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May 27, 2008

To: Phil Isenberg, Chair
Delta Vision Blue Ribbon Task Force

From: Michael Healey, Lead Scientist
CALFED Bay-Delta Program

Subject: Report on Science Program Workshop on Linking Hydrodynamic and Ecological Modeling in the Delta

On May 20, 2008, the CALFED Science Program hosted the second of two workshops on modeling and modeling tools for examining water conveyance through the Delta and its ecological impacts. This workshop addressed approaches to linking hydrodynamic and ecological models and their outcomes. Key conclusions from this workshop were as follows:

1. There is no comprehensive, predictive model of ecosystem dynamics for the Bay Delta System. This is in contrast to the powerful suite of physical process models discussed in the first workshop.

2. A visionary and holistic suite of linked models to explore the response of the Delta to scenarios of climate change is in progress (Comprehensive Assessments of Scenarios of Change for the Delta Ecosystem or CASCaDE). Some sophisticated models for predicting the response of individual species or ecosystem components to changing physical conditions are also being constructed (some as part of CASCaDE). As yet, however, none of these models is ready for application. Nor are they well designed to address policy and management questions about conveyance.

3. The conceptual models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) have begun the task of unraveling the complexities of ecosystem function for selected species and indicators. These conceptual models capture our current state of understanding, are rigorously peer-reviewed and documented with peer-reviewed literature. They constitute a valuable set of tools for examining qualitative ecosystem responses to change.

4. The leap forward in understanding of the Delta ecosystem that has occurred over the past decade is making possible the kind of model development discussed at the workshop. However, it will be some time yet before any comprehensive model linking hydrodynamics and ecosystem is available. In the mean time, Decision Analysis models that link

hydrodynamics to ecological data through a decision support interface (such as SacEFT described at the workshop) would assist decision makers in exploring the ecological implications of alternative conveyance.

5. There is a great sense of urgency to make decisions regarding the Delta catalyzed by the work of the Blue Ribbon Task Force. A similar sense of urgency is needed to ensure that the science, specifically ecological analysis and modeling, is available to support these decisions.

6. To facilitate the urgent process of developing ecosystem models more directly relevant to policy analysis the panel recommended establishing a Science Center to stimulate and coordinate data management, model development, model management and training in the use of models. The CALFED Science Program is taking initial steps to establish a modeling unit that could form the nucleus of such a Center. Additional staff and resources would be needed to make the Center a reality, however.

Below, I briefly summarize the workshop and my interpretation of the discussion leading to these conclusions. The complete report from the workshop expert panel will be posted on the CALFED Science Program web site when it is finalized.

In this second Delta conveyance modeling workshop, as in the first, a panel of experts heard presentations by researchers who are currently designing integrated hydrodynamic-ecological models for the Delta and then engaged in a technical discussion with the researchers about their models. The models discussed at the workshop link physical and ecological processes in different ways and at different scales. Jim Cloern (USGS) described CASCaDE, which is a multi-investigator project linking models of climate change, precipitation and stream flow in the Delta's watershed to hydrodynamics, sediment transport, and food web dynamics in the Delta. This model is designed to assess the implications for water supply and ecosystem of various future climate scenarios. Lisa Lucas (USGS) and Jan Thompson (USGS) described in more detail two sub-models of the larger CASCaDE project, a model of phytoplankton production in the Delta (Lucas) and a model of the abundance and dynamics of clam (*Corbula* and *Corbicula*) populations in the upper estuary and Delta (Thompson). Wim Kimmerer (SFSU) described an individual based model linking Delta smelt population dynamics to hydrodynamics through the particle tracking routines in the hydrodynamic models. An individual based model tracks the fate of individuals within the population, in contrast to more traditional population models that simply track aggregate numbers. Dave Marmorek (ESSA Technologies Inc.) described a model (Sacramento Ecological Flows Tool, or SacEFT) ESSA has been developing with The Nature Conservancy and Stillwater Sciences that links

Sacramento River hydrology to ecological targets through a decision analysis interface.

None of these modeling tools is as yet fully operational and none of the Delta focused models is designed to address the broad ecosystem questions faced by the Task Force. It should be noted, however, that this situation is the norm for ecological modeling around the world. In 2001, the US National Research Council recognized the pressing need for more comprehensive ecosystem models to address high priority environmental challenges and took action to mobilize the scientific community through the National Science Foundation. The modeling projects underway in the Delta are consistent with this national effort. Over time, the scientific resources devoted to these models will strengthen our understanding of the hydrology/ecology interface. But much remains to be done.

Additional information on the specific models discussed at the workshop will be available in the final report of the expert panel and in the internet links provided in that report. The panel also commented on four questions posed by the Science Program that are relevant to the challenge of assessing the ecosystem implications of changing Delta hydrology:

Question 1. Why are there no quantitative models of ecosystem dynamics for the Delta that are able to predict ecological response to changed physical conditions in a manner comparable to the hydrodynamic models DSM2, RMA2, UnTRIM?

The facile answer to this question is that ecosystems are complicated and modelers have, so far, failed to develop effective predictive models. Some analysts (e.g., Oreskes et al. 1994[1]), however, argue that it is not possible to construct predictive models for open, complex adaptive systems like ecosystems. Without a doubt, system complexity and self-organization are obstacles to ecosystem modeling. The panel also suggested that researchers familiar with the Delta have found it difficult to simplify the system in ways that make models tractable yet meaningful. Ecological modeling in the Delta has been focused on population models for individual species (such as Delta smelt) or specific processes (such as phytoplankton production). Although such models can be useful for management planning, they do not provide the kind of system-wide assessment of response that the hydrodynamic models do. The more comprehensive models discussed in the workshop (CASCaDE and SacEFT) take very different approaches to addressing the complexity of the ecosystem and how to manage it. CASCaDE seeks to stitch together detailed models of system components in an attempt to generate an overall

[1] Oreskes, N., K. Schrader-Frechette, and K. Belitz. 1994. Verification, validation, and confirmation of numerical models in the earth sciences. Science 263: 641-646.

quantitative system response. The intent of CASCaDE is to understand how specific scenarios of future climate will affect water supply, hydrodynamics, sediment transport, and Delta food webs. It is not designed to explore the consequences of alternative water management policies, although it could be used to assist with such assessments. SacEFT also stitches together existing models but makes greater use of expert judgment where detailed scientific understanding is lacking and is specifically designed (through the decision analysis interface) to explore the hydrological and ecological consequences of different water management policies.

Question 2. To what extent will the current research and development of ecological models for the Delta (e.g., CASCaDE, Individual Based Population Models, DRERIP, others) address this limitation?

It was the opinion of the panel that none of these models alone or in combination would provide the kind of comprehensive picture of ecosystem response that decision makers need. Modelers are making progress in developing population models and the DRERIP Conceptual Models illustrate the components of an ecosystem model, but a greater variety of approaches could be implemented. The models presented at the workshop were rich in biological detail but their elaboration into quantitative ecosystem models would be hopelessly complex. An unresolved issue was whether an ecosystem model of the Delta could be built with fewer components (for example, with species combined into functional groups) that would allow evaluation of scenarios of future change. The panel thought that a high level of spatial and biological detail was probably not required for many of the policy questions that need to be answered. The panel also thought that the spatial and temporal detail provided by the hydrodynamic models might have led the ecologists into a morass of detail that would not provide the kinds of answers that managers need. Clearly, many questions remain about how best to approach an ecosystem model for the Delta that would assess the ecosystem consequences of changing water operations and other policy alternatives.

Question 3. What is the prognosis for developing a fully linked hydrodynamic-ecosystem model for the Delta within the next decade?

Population models and models of some ecological processes are making good progress, as shown in the workshop. For example, it seems likely that a model linking phytoplankton production and hydrodynamics will be completed soon. Developing a quantitative model of the entire food web or ecosystem in the next decade seems less likely. New approaches that attempt to model a more simplified biological system might provide insights. The panel was not particularly optimistic that a comprehensive model would emerge from the current modeling research and development within a reasonable time.

Question 4. In the absence of quantitative ecosystem models that can be linked to hydrodynamic models, what is the most effective and efficient means to assess the ecological impact of changed hydrology?

There are a variety of ways that ecosystem consequences of changing water conveyance might be examined at least in a qualitative way. Once it is functional, the CASCaDE model will provide an assessment of future climate scenarios and might be adapted to incorporate the effects of management decisions. The hydrodynamic models examined in the previous workshop can be used to provide hydrodynamic scenarios whose ecological implications might be explored by means of the DRERIP conceptual models. The most important linkages in the DRERIP models might also be made quantitative by means of simple simulation software (such as STELLA). Until more rigorous predictive ecosystem models become available, however, an approach such as that taken in SacEFT would capture current knowledge in a way that is useful to managers.

The decision analysis (DA) tool in SacEFT is a critical component, absent from the other models discussed in the workshop that makes SacEFT highly policy relevant. The DA tool is a model that links management actions quantitatively to changes in the physical habitats of six key species on the Sacramento River. These quantitative linkages constitute a set of rules that specify how a management action will affect key species or their habitats. The DA tool is not intended to make accurate predictions of ecosystem behavior or outcomes. Rather, its main purpose is to characterize and explore potentially important ecological trade-offs and the relative impacts of various management alternatives. The SacEFT approach, which engages model builders and decision makers together in both model building and model application, provides an efficient means to clarify critical scientific and management uncertainties that require further research. Given the urgent need to address ecosystem implications of changing hydrology in the Delta, the SacEFT approach is an attractive model by which to initiate the work of the panel's proposed Science Center.