Summary of the April 3, 2008 CALFED Science Program Workshop on Conveyance Modeling in Support of the Delta Vision Blue Ribbon Task Force

Report by Science Advisors to the CALFED Lead Scientist

Executive Summary

The stated purpose for this workshop was "to publically discuss various Delta conveyance modeling tools, assumptions, and other variables, and to provide a facilitated discussion with organizations conducting Delta conveyance modeling." The panel of modeling advisors was asked to describe the models and modeling approaches being used, as well as the applications, strengths and limitations of the models and modeling approaches. The advisors summarize this information in this report, and also address the question of whether the existing conveyance models, modeling approaches, and model studies are adequate to address the Task Force needs for information regarding a dual conveyance system for the Delta. To this question the panel has an equivocal attitude; our answer is "maybe." We believe that before we can give a more definite answer, we need more information and details on the studies being done.

We also believe that the answer to the question depends to a large degree on the information the Task Force is seeking. Our answer is an unequivocal "no" if the Task Force is seeking clear information on how a dual conveyance system, or even a modified through-Delta conveyance system, will affect the estuarine ecosystem as a whole or even certain fish species of concern, such as delta smelt. We have learned from the past that the response of the Delta ecosystem to changes in the conveyance system is highly unpredictable, and our recent leap forward in understanding ecological processes has not changed that. While a dual conveyance system will likely reduce direct entrainment of fish at the south Delta pumping facilities, our models and understanding are not adequate to accurately forecast the overall ecosystem response to dual conveyance.

We do feel somewhat comfortable saying that our existing models, when carefully and skillfully applied, can provide reliable information to the Task Force on the response of Delta hydrodynamics (water flows and water heights) associated with conveyance changes. Our answer regarding predictions of the response of water quality variables, such as salinity, to conveyance changes is more qualified than for hydrodynamics. Making accurate salinity predictions is more challenging than for hydrodynamics, and some extra caution is advised depending on the problem being solved. For example, the modeling capabilities we presently have for predicting salinity intrusion as a result of sea-level rise are probably not adequate. On the other hand, predictions of the salinity response for, say, adding an individual gate or barrier to a particular Delta channel in the Franks Tract area should be reasonably reliable. When we add several gates or barriers, the problem becomes more difficult.

Although we advise caution in relying too heavily on the precise numbers that come from Delta models, we firmly believe that modeling studies are worthwhile and can provide useful information and insights into hydrodynamic, water quality and ecological responses to conveyance changes in the Delta. Indeed, for a complex engineered and natural system such as the Bay and Delta Estuary, computer-based modeling and simulation is virtually required. We simply advise that the Task Force should be aware that the various predictions of model studies have greatly varying degrees of uncertainty. In ecological modeling, the reliability of the conceptual models upon which the predictions are based is often not well known. In this case it is not possible to estimate the uncertainty associated with predicted outcomes. So great caution is advised with these models.

Models do provide a valuable role in focusing scientific debate. Models encapsulate the current understanding of the processes governing issues of concern to managing agencies. Model simulations provide a rigorous test of this understanding and serve to highlight gaps in knowledge and the types of information needed by managers to make fair, equitable and defensible decisions. Other essential roles of models include visualization and the refinement of monitoring programs to ensure the best use of limited funds and resources (such as sensors, boats and personnel). Visualization has proven to be a valuable communication tool for managers and to allow engineers and scientists to communicate across disciplines. For example, the particle tracking models have

allowed hydraulic engineers and fish biologists to collaboratively gain insights to fish behavior.

Therefore models have a vital role to play in the future management of the Delta and it is important that the evolution of models are conducted in a transparent and open-access manner to avoid conflicts arising between different agencies.

Ultimately, unless a particular management or policy question depends solely on prediction of flows, water heights, and salinity concentrations, conveyance models alone provide only part of the information that is needed for making informed decisions. Understanding Delta hydrodynamics and transport processes are essential but not sufficient for addressing all the criteria for evaluating conveyance options set forth in the Delta Vision, especially with regard to ecosystem health and resilience. We believe that the modeling tools themselves are impressive and, when skillfully applied, are indispensable tools. Information leading to a choice of a specific option for Delta conveyance that improves water supply reliability, water quality, and ecosystem health and resilience, must come from interdisciplinary discussions where conceptual models reflecting the best science on physical, chemical, and ecological processes are linked together. Indeed, those doing conveyance modeling to support the Delta Vision must be encouraged to keep abreast of the most recent multidisciplinary science in the estuary. It is vitally important that information derived from conveyance evaluations reflect the latest understanding of Delta science. In this report we list the many options available to modelers for keeping track of the emerging science in the estuary.

The body of this report addresses a variety of topics that provide additional information on models, the modeling process, and the kinds of conveyance-type modeling studies being done in the Delta. We had hoped to elaborate more on these topics, but the limited time we had to prepare our report prevented us from going into much detail. What we have attempted to provide, therefore, is useful background reading on the following topics:

- Model descriptions, including strengths and weaknesses, for the three primary hydrodynamic, water quality, and particle-tracking models being used in conveyance modeling studies (DSM2, RMA2/11, and UnTRIM).
- Model verification and validation

- Uncertainty in model results
- Maintenance of the vertical geodetic datum
- Types of model applications (for analyses of: sea-level rise, dual conveyance, levee breach scenarios, installing new barriers and other physical structures to modify through-Delta flow and salinity distributions, and fish transport using particle tracking models)

The panel also offers thoughts on how models are applied as part of a human enterprise in search of comprehensive Delta solutions. The topics are:

- The need for multidisciplinary thinking
- New conveyance project work team
- Communication of information and findings to policymakers
- Concept of a California Science and Modeling Center

In addition, the report includes our notes summarizing a few of the key points or topics addressed by the speakers at the workshop.

In closing, we also point out that modeling is not just a science but an art. A modeler, like an artist, relies a great deal on his individual abilities, knowledge, and skills for his work, and not just upon the tools he uses. Gaining an understanding of just the hydrodynamic, water quality, or ecosystem processes in the Bay-Delta estuary can take many years and no one individual is an expert on all three. Modeling studies should be done by teams with multidisciplinary expertise on the Delta and, whenever possible, the results from studies used by the Task Force should be peer-reviewed by the best available experts on the Delta.

Introduction

On April 3, 2008 the CalFed Science Program convened the first of two workshops on Delta conveyance modeling in support of the Governor's Delta Vision Blue Ribbon Task Force (Task Force). The Task Force has developed a vision for the Delta (Delta Vision Blue Ribbon Task Force, 2007) that recommends that "*new facilities for conveyance and storage, and better linkage between the two, are needed to better manage California's water resources for both the estuary and exports*." The vision calls for immediate improvements to the existing through-Delta export system and for studies to be done to assess a dual conveyance system as the preferred direction. Dual conveyance is defined as an optimized combination of through-Delta conveyance and conveyance around the Delta using some form of an isolated facility. The Task Force is charged with developing a strategic plan to implement their vision for the Delta by fall 2008.

Numerical models of Delta conveyance and storage systems are the primary tools that are being used to assemble information on the performance of alternative conveyance options. In their Vision, the Task Force recommends that the options be evaluated based on criteria that include at least the following performance standards:

- Water supply reliability;
- Seismic and flood durability;
- Ecosystem health and resilience;
- Water quality;
- Projected schedule, cost, and funding; and
- Additional performance standards that may be identified by the Task Force.

Because of the important role that models will play in the selection and evaluation of new conveyance options in the Delta, the Task Force asked the CalFed Science program to organize and host two workshops on conveyance modeling. The purpose for the two workshops was to publically discuss Delta conveyance modeling tools, assumptions, and representative case studies, and to provide a facilitated discussion with the

organizations conducting Delta conveyance modeling. The first workshop was aimed primarily at providing a forum to exchange information on the available models being used in Delta conveyance studies and to have the government agencies and other parties involved in using these models identify the studies that are presently being done. The presentations and discussions on the modeling studies focused on the current status in addressing the Task Force needs for information regarding dual conveyance.

In this first workshop, the science advisors were asked to host the morning session that was described colloquially as "Modeling 101." The session included discussions about the models and modeling approaches being used in the Bay-Delta, the challenges in modeling the estuary, the strengths and limitations of the models and the modeling approaches, and the uncertainties inherent in model predictions of hydrodynamic, water quality, and ecological processes in this complex estuarine system.

This brief report prepared by our panel summarizes the presentations and discussions at the workshop and provides independent feedback regarding the models, modeling approaches, and modeling studies that were described. Many of the current modeling activities were developed to address specific management questions and the panel also emphasized whether the modeling studies presently being done are useful for meeting the needs of the Task Force. We have also included a number of recommendations for improving the future of modeling in the estuary, both in the short term and the long term.

Overall, we were impressed with the conveyance modeling applications being done in the Bay-Delta and the significant improvements in models that have been made in the last ten years. The modeling capabilities have evolved considerably for both the estuary and its watershed, and the models have been used to address many important science and management issues.

Scope of Summary

Two categories of models were presented and discussed at the workshop: the basin-scale, water resources simulation models (CalSim II and CalLite) and the estuary hydrodynamic models (DSM2, RMA2, and UnTRIM).

The CalSim II model, first released in 2002, was jointly developed by the California Department of Water Resources (DWR) and the US Bureau of Reclamation Mid-Pacific Region (Reclamation). It is a generalized reservoir and river-basin planning model that simulates the operations of all the major system components for the Federal Central Valley Project (CVP) and the State Water Project (SWP). In essence, this model is a water accounting model that tracks the water storage, river discharges, diversions and return flows through the system and encapsulates a vast amount of knowledge developed by water managers during the past two decades. The model is a valuable tool for water management on a time step of days or months, but it is not intended to simulate the dynamics of the tidal flows, flood flows, the effects of island flooding or water quality. It is the best available tool for studying issues related to water-supply reliability and additional water storage reservoirs in the Central Valley of California. The CalLite model is a new, faster-running and simpler version of the CalSim II model that should prove valuable in the near term for evaluations of proposed storage and conveyance modifications, system operational changes, and climate change scenarios. The CalLite model is based on the CalSim II model.

External technical reviews of the CalSim II model (California Department of Water Resources, CalSim II Model Peer Review Process, accessed May 4, 2008) were completed in 2003 and 2006 by the CALFED Science Program and by the California Water and Environmental Modeling Forum (CWEMF). Because of these two recent, thorough reviews of the CalSim II model the science advisors chose for this summary to focus on the three estuarine hydrodynamics models that presently are being used in Delta conveyance studies in support of the Delta Vision process.

We found it convenient to organize this summary and our review comments around the following topics: model descriptions, verification and validation, uncertainty in model predictions, vertical geodetic datum, modeling studies, and other comments and recommendations.

Model Descriptions

The three numerical models described here include a one-dimensional (1D) model, a two-dimensional (2D) model, and a three-dimensional (3D) model. These are:

- 1D: Delta Simulation Model 2 (DSM2);
- 2D: Resources Management Associates Model 2 (RMA2); and
- 3D: Unstructured grid Tidal Residual Intertidal Mudflat (UnTRIM) model.

These models are among the most widely used models in the Bay-Delta and are selected to illustrate the range of models currently being used by different agencies and interests. The models all include components for simulating hydrodynamics (water-surface elevations and water velocities), water quality (salinity, temperature, or other variables), and particle tracking. The term numerical model here applies to the fact that they solve a system of partial differential equations (PDEs) for conservation of mass, momentum, and salt[1] throughout the estuary at successive time intervals.

- ***DSM2***

The DSM2 model has been, and continues to be, the most widely used of the estuarine models for studying the water conveyance system of the Delta and Suisun Bay portion of the estuary. It is a 1D (cross-sectional averaged), public domain model that is well-supported by the Delta Modeling Section of the Bay-Delta Office at DWR. The Delta Modeling Section hosts a user's group for the model and offers periodic training classes in the use of the model. The computer codes for the hydrodynamic and water quality components of DSM2 are programmed in the Fortran language and are based on well-established and well-verified numerical schemes that are among the best available. The particle tracking code, programmed in a mixture of the Java, Fortran, and C languages, uses a unique quasi-3D algorithm that applies vertical and transverse velocity profiles and mixing coefficients to simulate 3D dispersion of particles. Although the configuration of the DSM2 model code to the Delta represents one of the more complex 1D modeling systems in the world, it still runs very efficiently on today's modern computers. Five-year

[1] If additional water quality constituents are simulated, then additional equations are required.

simulations of the Suisun Bay and Delta (including both hydrodynamic and water quality runs) are possible with about three hours of computer time on a fast workstation. The model did undergo extensive calibration in 1997 to adjust the empirical coefficients (primarily friction and mixing coefficients) to obtain agreement between simulated and measured data for water level, flow, and salinity in the Delta. Independent validation of the model (without "tuning" any model parameters) in subsequent years has shown the predictions are in reasonably good agreement with measured data. Although the panel believes some additional calibration of the model would prove beneficial, what may be most limiting further improvements in the predictive ability of the model is the one-dimensionality of the code. The nature of the 1D approximations in the model ignore much of the complexity involving circulation and mixing in the large open-water bodies in the Delta (e.g. Franks Tract, Sherman Lake, Mildred Island, Big Break, etc.) and in Suisun Bay. Suisun Bay in particular is an especially challenging open-water environment to simulate using a 1D approximation because of the complex bottom topography there, and because of the significant density gradients, due mostly to salinity gradients, which occur both in the horizontal and vertical directions. The longitudinal gradient in density causes a gravitational (two-layer, tidally averaged) circulation pattern in the vertical dimension of the deepwater channels of Suisun Bay that affects saltwater mixing and is difficult to parameterize properly using a 1D model. Because the grid for the DSM2 model extends downstream only to the western edge of Suisun Bay, it is located at an especially challenging position in the estuary that undergoes frequent stratification and de-stratification.

We attempt to summarize some of the strengths and weaknesses of the DSM2 model as follows:

Strengths--

- Fast and efficient model for multi-year simulations of the Delta and Suisun Bay
- Public domain code freely downloadable from the web. This open access strengthens the defensibility of the model since limitations are known and comments from third parties have been included in the model development over the years.
- Code based on numerical solution techniques that are well-known and tested.

- Deals with all the complexities of Delta hydrodynamics (e.g., barriers, gates, Delta island consumptive use, etc.)
- Excellent support and training for the model available from the Delta Modeling Section at DWR
- Well documented in a series of reports published annually by the Delta Modeling Section of the California Department of Water Resources
- Freely available software for pre- and post-processing of model data and graphical presentation of results.
- The modeling system includes a unique, quasi-3D particle tracking code that has proven especially useful for ecological modeling applications.

Weaknesses--

- Limited by 1D approximations in large open-water bodies and at complex channel junctions
- Neglects any effects from density gradients or wind on Delta hydrodynamics
- Uses a challenging location at Martinez for the specification of seaward boundary conditions for the model
- Does not include the lower San Francisco Bay portion of the estuary so boundary conditions at Martinez must be estimated for planning simulations
- Specifies only daily (rather than hourly) variations in pumping at the SWP Banks Pumping Plant
- Specifies only daily (rather than hourly or shorter time interval) data for the landward model boundary condition on the Sacramento River that is tidally affected at low flows
- The Particle Tracking Model (PTM) is limited by 1D approximations at channel junctions and may not fully capture dispersive mixing properties within channels where large tidal variations and complex channel geometry occur, such as the western Delta and Suisun Bay
- The code for the PTM has proven difficult for others to modify and compile

- ***RMA2***

The RMA2[2] model is a 2D (depth-averaged) hydrodynamic model that was first developed in the early 1970s for the Walla Walla, Washington District of the U.S. Army Corps of Engineers (USACOE) by a California consulting firm called Water Resources Engineers. The model is now maintained by a consulting firm called Resource Management Associates (RMA) that is based in Fairfield, California. A version of the code is also supported as part of the TABS-MD (multi-dimensional) modeling system maintained by the Engineering Research and Development Center (ERDC) for the USACOE, in Vicksburg, Mississippi. The RMA2 model configured to the Bay-Delta has been applied in a number of recent large-scale modeling projects for CALFED and DWR, mostly focused on predicting salinity intrusion in the Delta. Two versions of the RMA2 model are used in the Bay-Delta depending on the requirements for the particular study. One version is configured for the entire Bay-Delta system with the seaward boundary condition applied at the Golden Gate. The other version is configured only for the Suisun Bay and Delta region with the seaward boundary condition applied at Martinez, similar to the DSM2 model. One feature of the model that makes it useful for applications to the Bay-Delta is its capability to represent different portions of the estuary using either a 1D or 2D approximation. This allows the San Francisco Bay and western Delta portion of the estuary to be represented using a 2D approximation and the many narrow channels in the Delta to be represented using a 1D approximation. The 2D computations are done using an unstructured, finite-element grid that consists of triangular and quadrangular elements (computational cells). This hybrid combination of 1D and 2D models is advantageous because the more computer-intensive 2D computations are employed only where they are needed instead of over the entire system. The 2D computations are expensive computationally, which makes the model considerably more expensive in terms of computer time to execute than the 1D DSM2 model. A several month simulation using just the Suisun Bay and Delta version of the model requires hours of computer time on a fast workstation. The model has undergone extensive calibration using data from 2002 as part of the DWR Flooded Islands Project (California Department of Water Resources, Franks Tract Project, accessed May 4,

[2] The RMA2 model is a hydrodynamic model only. A second model, called RMA11, is the water quality simulation model that is designed to accept input velocities and water depths from the RMA2 model. Here we are speaking about both models as one modeling system.

2008). A report on the calibration is available (Resource Management Associates, 2005).

We attempt to summarize some of the strengths and weaknesses of the RMA2 model as follows:

Strengths--

- Allows for 2D computations in the San Francisco Bay and the western Delta portions of the estuary and 1D computations in most other places within the Delta
- Code released upon request made to Resource Management Associates, Inc.
- Code based on numerical solution techniques that are well-established and have been used in many model applications around the United States
- Support for the model and pre- and post-processing software are available from the RMA consulting firm or Boss International Corporation
- Deals with all the complexities of Delta hydrodynamics (e.g., barriers, gates, Delta island consumptive use, etc.)
- Because of 2D capabilities, represents the circulation and mixing in large open-water bodies better than 1D models
- Uses an unstructured grid, which allows for extra grid points to be applied in areas of special interest
- Allows for representation of irregular boundary configurations
- Two-dimensional elements are allowed to wet and dry during a simulation
- A 2D and 1D particle-tracking code is available
- Coupled simulation of the hydrodynamic and density field can allow for inclusion of density gradient effects in the context of a 2D model. (The panel does not believe, however, that density gradient forcing has been included in most of the recent applications done with the RMA2/11 modeling system.)
- Two versions of the model (one including the lower portion of the Bay and one without it) are available depending on the requirements for the particular study

Weaknesses--

- The 2D calculations are done using a fully implicit numerical approach that is computer-intensive (even by 2D standards) and requires much more computer time for execution in the Delta than a 1D model
- For Delta-only simulations the model uses a challenging location at Martinez for the specification of seaward boundary conditions
- The 1D component of the model used for representing Delta channels is limited to trapezoidal-shaped cross-sections
- Support for the model and pre- and post-processing software are not free.
- Specifies only daily (rather than hourly) variations in pumping at the SWP Banks Pumping Plant
- Specifies only daily (rather than hourly or shorter time interval) data for the landward model boundary condition on the Sacramento River that is tidally affected at low flows

- ***UnTRIM model***

UnTRIM (Unstructured grid Tidal Resolution and Intertidal Mudflat) is a relatively new 3D hydrodynamic model that was developed over the last ten years by Vincenzo Casulli, an Italian mathematics professor at the University of Trento, Italy. An earlier version of the code, called TRIM3D, was available prior to the UnTRIM version. The method of solution in UnTRIM is a mixed finite difference and finite volume method as opposed to the finite element method used in the RMA2 model. The word “unstructured” in the model name means that, similar to the 2D RMA2 model, the model calculations use an unstructured numerical grid in the horizontal plane composed of triangles, quadrangles, or (most typically) a mixture of the two to solve the model equations. The earlier TRIM3D model allows only for a horizontal grid of square cells. The words “intertidal mudflat” means that the model allows wetting and drying of model grid cells, a feature that is not available in all 3D models. In the vertical dimension, the UnTRIM model uses a grid of horizontal layers that may, for example, be one meter in height for typical Bay and Delta applications. The model algorithms and mathematics have been documented well in the published literature. The TRIM3D and UnTRIM models have been applied to the San

Francisco Estuary for both research and consulting, primarily by scientists at the U.S. Geological Survey regional research office in Menlo Park, by graduate students from Stanford University, and by consultants that are graduates of Stanford University. The applications have mostly been to the San Francisco Bay where 3D calculations are most needed because of the effects on circulation from density gradients. For the San Francisco Bay applications the model has used a simplified geometry for the Delta that includes “false delta” areas that are appropriately sized to produce the correct tidal prism. During 2008, considerable effort is being spent to extend the unstructured grid of the model to include the entire Delta. The UnTRIM model is a propriety computer code that must be purchased from the developer (V. Casulli). The strength of the model is its very efficient and modern mathematical algorithms that make the 3D calculations for the entire estuary possible on high-end workstations. The unstructured grid allows for flexible placement of nodes for additional savings of computer time and for good representation of curved shoreline boundaries. The grids do require considerable skill, time, and care to develop correctly, however.

We attempt to summarize some of the strengths and weaknesses of the UnTRIM model as follows:

Strengths--

- Allows for full 3D computations in the San Francisco Bay and the western Delta portions of the estuary where density-gradient effects and lateral circulations are important. Extensions to the Delta are underway.
- Very efficient calculations for a 3D model
- Code based on semi-implicit, numerical solution techniques that are well-described in the published literature and have been applied to a variety of different applications.
- Support for the model is available from local consultants and at workshops held annually in Italy. Some pre- and post-processing software are available (for purchase).

- Because of 3D capabilities, the model represents the circulation and mixing in large open-water bodies better than 1D models
- Uses an unstructured grid, which allows for extra grid points to be applied in areas of special interest
- Because of unstructured grid capability the model allows for good representation of curved shoreline boundaries
- Grid cells are allowed to wet and dry during a simulation
- A coupled simulation of the hydrodynamic and density field is the normal way this model is run. It is the best model for inclusion of density gradient effects on hydrodynamics.
- A square grid version of the model is available if desired.

Weaknesses--

- The model is proprietary and a license for its use must be purchased from the developer. Access to the full computer code is not allowed.
- Although most of the model principles are in the peer reviewed literature, there are elements of the model that are not fully described.
- Although the 3D calculations are very fast (by 3D model standards) the model still requires an enormous amount of computer time to run simply because of the large number of computational nodes that are required in 3D simulations. It is unknown whether the model will be practical when full Bay and Delta simulations are attempted.
- There presently is not a Delta version of the model available. When a Delta version is available, it will need to be calibrated.
- Does not yet deal with all the complexities of Delta hydrodynamics (e.g., barriers, gates, Delta Island consumptive use, etc.)
- Formal training on the model is not available (but could be arranged upon request)
- A 3D particle tracking model is available, but it is brand new and still undergoing development.

- The model has no true 1D component that can be used for representing narrow Delta channels like the RMA2 model.
- Support for the model and for pre- and post-processing software are not free
- Handles calculations for flow through entrance gates to Clifton Court Forebay somewhat crudely.

Model Verification and Validation

It is very important that numerical models of the type discussed here are rigorously verified and validated. Our definitions of "Verification" and "Validation" come from the textbook by Roache (1998) and from those adopted in recent years by most of the engineering societies that publish computational studies. In succinct form, Verification is "solving the equations right," and Validation is "solving the right equations."

There are two types of Verification: Verification of the Code and Verification of the (individual) Calculations. Code Verification means that a model computer code has been tested using known analytical solutions and found to be free of coding errors; it also means, however, that the order of accuracy of the underlying numerical scheme in the model has been determined by the observed behavior of errors in the solution obtained from systematic grid convergence tests. The methodology for verifying the accuracy of codes and examples of applications are provided by Roache (1998) in chapters 3 through 8. A good recent example of verifying the accuracy of a 3D model is given by Lai and others (2003). In theory, Code Verification should be done once by the code developers and should not be a concern of the model user. In practice, however, many of the multi-dimensional model computer codes in widespread use today have not been rigorously verified, especially for determining accuracy, in the manner that is recommended as part of good modeling practice.

Unfortunately, if a model code is verified that is not enough. For each new application of a model to an actual problem, the individual calculations also must be verified to estimate if significant numerical error is occurring for the particular grid resolution chosen for solving the governing equations. This is called Verification of the Calculations (or

Calculation Verification) and is done by grid convergence tests. A good example of Calculation Verification that also considers the significant complications that arise in grid convergence testing on real water bodies because of bathymetry is given by Luettich and Westerink (1995).

While Verification involves strictly mathematics, Validation involves science/engineering. Field validation of a model involves comparison of the predictions from the model with field data. The need for realistic field validation of an estuarine hydrodynamic and transport model is to confirm that empirical coefficients (such as are used to parameterize friction, mixing, turbulence, surface wind stress, etc.) are adjusted properly for the unique field-specific conditions. A hydrodynamic/transport model also includes a large suite of conceptual modeling assumptions that result from choices made by the model developer in the design and formulation of the model code and by the model user in selecting among available code options for a particular field application. Examples of these choices include those for: the friction law and mixing formulations; the treatment of density (as either constant or variable); the number of dimensions in the model; the method for representing bathymetric, shoreline, and hydraulic data; and the specific manner in which model boundary conditions are applied. The applicability of conceptual modeling assumptions depends greatly on the model application. In some instances, the applicability of an assumption will be immediately obvious, such as the need for including a realistic bottom friction law in tidal predictions for a shallow estuary. In other cases it is much less obvious, such as the need for including a density-gradient forcing term in the equations used for the hydrodynamic predictions in the landward, low salinity portions of a tidal estuary or delta like the San Francisco Estuary. Validation also is important for revealing any errors that can occur in application-specific input data for a model such as topography or other geometric data, data for operations of physical structures, boundary conditions, or initial conditions.

It is almost never justified to rely upon predictions from a field model application without some form of validation. However, the degree of validation that is necessary, the validation metrics to be used, and the acceptable tolerance for agreement between measurements and simulations, often can be specific to the purpose for the model application and to how the model results are to be used. Without any validation,

however, no statement at all can be made about the accuracy of a model prediction; in the absence of this information, the usefulness of the model prediction is questionable.

The modeling teams should be strongly encouraged to verify their models mathematically and to validate their models with field data for each new application study and when new field data becomes available. Code verification for accuracy should be done for the multidimensional models to reveal the effective order-of-accuracy of the numerical schemes in real calculations. Calculation verification using grid convergence studies should also be done for the multi-dimensional models to assure that the level of grid refinement is adequate to reduce numerical solution errors to an acceptable level. The verification and validation results for all models should be published so that it is peer-reviewed and made accessible to others.

Uncertainty in Model Results

The complex physical processes governing flow and transport in the Delta are simulated using a number of approximations and assumptions in Delta models. While the predictive ability of numerical models in simulating historical conditions for the existing Delta conveyance configuration can be quantified through model verification, calibration, and validation, the quantification of model performance under modified or hypothetical conditions or configurations, or even under conditions outside the range of the calibration/validation process, has a much higher degree of uncertainty. In these "planning" model applications, it is most important that the uncertainty of model results be estimated so that conclusions about the quality of modeling results can be drawn in a realistic, self critical manner. Only through careful analyses and review can the results from planning model simulations be properly interpreted to gain insights and improve understanding on the questions being investigated. Getting the numbers is only an interim step.

Uncertainty estimates can be made from sensitivity studies on model input data and parameters. Some of the key uncertainties in Delta modeling are agricultural diversion and drainage in Delta islands, friction and dispersion in some channels, and salt transport through large water bodies such as Franks Tract. Much progress has been made recently, both in data collection and in model development, through dedicated

resources from the CALFED Science Program, USGS, DWR, RMA, and others. These latest improvements should be incorporated into the modeling of Delta Vision alternatives. Sufficient time and resources must be allocated to this analytical work, commensurate with its role in the decision process.

Uncertainties in the formulation of conceptual models, referred to as structural uncertainties, must also be addressed. Some examples are the different models of fish behavior in particle tracking models and ecological models. Estimating uncertainty in modeling results is especially important in planning studies, or studies where measured field data are not available. We need to make a distinction between "historical" and "planning" simulations. Uncertainty estimates are normally derived from sensitivity studies for model input data and parameters but can also apply to different conceptual models (structural uncertainty).

Vertical Geodetic Datum

The accuracy of models, estimates of sea-level rise, the effectiveness of levee programs, and wetland restoration design, all depend on accurate estimation of the height of landscape features. We must ensure that the elevation of levees, water stage, channel beds, and land topography are tied to a common and accurate geodetic datum. The foundation for all elevation measurements in the estuary is the regional geodetic benchmark network. Accurate estimation of the vertical landscape depends on periodic maintenance of the regional geodetic benchmark network (Figure 1).

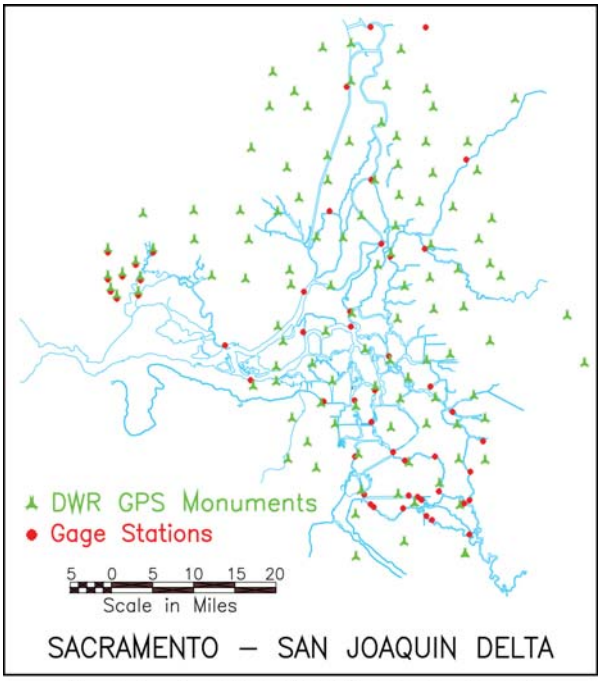

Figure 1 -- Location of GPS monuments and tide gages in the Delta/Suisun Marsh area.

Hydrodynamic and transport models of the Bay-Delta can only be as accurate as the data used to describe the Bay and Delta physiography to the model. Estuary models represent the actual estuary as a finite “grid” of points where

calculations of water velocity, water elevation, and constituent concentration are estimated. At each of the sometimes thousands of computational points within the models, there is an advance requirement for an estimate of the channel bed elevation along with the associated latitude and longitude coordinates. Taken together, the model responds directly to this complex estimate of the estuary's "bathymetry"—the underwater physiography of the system.

At present, there is no one agency or entity responsible for periodic and systematic maintenance of geodetic benchmark network accuracy. The National Geodetic Survey coordinates benchmark networks across the country and sets practice and performance standards but does not carry out field surveys. The current standard is the North American Vertical Datum standard of 1988. The benchmark network was realigned to the standard in 1991 and 2002 by an ad hoc partnership of DWR programs. The network is currently in need of realignment. Therefore, an integrated program is needed to coordinate the various dimensions of land and water surface elevation monitoring. Considering its fundamental importance to model accuracy as well as other concerns, the panel recommends establishment and funding of a coordinated interagency program to maintain the geodetic benchmark network and assure that land, water, and channel elevations are tied to it.

The Model Studies

It is difficult to answer the question whether existing model studies are addressing the needs of the Task Force. However, several Delta Vision issue types are tractable with the different available models and modeling approaches. These include:

1. Dual conveyance modeling. Dual conveyance modeling can address questions about channel capacities given seasonal cross-Delta export demands and Delta tidal and net flow patterns that would affect the salinity field and pelagic fish transport. These questions are largely tractable with one-dimensional models like DSM2.

2. South Delta barriers modeling. The agricultural and fish barriers in the South Delta affect many issues of concern to the Task Force. The barriers present a challenge for modeling because the processes they affect require different kinds of models. For

example, the barriers affect agricultural diversion water levels, the source (and thus quality) of water entrained by the water project pumps, and agricultural runoff contaminant transport. These issues are mostly tractable with one-dimensional models like DSM2, Hydro and Qual. The barriers also affect San Joaquin River fish passage through the Delta, an issue that will require behavioral particle tracking and two-dimensional vertically averaged models (like RMA2) to account for fish transport and tidal cycle behavior. Stockton Ship Channel dissolved oxygen is seasonally depressed by nutrient inputs, low flows, and temperature stratification. Understanding processes that stratify or mix the water column required three-dimensional models.

3. Delta geometry change. The likelihood of catastrophic levee breaches from seismic or flood events pose questions about the impact of large scale Delta geometry change. Flooding of islands will affect the tidal prism (or volume of water passing a given location during the tidal cycle), which can affect erosion and deposition patterns of sediment and instigate further changes in the morphology of the Delta channels. Associated issues include emergency response, ecosystem change, effect on the salinity field, export water quality among others. Again, the match between model capabilities and process conceptual models is a key issue for producing policy relevant results. This has been the focus of the DRMS project that has yielded limited success so far.

4. Particle tracking modeling. Particle tracking models are receiving much more use as the models mature and modeling approaches are devised for the improving conceptual models of fish life-history and tidal behavior. We are aware of efforts to use PTM's for so-called "Individual Based Models" of fish life history. We are also aware of PTM's being used to characterize transport timescales including residence time, flushing time, and age. We are hopeful about these new initiatives but maintain concern about the uncertainty of model results. Careful sensitivity analysis will be required to foster confidence in PTM/IBM model results.

5. Sea-level rise. Sea-level rise presents one of the key challenges to a vision of the Bay-Delta estuary that is sustainable and resilient. Models are powerful tools for estimating how the land-water interface might change as sea-level rise continues and water resource management initiatives proceed in the future. Sea-level rise modeling to date has been hampered by the limitations of model grids developed so far only for

present sea level conditions. In essence, the model "grid" is the internal map upon which calculations of water elevation and currents are estimated. As sea-level rises, the geographic extent of the land water interface will expand along the entire margin of the estuary from South Bay to the Delta beyond Sacramento. Accurate simulation of wave propagation requires that the grid include all parts of the estuary that have tidal influence. As sea level rises, tidal influence will extend further upstream in response. Models cannot accurately simulate this response unless model grids are expanded to include the future tidal influence zones.

See-level rise highlights and additional limitation of most models currently in use in the Bay Delta estuary. The salinity gradient along the axis of the estuary can generate its own current as fresh water is constantly trying to flow over the top of saltier water near the bottom. This phenomenon, known as "gravitational circulation," increases rapidly with water depth. Therefore, sea-level rise will expand the power of this salinity transport mechanism. In general, simulation of gravitational circulation requires either a three-dimensional model or a careful parameterization (fudge factor) of salinity mixing caused by gravitational circulation for one and two dimensional models.

The panel is aware of at least two modeling groups that have simulated the consequences of sea level rise on salinity. These preliminary studies used grids that are likely inadequate for accurate predictions. Gravitational circulation is also not included in either case. Modeler proponents in each case have been clear about this limitation of these preliminary sea-level rise analyses. Nevertheless, their results have been shared publicly. In the future, the science advisors believe that modeling groups attempting sea-level rise modeling should first make a careful effort to expand their model grid based on the best available land elevation data before additional sea-level rise modeling is offered. Secondly, since three-dimensional models will not likely be used directly for sea-level rise analysis, proponents of sea-level modeling should either include a gravitational circulation parameterization or be very clear when reporting results that one was not used.

Other Comments and Recommendations

- ***Multidisciplinary thinking***

The policy questions addressed by the Delta Vision usually depend on more than the predictions of flows, water heights, and salinity concentrations that models address. In fact, models provide few of the "answers" that are needed to support a comprehensive vision for the Delta. Understanding of Delta hydrodynamics and transport processes are essential but not sufficient for addressing the key issues of pelagic organism protection, drinking water quality, and environmental justice. We believe that the modeling tools themselves are impressive and, when skillfully applied, are indispensable tools. However, "answers," in the form of specific alternative Delta configurations that promote water supply reliability, water quality, and ecosystem resilience, will come from interdisciplinary discussions where conceptual models reflecting the best science on physical, chemical, and ecological processes are linked together. Indeed, conveyance modeling to support the Delta Vision depends on at least summary appreciation of the most recent estuary science. In this report we point to the outstanding resources available to modelers that summarize the state of science understanding. Conveyance modeling to support the Delta Vision should be informed by this emerging estuarine process understanding. We suggest that the Task Force hold modelers (and everyone else) to this standard.

- ***Data Needs***

The efficacy of models for decision support depends on more than just the models. Models are interpolators of system parameters (stage, flows, constituent concentration) between known "boundary" conditions. For example, the RMA2 hydrodynamics model is driven by a known water elevation at the Golden Gate as well as known flows entering the Delta at Sacramento, Vernalis, and other streams. Just as important, agricultural diversion and return flows come and go from hundreds of internal Delta locations and must be provided as data to the model. Finally, the geometry or three-dimensional "shape" of the estuary must be carefully specified to the model as bathymetry data prior to any model run. All of these data sets change with time, and are collected in disparate ways with different levels of quality control and meta data. Proper specification of these data to models is a primary source of error for model validation and model scenario studies. Constructing modeling studies currently requires modelers to contend with

several data sources with differing levels of reliability. Efforts have been made in the past to develop common boundary forcing and other model input data with limited success. The panel recommends that these modeling data consolidation initiatives be brought to fruition.

- ***New Conveyance Project Work Team (PWT)***

It might be helpful to establish a new Delta Conveyance PWT that deals with Delta conveyance issues (modeling, ideas, proposals, review etc.) in an open forum similar to the Estuarine Ecology Team (EET) sponsored by the IEP. There are currently limited forums for modelers to present preliminary results or ideas. The EET is effective because researchers are attracted to the informal and collegial atmosphere where new ideas, approaches, and results can be shared and debated. Researchers know that vetting their results through the EET will yield ideas for a games improvement, collaborations with others with similar interests, and ultimately the confidence to proceed to publication and decision support reporting. In short, if you can convince the EET, then you know you've got something important and useful. The panel recommends initiating a similar forum for conveyance modeling.

The panel is also aware that there is a need for improved coordination among modeling groups. We note that there has been some overlap in effort. This overlap can be useful for producing better results as long as the groups are communicating with one another. The communication would be facilitated by a PWT.

- ***Communicate information and findings to policymakers***

Modelers must constantly strive to convert their results to information and findings that are relevant and understandable to policymakers. Modelers tend to report results of modeling studies in gray literature as agency reports, and presentations to technical committees. Modelers have historically been wary of reporting results outside their agencies because they may perceive it exposes them to criticism. Modeling reports rarely advanced beyond "draft" stage. While the “model wars” have largely died down in recent years with the emphasis on openly available public domain models, it is still rather easy for modeling results to be disparaged in public meetings. Managers and policymakers have been confused by inter-modeling group disagreements in the past.

Managers and policymakers therefore have little opportunity to gain summary level understanding of modeling capability, limitations, applications, and findings.

The primary modeling groups working in the San Francisco estuary working on modeling for policy decision support include:

- DWR Delta modeling section (agency)
- Resource Management Associates (consultant)
- UC Davis (University/NGO)
- Contra Costa water District (agency)
- Jones and Stokes (consultant)
- URS (consultant)
- US Geological Survey (agency)
- US Bureau of Reclamation (agency)

The panel recommends that these organizations use one of the many options for reporting high-level science that is accessible to managers and policymakers including:

- CALFED “Science News” (monthly)
- CWEMF workshops and annual meeting
- CALFED "Science in Action"
- CALFED “Brown Bag Seminars” (~quarterly)
- Web-casts of Task Force issue workshops
- IEP Newsletter (quarterly)
- On-line journal SFEWS (~3x per year)
- IEP Workshop (annual)
- CALFED Science Workshop (bi-annual)

At the same time, managers and policymakers also have access to the same science information sources. The panel commends the CALFED Science Program for providing several opportunities and formats for managers to get distilled, information rich, state-of-the- science information. We believe that managers and policymakers are equally

responsible for taking advantage of the available science information resources to inform their decisions.

- ***The Concept of a California Science Modeling Center***

The US is entering a dramatically new stage in the ways that computer simulations can inform policy and management decisions. This change is being driven by several technological advances, including:

1. An explosion in technologies for detecting environmental conditions at an unprecedented spatial and temporal resolution. In many instances, these new technologies are also reducing the cost of acquiring and managing the information. Further these technologies also allow the data to be viewed and processed in real-time, or close to real-time. A summary of expected technological advances is available from a recent National Science Foundation Workshop (Arzberger et al., 2005). California is a leader in these technologies through Centers such as UCLA , UC Berkeley, Stanford and Davis/Merced. A schematic of some of these technologies is shown in Figure 2.

Figure 2 -- Emerging monitoring technologies for a river and estuarine system (Waters, 2008)

2. The Role of Cyberinfrastructure. Friedman described in, "The World is Flat" (2005), how scientific and business communities are functioning in a distributed but collaborative manner. This has resulted in the development of ‘community’ open source models to address difficult problems. The role of cyberinfrastructure in transforming science through engagement of large numbers of experts and the changes currently occurring at the national and global level are described by Atkins et. al. (2003). The ability to present information and to tap into entire communities of

experts often results in more defensible and more sophisticated models. At the workshop, Francis Chung (DWR) commented that the ultimate model validation and confirmation is the close scrutiny by the scientific community achieved by putting models into the public domain. The panel agrees with this line of thinking and encourages the use of public-domain, community-supported models.

3. Emergence of adaptive models that can assimilate data close to real-time and adjust predictions to support management decisions in critical periods.

4. Social scientists are taking a larger and more influential role in the development and application of ecological and hydrodynamic modeling (NRC, 2006). This approach help guide the development of scientific products as well as ensuring that economic and social factors are integrated into the decision process at an early stage of the process.

5. Acceptance of adaptive management practices – and the role of modeling in adaptive management

The advisory panel was impressed by the progress the modeling community has made toward addressing the scientific issues of the San Francisco Bay-Delta system and the tributary rivers. This community comprises experts from state agencies, federal agencies, NGOs, consultants and academia. Some examples of the maturity of this community include:

- The California Water and Environmental Modeling Forum (CWEMF). This organization has provided the mechanism for communication, discussion on future direction of modeling, model comparisons. Signature features include the highly regarded annual conference at Asilomar and awards that recognize significant contributions of peers.

- The desire of California DWR to see their models reviewed, used and fully understood is laudable. The distribution of models, organization of training classes and providing expertise to assist studies requires resources but is critical in building the sense of a modeling community.

- For specific scientific questions, diverse teams have formed around models that have special capabilities. Examples include UnTRIM and RMA.

The Bay-Delta community has garnered international recognition for fundamental research on estuarine mixing processes and for ecosystem restoration (particularly tidal wetlands). A fundamental question is how California can use this strong legacy and existing intellectual capacity to support the sustainable management of the Bay-Delta, to reduce the risk of catastrophic flooding, to avoid the collapse of the estuarine ecosystem and to prevent the Delta from becoming a burden on the regional economy. As part of a vision for the future, the panel recommends that California evaluate the concept of building a Modeling Science Center. This Center would co-locate academics, agency scientists and experts from NGOs and the private sector.

Similar centers already exist or are proposed in the Florida Everglades, the Water Science Center in Louisiana and the Idaho Water Center. A California Modeling Center would be focused primarily on hydrological, ecological and economic modeling. Advantages would include:

- Communication through seminars, informal meetings, joint supervision of graduate students or post-doctoral researchers.
- Shared cyberinfrastructure facilities, including IT technicians, databases, GIS and computational cores
- Synergistic activities such as collaborative proposals, web support, training sessions
- Diverse support for emerging technologies including modifications to existing code or new future models.
- Generation of the next generation of modelers and experts by providing opportunities for graduate students to participate in studies with DWR, USBR, USGS and other agencies.
- Collaborative calibration, validation and confirmation activities

Science Advisors

C. Enright – California Department of Water Resources

P. Goodwin – University of Idaho

KT Shum - East Bay Municipal Utility District

P. E. Smith – US Geological Survey (Emeritus)

This summary report and the speakers' presentations are posted on the CALFED Science Program website (http://science.calwater.ca.gov). An archived webcast of this workshop is available at http://www.visualwebcaster.com/event.asp?regd=y&id=46840 .

Key messages associated with individual presentations

Presentations by Science Advisors

Overview of Modeling Approaches -- Pete Smith and KT Shum

1. The Delta is complex. The physical processes driving flow and transport in the Delta are complicated and vary significantly spatially and temporally.
2. While numerical models cannot be expected to simulate each and every one of these processes exactly and in detail, Delta models are able to represent the Delta fairly well by using a number of insightful (and in a few instances, bold) assumptions and approximations. A sound approach and rigorous process to verify and validate a Delta model is critical.
3. The accuracy of numerical models in simulating <u>historical conditions</u> of the Delta is improved by fine-tuning a number of empirical parameters, in a process referred to as calibration, when these parameters are adjusted such that model results more closely simulate field measurements.
4. The success of the calibration process is limited by the accuracy of both model input and field measurements. For input data in Delta models, agricultural diversion and drainage to and from Delta islands have not been quantified with sufficient accuracy. For field measurements, the lack of synoptic flow data limits comparison with model output, and the lack of cross-sectional measurements of

salinity in those channels with significant vertical and lateral stratification limits comparisons with model results.

5. The uncertainties in model input data and field measurements make it difficult to ascertain the causes of discrepancies typically found between model results and field measurements.
6. Because hydrodynamic models are based on a sound theoretical foundation they can, to a certain degree, be applicable to a range of situations and conditions, but there are no assurances of that. When numerical models are applied to hypothetical situations such as alternatives contemplated in the Delta Vision process, some of the inaccuracies associated with individual assumptions and/or approximations may become more significant. In all such model applications, the limitations of the models used must be carefully reviewed in light of the questions the modeling exercise is performed to address.
7. Determining "uncertainty" in modeling results is especially important in planning studies, or studies where measured field data are not available. Uncertainty estimates are normally derived from sensitivity studies for model input data and parameters but can also apply for different conceptual models.
8. Interpretation of model results could only be made after careful analyses of the potential sources of error due to model assumptions and approximations. Conclusions must be drawn in a realistic and self-critical manner accordingly. After all, better understanding and insights into the problem at hand is more than just getting numbers from the models.
9. Although imperfect, models are extremely useful tools. For the complex engineered and natural system that the Bay-Delta estuary is, computer-based modeling and simulation is required. A lot of progress has been made in the past twenty years, both in data collection and model development, especially in the last ten years through dedicated efforts of CALFED Science, USGS, DWR, RMA, and others. These latest improvements should be incorporated into the modeling of Through Delta and/or Isolated Facilities alternatives, both as modeling tools and in the reliability assessment of modeling results.
10. Unfortunately, these advances have not always been widely disseminated and known to every modeling practitioner. To assure that the latest developments and understandings are applied, public workshops should be conducted to solicit input from the greater modeling community. These workshops should be organized by

entities without vested interests in the modeling outcome. Two such entities are the CALFED Science Program and the California Water and Environmental Modeling Forum. A standing committee could also be convened to oversee the modeling work.

11. For two- and three-dimensional models of the Delta, it is important to realize that one execution of the code can require hours or days on even the fastest computers. Executions for a large number of Delta scenarios would not be feasible. Higher-dimensional models are more suited for improving our understanding of the physical system and to validate modeling results of a limited number of Delta alternatives.
12. Sufficient time and resources must be allocated to the analytical work, commensurate with its role in the decision process.

Emerging trends in modeling -- Peter Goodwin

1. New technologies allow synoptic monitoring and provide real-time data for adaptive management of a watershed. Immediate feedbacks are effective means to address uncertainties in planning studies and should be incorporated into the programs developed in the Delta Vision process. Real-time data also allow model forecasts using latest initial and boundary conditions in model input.
2. The modeling community in the Bay-Delta has matured. The key modeling groups work together well in a positive and constructive environment to improve modeling capabilities and acceptance of modeling results by stakeholders. To further enhance model development, interim models should be disseminated (perhaps released with disclaimers) to encourage input from the broader modeling community. Training sessions of new models such as those organized by the Modeling Support Branch at DWR are valuable.
3. A centralized modeling center to house development of models and data would provide much synergy and improve interactions and collaboration among technical professionals. This could be a more effective arrangement to meet the challenge of developing new tools needed for the management of the Delta.
4. Centralized and collaborative efforts have been initiated in the country and elsewhere in the world. The National Science Foundation and the US

Environmental Protection Agency have led the development through initiatives such as CUASHI (www.cuashi.org) and the WATERs Network (http://watersnetwork.org).

Modeling and the decision-making process -- Chris Enright

1. The role of modeling in management decisions ultimately depends on how effective modeling results are communicated to policymakers. There is an ongoing schism between modelers and policymakers due to differing perspectives on planning and issue contexts as well as differences in communication styles. This communication has improved in the past decade, but more needs to be done. Modelers must understand the big picture decisions they are supporting, while policymakers must make more effort to understand modeling capabilities, limitations, and results.
2. Successful modeling for decision support has three key components: 1. Accurate models; 2. accessible data; and 3. Institutional arrangements that foster turning model output into decision-worthy information.
3. Improved understanding of biological conceptual models is critical to improve the application and further development of Delta models to address ecological issues. In general, too many modeling "studies" are conducted because modelers are attempting to cover all the bases of an often poorly understood ecological problem. Modelers would benefit with an up-front investment in clear understanding of the most current conceptual models about chemical and biological processes. Many accessible and information efficient resources are available including those listed in the section above on communication of findings. A high-level understanding of basic process conceptual models would allow modelers to conduct fewer models studies while more deeply mining model results for information that is relevant to the conceptual model or hypothesis under study. Better understanding of biological conceptual models would therefore improve and expedite modeling analysis by affording better choices about modeling tools and most advantageous modeling approaches.
4. Current models are inadequate to address a number of emerging issues that are critical to the long-term management of the Delta. In particular, current Delta

models are unlikely to be able to accurately simulate the effects of sea level rise. Current formulations may not adequately reflect the changing characteristics of key processes governing flow and salt transport in the Delta. Additional bathymetric data are also lacking.

Questions and general comments following panel presentations--All

The discussion focused on the role of modeling in the Delta Vision process. The points raised include:

1. Decision makers listen to people, not models. Effective communication is critical to increase the role of modeling results in decision making.
2. The reliability of using historical hydrology to simulate performance of alternatives in a changing future should be addressed. How model output can be interpreted given the uncertainties surrounding climate change and other factors is an issue that must be dealt with.
3. Modeling is only one part of technical work. An analysis should start by studying the problem and reviewing the key drivers and cause and effects before starting on numerical modeling. More can be learned by comparing modeling results to our understanding, especially when the modeling results are different from what were expected.
4. How water must be managed in California has been changing and will continue to change. Models take years to develop and are limited by the extent of understanding and knowledge on the system. Foresights, a broad view, and continuing fundamental research are essential to developing the tools for well-supported decision making.

Presentations by Invited Speakers

Presentations in the afternoon offered an overview of ongoing modeling activities of interest to the Task Force. Except for the presentation by Dr. Fleenor, only general outlines of the projects under study were discussed and no results were shown. Further, how the modeling results from these studies will factor into policy and decision-making

was not discussed. The science advisors look forward to the second workshop in this Two-Part Discussion on Delta Conveyance Modeling, when the appropriateness of the models, reliability of the results, and the implications of the modeling work to policy and management decisions may be addressed in more detail.

Modeling at DWR of interest to the Task Force – Francis Chung

The Modeling Support Branch at DWR has developed a suite of models to address water management needs in California. These models include hydrologic and reservoir models CalSim II and its abridged version CalLite, Delta hydrodynamic and water quality models DSM2 and an artificial neural network (ANN) model developed to emulate DSM2, groundwater model C2VSIM, and adoption of a semi-empirical relationship to project sea level rise. The latest is a rapidly evolving science and DWR's approach will be improved in the future accordingly. This suite of models is being applied in support of the Bay-Delta Conservation Plan. Additional modeling capabilities are incorporated to address a broader range of alternatives.

Modeling in support of studies for the Public Policy Institute of California – Bill Fleenor

Modeling tools recently developed by Resource Management Associates are used in this work to further investigate the alternatives discussed in the 2007 PPIC report. These tools include a tidally-averaged model of a simplified Delta channels network and a much more detailed (in both spatial and temporal resolution) two-dimensional model. Modeling analyses address flooded islands, sea level rise, and the performance of an isolated facility with various capacities.

MWD modeling initiatives – Paul Hutton

The presentation provided a brief overview of ongoing modeling work initiated by the Metropolitan Water District of Southern California. Model development includes a Delta Smelt Entrainment Population Model (DSE). Modeling studies address changing Q_{west} (e.g. through export reduction); Delta Cross Channel operations, Middle River corridor (through installation of operable barriers); and the installation of an operable gate on Threemile Slough.

Reclamation modeling studies – Lee Mao

This presentation gave an overview of the ongoing studies by Reclamation and its consultants. The list includes a Recirculation study (in the Delta-Mendota Canal and San Joaquin River through the Newman Wasteway and the C. W. ”Bill” Jones Pumping Plant); Through Delta Facility Alternatives; North and Central Delta Improvement Study; and the Biological Assessment and Biological Opinions of the Operations Coordination and Plan.

Questions and general comments following invited speaker presentations

The discussion is more specific and addresses a range of modeling approaches and assumptions including:

1. The modeling process could start by optimizing the (seven) goals listed in the performance criteria individually and separately. These goals were listed under Recommendation 8, new facilities for conveyance and storage starting on p.12 in the 2007 Delta Vision Blue Ribbon Task Force report.
2. Subsidence on some Delta islands is many times that of the highest rate of projected sea level rise. This fact must be accounted for in addressing the effects of sea level rise.
3. Turbidity, a key factor in the entrainment of Delta smelt at project pumps, is not simulated in Delta models. This poses a challenge in applying modeling results to ecologic performance.
4. The effects of wind and turnover may be significant in the summer in large open water bodies such as Franks Tract. Its significance needs to be further reviewed.
5. Salinity values used in model input has large uncertainties. For example, drainage salinity from Delta islands would vary with salinity of irrigation water, and the inflow salinity from the San Joaquin River would vary with the salinity of export water in the Delta Mendota Canal. Both dependencies are not accounted for in Delta models.

6. The status of modeling fish populations was not seriously discussed in this workshop.

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