay up the Sacramento and San Joaquin River channels. The Delta EFDC model provides a robust numerical modeling tool that can be used for Delta management to (a) support evaluations of proposed regulatory controls on nutrient sources and (b) provide a load-response model for a nutrient numeric endpoint framework. The results from this model have also been linked to a process-based lower trophic level ecological model to understand the effects of environmental conditions on the food web in the lower salinity zone.

Keywords: EFDC, water quality, model, nutrients, algae, oxygen, Suisun Bay Delta

Thursday, October 18, 2012: Room 306, Modeling (II)– Order 6

Assessment and Comparison of One- and Two-Dimensional Models for Predicting Flow and Salinity in the Delta

Fabian Bombardelli, University of California, Davis, Department of Civil and Environmental Engineering, fabianbombardelli2@gmail.com
Swetcha Reddy, Northwest Hydraulics Consultants and UC Davis, svreddy@ucdavis.edu
James Kohne, University of California, Davis, jrkohne@ucdavis.edu
Mark Gowdy, California Water Resources Control Board, MGowdy@waterboards.ca.gov

The social, environmental, and economic importance of the Sacramento-San Joaquin Delta has led to the development, application and validation of several numerical models to address hydrodynamic and water quality conditions. Those models range from one-dimensional (1-D) approaches in channel networks, to 2-D and, recently, 3-D models. In the last 20 years, the Delta has been the subject of at least 10 independent modeling efforts using codes such as DSM2 (1-D), WAM (1-D), RMA2 (2-D), TRIM (2-D and 3-D), UnTRIM (3-D), Delft3D (3-D), EFDC (3-D), SUNTANS (3-D), etc., which provide a wealth of information about the system. No systematic comparisons of results of these efforts have been attempted. Yet future physical, biological and social challenges to the Delta will require even more demanding applications of these models to simulate climate change, water management, habitat, island failures, and land development conditions.

This work presents a rigorous assessment and comparison of Delta-specific models developed by Resource Management Associates (RMA), RMA2 and WAM, and the Department of Water Resources (DWR), DSM2. This work starts with a thorough analysis of the models from the theoretical and numerical points of view, and highlights differences and similarities in the approaches. Subsequently, it discusses scenario-driven comparisons of performance of each model to historical data, and investigates model “accuracy” and sensitivity to varying levels of export pumping values, each within dry and wet water years. For the first time to the best of our knowledge, this work evaluates ranges of differences among model predictions and data for the Delta.

Keywords: DSM2, RMA2, WAM, model performance, data, Delta, salinity, numerics

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 7

Flood Modeling in the Yolo Bypass to Support Habitat Evaluation

Chris Bowles, CBEC Eco Engineering, Inc., c.bowles@cbecoeng.com
April Sawyer, CBEC Eco Engineering, Inc., a.sawyer@cbecoeng.com
Chris Campbell, CBEC Eco Engineering, Inc., c.campbell@cbecoeng.com
Ray McDowell, DWR - FESSRO, rmcdowel@water.ca.gov
Marianne Kirkland, DWR-Division of Environmental Services, marianne@water.ca.gov

The Yolo Bypass is a major seasonal floodplain in the Central Valley and the Delta that provides rearing habitat and serves as a migratory pathway for juvenile Chinook salmon and splittail. In support of the Central Valley Flood Protection Plan (CVFPP) Restoration Opportunity Analysis (ROA), two-dimensional (2D) hydrodynamic modeling was performed using MIKE 21 FM to evaluate seasonal inundation patterns in the Yolo Bypass under a range of historical flows to understand habitat conditions for juvenile Chinook salmon and splittail. Inundation patterns are complex in the Yolo Bypass given the variability and timing of the source hydrology. Prior habitat use studies in the Yolo Bypass (e.g., Sommer et. al., 2005) have shown the importance of sustained inundation in the Yolo Bypass on fish success. As such, the objective of this study was to investigate habitat conditions in the Yolo Bypass under a range of flow conditions in years when spatial and temporal trends in juvenile Chinook salmon use were monitored. Historical hydrology for two high performing years and two low performing years for juvenile Chinook salmon and splittail were simulated in addition to two flood events (i.e., 2-year and 10-year) and used to assess habitat suitability and identify differences between years.

Keywords: Yolo Bypass, 2D modeling, habitat evaluation, fisheries, floodplain management

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 8

Tidal Salt Marsh Susceptibility with Sea-Level Rise: The Importance of Spatially-Explicit, Local-Scale Models to Assess Outcomes for Endangered Wildlife

Karen Thorne, USGS, kthorne@usgs.gov
Kevin Buffington, USGS, kbuffington@usgs.gov
John Takekawa, USGS, john_takekawa@usgs.gov
Deborah Elliot-Fisk, UC Davis, dlelliotfisk@ucdavis.edu

Coastal salt marshes and estuaries are projected to be disproportionately impacted by climate change and sea-level rise, according to the IPCC. Salt marshes along the west coast have been lost to urban development and landscape modification, limiting the habitat available for listed wildlife species. The maintenance and expansion of habitat is crucial to the successful recovery of these endangered species, but it remains unknown how much of an effect sea-level rise may have on the amount and quality of habitat. The focus of our interdisciplinary study is a bottom-up site-specific approach evaluating sea-level rise impacts to salt marsh habitats and wildlife by synthesizing field data and predictive modeling to develop habitat impact models. Our project has expanded to five sites along the Californian coast and is being implemented along the Washington and Oregon coasts. Elevation and sediment models, vegetation characteristics relative to elevation, and tidal inundation patterns have been established at each site to better understand potential future habitat changes. We hypothesize that a relatively small rise in sea level may result in increased drowning, nest failure, and an increase in predation pressure for many salt marsh species. Results from a new, spatially explicit sea-level rise response model for San Pablo Bay NWR will be discussed and compared with existing modeling efforts. Our model projects with 1.15 m of sea-level rise by 2100 that 80% of the existing marsh at San Pablo Bay refuge will transition to mudflat by 2060 with the remaining 20% converting by 2080. Our work illustrates the variable risk to wildlife species and identifies critical sea-level rise thresholds for salt marsh species.

Keywords: sea-level rise, salt marsh, response modeling, sediment, endangered species

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 9

Investigating the Influence of Tides, Inflows, and Exports on Sub-Daily Flows at Junctions in the Sacramento-San Joaquin Delta

Phil Gaskill, Cramer Fish Sciences, pgaskill@fishsciences.net
Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Jenny Melgo, Cramer Fish Sciences, jennym@fishsciences.net

The relative influence of tides, inflows, and exports on flow patterns in California's Sacramento-San Joaquin Delta continues to be a source of confusion and uncertainty for resource managers. The potential for impacts to sensitive fish species from export pumping remains highly contentious and has been the focus of recent Endangered Species Act Section 7 biological opinions. Particle tracking models (PTM) have been used to assess Delta flow patterns and entrainment risk of fish. PTM results are sensitive to net water movement within Delta channels and have not been used to describe daily and sub-daily variations in flow due to the interaction of tides with river inflows and exports. Yet, tidally-driven variations are known to influence salmon migration, and recent studies have pointed out that the interaction of complex fish behaviors and sub-daily changes in flow is the key to understanding migration and entrainment, particularly at junctions. We take a new approach to analyzing water movement in the Delta; one that is potentially more useful in describing water movement relevant to migrating salmon than PTM. Informed by recent acoustic tagging studies, and starting with inflow and export scenarios from Kimmerer and Nobriga (2008), we used flow data taken at 15-minute intervals from a Delta Simulation Model-2 Hydrodynamics model simulation to analyze sub-daily flow patterns in nine key Delta junctions. We obtained a detailed description of how tides, river inflows, and exports interact to influence juvenile salmon route selection. We found that tidal flow and stage are the primary influence on flow patterns, as well as on the proportion of water which enters the interior Delta, and that river inflow and export levels have a minor influence on flow patterns at most junctions. These findings sharply contrast with the results of PTM studies, and provide new insights for Delta water management.

Keywords: salmon; DSM2 Hydro; flow; junctions; migration; entrainment; tides; inflows; exports

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 10