Review Panel Report
San Joaquin River Valley CalSim II Model Review

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CALFED Science Program – California Water and Environment Modeling Forum

12 January 2006

ACKNOWLEDGMENTS
The CALFED Science Program and the California Water and Environment Modeling Forum sponsored, supported and oversaw this review process. We thank the many commenters on the model and its supporting data, the modeling agencies (the US Bureau of Reclamation and California Department of Water Resources), particularly Lloyd Peterson, Randi Field and Eric Reyes, Levi Brekke, the consultants to the modeling agencies, Walter Bourez and Daniel Steiner, Anna Fock, and Yung-Hsin Sun, the 75 people who attended the first review workshop, 50 people who attended the second workshop, and the 11 people who submitted comments to the review panel. Laurie Benson is thanked for compiling the acronym list in Appendix G.

EXECUTIVE SUMMARY

This review of the CalSim II model representation of the San Joaquin River Valley provides information and recommendations intended to help managers and modelers make good use of available modeling options and improve the data and tools for providing insights into present and future water management problems. Ultimately, managers and modelers cannot escape the responsibility of carefully reviewing and interpreting model results according to known and estimated uncertainties and tests of the model. The major findings and recommendations of the review include:

- The new representation replaces many highly uncertain empirical formulations in the old representation with more analytical estimates. It provides many functional and developmental improvements and enhances the flexibility of the CalSim II model to address a variety of water management problems.
- However, large uncertainty remains in the new representation due to large unaccounted for flows and salt loads (closure terms) and bias in the salinity model.
- The Panel supports further development of the new representation, and believes further improvement efforts on the old representation would have much less promise for improving its accuracy.
- The panel finds that endorsing (or condemning) a model or model version in general or for particular areas of application potentially shifts responsibility for model use and quality control from modelers and managers to a review panel which would be remote from model application details and current model development. Model endorsement, even for a narrow range of applications, would induce unwarranted complacency in modeling and model development.
- Immediate-term recommendations include:
  - Estimation of the magnitude of model errors under various conditions from a formal and documented error analyses
  - Improving the documentation (further)
  - Further investigations to quantify and reduce potential errors in the salinity model
- Longer-term recommendations include:
  - A CalSim development plan which moves from a “comparative” to an “absolute” approach to modeling results
  - Protocols for model documentation and testing
  - Separate closure terms for residuals in water and salt balances
  - More explicit procedures for future land use data as an input
  - Explicit representation of groundwater
  - Land-use based Westside demands, hydrology and drainage flows
  - Improved data collection and analyses

FOREWORD

This Review is jointly sponsored by the CALFED Science Program and the California Water and Environmental Modeling Forum (Modeling Forum). The Review required substantial time and effort from the staff and consultants of the U.S. Bureau of Reclamation (Reclamation), and would not be possible without the staunch support and considerable resources committed by Reclamation and the California Department of Water Resources. Additional funding is provided by the U.S. Environmental Protection Agency (from funding to the CALFED Drinking Water Quality Program), San Joaquin River Group Authority, State Water Contractors, and the San Luis Delta Mendota Water Authority. However, these funding agencies did not participate in the administration of this Review.

This Review is different in nature from the previous CalSim II review sponsored by the CALFED Science Program in 2003. The previous review addressed the general approach used in the model. The current Review, on the other hand, focuses on the detailed formulations of one geographical area in the model, the San Joaquin River Valley.

External technical reviews conducted by the Modeling Forum and the CALFED Science Program are not intended to provide a "stamp-of-approval" or to reject models but rather, to (1) document strengths and weaknesses, (2) provide a practicable roadmap for further improvements, and (3) discuss appropriate model application. External review reports aim to provide constructive feedback and objective, impartial criticisms, promote understanding and acceptance of models and model results, and identify and clarify avoidable and unavoidable model limitations.

The Review Panel evaluated the model using a high standard commensurate with the important role of CalSim II in water management decisions. They found many significant improvements in the new representation over the previous formulation in CalSim II, making analyses of a much broader range of water management issues possible. The Review Report provides a better understanding of model reliability for different applications. In addition, it calls for the development and discussion of quantitative estimates of uncertainty in presenting model results. These estimates would provide users of model results the critical information needed to assess model accuracy for water management analyses.

The Report identifies areas of further improvements in both the immediate future and the longer-term. The value of this Review would be enhanced if Reclamation commits sufficient resources to address these recommendations in a timely way. In the immediate term, a more detailed documentation on the justifications and sources of the values assumed for model parameters would be a high priority, as would explicit quantitative error analysis and refinement of some aspects of the salinity module. The longer-term actions require substantial resources, especially in data collection and data management. A long-term development plan that prioritizes tasks and quantifies the costs and benefits is critical to securing sustained support for this critically important model.

CalSim II is undergoing continuous improvement. Peer review of such a "moving target" is always difficult. Some of the issues raised in this Review may have already been addressed by the time the Report is released. This Review identifies several significant issues that could be resolved within a few months. These improvements, along with the most recent progress made by model developers, would call for an update of this Review Report. The Modeling Forum and the CALFED Science Program are planning to work with Reclamation and DWR to extend the Review Panel's effort to account for these developments.

We have received many questions and constructive comments from the water community over the course of this Review. The comments fall into three main categories:

1. Documentation – including details on
   - Sources and justifications of data for hydrology, accretions, demand, and salinity, and how their values might change under future levels of development
   - Assumptions used in simulating the Environmental Water Account, water transfers (in and out of basin and changes in return flows), wetland operations, and groundwater
2. Model domain – in particular the portion of the San Joaquin River Valley currently not included in the model such as
   - Upstream Tuolumne River
   - Upstream San Joaquin River
3. Model Applications – specifically, the panel is requested to provide a user's guide to discuss
   - Range of scenarios over which the model is valid
   - Uncertainty in results for different applications and to make the model accessible and "users-friendly" to the stakeholders community

While these questions and comments are not responded to individually in the Report, many of the issues addressed throughout the text would be applicable to the questions raised.

California Water and Environmental Modeling Forum
CALFED Science Program

A. INTRODUCTION

CalSim II, developed jointly by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) is the official planning model of both agencies for the Central Valley Project and State Water Project. It is used extensively to support a variety of studies of alternative policies and scenarios that vary infrastructure, operational rules, regulations, water demands, and/or climate (http://modeling.water.ca.gov/hydro/model/; Reclamation, 2005). A general external review of the methodology, software, and applications of CalSim II was conducted in 2003 (Close, et al. 2003; Ferreira, et al. 2005).

The current external review focuses on aspects of the CalSim II model of the San Joaquin River Basin (Figure 1), one of the more recent efforts in a long history of water management studies (CDWR, 1931). The original CalSim II representation of the San Joaquin River Basin used simplifying assumptions to define some hydrologic factors and demands, precluding dynamic interaction with new and evolving river system operations decision processes, or of projected land use change effects on San Joaquin Basin operations (Reclamation, 2005). These were characteristics shared with earlier models of the San Joaquin River system, such as SANJASM.

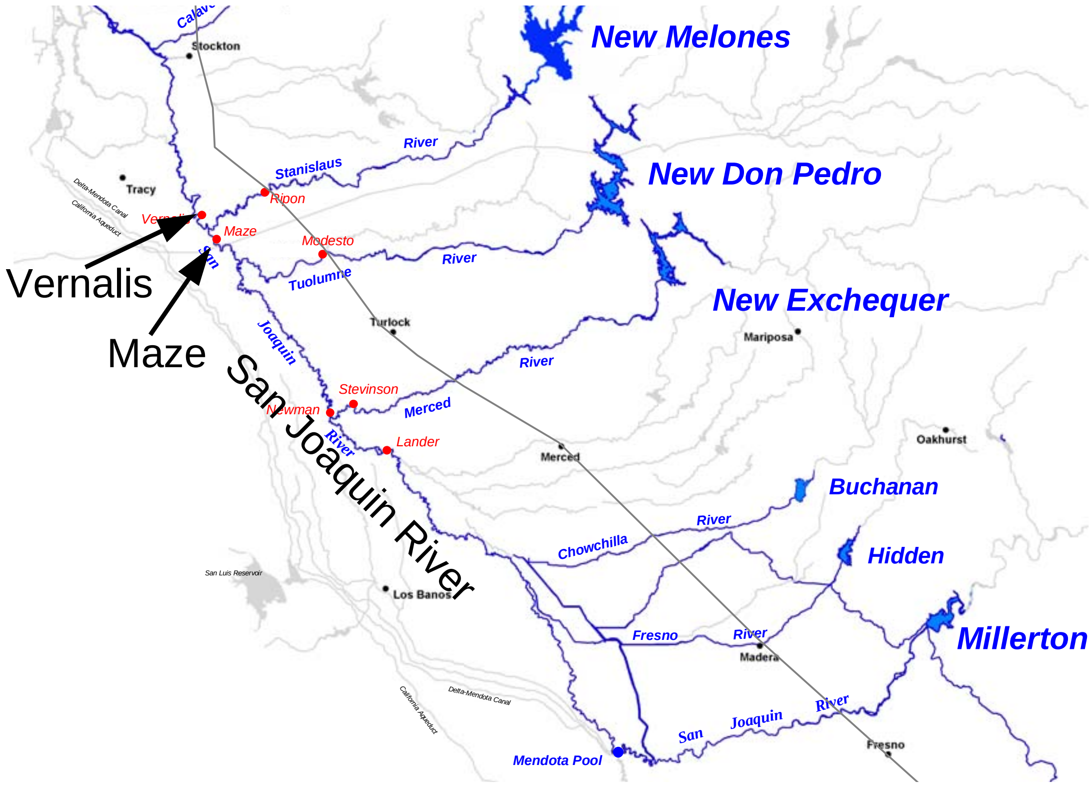

Figure 1. The San Joaquin River Valley (adapted from MBK Engineers, Inc.)

Over the 2002 – 2005 period, the U.S. Bureau of Reclamation has sponsored several efforts to improve some major aspects of the San Joaquin River Valley system in the CalSim II model. These efforts have focused on modeling:

- Eastside Surface Hydrology and Operations,
- Eastside Water Demands, and
- Salinity in the San Joaquin River Mainstem.

The new San Joaquin CalSim II model (officially SJR_2001X10A_PRELIM_040105) is proposed to replace a 2002 benchmark version (OCAP_2001D10A_TodayEWA_012104). Both models are for 2001 water management and water use conditions (level of development).

This report begins with a summary of the panel's charge from the CALFED Science Program and the California Water and Environmental Modeling Forum (CWEMF) and a summary of the process used to address this charge. The major findings and recommendations of the panel are then presented, followed by discussion and responses relevant to the questions posed in the panel's charge (which are the bulk of the report). Various appendices are also included for reference, A) Review Panel Charge, B) Supporting analysis of water quality results, C) a summary of basin and model statistics, D) Presenters and Oral Commenters to Panel, E) Written Public Comments, F) Panel Qualifications, and G) Acronyms.

Overall, the report praises many aspects of the modeling work, raises several concerns, makes short-term recommendations for addressing the greatest concerns, and makes recommendations for longer-term improvements in accuracy, transparency, model utility, and coherence.

B. PANEL CHARGE AND PROCESS OVERVIEW

The CALFED Science Program and the California Water and Environmental Modeling Forum jointly developed the review panel charge appearing in Appendix A. This charge called for the panel to respond to 9 questions, grouped into two categories regarding three major aspects of the San Joaquin River Valley CalSim II model. These questions appear in Table 1 below.

Table 1: Questions in Review Panel Charge

Part I: Merits of recent work compared to prior representations

For each of the three areas of recent development (Eastside hydrology and operations, Eastside water demands, and San Joaquin River salinity),

1. In what ways are these new representations more accurate than prior representations?
2. In what ways are these new representations less accurate than prior representations?
3. In what ways would CalSim II results using these new representations consistently differ from the prior model?
4. Are the new representations expected to lead to any systematic bias in CalSim II results?

Part II. Improvements to the recent work

For each of the three areas of recent development in San Joaquin Valley representation,

5. How well are the new representations and their underlying data documented? What additional documentation should be prepared?
6. How well have the new representations and their underlying data been tested? What additional testing should be performed?
7. What is the accuracy expected and what are major errors remaining (if any) in the representation of the San Joaquin Valley?
8. How might the new representations be improved?
9. What practicable procedure(s), if any, could be followed in every model application to test the validity of model results and assess their uncertainty and sensitivity to assumptions?

In its review, the panel is charged to consider:

- Materials presented to them in oral and written forms
- Written comments of interested parties
- Prior documentation concerning CalSim II and previous CALFED CalSim II reviews
- Other information sought and received by the review panel members.

The panel was not charged with discovering or reviewing materials available on other models of the system or other applications of those models. Instead, CalSim II was considered on its own merits. Similarly, the panel did not undertake application of the model, nor did we review the actual computer code or algorithms.

A public review draft of this report was released on November 20, 2005. We received four sets of written comments, which are included in Appendix E. These comments suggested areas where the panel's recommendations and other comments could be clearer and resulted in some major improvements to the report.

The CalSim II modeling work under review was not done with explicit expectation of a formal external review. This is the first detailed formal external review of any part of the CalSim II model. As such, the modelers' work and documentation is receiving an unprecedented level of formal external scrutiny. As a first formal detailed review, there are not yet firm review expectations or standards for this model or setting. The ability to document parts of this model suffers somewhat from the informality of previous data development in years past.

It was not the purpose of this review to comprehensively evaluate the appropriateness of the model to answer all applications questions being asked of it. Each application will have different requirements and considerations. Some of these aspects are considered here and were considered in the previous review (Close, et al. 2003). The model review does however include: 1) an exploration into systematic error and bias in model results (question 4) which is important for model applications; and 2) recommended quality control procedures for model applications (question 9).

An active model is never completed, and new materials became available during this review process. We ended our consideration of materials as of October 21. As we began our assessment and presented preliminary conclusions, we learned that agency staff and consultants were busy refining the model and their analyses. Some revisions and refinements were prompted by our comments and our writings; others were not. Some of those revisions and others will improve the model and the results, addressing concerns that we raise here. Nevertheless, as a review panel, we must review that which now is, not that which is soon coming, and we must issue our assessment based on information available to us. That is what we have done here, realizing that even before this report is distributed, the model and the results may change. This awareness has helped shaped some of our recommendations.

While some have argued that the panel cannot possibly review the accuracy and appropriateness of the CalSim II without actually running the model, we disagree. The CalSim model is complex, and those most knowledgeable about how to use it are the agency staff and consultants who are using it and whose work we are reviewing. To pretend that within a few days time we could fill their shoes and improve upon their application by running the model ourselves is wrong. The documentation that they have developed and presented to us is extensive and carefully prepared, and we have relied upon that. Further, staff and consultants shared information beyond that which was included in the documentation. It was not the purpose of this review to verify model computer code by independently running the model. However, the review panel did inspect model assumptions, methods, algorithms, and test results, including requests for additional test model runs. With that information, we were able to draw valid conclusions about the application.

C. MAJOR FINDINGS

Our major findings are summarized here. Details of these findings and other observations follow.

Overall

We found that the new version of the model is improved, in many ways, over the older model. However, the new version has weaknesses, detailed herein. These are weaknesses in the sense of imperfections rather than in the sense of fatal flaws that render a model useless.

In all three areas that we were charged to consider (eastside surface hydrology and operations, eastside water demands, and mainstem salinity), the newer model is significantly updated, improved methodologically, and better documented. These new representations have considerably greater functionality and flexibility for representing potential future planning and management decisions and scenarios and with proper inputs and calibration they will be more accurate. If knowledgeably and thoughtfully employed and interpreted the new model should provide a firmer basis for evaluations and insights than the previous model.

While our findings are largely positive, we note some concerns and make immediate-term recommendations intended to improve model and data documentation and provide a basis for better understanding and delimiting the quantitative strengths and weaknesses of the new model. With these improvements, we believe the new model can be used with a better known and better established level of confidence. The panel's longer term recommendations seek to provide a basis for strengthening and improving our quantitative understanding and modeling of water and salinity flows and management in the San Joaquin River valley.

Model Endorsements

The panel has reviewed the new version of the CalSim II model of the San Joaquin River Valley within the context of our charge. Some readers will hope now for an explicit endorsement or condemnation of the model. They will not find it. The panel does not in any way certify or endorse the model presented. On the other hand, we do not disapprove of or discourage its use by knowledgeable users.

Users must take responsibility for model selection and application, and they must accept the responsibility for decisions that they make with information produced by the model. Relying on an external body to provide a blanket endorsement covering all possible applications is a dangerous practice. It tempts users to avoid accountability for their work. It tempts decision makers to place responsibility on general model reviews which are remote from a particular application. Further, it opens the door to intentional and unintentional abuse, negligence or complacency by model users and developers, or their managers who may shift responsibility to tools or some external general review panel for decisions made or actions recommended based on their use of a model. Good decisions require good information. Careful application of an appropriate model will yield that information. Certification of the model does not guarantee production of good information. Lack of certification does not preclude it.

The panel does endorse efforts to enhance the current version of the model, and we do not recommend continued development of older versions. We note with some pleasure that since we initially identified some issues with the formulation, the model developers have responded by beginning to conduct error analyses, improvements in documentation, and further investigations of mainstem salinity. We commend this and encourage continuation of these efforts.

Some have asked this review panel to distinguish "appropriate" from "inappropriate" uses of the model. Much like the request for endorsement or certification of the model, this request presumes too much of a review panel and (in our view) reflects a misunderstanding of models and their value for water management. G.E.P Box noted that "All models are wrong, but some are useful." Useful models used appropriately provide understanding and insights into problems and potential solutions. In some cases, even a simplistic model can provide useful insights. It falls to the users and critics of specific model applications to scrutinize and interpret model results in the context of a particular application. Models are only "wrong" in a strict sense, and it is their interpreted use which makes an application of model results more or less insightful. The thought involved in a model's application and the interpretation of its results is typically more important than the inner workings of the model alone. A review panel cannot foresee all detailed problem applications and all the ways a model might be either abused or judiciously and productively used and interpreted even for problems for which it is not ideally suited. Thus, it must remain beyond the purview of a general model review to declare before the fact and in general terms what is appropriate use and what is not.

Eastside Hydrology and Operations

The new Eastside hydrology and operations representation is methodologically superior to the older model, but retains significant gaps present in the old model, particularly the lack of explicit groundwater representation. The new representation has involved an updated examination of hydrology and operations, incorporating new gage and local data and detailed discussions with many local water managers and operators. More testing has been done of this new representation by model developers than has been documented.

Eastside Water Demands

The GIS/land-use based demand accounting for the eastside is an improvement in methodology. This method will be more accurate if sufficiently accurate inputs are used and the model’s parameters are well estimated. However, whether this actually is an improvement in the analysis is difficult to determine. The procedure that lumps errors and uncertainties into estimates of groundwater pumping obscures gains in accuracy.

San Joaquin River Salinity

The new representation of mainstem San Joaquin River Salinity is a substantial advance over the older “Kratzer equation” representation. Under most circumstances, the newer model will be more accurate. While providing a more physical basis for the model and much greater flexibility to represent operational and water implications of management actions, the new representation also requires more data for mainstem inflows and diversions of water and salts than is currently available. As a consequence of this, simplified or incorrect input data may contribute to inaccurate model results that mask improvements in model results that would otherwise been obtained through the improved model representation.

In absolute terms the new representation systematically underestimates salinity due to: 1) use of incomplete data sets (lacking critically dry years), 2) lack of consideration of variability (e.g., operators responding to field conditions, rather than mean field conditions), and 3) biased calibration of Maze electrical conductivity (EC). This underestimate of salinity causes underestimates of releases from New Melones Reservoir that in turn leads to overestimated water availability to entities dependent on New Melones storage. We think these problems can be largely resolved. Bias in estimates using the prior representation was not extensively examined in this review.

Other findings apply to several of the representations, and often have wider implications for the development and use of planning and operations planning models of the San Joaquin River System.

Documentation

The documentation for these new representations in the model is superior to those available for previous CalSim II studies and development efforts. The authors of this new work (consultants and Reclamation employees) are congratulated on these substantial improvements in transparency and quality control. This work establishes a substantially improved standard for documentation of model input, calibration, and results. A review of this detail would have been impossible without this level of documentation.

Nevertheless, the present documentation and testing alone are not sufficient to provide users of the model or model results with a complete reasonable basis for understanding the general accuracy and limitations of CalSim II results. Many assumptions are made without adequate justification and without assessment of their impact on model results. Consistency on some documentation issues, such as documentation of the periods of record for field data used in model inputs, could be improved. Too often, discrepancies and issues, sometimes well addressed in oral presentations, and important for model use and interpretation, are not discussed in the documentation or are only slightly mentioned. Written documentation has more long-standing and widespread value than oral presentations. The modelers have done a better job (based on their oral presentations and discussions) than they have documented. Regarding documentation, "Don't say it if you didn't write it," should be a guiding principle. Documentation for the entire CalSim software and model should be improved to a level that sufficiently justifies assumptions and assesses the effects of major uncertainties on model results. Major elements of the system (e.g., groundwater) that are not well modeled by CalSim II, should be discussed in the documentation. A modest additional effort can address these concerns.

Testing, Quality Control, and Quality Assurance

Testing of the new elements of the model is significantly superior to those available for previous CalSim II studies, including the older CalSim model of the San Joaquin River System. However, at a scientific level, CalSim II work fails to adequately report technical results that would give knowledgeable readers some sense of the quality, accuracy, sensitivity, or uncertainty present in the results. This issue was prominent in the previous CalSim review panel report (Close, et al., 2003).

Model testing can take several forms, including: a) relevant historical comparisons, b) model parameter uncertainty analysis (sensitivity analysis), and c) the involvement of local experts on the system. The modelers have made explicit comparisons with historical field data and runs of the prior model with some discussion of the differences and implications. The modelers also have substantially involved local experts in representing components of the system. These are significant improvements over past practice.

However, the testing of the model and new representations has not been documented to prove the superiority of the new representations. For example, there are substantial differences in some operational and delivery results, as presented later in this report and discussed in modeler oral presentations (August 4, 2005 public meeting presentations) and somewhat in the written documentation. The explanations for differences between the new model results and previous results and historical data are not often or thoroughly discussed in the documentation, although explanations typically became available through discussions and oral presentations.

The new CalSim II representations are substantial methodological improvements over the previous version, and therefore should have statistically better accuracy than previous representations for the same level of input accuracy, particularly for current conditions under which the model was calibrated. However, we have concerns about their overall absolute accuracy and completeness, particularly for future water management and hydrologic conditions outside the model's range of calibration. Nevertheless, given the improved methods and updated attention to details and data in the model, we would be surprised to find error in the new representations to exceed those of the older model, whose testing and calibration appear to have been less thorough and less recent.

Closure Terms for Water and Salinity Balances

Closure terms should be explicit. Closure terms must exist in water and mass balances; we almost never know flows in and out of balance locations with complete accuracy. In the new representations, as with the older model representations, the closure terms in water and salinity mass balances have been lumped (in effect hidden) in groundwater pumping, local streams, or other terms. Terms in mass balances should be independently estimated, allowing distinct closure terms to indicate the accuracy of the overall mass balance. Where all hydrologic terms cannot be estimated independently and closure terms must include real flows, these combined terms should be so labeled, such as "groundwater and closure" or "local inflows and closure."

Groundwater

Groundwater is the most important process not included in the newer model, and was absent from previous models. It is clear from the documentation and the oral presentations that adding groundwater to the model was not part of the scope of work for this project. Thus our comments on groundwater are not intended as a criticism of the work done to improve the model. They are intended to point out an important missing element in modeling water management in the San Joaquin valley. Groundwater interaction with various components of the model is critical for several reasons:

- Groundwater is an important basin water supply, especially during droughts.
- Groundwater is an important source of tributary inflows, mainstem inflows, and is a potentially important source of salinity from the Westside.
- Groundwater is an important subject of management within the basin, with important interactions with the surface water demands and processes involved in the CalSim model of this region.

The lack of a groundwater component was noted as a major deficiency in the first CalSim Peer Review (Close et al., 2003). The Sacramento Valley portion of CalSim II currently has a groundwater modeling component being implemented (by DWR).

The new model relies on groundwater conditions remaining similar to those during recent calibration conditions. Without explicit groundwater representation, the model's applicability to planning, policy, and operational problems under future water management and hydrologic conditions could be severely limited. This problem will become increasingly limiting for planning applications involving activities that affect the availability of groundwater (including any ongoing overdraft), groundwater return flows, and groundwater management. Given the difficulties and expense of groundwater modeling and data for such a large region, it is understandable why this was not included in the effort being reviewed. However, explicit groundwater representation is likely to be important for future applications.

Loss rates

In many cases, loss and return flow rates have been taken directly from older model studies without the re-examination and scrutiny that has been applied to other areas of the new representations. More scrutiny, examination, and documentation would be useful here. The 10% non-recoverable delivery loss rate has been an icon of water modeling in the Central Valley for decades. Everyone uses it, but there is little technical explanation why. Deep percolation of applied and canal waters also merits similar independent scrutiny.

Westside Demands, Hydrology, and Drainage Flows

Westside water demands were not part of the package of changes made to the CalSim II model. Westside demands and drainage flows have important implications for the San Joaquin River and should be represented in ways consistent with Eastside demands, operations, and flows. The Eastside area representations are now more realistic. Westside representation relies on a combination of contract-based demands and new calibration of return flows and loads to the San Joaquin River mainstem based on recent historical period calibration. To allow the model to better address changes in Westside water management conditions (such as drainage and water market activities), Westside representations should be more detailed and consistent with that of Eastside operations, hydrology, drainage, demands, and further expanded to include groundwater. Serious model limitations and lack of flexibility will remain, particularly regarding mainstem salinity, without better accounting for Westside water and salt flows. The impact of Delta Mendota Canal (DMC) water quality on drainage water salinity is absent from the model. Delta pumping for the Central Valley Project (CVP) tends to limit Westside deliveries well before water contracts or likely water demands. To the extent this is this true, Westside land-use based demands might not be urgent. Model error analysis studies should be able to provide some insights into conditions where Westside errors are benign or particularly problematic.

Fundamental Data

Modeling rests on data. Many major uncertainties and gaps in modeling this system arise not from the conduct of the modeling effort, but from a long-standing narrowness of scope for the CalSim II model and accompanying limited regional data development. The lack of a groundwater component (and data to support it) arises from the consideration of the San Joaquin River Valley as only a surface water system, despite long-standing and growing importance of groundwater for regional and statewide water management. The large closure terms in accretions and salt loads, the rough estimates of deep percolation, irrecoverable losses, evapotranspiration, and irrigation efficiency and coarse representation of the San Joaquin River above Newman also indicate the pressing need for systematic data development for the San Joaquin Valley. Agencies interested in water deliveries and management in the San Joaquin Valley should insist on and contribute to efforts to improve water quality and surface flow data collection and groundwater data development that would improve the factual basis for modeling and water management in this region. It will be difficult to substantially raise the accuracy of modeling efforts for the San Joaquin Valley without such data development efforts.

Uncertainty in model results

Model results are always somewhat uncertain. All models have a general level of error or "noise" in model results, below which it is not particularly useful to interpret results. Currently no general guidance is available to indicate whether differences of 1 taf, 50 taf, 100 taf, or 500 taf are significant enough to rise above the level of error and noise inherent in the model. Additional modeling studies should be able to better define this range and give a firmer and more transparent basis for an uncertainty assessment for some important locations and conditions. Such error estimates of model results should be especially useful in guarding against over-interpreting (or under-interpreting) model results and identifying assumptions in greatest need of additional refinement and data.

At a minimum, error analyses should be conducted, combining a sensitivity analysis of critical model results to some of the largest and least well supported model assumptions with an assessment of the likely range of error in these major model parameters and assumptions. An example is the sensitivity of New Melones releases to the quantity, quality and seasonality of 'worst-case' groundwater accretions to the San Joaquin River. Similar error analysis would apply to many of the concerns and potential concerns identified in this report. Ultimately, a more sophisticated Monte Carlo type of error analysis might be worthwhile, if cross-correlation of input and parameter errors can be assessed. However, at this point, the main intent of simple error analysis is to provide a direct and interpreted assessment of the likely uncertainty in major model outputs resulting from estimated uncertainties in major model parameters and assumptions.

Future Levels of Development

The data in the model being reviewed is for 2001 level of development and the model was calibrated for such recent conditions. However, policy and planning applications of the model will be for future conditions. To reduce confusion and increase transparency, protocols should be developed to establish assumptions and methods for estimating future demand, operational, and hydrologic conditions. Such an effort will be challenging and controversial, but is necessary to produce greater consistency and transparency in model results, with a greater likelihood of consensus buy-in.

D. MAJOR RECOMMENDATIONS

Many of the recommendations here follow those from the 2003 external review of the larger CalSim modeling effort (Close, et al., 2003). Some of these recommendations should be fairly easy to implement; others will require substantial commitments.

Recommended Immediate Actions (6 months)

Three near-term actions would provide greater assurance that the new representations are substantive as well as methodological improvements over the earlier representations and provide a basis for interpreting model outputs in the face of significant remaining uncertainties. These actions can be reasonably accomplished by the Reclamation and consultant team within a short time, resulting in a rather transparent model of roughly known accuracy and defined limitations for the coming few years, until some of the longer-term concerns can be addressed. A small review of written products from these three short-term actions might provide more definitive closure to these issues.

Expansion and Improvement of Presented Model Documentation

A moderate expenditure should be made to improve the existing documentation of the San Joaquin River System portion of the CalSim model. The documentation is generally quite good, but many points of absent and unclear documentation should be fixed. Improving the documentation would address many of the concerns expressed in this review. These improvements will be of long-standing value for understanding the model and model results, as well as understanding water management in the San Joaquin River Valley. Model testing documentation should include explicit and self-critical discussion of (a) relevant historical comparisons, (b) numerical error and uncertainty analysis, and (c) the involvement of local experts on the system.

Error Analysis Studies

All models and input data contain errors and simplifications which affect results. This leads to some level of uncertainty or noise in model results. Experienced modelers have some idea of how much error exists, and how strictly to interpret model results. This experience-based assessment of error in model results has not been documented to reassure those with less or different experience. To supplement, substantiate, and test this experience-based understanding of error or "noise" in model results, there should be formal numerical error analysis based on realistic assessments of uncertainties in model inputs and parameters. These might take the form of simple single-parameter sensitivity studies or more elaborate Monte Carlo studies. While such studies would represent simplifications of known errors and uncertainties in the model, they would provide a source of understanding of model uncertainty which everyone could understand. A standard set of error analyses might be supported by software to automate much of the error analysis. It is highly desirable to have a basic error analysis as part of the model's development phase. Without such a basic error analysis, general model result applications and general impressions of model accuracy will be uninformed regarding the likely levels of error and sensitivity. There is a common unease regarding the accuracy of water models in California. Model developers would be wise to respond to this with explicit error analysis for some commonly important conditions. Additional error analysis can also be desirable for specific model application studies; such application-specific error analysis would be especially useful if documented.

A priority for error analysis should be the flow and salt load "closure" terms in the water quality module. Since the "closure" terms are error terms for what is largely a system of mass conservation equations, plotting closure quantities might be useful for estimating uncertainty in the model for some locations or processes.

Examination and Re-Calibration of Maze EC Predictions and Resulting New Melones Operations

There appear to be problems and potential problems with the prediction of Maze EC in the model. These should be investigated, perhaps with re-calibration so that the model-predicted EC more closely matches the historical EC. The calibration should consider not just matching the mean EC for the calibration period. Rather EC should be calibrated to provide a good match with historical EC during low flow and historically high EC periods since these are critical periods for estimating New Melones operations. We know that work has continued on this subject since the work presented to the panel.

Recommended Longer-Term Actions

Some additional actions are required to realize the flexibility and accuracy potential of the methodological improvements in the new representations over the long term. These will require sustained and serious effort.

CalSim Development Plan

California water modeling faces significant challenges unparalleled since the early days of California water resources development. A strategic plan and effort is needed for both data and model development (CWEMF 2005). CalSim II development should be guided by a clearly articulated development plan, based on a set of stated modeling objectives for a range of expected water management problems. The CalSim III effort provides some of these elements. A development plan, created collaboratively by the Reclamation, DWR, and other entities, would provide rationale, prioritization, and support for model and data development efforts and make it easier for developers of groundwater, economic, water quality, and other modeling efforts to make their work useful within the context of CalSim II. A CalSim II model and data development plan also should address appropriate funding, management, resources, documentation, testing, model maintenance, and quality control issues. The CalSim development plan also should be interested in quality control and accuracy of tributary models providing input to CalSim II, such as the CU model.

"Absolute" vs. "Comparative" Modeling Expectations

As concluded by the previous more general peer review of the CalSim II model (Close, et al., 2003), the applications of CalSim II are increasingly "absolute" and less "comparative." Whatever the potential virtues of "comparative" applications, this shift to more direct use of CalSim II results implies a greater need for accuracy and estimation of the unavoidable error in model results. Development of CalSim II models for "comparative" purposes alone is unrealistic. The limitations that model uncertainty imposes on the utility of the model to predict an absolute future condition should be explored. If model developers agree that model uncertainty is sufficiently large to make such predictions unreliable then this message should be documented and clearly conveyed to model users and decision-makers.

Protocols for Documentation and Testing

A set of documentation and testing protocols for CalSim II would improve documentation and testing, reduce documentation costs, and make documentation and testing more useful for model and results users and water managers. Each model parameter's value should have a methodological, personal, or literature source, justification, and a reasonable discussion of associated uncertainty. The differences between new and old model results and relevant historical data should be plotted (as they have been in the present documentation) and explained. Involvement of local experts and error analysis also should be documented. This approach will provide greater assurance and understanding of the model's results. To do this, the water community is likely to need a more accessible and thought-out framework for data and model documentation and testing (CWEMF 2005). An organized database and web-based documentation system should be considered to allow better access and updating of data and parameter documentation.

Groundwater and Westside Components

Several pieces of the San Joaquin River System representation have not yet been developed and will become needed for applications. These include an explicit representation of groundwater and explicit Westside land-use based demands and physically-based return and drainage flows. CalSim II applicability will be increasingly hampered by the absence of these major components as water management and hydrology for the region diverge from historical conditions. This will require a major effort, but it is essential if the CalSim model is to have long-term utility and accuracy.

Data Development

A more comprehensive long-term effort of water quantity and quality data gathering and development is highly desirable for this basin. Data collection and development efforts should include:

1. Expansion of the stream-gage system. Additional streamflow measurements will benefit both water users in the system and those seeking protection from flooding. Additional volume measurements will enable better calibration of flow and water quality models and will permit adjustments of the representation of operations.

2. Assurance of continuation of the availability of currently-available streamflow data. Funding for existing gages is subject to reduction, so that gages may be abandoned. Reclamation should work cooperatively with DWR to ensure that current data sources are not lost.

3. Monitoring of Westside return flows, salt loads, and perhaps other water quality constituents.

4. Quantifying groundwater-surface water interactions in terms of water and salt fluxes.

5. Groundwater data is needed to improve our understanding of San Joaquin River System flows and resources.

6. Improved sharing of reservoir and irrigation data. In some cases, reservoir operators and

irrigation districts may be reluctant to share data. Reclamation and DWR should continue efforts to acquire these data with assurances to the operators that they will be used to enhance the model. In the long-term, a regional database integrating these data and water quality data with Westside returns and stream gage data would be worthwhile.

7. Investigation of use of remotely sensed data. Use of remotely sensed land use, evapotranspiration, and other relevant inputs to the models may improve the calibration.

E. RESPONSES TO QUESTIONS IN PANEL CHARGE

For each area of this review, Eastside hydrology and operations, Eastside water demands, and San Joaquin River salinity, we present a discussion of our thinking and concerns, followed by more focused responses to the questions posed in the charge.

1. EASTSIDE HYDROLOGY AND OPERATIONS

While the representation of Eastside hydrology and operations has been improved over the prior CalSim model, several aspects are of particular concern.

a. Groundwater

Groundwater is not explicitly accounted for in the current or previous versions of CALSIM II (Reclamation, 2005). In the model, groundwater is represented through the assumption that unmet surface water demands are satisfied from groundwater pumping, except as limited by demand area pumping capacities, especially on the Eastside (p.124, Reclamation, 2005). However, groundwater pumping and deep percolation from agricultural areas are not linked to any aquifer storage representation. As the modelers presented and discussed, lack of groundwater representation is a limitation of CALSIM II in terms of its ability to model general water management in the San Joaquin Valley. Groundwater is a major source for the basin, averaging 2.1 million acre feet per year (maf/year), according to the model calibration. This quantity rises to 2.7 maf/year in critically dry years, illustrating the drought storage role of groundwater in the San Joaquin Valley. As districts and farmers make more conjunctive use of ground and surface waters, groundwater representation will become more important for future planning and policy studies and groundwater conditions are likely to depart from the conditions under which the model was calibrated.

The need for groundwater representation in CalSim-II was noted in the first CalSim II Peer Review (Close et al., 2003) and recommendations for improving this were made in the response to that review (DWR, 2004). Groundwater is being incorporated into the Sacramento Valley portion of CalSim II through the use of “response functions” derived from calibrated groundwater models (CDWR, 2004). This approach of including groundwater interactions in river basin optimization models, which is well documented and tested, might prove useful in the San Joaquin River model as well (Maddock, 1972; Illangasekare and Morel-Seytoux, 1986; Maddock and Lacher, 1991).

While the approach to representing groundwater taken in CALSIM II may be adequate for short-term applications, it is problematic for long-term applications, as it neglects cumulative and seasonal groundwater storage effects. The absence of a more explicit representation of groundwater will be problematic where: groundwater use changes affect inflows or salt loads to surface waters, groundwater pumping costs begin to exceed the value of some water uses (prompting farmers to forego some activities and crops to avoid some pumping costs), where well depth limits groundwater access during drought, or where conjunctive use of ground and surface waters is being considered. Salt loads from groundwater are likely to be important on the Westside.

Deep percolation of applied water, an important component of the surface water – groundwater system, is specified in CALSIM II in a lookup table as a fixed percentage of applied water less the surface runoff. These percentages are based on average percolation rates that are output from the historical run of the Central Valley Groundwater - Surface Water Simulation Model (CVGSM), water district budgets, and judgment (Reclamation, 2005). However, the percentage of applied water percolating to groundwater is assumed to be almost uniform for all areas in the model (25% or 30% for most areas and not specified at all for many areas). The basis for this assumption is not reported and technical justification is needed for these values. The sensitivity of model results to this assumed parameter value should also be tested.

Typically, deep percolation varies significantly with soil, irrigation technology, and crop characteristics. Other modeling efforts also have found deep percolation to be problematic (Jenkins et al, 2001), and have adopted deep percolations varying by irrigation area (albeit as a calibration parameter for crude groundwater balance models). Deep percolation is typically estimated and difficult to measure. As irrigation technology and practices change, deep percolation is likely to change. Deep percolation estimates will become particularly important if explicit groundwater representations are added to the model.

b. Accretions

A major objective of the new version of CalSim II for the San Joaquin basin was to provide improved estimates of accretions/depletions. Accretions are estimated from mass-balance calculations for the river reaches using gage data to define upstream and downstream flow for the reaches plus diversions minus return flows. The result is an estimate of the local runoff, stream-groundwater interaction, and gage errors, adjusted to account for current land use development. The land use development adjustment modifies the accretions to reflect increases or decreases in runoff resulting from land use changes over time derived from historic records of land use, precipitation, diversions, and streamflow. While this should work and be appropriate for 2001 conditions (for which it was calibrated), it might work less well for future land use, water management, and hydrologic conditions, particularly where future conditions affect groundwater-streamflow interactions and groundwater pumping.

The mass balance accretion/depletion method did not work well for the **San Joaquin** prior to 1970 and a regression method was used. The mass balance accretion/depletion method showed that this was a losing reach during the 1920s. This result was rejected because "the Vernalis stream flow gage was not in place until about 1929, and flows at Vernalis before this date were roughly estimated based on …" other gages (p. 58, Reclamation, 2005). There should be more documentation of the analysis that led to abandoning the mass balance approach. The justification seems to be that the developers do not believe the regression used for the period before the Vernalis gage was installed. However, no justification is given for the method that was adopted and there was no comparison made except between the mass balance and regression methods. The method seems to be a linear, multivariable regression approach (see Table 3-1, p.

61, Reclamation, 2005), but there is little discussion of this or presentation of the regression statistics allowing one to assess the quality of the fit. Why were the model variables chosen? What statistical tests were used in the coefficient estimation process to indicate if they are significantly different from zero? What method was used to estimate the coefficients? A plot of residuals from the regression would be very informative.

In the Table of coefficients reported in the documentation, the coefficient for previous month precipitation is always zero, so the variable should be dropped from the equation. Similarly, the current month precipitation is only non-zero in July (with a very large coefficient value) and it rarely rains in the San Joaquin Valley in July, so the statistical significance of this coefficient is suspect and the variable should probably be dropped from the equation. The coefficients for previous month upstream flow are very small for February through September and the statistical significance of these coefficients should be checked before they can be accepted. Similarly, almost all coefficients for current month upstream flow are very small and should be checked. No justification to support the coefficients and no quantification of the sensitivity of modeled accretions to these coefficients are provided. The units of the independent variable are not stated.

As discussed in the San Joaquin Model Report (Reclamation, 2005) and the Review Panel public meeting August 4, 2005, the accretions in this reach of the river can affect New Melones reservoir operations. Thus, these questions about the method of calculating the accretions and depletions should be checked carefully and thoroughly and well documented.

The file “Regressions_032604.doc (Memorandum, Levi Brekke, Reclamation, 2004)”, contains a discussion that the “regression models included predictors that do not pass parameter significance testing and seem to be affected by multi-collinearity.” Re-development of the regression models, using a stepwise regression method is described. Several of the resulting R^2 values are extremely low and probably unreliable for June (very low 0.32), August (low, 0.54), and September (very low 0.28).

Error analysis from the regressions, such as the distribution of residuals, can provide information useful for error analysis for the overall model. Much of this issue might be addressed with improved documentation, at which time it will become apparent if additional work is needed on this subject.

c. Distribution System Losses

> “…distribution system losses are estimated as 30 percent in dry years and 40 percent in normal years,…” for Madera ID, (p. 27, Reclamation, 2005)

Little justification or investigation is given for distribution system loss rates. These numbers seem to vary by irrigation district and some districts use absolute flow series. Revealing sources would be useful and contribute to the credibility of these parameter values. What effect does this parameter have on model results?

What is the basis for the assumed 75% irrigation efficiency? What is the basis for the assumed 10% non-recoverable loss rate? Might deep percolation and low irrigation efficiencies be used in some districts to foster conjunctive use? The documentation of these hydrologic parameters and their use should be improved, and some error analysis on reasonable uncertainty in these parameters should be undertaken.

Overall, given the significant undocumented and untested (or un-testable) assumptions and approximations made and required in model development, one could conjecture that uncertainty in model results might exceed arbitrary some quantity at Vernalis; error analysis could refute or support such a conjecture.

d. Historical Comparison: Operations

"San Joaquin Basin projects are functionally quite independent of each other and have had relatively constant operational objectives for several years if not decades. This relatively stable history of operations allows the CalSim II simulation of operations to be compared to historical operations." (p. 136, Reclamation, 2005)

Several graphs comparing CalSim II versus historical releases and reservoir storage are shown in Section 9 (e.g., Figures 9-1 to 9-13, Reclamation, 2005). There is no interpretation or explanation of these results offered in the documentation. There are no quantitative analyses of these results. While the graphs do look like the model is performing adequately, this is simply from visual inspection and not a quantitative measure of the difference between the model and historical behavior. More analysis should be performed to quantify these results and an explanation of the results provided.

Based on more detailed, extensive, and in some cases corrected data obtained from the modeling team, several comparisons are made of the new CalSim II with recent historical data up to 2003 and older CalSim II results (which extend up to 1994). Note that many changes in water management facilities, regulations, and operations have occurred over the historical period which make historical comparisons less relevant into the past. In the following plots, OCAP refers to the older CalSim II model and "simulated" refers to the newer CalSim II model.

Friant Releases and Diversions

Releases downstream from Friant Dam appear to match those of recent history (not shown here). However, the larger releases from Friant Dam are to the Madera and Friant-Kern diversion canals. These results seem to match fairly well, with model results seeming to under-predict peak diversions a bit in the most recent years, except for some over-predictions in wet years (1995 and 1997), as seen in Friant-Kern Canal diversions, Figure 2.

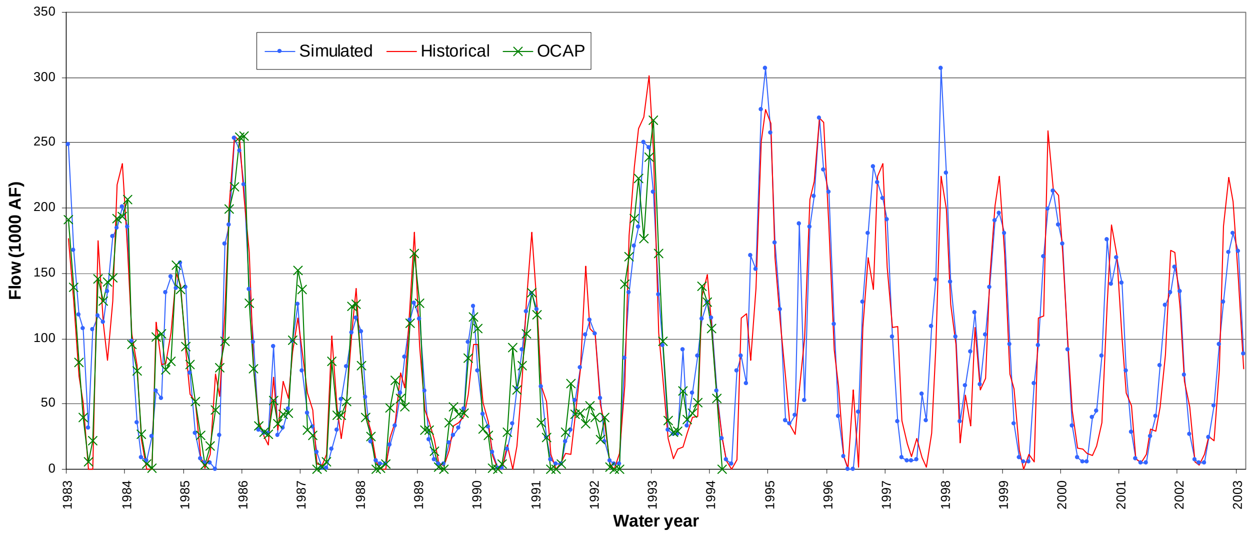

Figure 2. Historical Data and New (Simulated) and Old (OCAP) Model Results for Friant-Kern Canal Diversions (OCAP ends with 1994)

<u>New Don Pedro</u>

Updated comparison plots, improving on those available in the original documentation, for New Don Pedro storage, releases downstream, and deliveries to Turlock Irrigation District appear below (Figures 3 – 5). These comparisons appear, by visual inspection, to be significantly improved from those available in the original documentation.

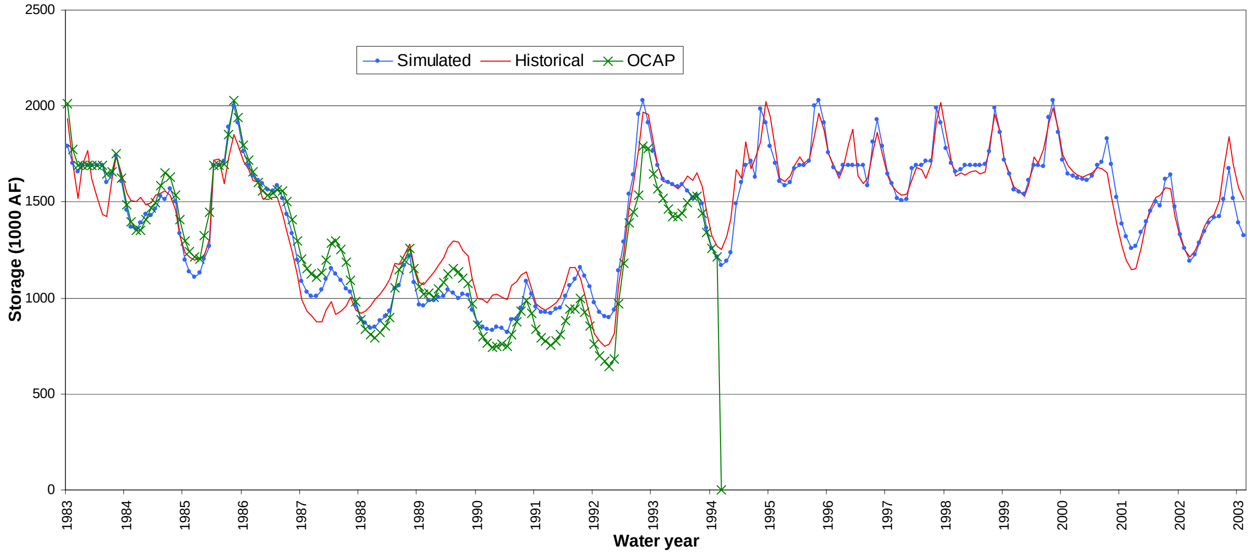

Figure 3. Historical Data and New (Simulated) and Old (OCAP) Model Results for New Don Pedro Storage (OCAP ends with 1994)

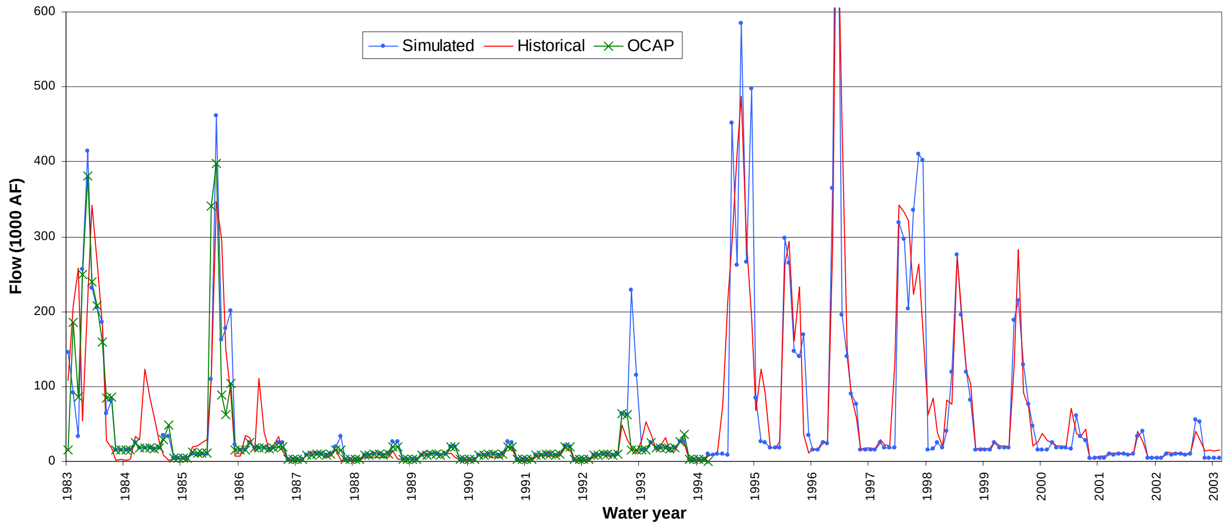

Figure 4. Historical Data and New (Simulated) and Old (OCAP) Model Results for Tuolumne River Flows Below LaGrange (OCAP ends with 1994)

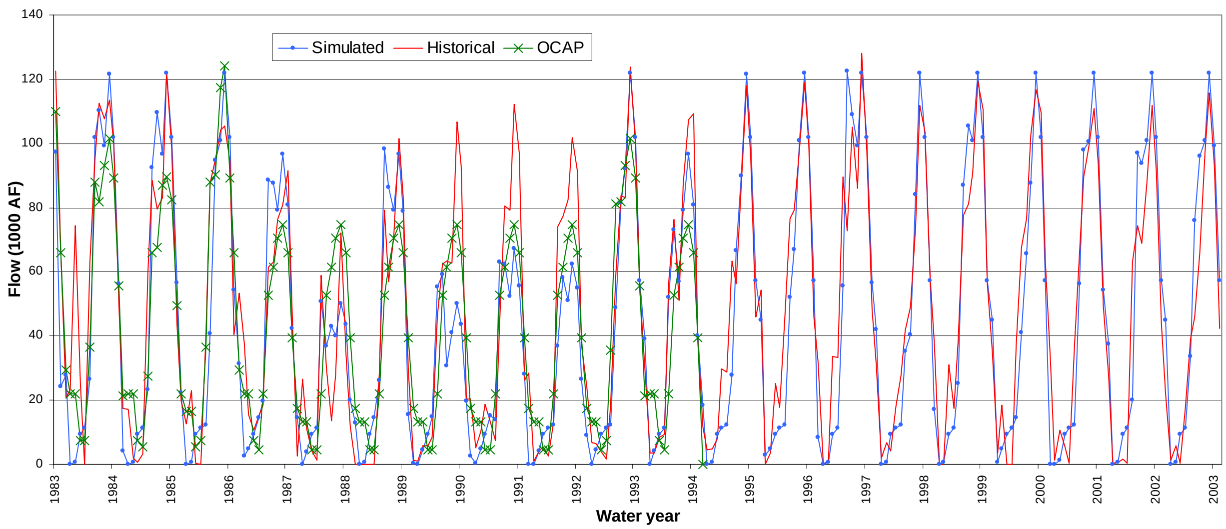

Figure 5. Historical Data and New and Old Model Results for Turlock ID Diversions (OCAP ends with 1994)

New Melones

The report (p. 146, Reclamation, 2005) states, "Simulated Stanislaus River operations and diversions track well with historical operations and diversions (see Figure 10-9 and Figure 10-10).). The closeness of the simulation results to the actual recorded operation is somewhat coincidental in recognition of the change in operational objectives that have occurred at New Melones in recent history." Updated comparison charts appear below in Figures 6 and 7 (Goodwin is downstream of New Melones). Contrary to the statement in the report, looking at the results, there seems to be a pattern of model releases being much lower than historical releases during late winter and spring periods. There is no discussion of this issue in the documentation. The modelers explained orally, after the formal presentations, that there were major changes in CVPIA, VAMP, and new operating rules which make a simple historical comparison inappropriate for this period. Such important discrepancies should be explained in model documentation.

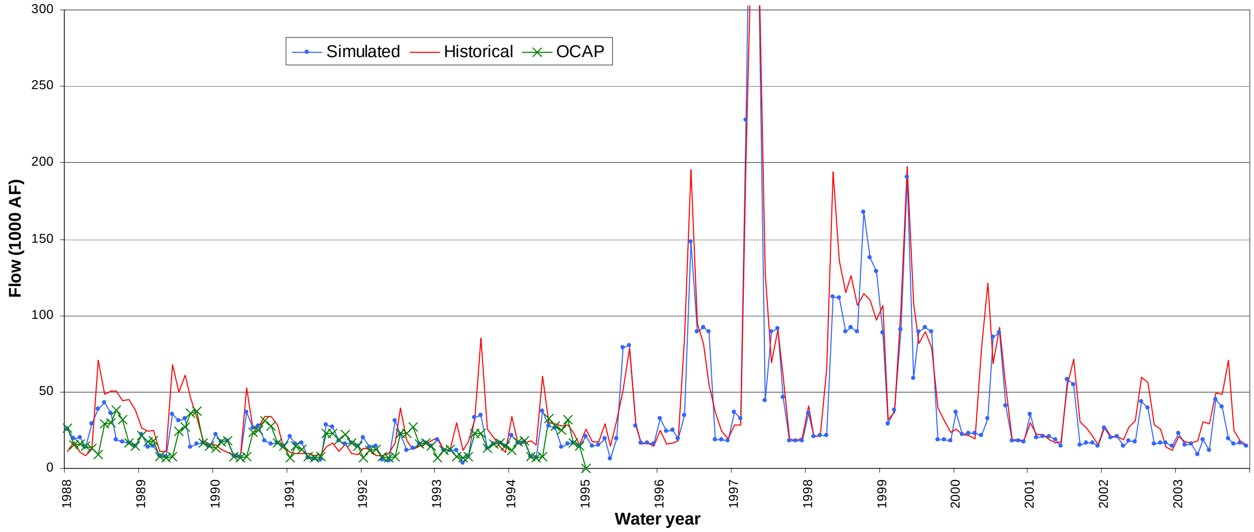

Figure 6. Historical Data and New (Simulated) and Old (OCAP) Model Results for Stanislaus River Flows at Goodwin (OCAP ends with 1994)

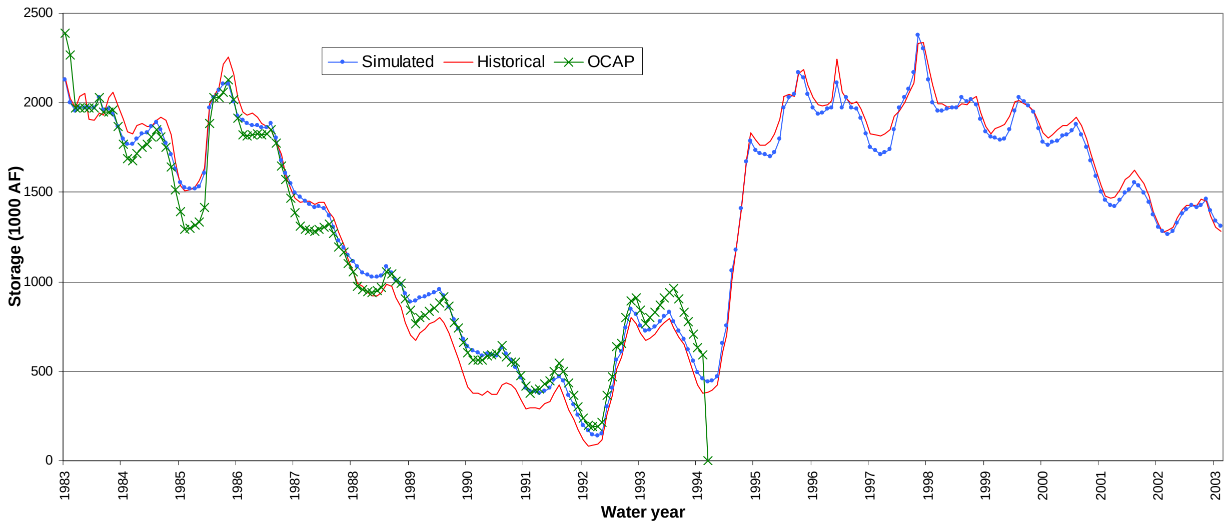

Figure 7. Historical Data and New (Simulated) and Old (OCAP) Model Results for New Melones Storage (OCAP ends with 1994)

<u>Vernalis Flows</u>

The flow at Vernalis has been used to indicate the "goodness" of CalSim II. The updated comparisons for recent years appear to agree fairly well, even when plotted on a log scale to accentuate differences at low flows (Figure 8).

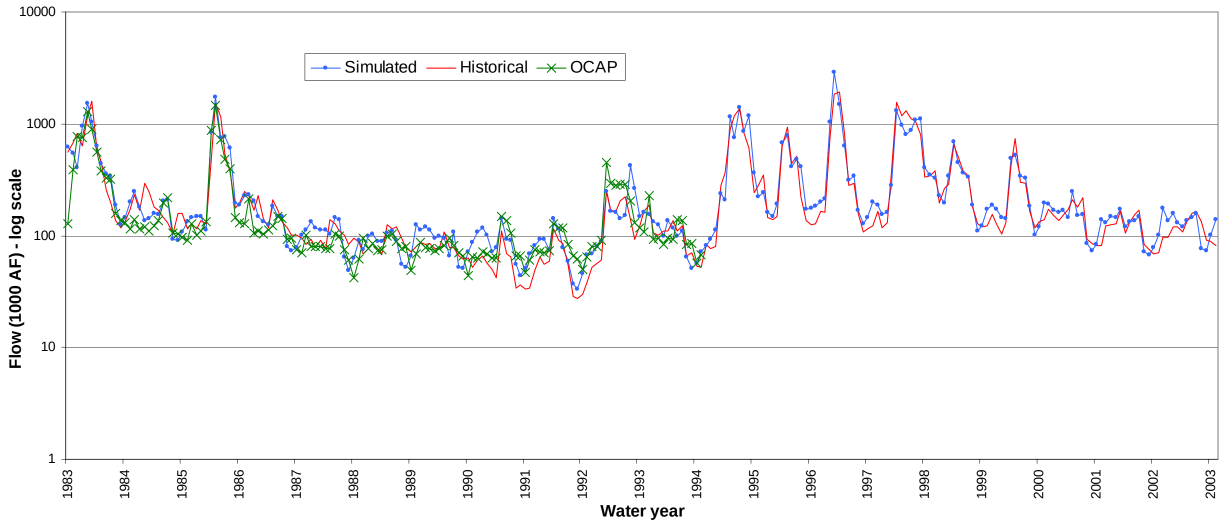

Figure 8. Historical Data and New (Simulated) and Old (OCAP) Model Results for Vernalis Flows (OCAP ends with 1994)

Part I: Merits of recent work compared to prior representations

1. *In what ways is this new representation more accurate than prior representations?*

The new representation is more up-to-date than earlier versions of the model. Inflows, local accretions and depletions, and reservoir operations all appear to be better established with more and more recent field gage data and discussion with system managers and reservoir operators. In comparisons with recent historical flows and operations, the modeled results appear to match well with some noted exceptions, and some more major deviations from historical flows and operations are well explained in the presentation and subsequent discussions, though much less so in the more permanent documentation, by changes in operating policies and regulations in recent years, gage errors, or other factors. The new representations of surface hydrology and operations appear to be substantially more accurate than the previous representations, particularly for recent conditions.

The new representation is more structurally accurate than the previous model, including more realistic depictions of water demands, and disaggregation of the salinity inputs into the San Joaquin River. However, the question of whether the new representation provides more accurate output can only be answered in the context of strict qualifiers. First, with all models, data requirements increase with the level of model sophistication, and this has certainly occurred here. More specifically, temporally and spatially distributed model input data on water demands (based on land use), Eastside operating patterns, and Westside drainage and accretions are needed. Model output will be affected by the time period for which these inputs are gathered or calibrated. As future applications depart from within the range of conditions for which the model was calibrated, the model's accuracy becomes less certain.

Second, there are errors or uncertainties associated with the input data, both in terms of "noisy" field data and in terms of assumptions for data that are unavailable or impractical to collect. This second issue is more damaging to model credibility if input errors are large, or remain unquantified, especially in the absence of formal error analysis studies.

2. *In what ways is this new representation less accurate than prior representations?*

No lessened technical accuracy is evident for the newer model calibration and data. However, some risk exists that expectations of greater accuracy might lead policy-makers to interpret the model results too finely. For example, small changes in flows relative to the total quantity of water being managed might be of no technical or scientific significance, despite being numerically different. Such technically insignificant numerical differences in results might tempt policy-makers to make policy changes based on insubstantial technical differences. We propose that Reclamation employ numerical experiments (error analysis) to demonstrate the level of uncertainty present in the model's results. The only potential lessened accuracy is where rising expectations of technical accuracy exceed the real improvements in accuracy from this effort.

The new representation generally should be more accurate, provided that input data are sufficiently accurate and hydrologic and water management conditions have not varied too far from calibration conditions.

3. *In what ways would CalSim II results using this new representation consistently differ from the prior model?*

There is no reason that the results should be "consistently different" than the previous formulation, except where there have been substantial operating policy changes. However, there is more accurate depiction of several elements (e.g., land-use based demands and semi-disaggregated accretions-depletions) that should produce consistently more accurate results. The level of improved accuracy, as noted above, is difficult to assess until the uncertainty (level of noise) of the model is better known. Mainly, the CALSIM II results using the new representation will be capable of addressing monthly and inter-annual variation in flows and water quality with greater spatial resolution than the prior model.

Some seasonal comparison quartile plots of flows indicate there are substantial similarities and differences between the proposed and previous models. Differences in flow in the Tuolumne River are occasionally substantial, but there is good agreement for most months in most years.

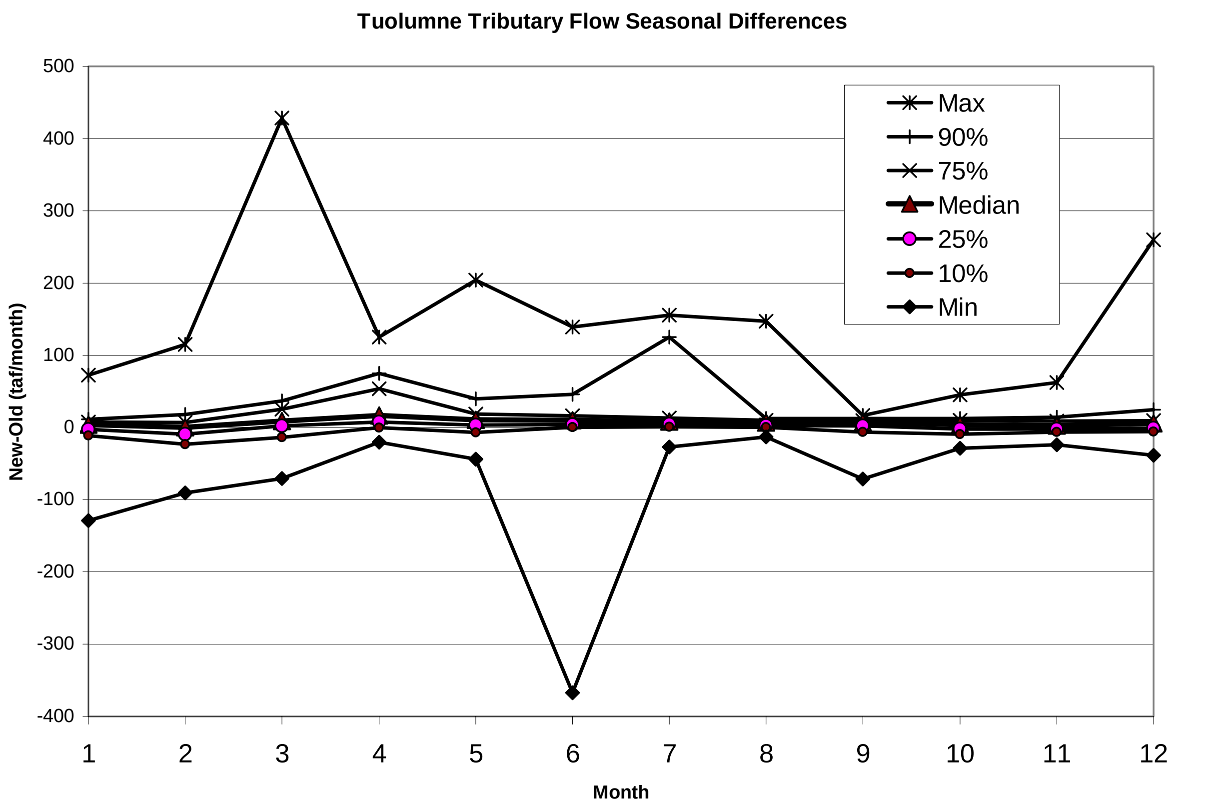

Figure 9. Seasonal New Minus Old Model Results for Tuolumne River Flows Downstream of New Don Pedro

Table 2. New Minus Old Model Flows at Vernalis (taf/month)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	23.8	16.4	4.9	-4.7	3.3	-5.1	-7.9	8.0	28.3	13.1	40.1	33.9

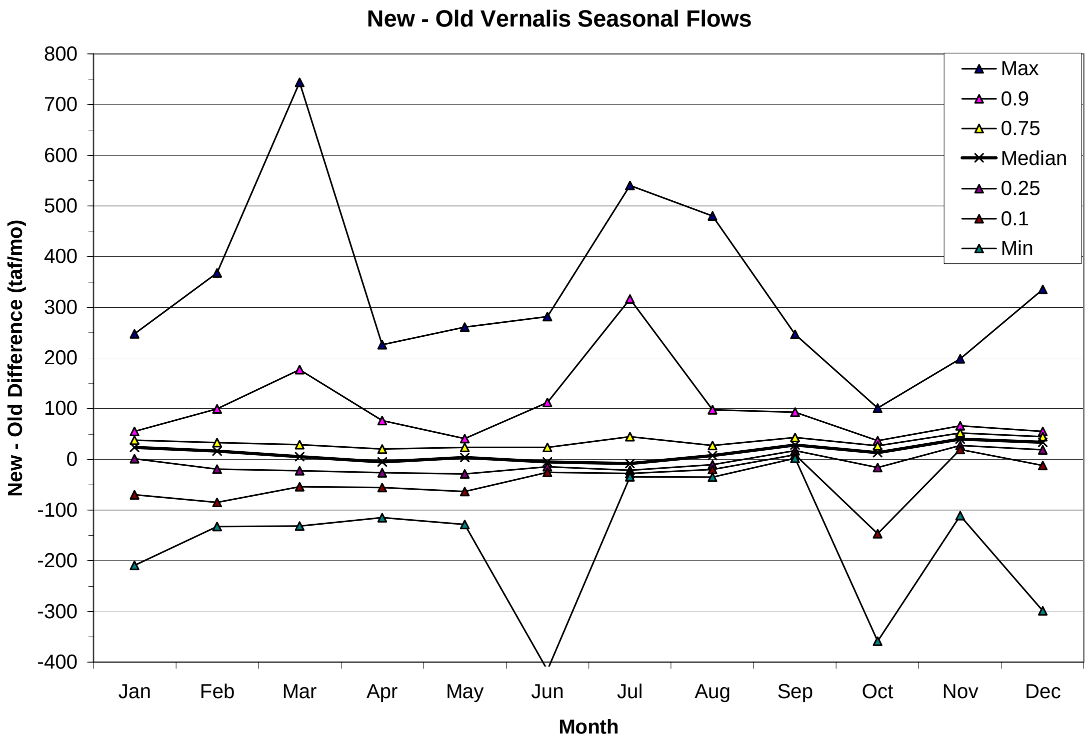

Figure 10. Seasonal New Minus Old Model Results for Flows at Vernalis

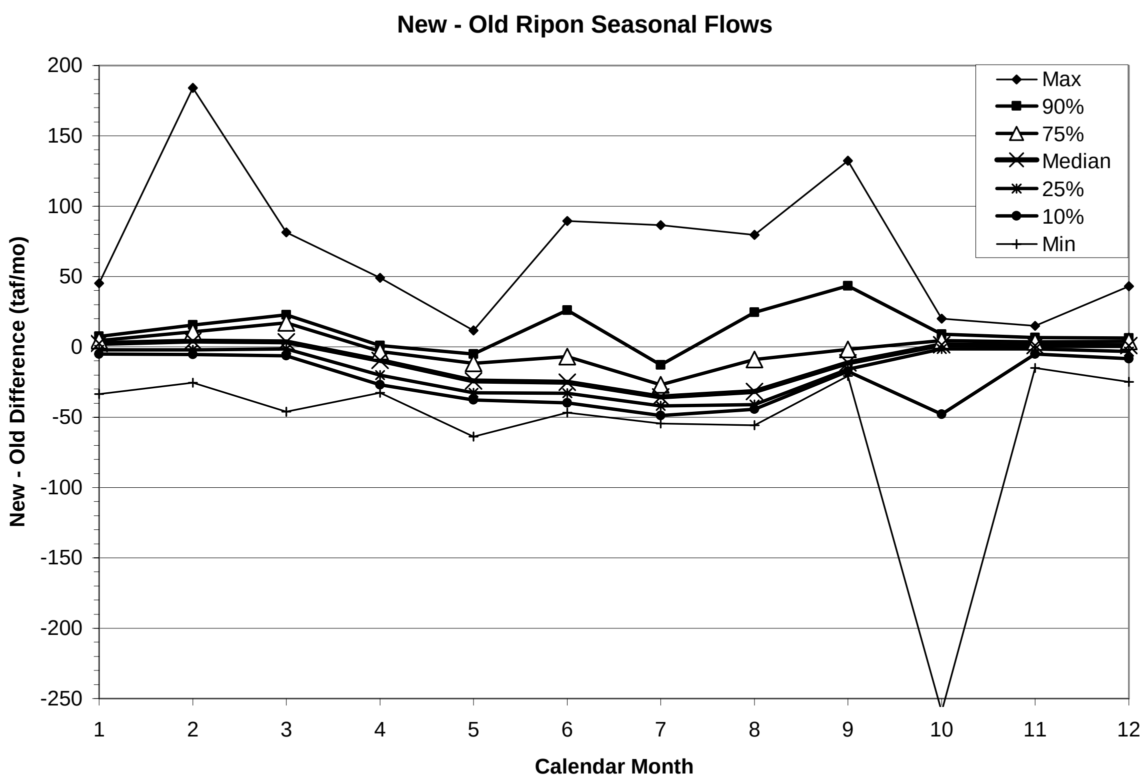

Figure 11. Seasonal New Minus Old Model Results for Stanislaus River Flows at Ripon

The Vernalis flow comparisons indicate significant differences between the two models, with some pronounced differences for winter months (September through February), Table 2. Flows in the Stanislaus River downstream of New Melones at Ripon also show some differences, tending to be less in May through June, Figure 11.

4. *Is this new representation expected to lead to any systematic bias in CalSim II results?*

While the new representation produces results that differ from the older model, we find little evidence of systematic “bias” in the results of this new representation. However, there are a few concerns.

For long droughts, the lack of representation of groundwater could mis-represent any reduction in groundwater use or base surface water flows from groundwater that would accompany increased pumping heads/costs and decreased groundwater availability from multiple years of expanded groundwater use. This seems more likely to affect Eastside accretions to streams in prolonged droughts. Such groundwater problems become more likely for applications where water management and hydrologic conditions diverge from those in the model’s calibration.

There is a thought that the optimization algorithm used for CalSim to implement monthly water allocation priorities might be “too smart” in terms of allocating exactly the amount of water needed for each demand and instream flow target. It seems likely that reservoir operators would release a little more water than actually needed under many circumstances, merely to ensure that adequate water arrives for a downstream delivery or instream flow target where there is inaccuracy or uncertainty in downstream accretions/depletions or actual water demands. Conceivably the expected amount of additional release might be greater in wet years (when there is little cost to a modest additional release) and less in dry years (when any resulting water “spill” would have greater opportunity cost). If this is found to be a problem, then some increase in demands or flow targets, perhaps representing a chance constraint approach (but implementing via demands rather than constraints) might be appropriate.

Part II. Improvements to the recent work

5. *How well are the new representation and its underlying data documented? What additional documentation should be prepared?*

The documentation provided of this new representation is a fine compendium and discussion of the operations and characteristics of tributaries in the system. Organizing the presentation by tributary is appreciated and valuable. The new representation of Eastside San Joaquin hydrology and operations is the best documented representation in the entire CalSim II model and is in some ways the most thorough public documentation of any major model of water we are aware of in California or other major systems in the U.S.

While the documentation presented is superb, relative to previous efforts, the complexity of the system means that a considerable amount of documentation is required. For each parameter in the model, there should be a clear presentation where these values come from and the likely range of uncertainty in these values, preferably with a source citation. Additional effort should be given to developing a more usable form of documentation than traditional reports (even those in pdf form). For instance, documentation of parameter values might be stored so they could be accessed electronically from an electronic schematic, and searched for in a database. This more accessible form of documentation should encourage greater use and more frequent updating, since it could be updated as each model revision is consolidated before release.

Additional areas where the documentation could be improved are discussed below: Documentation should include the source of the data for the rim flows for each tributary reported and the method of their development. There are major reservoirs upstream of the New Melones, New Don Pedro, and Millerton reservoirs, which will affect these inflows. Actual New Don Pedro inflows, as suggested by one commenter, are affected by upstream operations include 3 reservoirs with almost 550 taf of storage capacity and a major diversion out of the basin from the Hetch Hetchy project. Current and future assumptions regarding operation of the Hetch Hetchy Aqueduct would directly affect New Don Pedro inflows. Such assumptions are especially important for future time-frames.

One area that is vague is the use of the results of previous modeling efforts to disaggregate CALSIM variables. In a few cases there is some confusion between data for model derived from field data and outputs from other models (SJRIO, Rim flow models?) used as inputs to CalSim II. In Table 2-3 of the WQ Module report, the use of SJRIO and DSM2-SJR for “location and quantity” is difficult to track without intimate knowledge of the prior efforts. The assumptions underlying those modeling efforts seem to be lost in the analysis here and, in effect, their output seems to become like real data.

Some detailed documentation improvements include:

- **Tuolumne River** flow at Modesto for 1922-1940 is estimated based on a regression with the Tuolumne City gage. No statistical correlation value is reported for this case. It would help if the USGS gage numbers had been included in the documentation for this case.
- The **Merced River Slough** regression R^2 is 0.626 and that seems very low. What is the reason for this? No discussion is provided in the documentation. From discussions with the modelers, there is apparently a very wide flood channel at this location, with a difficult gage. Some discussion in the documentation would clarify this situation.
- The Eastside return flow values are unusual compared to the Westside values used in the model. The average return flow for the Central Valley Project Exchange Contractors is 10% of deliveries (7% in most months, and 20% in winter months). The same factors are applied to the CVP Agricultural Contractors (see Table 7-3: Monthly Return Flow as a Percent of Monthly Delivery, Reclamation, 2005, p. 125). Differences between Eastside and Westside return flows should be discussed. Documentation should be provided on the source of information on Westside return flow values.

Several distribution systems loss estimates seem insufficiently documented:

- “The total annual return flow from Mendota Pool CVP refuge contractors is assumed to be 61% of their annual delivery” (p. 127, Reclamation, 2005). Some reference for the origin of this value should be given in the documentation.
- “Agricultural water contractors in the Lower DMC area are assumed to have no return flows to the San Joaquin River (p. 129, Reclamation, 2005).” Some justification and reference for this assumption should be provided. The documentation states that the model is set up to handle this return flow, but it is left out and no justification is given. The CVP Agricultural Contractors in the Lower DMC use 124 taf per year.

- The distribution of accretions/depletions above and below Maze seems to be based on river mile between Newman and Maze and Maze and Vernalis. If this is the case, then the documentation should state that or present another explanation.
- "The San Joaquin River reach between Gravelly Ford and Mendota Pool was estimated to lose up to 200 cfs of the available flow at Gravelly Ford." (p. 65, Reclamation, 2005). Some reference for this assumption should be given and some discussion of the value 200 cfs (~144 taf/year) should be provided. Is this value constant day and night, in every month, and in every year?
- "Salt Slough and Mud Slough systems are modeled … as a combined stream network. As a component of its connection to the San Joaquin River, a base flow is assumed for the streams. Flow from the Grasslands Bypass Project is explicitly modeled…" (p. 66, Reclamation, 2005). This description is so vague that there is no way to understand what is meant or how these elements of the system are modeled. Public comments were received indicating that the method of modeling Grasslands Bypass is controversial. This portion of the documentation should be improved.
- No diversion amounts are documented for the San Joaquin River Main Stem Riparian Diversions and the return flows are all assumed to be 30% of deliveries (p. 133, Reclamation, 2005). More accessible documentation would be useful.

6. *How well has the new representation and its underlying data been tested? What additional testing should be performed?*

The testing of the new Eastside hydrologic and operations representation has been more explicit and public than previous CalSim II efforts. This testing is slightly described in documentation, but was better described in the workshop presentation. Testing has taken several forms. First, there is testing of the representation against the local knowledge of local irrigation districts and water managers in the course of developing the local hydrology and reservoir operations of each tributary. Second, there is an explicit comparison of modeled flows against recent historical flows on each tributary and at mainstem locations. While such historical comparisons should diverge at times, due to changes in operating policies and regulations over recent years and gage errors in the historical record, they provide a useful basis for testing the model's representation at various locations throughout the system, especially if the divergences can be explained by known differences between past and present operation policies and known gage inaccuracies. In this case, the modelers have provided explanations in presentations and discussions (but not in model documentation) for most large short-term and averaged differences between modeled and historical flows.

In general, the modelers have made good use of existing data to test the model, but there is, in a larger sense, inadequate field data for model testing. In the longer term, it would be desirable to have additional gage data at various locations throughout the basin to provide a basis for 1) improved spatial representation in the model, 2) better hydrologic calibration in some areas, and 3) better model testing. While testing against historical flows has been widespread, additional numerical testing should be conducted in the near term to estimate the amount of uncertainty in model estimates, based on uncertainties in parameter estimates in the model.

7. *What is the accuracy expected and what are major errors remaining (if any) in the representation of the San Joaquin Valley?*

All quantitative representations, whether computer models of the San Joaquin River system or accounting estimates of the financial health of a corporation, contain inaccuracies and errors. The important point is not that inaccuracies exist, but the degree to which such inaccuracies limit the ability to usefully interpret model results for a particular purpose.

For a particular purposeful application of the model, it would be useful to compare estimated error in model results with the kinds of accuracy needed for the particular operational, planning, or policy application. Estimates of the error in model results should be possible generally from numerical error analysis studies, and perhaps more roughly from field data comparisons for a few particular cases where gage data is both representative and of high quality.

8. *How might the new representation be improved?*

The most desirable improvement for the representation of Eastside hydrology and operations is to include an explicit representation, even if it is very approximate, of groundwater storage, processes, and use. Groundwater is a major source of both water supply and storage in the basin, and it is well accepted that it will be of increasing importance in the future. The increasing integration of surface and ground water operations in the basin implies that accurate modeling of the major water projects will require explicit consideration of groundwater, particularly for drought years. The explicit incorporation of groundwater in the model also would facilitate examination of a wider variety and integration of water management options in the basin.

Dissagregation of some reaches in the mainstem of the San Joaquin River also might be desirable for many anticipated modeling purposes, particularly representations upstream of the Newman gage. Current models of the water quality (salinity) at Vernalis assume that there is one long reach in the San Joaquin upstream of Mud/Salt Slough. There are several sites where side inflow is significant in this reach and most stretches of the reach are receiving diffuse base flow from shallow groundwater or tile drain systems. These incremental side inflows and their associated salt loads are important in calculating the salinity in the reach.

The number of gages in the main stem of the river above Vernalis is limited and should be expanded. Additional gage flow and groundwater data development would help support these desirable expansions to the model.

In the Eastside hydrology and operations area, the model should generally work well, when hydrologic and water management conditions lie within its calibrated range. This should apply to many near-term conditions, with the possible exception of critically dry years, which are under-represented in the calibration period. Adding a land-use based representation of Westside demands should help with return flow and salt load estimations useful for mainstem flow and salinity modeling.

For some modeling purposes, it might be useful or important to include representations of upstream storage capacity and operations, particularly for the upper San Joaquin (~0.6 maf) and Tuolumne (~0.55 maf) rivers, and upstream diversions from the Tuolumne River to the San Francisco service area. According to one of the Reclamation consultants, there are 9.3 maf of surface storage in the basin, but the model includes only about 6.5 maf. Under some circumstances and for some problem applications, these diversions and capacities can be important.

More explicit representation of Tulare basin exports also might be useful, as the integration of California's water management increases. Withdrawals of very high quality water from Millerton Reservoir to the Tulare basin via the Friant-Kern Canal are by far the largest diversion in the system, and a major conjunctive use activity. To some degree, the San Joaquin Valley and the Tulare Basin operate together in a statewide context, especially in conditions with substantial water market activity. This will become particularly important as water pricing, water transfers, water demands, and operational changes occur in the Tulare Basin which diverge from the calibration conditions of the current San Joaquin River model.

Although there are ongoing efforts to improve the Eastside hydrology and operations representation, the lack of an explicit model and data development plan and a model and data documentation framework is a long-term concern.

EASTSIDE WATER DEMANDS

Demands of 3 types are considered in the study: agricultural, municipal and industrial, and refuge. To estimate the demands, the study incorporates a new procedure (at least new to CalSim San Joaquin applications) for computations on the Eastside of the basin. The new procedure estimates demands as a function of land-use, with consumptive use of applied water (CUAW) computed from irrigated acreage. The computation uses a 1994 model developed by DWR, the CU model to develop a more detailed water budget for land-use based water demands.

In this study, a linkage between the CU model and database of land use, stored in georeferenced form, is established. Data in the database are from recent DWR land use surveys, but in that, demand areas do not necessarily coincide with demand areas convenient for the CalSim model. The geographic information system (GIS) created with the georeferenced land use permits CUAW demands to be developed for any defined demand areas and with land use forecasts or with historical use for any period for which data are available.

This effort to link the consumptive use analysis with a GIS tool is laudable. While the development surely was time consuming (and likely frustrating to the analysts), this effort and the resulting tools will be of great value to subsequent studies. For example, questions have arisen about using future land use projections (and consequent changes in water demands) and the need to "synchronize" the land use estimates as DWR Bulletin 160 is updated. While the details of synchronization is best considered in another setting, the tools to permit this are now available as a consequence of the work completed.

In the current application, 21 demand areas are used. Consumptive use is estimated by reclassifying the stored land use data for the demand areas (as determined with GIS manipulations) into 13 crop types recognized by the DWR CU model. Appendix C of the documentation provided shows how each of several dozen DWR land use survey categories is reclassified. (As an aside, the logic behind and impact of the reclassification is not clear. For example, why are all lands identified as *idle* in the DWR land use survey classified as *non-*

consumptive for the CU model analysis? Why are all lands not surveyed classified as *non-consumptive* for the CU model analysis? What is the impact of this? That is, would small variations in this reclassification have a significant effect on the water balance? If not, perhaps so stating would eliminate further doubt.) Why are the detailed land use survey results aggregated into only 13 crop types for the water demand estimation?

The report on demand development fairly notes some potential weaknesses of the DWR CU model, including the lack of consideration of dynamic meteorological conditions. Estimates of evapotransporation (ET) are based on a 1976 report, based on 1957-72 data. Crop water use has changed significantly for several major crop varieties since this time. As the documentation notes, *…inaccurate ET assumptions could influence results of the water budgets and consequently, water district budgets*. In fact, with the present structure of the model, determining if this creates inaccuracies is quite difficult, as noted below. Estimates from the CU model would be another worthy subject for error analysis.

The water budget is determined for each Eastside demand area by combining CUAW *…with conveyance losses, operational spills and tailwater (return flow), non-recoverable loss, and deep percolation of applied water…* Depending on the demand area and the available data, the latter components are estimated as a fixed percentage of applied water less surface runoff and/or with actual historical records of losses and spills. The current study report presents step-by-step accounts of methods by which the components of the water budget are estimated for each demand area. But some of the presentation leaves the reader wondering what actually was done. For example, the report notes that *DWR employs a method to identify a proportion of applied irrigation water that is not used in crop ET….* However, the report provides no detail about the method. Of course, with sufficient probing and reading more documentation, an interested reader may discover what the method is. Can this method be described briefly or a reference cited?

In the water budgets, the analysts aggregate all errors and uncertainties in the procedure into estimates of groundwater pumping. This ensures conservation of volume throughout the analysis. But how the computed groundwater pumping volumes actually conform to observations where available is not clear. Because of the interaction of all components in the demand estimates, unaccounted volume that is truly due to an error in the CUAW analysis (perhaps due to misclassification of the land use, errors from the CU model, etc.) manifests itself as an increase or decrease in groundwater pumping in the agricultural areas. The groundwater term includes the closure term for errors in agricultural water use estimates.

Urban water demand also is estimated using GIS tools to aggregate population, land use, and per capita use data to water budget areas. Here, annual data from the DWR Division of Planning and Local Assistance (DPLA) are used. The report notes that the annual data are disaggregated to a monthly time step for use with CalSim's monthly time-step.

(Incidentally, the report does not distinguish between the linear programming model used to make water allocation decisions and the support tools used to develop parameter values in that allocation model. Is this appropriate? That is, should the demand analysis procedure be considered a part of CalSim? Perhaps this is a picky point, but making the distinction could focus any arguments or disagreements to the appropriate component of the effort. No need, for example, to engage in criticism of the linear programming component when we disagree about demands that are computed separately of that component. This is more a comment on the strategic organization of the overall modeling framework.)

Part I: Merits of recent work compared to prior representations

1. *In what ways is this new representation more accurate than prior representations?*

The new representation of Eastside water demands is based on land use, instead of water contract amounts. Land use-based demands should generally provide a more accurate basis for estimating water demand quantities and a more flexible basis for assessing water demands and their role in water operations in an era when water markets, water banks, conjunctive use, and other more flexible arrangements are increasingly common.

This new land use based approach is an appropriate step toward relating water demand to real needs, and has the potential to be more accurate than the previous approach. However, the land use based approach does require a large number of temporally and spatially dependent parameters (e.g., evapotranspiration) to be accurate. For current conditions of crop varieties, irrigation technology and practices, and irrigation and pumping costs, the newer representation of Eastside water demands should be more accurate.

2. *In what ways is this new representation less accurate than prior representations?*

The new representation of water demands is considerably more explicit and flexible than previous contract delivery representations and should be more accurate for 2001 level of development. For applications beyond 2001, explicit links to agricultural and urban land and water use models are needed with explicit development and testing of these land and water use models (such as CALAG). This will involve estimations of irrigation efficiencies, substantiation of non-recoverable loss rates (beyond veneration of the long-assumed 10% non-recoverable loss rate), etc.

3. *In what ways would CalSim II results using this new representation consistently differ from the prior model?*

District water demands are lower, as they should be with land-use based demands, rather than contract surface demands, as illustrated below for Merced ID (with corrected data and figures received from Reclamation after August 4, 2005). It would be nice to have data for a direct comparison between older contract demands and newer land-use based demands for all districts. Water demands should now be more variable with hydrologic conditions, as they are in reality, than they were with contract-based demands.

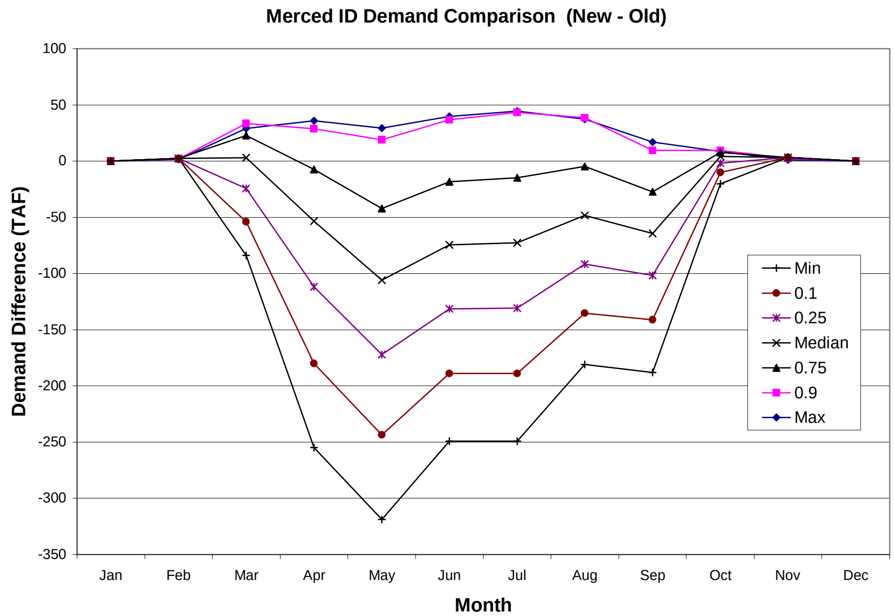

Figure 12. Seasonal New Minus Old Model Results for Merced ID Deliveries

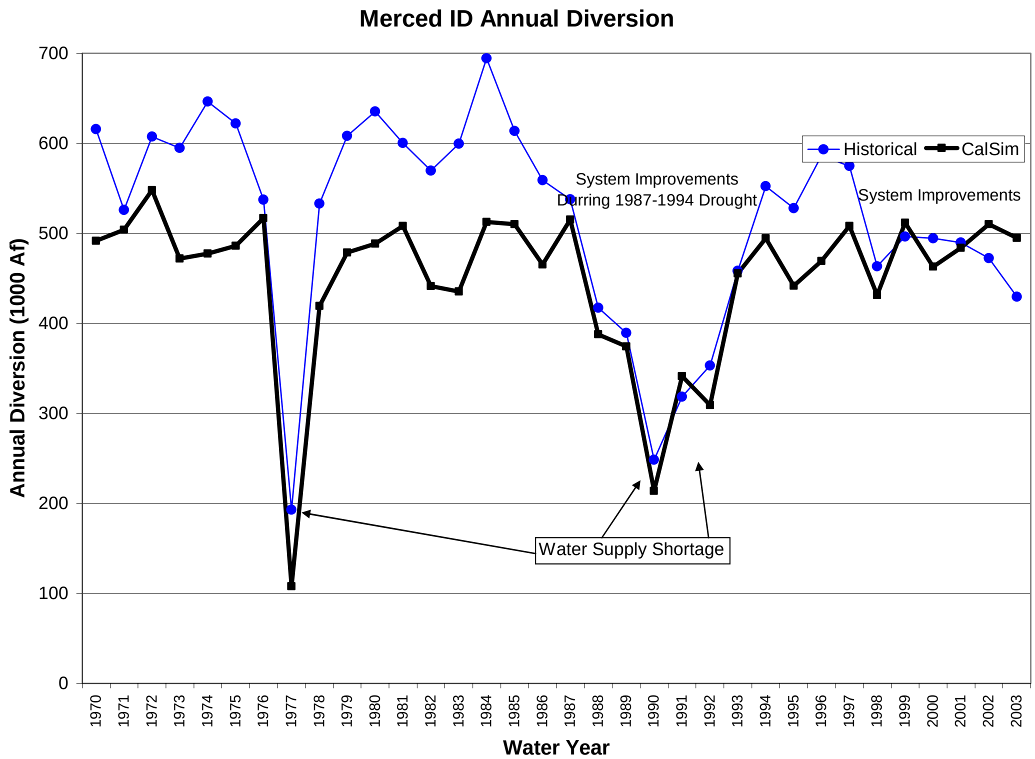

Figure 13. New CalSim Results and Historical Data for Merced ID Annual Diversions (Results and comments from Reclamation modeling team)

4. Is this new representation expected to lead to any systematic bias in CalSim II results? If the 2001 level of development land-use based demands are used for future (post-2001) planning or policy conditions, they could be significantly in error. Bias in the demand estimates from this method will depend on the estimates of future land uses, as well as the representation of irrigation technologies and practices under future conditions. For present conditions, these aspects are known and part of the 2001 level of development model calibration.

Using land use based demands for Eastside water users and contract based demands for Westside water users might bias water allocations within the basin. The LP based allocation algorithm will make decisions that will deliver to the Eastside users water that is, in fact, needed or applied (according to the estimates derived with the land-use based accounting.) On the other hand, the LP will allocate to the Westside users water that is contracted, whether historically used or not, raising return flows. These discrepancies induce some biases in return flows from the respective areas that are important for calculations of return flows and salt loads into the mainstem. However, since Westside deliveries are limited by CVP supplies more than actual demands, this might not be a major problem under current conditions.

Urban return flows are currently neglected. Surface return flows from urban demands are not now large, but might become important in dry years after several more decades of urbanization. The modelers seem well aware of this issue. Cities of Modesto and Turlock both seasonally discharge to surface water but account for less than 1 % of flow and 2% of salt load in the San Joaquin River (mean annual contribution, somewhat higher percent of total in dry years); the documentation should, however, explain why surface discharges from wastewater treatment plants are (and may justifiably be) neglected in the model.

How does CUAW vary with hydrologic conditions? This is important for urban demands in Southern California, where MWDSC models such variation for operations and planning purposes. Agricultural water demands also are likely to vary with hydrologic conditions, affected not only by precipitation contributions to consumptive use, but also lengthening of the planting season. Currently, any such variation would be obscured in the groundwater pumping term for 2001 conditions. This is not an urgent matter, but seems worth some thought.

Regardless of model structure accuracy, any representation will be biased to the extent that its input data are biased. A potential example of such bias (acknowledged in the CALSIMSJR_DRAFT report, but worth reiterating in this review) is that the land use designations are taken from recent DWR land use survey data, and this probably biases land use toward agriculture (as opposed to on-going urbanization of the landscape since that time). Unless updated from the surveys, this land use would overestimate water demand some, and therefore agricultural return flow, and underestimate urban uses. This short-coming is acknowledged in the April 2005 CALSIM II SRJ Model Draft Report by Reclamation.

For 2001 conditions, the calibration condition, bias should be small, with the possible exception of critically dry years which were absent from the calibration data set. For future conditions, these biases could be significant. The potential magnitudes of any of these concerns of bias can be tested through error analysis.

Part II. Improvements to the recent work

5. *How well are the new representation and its underlying data documented? What additional documentation should be prepared?*

The documentation is well done. The district-by-district discussion is especially appreciated. The organization of documentation, systematic discussion of details and limitations, and their accessibility make the documentation more useful, both for model and results interpretation, as well as for educating new modelers and water managers.

There is lack of detail in specifying the rationales for deep percolation and non-recoverable delivery losses. How might these apparently rough numbers be improved? This is especially important for long-term planning and policy applications.

6. *How well has the new representation and its underlying data been tested? What additional testing should be performed?*

Given the lumping of the closure term into the term for groundwater use, it is difficult to test this new representation, overall. One must rely on testing of the component estimates in the calculations, those of ET, CU, losses, and surface deliveries. Such component testing has not been done or cited.

The agricultural land use GIS data range from 1994-1998, with the model nominally for 2001 level of development. How were changes in crop acreages reconciled? How were they updated to 2001? Were Country Agriculture Commissioners' reports used? How would these land uses be updated for planning studies? The report fails to present this information.

7. *What is the accuracy expected and what are major errors remaining (if any) in the representation of the San Joaquin Valley?*

The panel cannot assess absolute model accuracy without comparisons against historical water demands and without studies of model sensitivities to important assumptions and potential errors. Remaining errors in this representation should be apparent when such results become available.

8. *How might the new representation be improved?*

The 2001 level of development water demand estimates have benefited from the availability of data that will not be available for future planning and policy applications. These include land use quantities, estimated groundwater pumping capacities, and gage and irrigation district flow estimates. For future applications, these quantities must be estimated. Unfortunately, this aspect of the development of land use based demands is not as well developed, relying on some very old assumptions for irrecoverable loss rates, within-district reuse of applied water, irrigation technology, and groundwater use.

For applications of the model well beyond 2001, there is some concern that fundamental compatibility is lacking between land-use based water demands and the most common methods of estimating future land use and irrigation technology for various crops (e.g., CVPM, CALAG, and SWAP agricultural production models). Agricultural production models are usually at an annual time-step with little representation of changes in water demand between wet and dry years, but can provide estimates of the water cost at which farmers would forego some water delivery or pumping. However, CalSim represents monthly water demands as fixed annually-varying quantities. This fixed representation of demand targets in CalSim can be inferior to economic representations if water market activity is common or farmers select water sources based on economic criteria. For applications of the model to post-2001 planning and policy applications, there should be an effort to resolve compatibilities between economic and operational representations of water demands. Others (Jenkins et al. 2001) have noted problems reconciling operations and economic land use models of agricultural water demands.

More explicit representation of water demands for the Tulare Basin, to better estimate withdrawals from Millerton Reservoir for the Friant-Kern Canal, is desirable in the future. This is one of the major demands on the San Joaquin River system, which could change in the future as a result of many economic, legal, and other factors.

Expansion of land-use based demands to the Westside of the San Joaquin River Valley is a natural future improvement to the San Joaquin CALSIM II model. This will be somewhat more difficult, due to the greater water marketing activity in this area, the greater occurrence of managed wetlands, and the importance of saline drainage from this area. Managed wetland uses of land and water are likely to differ from conventional agricultural water use, and drainage water production.

SAN JOAQUIN RIVER SALINITY

Model developers are commended for their effort to improve representation of salinity in the mainstem of the San Joaquin River. The new representation is a more accurate depiction of the physical system. In particular, the model disaggregation effort now enables the model to capture system variability and extreme events where the former representation did not. The developers provided a large amount of useful information, including: 1) model documentation; 2) presentation materials at the peer review workshop; and 3) subsequent communications with the panel. The extent of the model documentation and the openness of the developers with respect to their modeling approaches and rationale made this in-depth review possible.

It is clear from the documentation, presentation of materials at the peer review workshop, and subsequent communications with model developers that this is an interim product and that further work on this module is continuing and should continue. The executive summary of the documentation for the Water Quality Modules version 1.00 for CalSim II (CalSim, 2004) states in its "*paradigm for future planning studies*":

> *"WQ Module ver1.00 should be viewed as a first-generation CALSIM II product for salinity mass-balancing along the San Joaquin River. This product's intended use is for incremental planning studies that reveal the effects of changes in below-Lander salinity management to New Melones operations and Vernalis outcomes. These studies should not be performed without consideration of key Module limitations related to source EC assumptions, Above [sic] Newman accretion/depletion, and assumptions on San Joaquin River flow-EC relationships that were used to identify load residuals. Among these limitations, the most critical assumption appears to be the historically-based flow-EC*

> *relationship at Maze used to identify Maze load residual (i.e. a comparison of upstream source assumptions relative to historical flow-EC conditions at Maze). It was found that this assumption was the controlling factor on simulated New Melones WQ release operations."*

The panel recommends that this paradigm provided by the modeling team be appended with cautions to model users on the appropriate use of this interim model. If used for purposes requiring absolute (rather than comparative) predictions, suitable guidance should be prepared regarding likely error magnitudes and particularly troublesome conditions. The general improvement in accuracy from the new representation is not complete and should not be over-stated.

The primary goal of the new water quality module is to improve representation of salinity in the mainstem of the San Joaquin River so the effect of actions which change salinity in the San Joaquin River can be evaluated. In particular, the new representation is intended to provide better estimates of salinity at Maze for purposes of estimating water quality releases from New Melones reservoir to attain salinity standards at Vernalis. It is not entirely clear from the information provided to the public and panel for this review how well this goal has been achieved. Although the physical representation of the San Joaquin River has been greatly improved, there is limited information available to take full advantage of this improvement. As a consequence, simplified or incorrect input data assumptions may contribute to inaccurate model results that mask any improvement in model accuracy that may have been obtained through the improved model representation.

The documentation provided contained no evidence of a systematic effort to delineate the effects of parameter uncertainty on model results (e.g., confidence intervals for key results based on simulations exploring plausible ranges of parameter values). Such results were absent for the previous representation as well. The panel strongly recommends that long-term planning and policy makers call for model results results cast in the context of reliability or uncertainty for two reasons:

1. The model as currently designed and used has a bias towards underestimating Maze EC, but we think this bias could be corrected through better use of existing data. Possible reasons for this bias merit further investigation but could include the following: (1) the model was calibrated during a relatively wet period, and (2) uncertainty and variability of model inputs are not considered. This finding is discussed further below and is the subject of on-going investigations by the model developers. Uncertainty is particularly important during extreme dry events, when it is likely to have large effects on model output such as the need for dilution flows from New Melones.
2. Overall confidence limits of model results are not provided. Based on the information provided it is impossible to know how frequently and by how much model results are expected to diverge from some baseline or future condition.

In the absence of any probabilistically framed results or confidence limits, and based upon the approaches and calibration conditions employed in the CalSim II modeling effort presented to this panel, decision makers and model users are cautioned to use the model for comparative purposes. Use of the model for absolute purposes, such as quantifying needed releases from New Melones, currently provides results that are biased towards underestimates in New Melones releases and should be informed by an effort to assess (ideally in probabilistic terms) quantitative error in absolute estimates.

Part I: Merits of recent work compared to prior representations

The work done to update the representation of the San Joaquin River portion of CALSIM has clearly succeeded in better representing the physical system with regard to hydrology, operations, and water quality. The model refinement comes with a cost of much greater data needs. In the absence of complete data sets, model developers used various methods and assumptions to calibrate the water quality portion of the model (e.g. use of a load residual regression analysis). Though use of such methods should allow model developers and users to take advantage of the improved representation of the physical system, care must be taken that generated data sets and regression analyses do not contribute to errors similar to those present in the prior representation (e.g. use of a simple flow versus EC regression for Maze). This observation leads to the recommendation that model sensitivity analyses be undertaken to identify critical data needs and that resources be allocated to address those needs. Rather than simply comparing and contrasting the merits of the new representation relative to the prior representation, this discussion focuses on the appropriate use of the new representation, particularly in the absence of sufficient data to independently parameterize more aspects of the model. A comparison plot of old and new model results with historical results appears below.

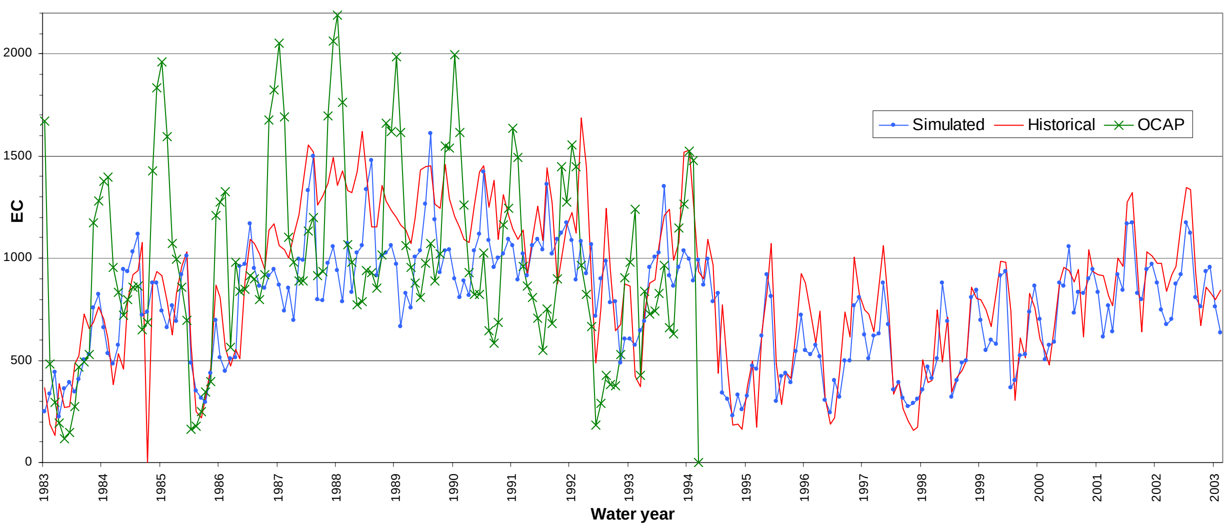

Figure 14. New (Simulated) and Old (OCAP) Model Results and Historical Data for Maze EC (μS/cm) since 1983 (OCAP ends with 1994)

1. In what ways is this new representation more accurate than prior representations?

The new representation more accurately represents the physical system of the San Joaquin River Basin. Conceptually, the new representation, while still simplified, more accurately represents the physics of salinity concentrations as affected by salt loads and water flows. The new representation is capable of better capturing the dynamics of dilution operations and the effects of long-term changes in drainage, drainage management, and return flows on mainstem salinity. It is not clear, however, that the available input parameters for the model are sufficient to take full advantage of the new representation's capabilities. Thus, we recommend that subsequent modeling efforts improve the presentation and interpretability of results by relating input parameter uncertainty to the reliability of results.

The old representation assumed a single mixed source of water in the San Joaquin River system at Maze Road; this mixed source was defined by the so-called 'Kratzer equation' (a regression-based estimate of EC based on mainstem flow). Use of this flow versus EC relationship yielded inaccurate results if the model was used to quantify the effects of changes in the physical system upstream of Maze. CALSIM results based on use of this relationship would, for example, incorrectly model the effects on Maze Road water quality caused by a reduction in high salinity inflows. The prior representation would incorrectly degrade water quality rather than improve it. The simple flow versus EC relationship in the prior representation also did not capture the natural variability that is likely for even that simple flow versus EC relationship. A specific flow always resulted in a specific EC with no variance, thereby missing the effects of natural variability.

Sources of salinity upstream of the San Joaquin River at Maze Road are disaggregated in the new representation. This increased level of detail is expected to generally improve the accuracy of model results, provided sufficient data are available to run the model**.** The new representation disaggregates many of the flow and salt sources upstream of Maze Road, including:

- Eastside tributaries and San Joaquin River at Lander Avenue
- Eastside return flows
- Subsurface agricultural drainage conveyed to San Joaquin River via the Grassland Bypass Project
- Mud and Salt Slough

Model studies conducted to assess the effects of changes to these newly disaggregated model inputs will have much more accurate results than could have been obtained using the prior representation. For example, model results using the new representation will better reflect the correct change in water quality and needs for dilution flow from New Melones Reservoir in response to a reduction in tile drainage discharges from the Grassland Bypass Project. Generally good results can be expected using the model to assess the effect of such changes on baseline water quality and baseline needs for releases from New Melones.

Other upstream flows and loads, however, including groundwater accretions, are still not explicitly modeled. Groundwater and missing flows and loads are included in a term called 'local creek inflow'. This 'local creek inflow' appears to lump all flows and loads for unassigned, missing, and assigned but inaccurate flows and loads. It is this relatively large flow and load residual that will be further discussed as it relates to bias in CALSIM salinity results.

2. In what ways is this new representation less accurate than prior representations?
As described above the new representation should, in general, not be less accurate than the prior representation. The new representation, however, is much more complicated, making it more difficult for model developers and users to identify any bias or uncertainty in model results.

The new representation should become less accurate when modeling low flow conditions due to reliance on a large closure term for the salt balance under these conditions. This possibility arises because of limited recent data for low-flow conditions. In contrast, the earlier highly simplified salinity representation (Kratzer equation approach) is likely even less accurate under similar conditions.

As with the hydrology and operations representation, one risk is from over-interpreting model results, expecting greater gains in model accuracy than have actually been achieved.

3. **In what ways would CalSim II results using this new representation consistently differ from the prior model?**

Results using the new representation can be expected to consistently differ from the prior representation in the following ways:

- Improved representation of variation through disaggregation efforts
- Seasonal shifts in modeled EC
- Consistently lower salinities and need for releases from New Melones during the irrigation season (and higher during the non-irrigation season)

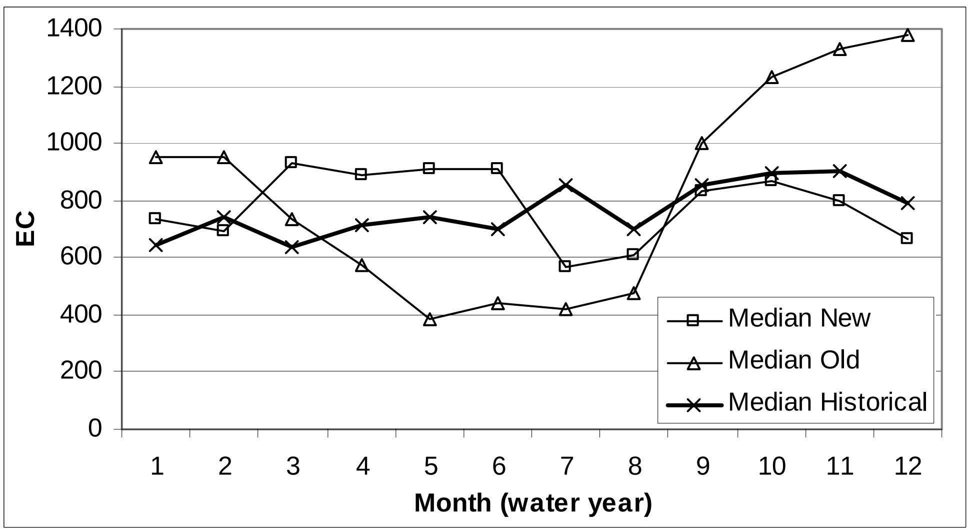

Figure 15. Median Monthly Maze EC (μS/cm), 1940-2003 (old model to 1994)

The model disaggregation effort has improved the model's ability to better capture some of the variation and extreme events in the system. This is a result of assigning separate flows and salinities to specific sources in the model upstream of Maze rather than assigning a single EC for a specific flow. There is much more that could and should be done to better represent model uncertainty, as discussed in later sections.

With respect to seasonal shifts, the new representation and assumptions used in the modeled dataset have shifted the time during which EC is elevated in the San Joaquin River (Figure 15). The new representation is expected to consistently calculate lower salinity during the irrigation season and to consistently calculate higher EC during the non-irrigation season than did the prior representation. The large differences in calculated EC are attributable to: 1) use of a different method of calculating Maze EC and 2) calibration for a new time period. As stated in section one above, new representation's results should be more accurate than results from the prior representation since the new representation is based on a disaggregation of sources. Since the model is calibrated to a relatively wet time period, however, it is possible that the results are biased to conditions not reflective of a drier period. This and other sources of potential bias are explored in the following section.

4. Is this new representation expected to lead to any systematic bias in CalSim II results?

Several elements of the new representation were identified by the panel as being likely to contribute to a systematic underestimate of salinity for the San Joaquin River at Maze. Under lower flow conditions, this model bias will lead to systematic underestimates of calculated releases from New Melones Reservoir. Model elements contributing to this bias include:

- Use of October 1996 through September 2003 for the calibration period (a relatively wet period for calibration, when concerns for water quality tend to heighten during low-flow periods).
- Underestimated Maze EC for the October 1996 to September 2003 calibration period
- Large residual flow and salt loads (i.e., uncertainty in model parameters related to flow and salt loads)
- Lack of variability in model elements
- Lack of explicit groundwater element

Summary discussion of each point follows. Detailed analyses and quantification of these points are provided in Appendix B. The calculations and results reported in this appendix represent first approximations of the potential impact of various calibration periods, parameter estimates and their effect on model results for exploratory purposes. They are NOT to be taken at "face value," as quantitative errors in the current CalSim representation. Instead, they are to be used only as evidence that further investigation and analysis is warranted.

<u>Use of October 1996 through September 2003 for the calibration period</u>

October 1996 through September 2003 was relatively wet compared to the full record of water years from 1901 through 2004. This seven-year calibration period contains no critically dry years, whereas, critically dry years accounted for 16 percent of years during the full 104-year record. The significance of calibrating the water quality module of CalSim to a wetter time period is unclear. However, it is likely that any errors inherent in the model will be magnified during critically dry low flow years because poorly quantified sources, such as groundwater accretions, would have a disproportionately large effect on water quality during such critical periods. The effects on model results of calibration error during critically dry years should be explored. Summary statistics for the calibration period and the full record, along with additional discussion, appear in Appendix B.

The use of the flow versus EC relationships for calibration likely introduces additional potential errors. It appears that the flow versus EC relationships developed for Newman and Maze largely determine Maze load. The differences from use of the 'Kratzer' equation are:

- Calibration is first done at Newman then at Maze (though the calibration at Newman has no effect on the final calculated Maze EC)
- Use of six seasonal regressions at Maze.
- Use of a different (wetter) time period for development of the regression

The mass balance portion of the water quality module adds computational value only if trying to determine the effects of changes to mass balanced sources on the baseline. The baseline EC at Maze depends entirely on regressions of flow versus EC developed for a seven year period (1997 to 2003). This, as we have already discussed is a wetter period than the dataset upon which the Kratzer equation was based.

<u>Underestimate of Maze EC for the October 1996 through September 2003 calibration period</u>
Although EC was calibrated using October 1996 through September 2003 data, model calibrated EC is consistently lower than historical EC. The panel explored this apparent bias using illustrative calculations detailed in Appendix B (also reported in the panel's preliminary findings presentation). By one analysis, the bias might be increased by an uneven improvement in the accuracy of the model. The purpose of this illustrative calculation is to explore the potential effects of this bias on sensitive model results. Relatively small errors in model calculated Maze EC have the potential to contribute to not insignificant errors in calculated need for releases from New Melones. We expect such errors can be corrected, and we know work is ongoing.

Errors contributing to the underestimate in Maze EC (including overestimates in Maze flow) should be explored. Effects of these errors on calculated need for New Melones releases also should be explored and quantified. And finally, even if known errors are accounted for, the sensitivity of the calculated need for releases from New Melones to Maze EC should be quantified.

<u>Large residual flow and salt loads</u>
The model was calibrated to fit with observed salinity for the 1996 to 2003 period. This calibration was apparently applied to a relatively large salt load residual (see Appendix B for more details and rough estimates of residual terms). The size of this salt load residual was not clear from information presented during the 4 August technical presentations. Inspection of additional information submitted to the panel subsequent to the 4 August presentations yielded a range of results. The large load residuals limit the utility of model results to correctly evaluate the effect of changes in modeled elements on Maze EC and New Melones releases. This large load residual also limits the use of this model in making absolute predictions of a likely future condition outside the range of calibration conditions since the effect of the large error term would be magnified during low flow conditions (which were absent from the model calibration period). Parameter uncertainties leading to these large closure terms need to be explored and a plan for reducing their magnitude should be formulated.

<u>Lack of variability in model elements</u>
When New Melones operators respond to salinity concentrations at Maze, they respond to actual gage readings of flow and salinity where the relationship between Maze flow and EC is variable and somewhat uncertain. In the model, a number of regressions are used to estimate water quality at Maze, including regressions for flow versus EC for Lander Avenue and regressions used to resolve the load residual at Maze. This can reduce the variability of some model inputs

(in this case, EC) and prevent the model from correctly assessing critical conditions regarding water quality. Reliance purely on mean monthly inputs (based on long-term averages) will dampen deviations from the mean in model results. Such deviations may only be apparent during extreme events such as critically dry years. These deviations can have a large effect on the calculated need for releases from New Melones. Such deviations from the mean, as they relate to New Melones, are not necessarily "self correcting." Additional releases required to satisfy a critical condition during a low flow period cannot necessarily be offset by storage and release during wetter periods. The operations model has constraints that sometimes prevent such carryover storage. An underestimate in need for New Melones in one month will not necessarily be cancelled by an equivalent overestimate in need for a later month.

Components of the water quality module must sufficiently disaggregate and seasonally vary inputs to accurately reflect extreme events and accurately calculate the need for releases from New Melones. Information presented in the peer review suggests that disaggregated water quality model components do not all vary seasonally and annually. The sensitivity of calculated New Melones releases to this lack of variability should be explored by setting select disaggregated model inputs to a critical condition (rather than to a mean). For example, rather than estimating EC based on a best-fit regression, EC could be estimated using a higher confidence level (for a higher EC). The potential error introduced through use of simple regression analyses (as was used for the load residual) is provided in Appendix B. This type of error, however, will occur whenever model data is used that insufficiently characterizes the natural variability of the actual data. Using a higher confidence interval from the regression might correct this source of bias.

Lack of probabilistic model results makes it impossible to assess the frequency and magnitude that a specific set of quality and quantity conditions will be exceeded. This, in turn, limits the utility of this model to represent an absolute condition. Absent such probabilistic model results, the model is best used only for comparative purposes for a limited range of scenarios. Lack of probabilistic model results severely limits the ability of decision makers to rely upon this model to make informed long-term planning and policy decisions. This limitation could be quantified and delimited through error analysis.

<u>Lack of explicit groundwater element</u>

The lack of an explicit groundwater element, in conjunction with calibration of the model during a series of relatively wet years, is likely to lead to a bias towards lower salinity estimates. Since groundwater accretions are lumped into one large residual/closure term, the model cannot accurately simulate conditions when groundwater accretions are likely to contribute a larger proportion of total flows and salt loads.

The lack of explicit groundwater representation for the agricultural water supply will also lead to an under-prediction of salinity at some mainstem locations under future dry-year conditions, because greater use of groundwater could increase salt loads from the Westside, where demands remain contract-based and groundwater is likely to be more saline. (Phillips et al, 1991)

Summary of Potential Bias

Several potential sources of bias towards underestimate of Maze EC and underestimate of calculated need for releases from New Melones have been identified. Much of this bias and inaccuracy also was present in the earlier CalSim II model. Follow-up discussion with model developers suggests that some additional work has already been done to address these potential sources of bias. Model developers are encouraged to identify and correct any apparent errors (such as Maze EC calibration) that could contribute to bias, since the model is acknowledged by all to be a "first-generation CalSim II product for salinity mass-balancing along the San Joaquin River." An on-going effort should be made to provide alternate baseline conditions that consider bias and uncertainty in model results.

The panel suggests that the model developers discuss these issues by answering the following questions:

- Are the estimates of load residuals correct? If so, how does the size of this residual affect the accuracy and uncertainty of model results?
- Do the large residual terms and lack of consideration of variability affect the ability to use the model to predict an absolute flow and water quality condition? If so, how?
- Do the large residual terms and lack of consideration of variability affect the ability to use the model for comparative purposes? If so, what comparisons cannot or should not be made?

Part II. Improvements to the recent work

5. **How well are the new representation and its underlying data documented? What additional documentation should be prepared?**

A large amount of useful information is presented for the water quality module of the new representation. Detailed descriptions of the methods used to disaggregate the upstream sources of salt are provided. The documentation includes extensive discussion of some reasonable model limitations and concerns. The documentation, however, lacks important summary information regarding the new representation, including a clear summary and assessment of unaccounted sources and quantities of salt. Additional explicit summary information should be included about load residuals as described above.

Documentation that refers to water quality data sources should be clarified. The model should be based and calibrated on primary data sources linked to actual data, where such data are available and applicable, rather than on datasets from other models. While companion modeling efforts may be the only source of input estimates at this stage of the model development, a commitment to field work and monitoring to provide primary data is recommended. For example, many references are made to SJRIO as a data source. It is not clear if the reference is to a SJRIO output dataset or to the methods and assumptions used in SJRIO. The Water Quality module employs SJRIO results in estimating the salt balance for San Joaquin River reaches. Details of this model fusion are, however, vague. As with all models of this complexity, the SJRIO results feeding the WQ model are subject to large assumptions regarding model structure and parameterization, and produce results with a substantial amount of uncertainty (Grober, 1996). This uncertainty needs to come out more in the report and, more importantly, be propagated through the water quality model. Similarly, WETMANSIM model results are used to calibrate return flow volumes and EC levels, and uncertainties from this source should be explored.

Some of the terminology should be changed to better reflect model uncertainty. Use of the term "local creek inflows" for the large residual Westside flow and salt loads is misleading.

6. How well has the new representation and its underlying data been tested? What additional testing should be performed?

Insufficient data has been presented to quantify both the uncertainty in model results and the sensitivity of model results to many of the large underlying assumptions. The water quality module relied upon a relatively large residual / closure term to account for unknown sources and quantities of salt. Included in this closure term was any error attributable to several sources and sinks such as diversions and drainage that occur along the main stem of the San Joaquin River. Additional model runs should be conducted to assess the sensitivity of the model to:

1. model elements that affect Maze EC
2. a likely range of groundwater accretion quantity and quality

7. What is the accuracy expected and what are major errors remaining (if any) in the representation of the San Joaquin Valley?

As noted previously, the representation has the potential to better capture the dynamics of this system, but the decision makers need to see results cast in terms of their reliability using a plausible range of model input parameters to drive the simulations. A simple assessment of the data by the review panel, however, reveals that significant discrepancies between modeled and observed Maze Road salinity, a result which can influence releases from New Melones. A non-rigorous estimate of the magnitude of this margin of error is provided in the analysis (Appendix B), and requires additional model investigations to better resolve. Model developers have recently undertaken this task following the panel's preliminary findings presentation.

In addition, the closure terms used in calibrating the water quality module seem to be quite large for low-flow conditions. While the historical comparisons for 2001 conditions seem to be fairly good, the reliance on this large closure term indicates some uncertainty for applications to future conditions where return flows and salt loads could be very different. Model input sensitivity analyses need to be undertaken to help identify the source of this large degree of uncertainty and, if possible, identify a strategy for reducing this uncertainty.

8. How might the new representation be improved?

Overall, the representation does not need to be re-formulated so much as does the way in which the model is parameterized and run. As discussed above with regard to model documentation, data used to run the model should be based on primary information and not model output. To provide more meaningful results for planning and policy alternatives, even for comparative purposes, a range of baseline hydrologies and water quality conditions should be developed, rather than a single historical baseline alone. Additional baseline hydrologies (including all inflow and depletion inputs to the model) should represent particular scenarios of concern, such as a set of critically dry years.

One manner in which the representation of water quality could be improved is through the addition of an explicit groundwater element. Even if sufficient information is not available to populate the groundwater element, such an addition could be used to explore the potential sensitivity of model results to various groundwater assumptions, and improve our operational understanding of groundwater's effects on mainstem salinity.

More explicit cautions should be provided to users of this 'interim' product to assure the model is not inappropriately used while significant uncertainty exists for several key model elements. As is stated in the Limitations Section of the *16 December 2004 draft report for external review* of the *San Joaquin River Water Quality Module 1.00 for CALSIM II,* the module "should be viewed as a first-generation CALSIM II product for salinity mass balancing along the San Joaquin River." This section goes on to describe key uncertainties regarding:

- Source EC assumptions
- Above Newman accretion/depletion
- San Joaquin River EC Assumption at Above Newman
- San Joaquin River EC Assumption at Maze

The water quality module model developers recognize that the continued use of a San Joaquin River EC assumption at Maze has "some similarity with the preceding model paradigm" that was based entirely on a Maze flow EC relationship. Model developers recognize and acknowledge this as a limitation. Limitations of the model and model uncertainty should be stated clearly in documentation, including in the summary descriptions of the water quality module contained in the CALSIM II San Joaquin River Model report.

Model developers also appear to agree that the current representation should be used preferably for comparative purposes and that model output *is not ideal to forecast an absolute condition.* If true, this message should be clearly conveyed to model users and decision-makers. The new baseline hydrology and water quality obtained from the new CALSIM representation have already been used by some model users to suggest that the San Joaquin River has more water of better quality than the previous model. Model developers appear to agree that the new baseline hydrology and water quality is just that-- a baseline upon which appropriate scenarios can be compared. It is recommended that a clear disclaimer be provided in model documentation to assure that model results are not used inappropriately. Appropriate error analysis would help with non-ideal applications of the model for "absolute" predictive purposes, such as delivery-reliability studies.

Additional salinity and drainage flow data is valuable to better estimate parameters in this more physically-based representation of San Joaquin River salinity and to test and assess the accuracy of the results of this water quality module. Other modeling efforts will also require such data, such as extending DSM2 up the San Joaquin River.

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APPENDIX A: PEER REVIEW OF THE CALSIM II SAN JOAQUIN RIVER VALLEY REPRESENTATION

The CALFED Science Program and the California Water and Environmental Modeling Forum (CWEMF), in collaboration with the US Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), California Regional Water Quality Control Board, Central Valley Region (RWQCB-CVR), and the US Environmental Protection Agency (Water Quality Program), are cosponsoring a technical review of the recent improvements in the simulation of the San Joaquin River Valley in the CalSim II model. The review will focus on recent model developments in three specific areas:

- Eastside hydrology and operations
- Eastside water demands
- San Joaquin River drainage flow and salinity, and in particular salinity estimate at Vernalis

Eastside, in the context of this review, refers to the model area that covers the tributaries east of the mainstem San Joaquin River (Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, and Fresno River) and includes the San Joaquin River below Millerton Lake. In addition, the panel may also propose further improvements in these areas as well as the overall representation of the San Joaquin River Valley.

The Review Panel

The panel consists of five external reviewers, plus one staff representative each from Reclamation and DWR. Panel members are selected for their expertise on the San Joaquin River (SJR) system, project operation modeling, river water quality modeling, water demand modeling, and agricultural operation modeling. The five external members are Prof. Jay Lund (U of California at Davis) who will serve as Chair of the Panel, Les Grober (RWQCB-CVR), Prof. Daene McKinney (U of Texas at Austin), David Ford (David Ford Consulting), and Prof. Tom Harmon (U of California at Merced).

Specific charges to the Review Panel

The San Joaquin River is a very complex and controversial sub-system of California's larger water management system. The focus of this review is on new representations of three of the most important aspects of the San Joaquin River system in the CalSim II model. It addresses two key questions of immediate concern to many stakeholders - 1) Are the new representations better than before? and 2) How good are they? Accordingly, the charges to the Panel are in two parts. The first addresses the accuracy of the new representations relative to previous representations - if the new representations may have major flaws and if they are improvements over the previous representations. The second part addresses further improvements to the new representations of the San Joaquin system in CalSim II and recommendations for conducting accuracy checks in application studies. Specifically, the questions posed to the Panel are as follows:

Part I: Merits of recent work compared to prior representations

For each of the three areas of recent development (Eastside hydrology and operations, Eastside water demands, and San Joaquin River salinity),

1. In what ways are these new representations more accurate than prior representations?
2. In what ways are these new representations less accurate than prior representations?

3. In what ways would CalSim II results using these new representations consistently differ from the prior model?
4. Are the new representations expected to lead to any systematic bias in CalSim II results?

Part II. Improvements to the recent work

For each of the three areas of recent development in San Joaquin Valley representation,

5. How well are the new representations and their underlying data documented? What additional documentation should be prepared?
6. How well have the new representations and their underlying data been tested? What additional testing should be performed?
7. What is the accuracy expected and what are major errors remaining (if any) in the representation of the San Joaquin Valley?
8. How might the new representations be improved?
9. What practicable procedure(s), if any, could be followed in every model application to test the validity of model results and assess their uncertainty and sensitivity to assumptions?

In its review, the review panel will consider:

- Materials presented to them in oral and written forms
- Written comments of interested parties
- Prior documentation concerning CalSim II and previous CALFED CalSim II reviews
- Other information sought and received by the review panel and its members.

Review Materials

- Presentations in the August 4, 2005 Workshop

Additional Background Materials

- Previous CalSim Review conducted by the Bay-Delta Science Program
- Background information on CalSim

Schedule

Three public workshops have been scheduled:

- Workshop #1 - August 4, 2005 at Doubletree Hotel in Modesto, CA This is an information gathering workshop. Materials will be presented by model developers (agency staff and consultants) to the review panel. Adequate time will also be allocated for comments and questions from stakeholders.
- Workshop #2 - September 30, 2005, Resources Building, Sacramento, CA. Present draft report presentation in and receive stakeholder input.
- Workshop #3 - January 17, 2006, CBDA, Sacramento, Presentation of Final Report, including to response to stakeholder comments on draft report.

Public Input

Written comments on the San Joaquin River Valley representation in the CalSim II model should be emailed to review@cwemf.org. Please state accordingly if the comments submitted are not for attribution.

APPENDIX B. Supporting Calculations and Illustrative Examples Regarding Systematic Bias in CalSim II Water Quality Results

Note: The calculations and results reported in this section represent first approximations of the potential impact of various calibration periods, parameter estimates and their effect on model results. They are NOT to be taken as quantitative errors in the current CalSim representation. Instead, they are to be used only to indicate that further analysis of the CalSim II water quality module is warranted.

Use of October 1996 through September 2003 for the calibration period

The seven-year period from October 1996 through September 2003 is skewed towards wetter conditions than the full period of record. None of the years from 1997 to 2003 were classified as critically dry according to the San Joaquin Valley Water Year Index (SJVWYI) of unimpaired flows.[1] This seven-year period consists of two wet, two above normal, one below normal, and two dry years. The following summary statistics for the 1901 to 2004 record compared to the 1997 to 2003 calibrations period show that the calibration period is skewed towards wetter years.

Table B1. Statistical comparison of San Joaquin Valley Water Year Index (SJVWYI) for historical and water quality model calibration periods

SJVWYI	1901 to 2004	1997 to 2003
Mean	3.34	3.44
Median	3.24	3.38
Standard Deviation	1.31	1.19
Skewness	0.63	1.04
Min	0.84	2.20
10th Percentile	1.89	2.28

In contrast, critically dry years have occurred 16 percent of the time, on average, during the 1901 to 2004 period:

Table B2. Comparison of hydrologic year-types for historical and water quality module calibration periods

Time Period		Year Type						
		Wet	Above Normal	Below Normal	Dry	Critically Dry	Total	mean index
1901 to 2004	no. yrs	34	21	17	15	17	104	3.34
	%	33%	20%	16%	14%	16%	100%	
1997 to 2003	no. yrs	2	2	1	2	0	7	3.44
	%	29%	29%	14%	29%	0%	100%	

[1] As defined at http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST
San Joaquin Valley Water Year Index = 0.6 * Current Apr-Jul Runoff Forecast (in maf) + 0.2 * Current Oct-Mar Runoff in (maf) + 0.2 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 4.5, then 4.5 is used). This index, originally specified in the 1995 SWRCB Water Quality Control Plan, is used to determine the San Joaquin Valley water year type as implemented in SWRCB D-1641. Year types are set by first of month forecasts beginning in February. Final determination for San Joaquin River flow objectives is based on the May 1 75% exceedence forecast.

Underestimate of Maze EC for the October 1996 through September 2003 calibration period

Although EC was calibrated using October 1996 through September 2003 data, calibrated EC is consistently lower than historical EC. Follow-up discussion with model developers clarified that the model was calibrated to match Maze salt loads. Although loads were correctly calibrated, flow was overestimated, resulting in an underestimate of Maze EC. Differences in Maze EC are therefore attributable to overestimates of Maze flow (rather than underestimates of load). Some potential causes and implications of overestimates of Maze flow are presented earlier in the report.

The following example is provided to demonstrate that relatively small errors in EC (or flow) can have not insignificant effects on the calculated need for releases from New Melones.

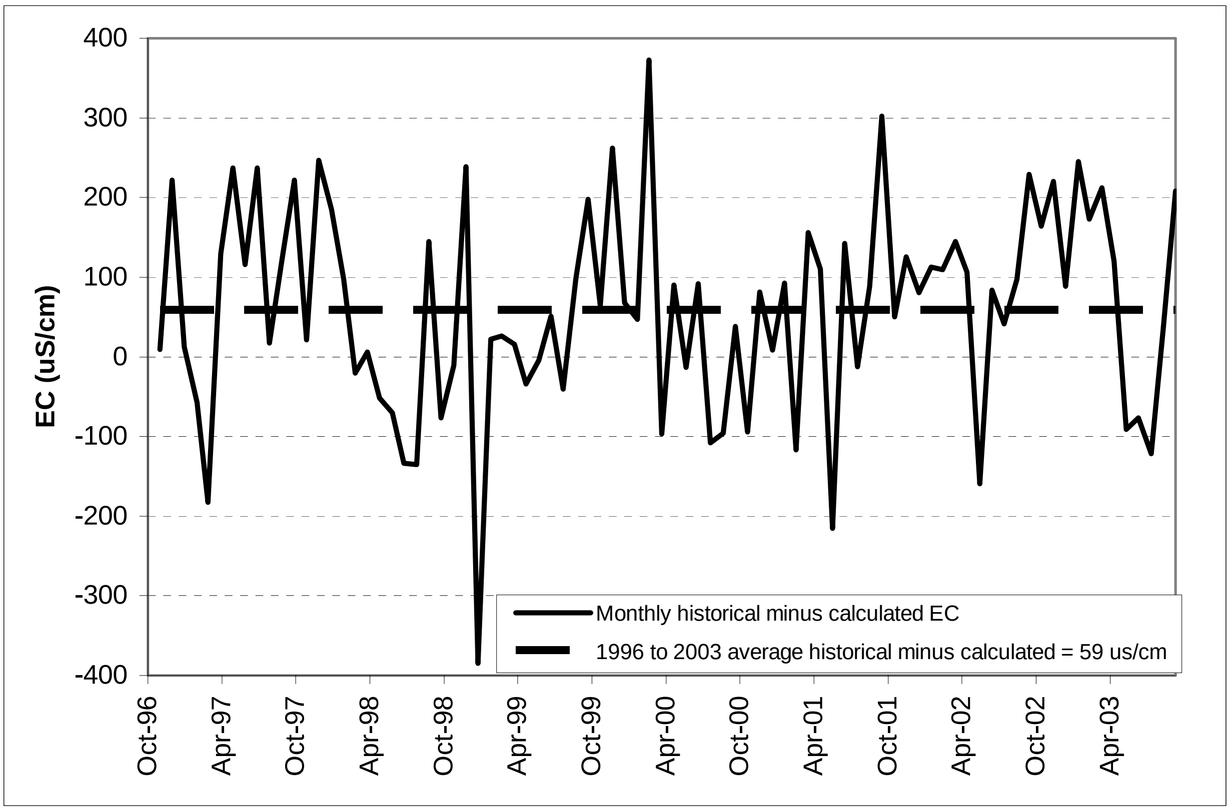

Figure B1. Historical minus Calculated Maze Road (μS/cm)

Monthly differences in Maze Road EC concentration, if applied to CALSIM model calculated flows, can yield a simple monthly excess Maze Road salinity load for all months when the standard is not met (seasonally 700 or 1,000 μS/cm). An estimate then can be made of the additional New Melones water that would be needed to dilute this salt load to achieve the salinity standard at Vernalis. We recognize that other factors also control releases from New Melones and that not all of this load would result in the need for additional New Melones releases, but this calculation does demonstrate two things:

1. The magnitude and possible effect of this bias towards low EC at Maze
2. A means of assessing sensitivity of a critical model result (New Melones releases) to an important model element (small changes in Maze EC)

The combined overestimates and underestimates of Maze Road EC applied to calculated Maze flows for all months during which Maze EC exceeds the Vernalis EC standard, yields a mean annual *potential* additional need for New Melones releases of approximately 50 thousand acre-feet (taf) per year for October 1996 through September 2003. This is only a *potential* additional need for additional releases because the need may occur when these releases would be met for other reasons, such as a flood, fisheries, or other New Melones releases. In other words, if a need for potential release occurs during a month in which an equal or greater volume of water is already being released from New Melones, then no additional release for water quality would be needed. This, however, does not negate the need to calculate an unbiased potential need for New Melones releases.

For the sake of comparison, the 'baseline' potential need for releases from New Melones, based on baseline model results for Maze EC, is approximately 60 taf per year. This contrasts with the actual need for New Melones of approximately 20 taf/year as calculated in the CalSim II model (Dan Steiner, personal communication). This means that for the baseline analysis presented for peer review, the mean annual actual need was only one third of the baseline potential need of 60 taf/year. The difference between potential and actual need is accounted for with flow needs met by flood, fishery, and other releases considered in the CalSim model.

If the actual potential need for New Melones release is, however, underestimated by 50 taf/year (or some other amount, pending recalibration of the model), then model developers should evaluate how much of this potential need translates into an actual need.

Errors contributing to the underestimate in Maze EC (or overestimate in Maze flow) should be explored. Effects of these errors on calculated need for New Melones releases also should be explored and quantified. And finally, even if known errors are accounted for, the sensitivity of the calculated need for releases from New Melones to Maze EC should be quantified.

In addition to illustrating the effects of bias resulting from the problematic calibration, this brief analysis points out the need for providing summary statistics and sensitivities for reviewers and users of the model. Quantification of the potential errors in flow and water quality help to quantify uncertainty for those interested in using the model.

Another view of both the improvement in accuracy and the bias of the old and new CalSim II models appears in the following figure. Here, differences between model and historical EC were cumulatively summed for the new and old CalSim II models, with positive differences (over-predicted Maze EC) separated from negative differences (under-predicted Maze EC). The sums begin in 2003 for the new model. In 1994, old model accumulations are provided, beginning at the 1994 values for the newer model, to improve comparability. Even for recent periods, since 1994, cumulative negatives exceed positives for the new model. Going backwards in time from 1994, both negative and positive errors in Maze EC from the old model accumulate faster than for the new model. This would seem to indicate that, despite the difficulties of making historical comparisons so far back in time, the newer model appears to be more accurate than the older model. However, the reductions in error are much greater for the positives (over-predictions). Perhaps a model's accuracy can increase at the same time as its bias. But this is just an illustrative example of the complexity of assessing the comparative and absolute accuracy and bias of these models.

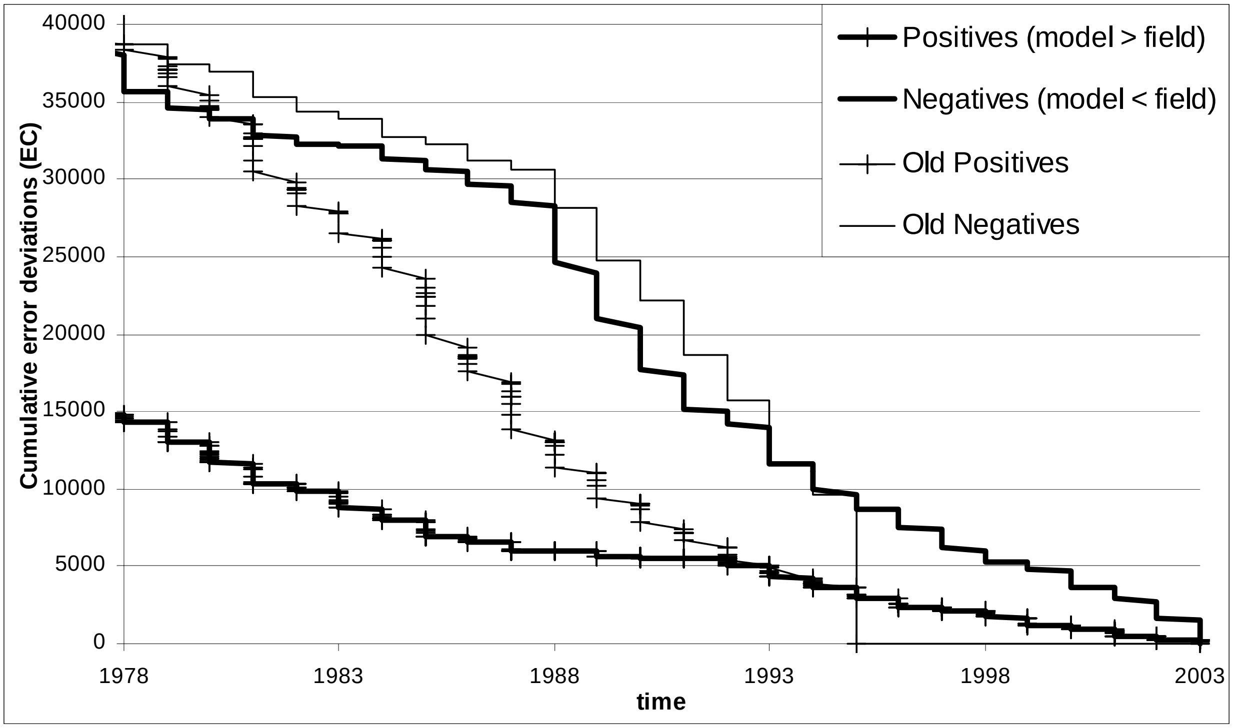

Figure B2. Cumulative positive and negative deviations of new and old CalSim II models from historical data, going backwards from 2003. Old model results (which end in 1994) are begun at the same values as the new model in 1994.

<u>Large residual flow and salt loads</u>

The model was calibrated to fit observed salinity from 1996 to 2003. This calibration apparently resulted in a relatively large salt load residual. The size of this salt load residual was not clear from information presented during the 4 August technical presentations. Inspection of additional information submitted to the panel subsequent to the 4 August presentations yielded a range of results.

An analysis based on updated load residuals obtained from model developers after the 4 August workshop yielded the following flow and load residuals:

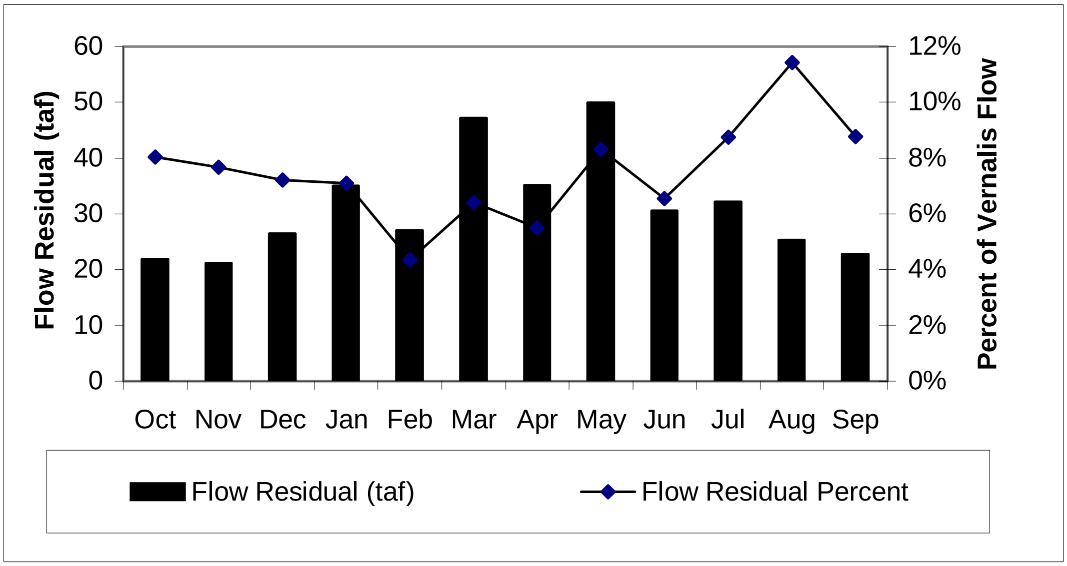

Figure B3. Flow residual averages (instream flow – sum of estimated inflows) at Vernalis

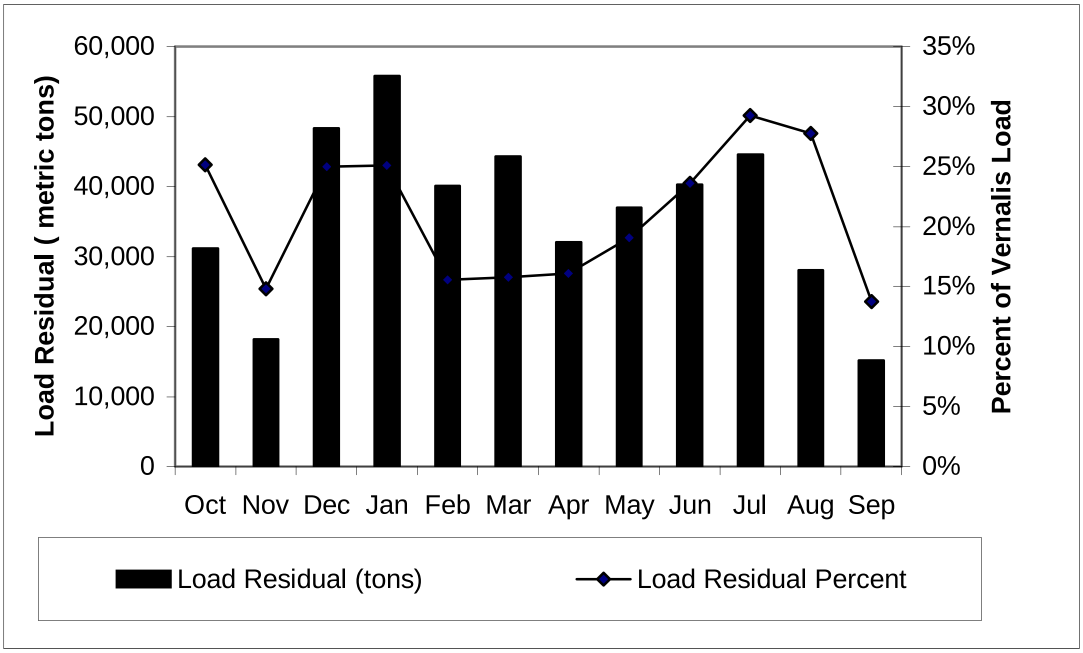

Figure B4. Salinity load residual averages (instream load – sum of estimated inflow loads) at Vernalis

The load residuals are the sum of 'EC*FLOW'units for Local creek inflows I636 (Maze) and I637 (Vernalis). The EC*FLOW units were converted to tons assuming a TDS/EC ratio of 0.62 so that the load could be compared to total loads at Vernalis. This dataset is similar to the datasets included in Appendix B to the June 2004 Water Quality Module Report (tab 8 in Peer Review Binder). The load residuals in this updated dataset are lower than the residuals contained in the June 2004 report.

Analysis of this updated dataset, however, still suggests that the load residuals, as a percent of total load at Vernalis, are extremely high. They range from 15 to just under 30% of the total monthly load at Vernalis, after accounting for flows and loads removed in San Joaquin River diversions.

The large load residuals limit the utility of model results to correctly evaluate the effect of changes in modeled elements on Maze EC and New Melones releases, particularly for hydrologic and water management conditions which vary from calibrated conditions. This large load residual also limits the use of this model in making absolute predictions of a likely future condition since the effect of the large error term would be magnified during low flow conditions (which were absent from the model calibration period). This occurs because during low flow periods relatively high quality (low EC) water would be the first water to be removed from the system. In contrast, poor quality (high EC) water, such as groundwater accretions are likely to remain and have a disproportionately large effect on water quality. A regression used to account for load residuals comprised of both surface agricultural return flows (tail water) and groundwater would incorrectly track the effect of a shift to zero tailwater and relatively constant groundwater accretion. This type of shift would be expected to occur during critically dry years. Such critically dry years were not considered in the development of the regression.

Lack of variability in model elements

Variations from the mean may not be adequately represented when only mean values are considered in model inputs. This was a limitation of the prior representation that remains in the new CalSim II representation. Explicitly considering the possible effects of underestimating a critical condition that is not sufficiently characterized by mean values may overcome this limitation.

An example that demonstrates the effect of inadequately representing variations from the mean is the potential effect of critically low flows from incompletely understood sources on the estimated need for releases from New Melones. A limitation of the prior representation, shared in part by the new representation, is use of a simple flow versus EC relationship for Maze. The new representation uses EC-Flow rating curves (regressions) to account for residual loads at both the San Joaquin River at Newman and Maze. EC-flow rating curves based upon paired monthly flow-EC data for 2000 through 2004 were used for Newman. EC-flow rating curves based upon paired monthly flow-EC data for 1997 through 2003 were used for Maze. Use of a simple flow versus EC relationship imparts two types of errors:

1. Extrapolating beyond the time period for which the regression was developed
2. Imposing a mean condition on variable data

The following graphic illustrates why the second type of error is important. Figure B5 is a copy of the figure presented as slide 37 in the Microsoft PowerPoint™ presentation of the water quality module presented to the panel on 4 August. This figure contains regressions used to resolve the load residual term at Maze for three time periods: February to March; April to May; and June to July. Data for flows exceeding 5,000 cfs were omitted to allow for better resolution of the low flows. The regressions approximate a mean water quality condition for a range of flows. The error that use of such a regression may impart on a regression-estimated EC can be seen by considering the regression estimated EC for a flow of 2,050 cfs using the April to May curve. The regression estimates an EC of approximately 750 μS/cm whereas the EC for a flow of 2,000 cfs was actually 945 μS/cm (data pair of 945 μS/cm and 2,055 cfs).

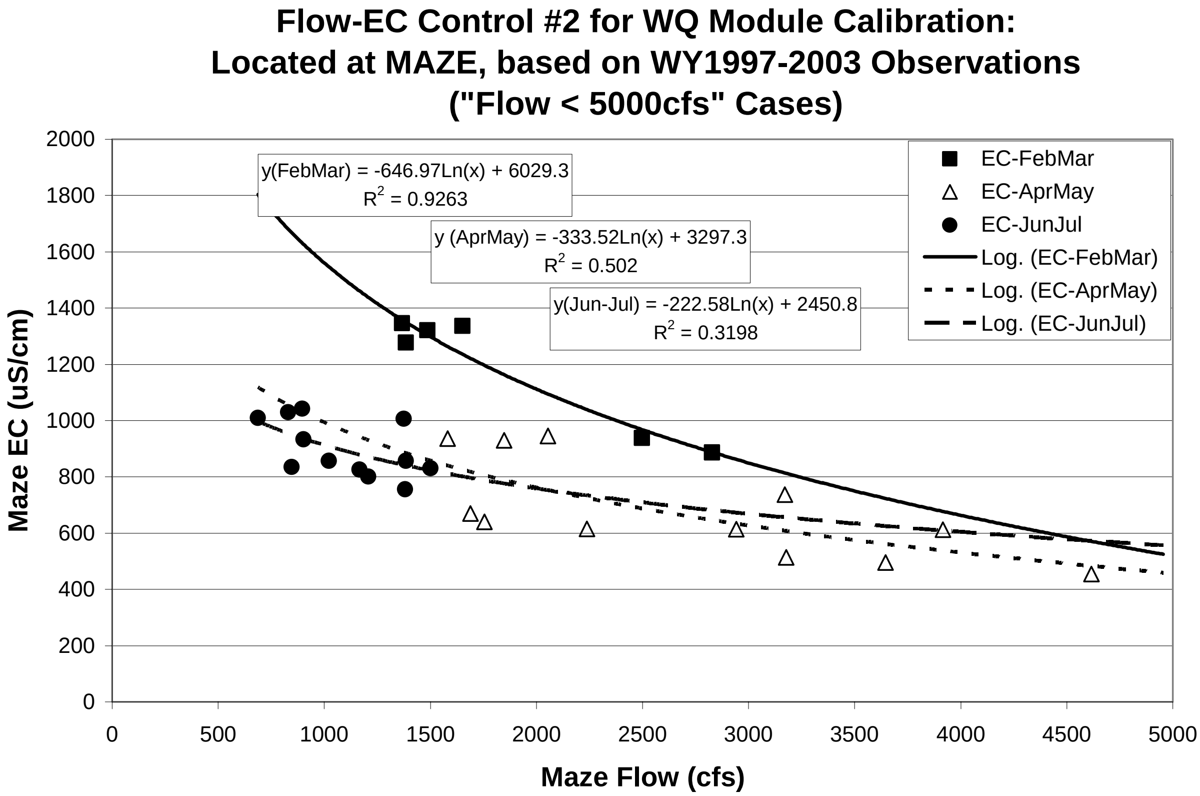

Figure B5. Flow versus (μS/cm) data for Maze

In this example, reliance on only the mean value, without consideration of the variability in the actual system, results in an underestimate of approximately 200 μS/cm, unless this effect is linearly counterbalanced by other potential realizations. As has already been shown in previous examples, underestimates of this magnitude will contribute to a consistent underestimate in the potential need for releases from New Melones.

The type of error resulting from a lack of variability has been demonstrated here using the simple model of a flow versus EC relationship. That is only one model element of the CalSim II that could contribute to this type of error however. This type of error will also occur whenever model data is used that insufficiently characterizes the natural variability of the actual data.

APPENDIX C - CALSIM-II SAN JOAQUIN RIVER BASIN REPRESENTATION

Consumptive Use of Applied Water	Annual (1000 AF)		
Test simulation inputs statistics (1922 - 1998)	Average	Maximum	Minimum
Stockton East WD	121	153	98
Oakdale ID North of Stanislaus	67	74	56
South San Joaquin ID	131	158	104
Lands Adjacent to Stanislaus River	12	15	10
OID South of Stanislaus	84	95	70
DAU 207 East of Modesto ID and Oakdale ID	29	34	23
Lands Adjacent & East of San Joaquin R.(Tuolumne to Stanislaus)	13	16	11
Modesto ID	148	177	120
Lands Adjacent to Tuolumne River	4	5	3
Turlock ID	335	400	272
DAU 209 East of Turlock ID	156	187	127
Lands Adjacent & East of San Joaquin R. (Merced to Tuolumne)	18	21	15
Lands Adjacent to Merced River	18	21	14
DAU 211 East of Merced ID	43	50	33
Merced ID	263	308	212
DAU 212 West of Merced ID	282	330	225
Chowchilla WD	159	189	126
DUA 215 West of Madera ID	210	249	165
Madera ID	228	268	184
DAU 214 East of Madera ID	137	165	107
Total	***2459***		

* See Land Use Aggregation graphic for specific locations (DAU = Detailed Analysis Unit)

River Diversions	Annual (1000 AF)		
Test simulation inputs statistics (1922 - 1998)	Average	Maximum	Minimum
Diversion and Losses - San Joaquin River Friant to Gravelly Ford	117	117	117
West Bank Diversion from San Joaquin River (Merced to Tuolumne)	77	100	56
West Bank Diversion from San Joaquin River (Tuolumne to Stanislaus)	39	50	28
West Bank Diversion from San Joaquin River (Stanislaus to Vernalis)	28	32	21
Total	***261***		

Reservoir Inflows	Annual (1000 AF)			
Test simulation inputs statistics (1922 - 1998)	Average	Maximum	Minimum	MaxCap.
Millerton Reservoir	1751	4688	383	520
Hidden Reservoir	87	356	6	90
Buchanan Reservoir	72	332	1	150
Lake McClure Reservoir	979	2871	142	1000
Don Pedro Reservoir	1594	4415	223	2000
New Melones Reservoir	1098	2900	271	2400
New Hogan Reservoir	156	565	7	320
Total	***5737***			***6480***

River Accretions	Annual (1000 AF)		
Test simulation inputs statistics (1922 - 1998)	Average	Maximum	Minimum
Accretion Stanislaus R. New Melones to Tulloch	32	120	2
Accretion Stanislaus R. Tulloch to Goodwin	2	9	0
Accretion Stanislaus R. Goodwin to Ripon	109	241	10
Accretion Tuolumne R. LaGrange to Modesto	205	492	65
Accretion Merced R. Exchequer to Crocker-Huffman Dam	-24	74	-559
Accretion Merced R. Crocker-Huffman Dam to Cressey	85	546	-1
Accretion Merced R. Cressey to Stevinson	16	109	-244
Accretion SJR Upstream from Merced (Positive values)	241	1358	7
Accretion SJR Upstream from Merced (Negative values)	73	395	0
San Joaquin River Accretion Newman - Maze	369	1197	143
San Joaquin River Accretion Maze to Vernalis	19	63	8
Mud and Salt Slough Base flow	23	36	22
Calaveras R. Accretion from new Hogan to Bellota	14	41	0
Total	***1167***		

Simulated Flows (1922-2003)	Annual (1000 AF)		
	Average	Maximum	Minimum
SJR Flow at Vernalis	3075	16621	920
Stanislaus R below New Melones	1024	2829	634
Stanislaus R below Goodwin	465	2399	184
Tuolumne R below Don Pedro	1527	4375	647
Tuolumne R below LaGrange	655	3621	94
Merced R below Exchequer	944	2844	256
Merced R below Crocker-Huffman	462	1849	171
SJR at Newman	1326	8679	427
Chowchilla R below Buchanan	64	332	1
Fresno R below Hidden	79	343	4
SJR below Friant	367	2728	117
DMC to Mendota Pool	847	1012	219
James Bypass to Mendota Pool	155	2307	0

Simulated Diversions (1922-2003)	Annual (1000 AF)		
	Average	Maximum	Minimum
Goodwin diversion	537	600	353
Modesto ID divesion	300	364	211
Turlock ID diversion	572	748	324
Merced ID diversion	460	548	53
Chowchilla WD diversion	124	181	17
Madera Diversion	157	276	18
Madera Canal diversion	260	451	36
Friant-Kern Canal diversion	1080	1721	240
Total	***3489***		

Simulated Groundwater Pumping by SJR Index Year Type (1922-2003)	***Average Annual Groundwater Pumping (TAF)***					
	All Years	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Modesto I.D. and Non-District areas	124	106	107	118	117	180
Oakdale I.D.	84	73	76	84	87	105
Turlock I.D. and Non-District areas	472	403	419	461	466	641
Merced I.D., Bear Ck. Refuge and Non-District areas	188	161	167	171	174	275
Chowchilla W.D.	120	79	105	129	143	168
Madera I.D.	403	329	383	430	446	478
West of Madera I.D.+Chowchilla W.D.	195	170	189	202	215	219
West of Merced and Non-district DAUs 210 and 212 areas	257	219	244	261	279	306
Stockton East W.D.	77	70	74	74	79	92
South San Joaquin I.D.	78	56	60	72	82	131
East Bank of San Joaquin River, Tuolumne to Stanislaus	0	0	0	0	0	0
East Bank of San Joaquin River, Merced to Tuolumne	11	10	11	12	13	12
Central San Joaquin W.C.D.	87	47	69	92	116	138
Areas also include M&I pumping. TOTALS:	**2097**	1724	1903	2106	2216	2746

APPENDIX D – PRESENTERS AND ORAL COMMENTERS TO PANEL

4 August 2005

Presenters

US Bureau of Reclamation
Levi Brekke
Randi Field

Consultants
Dan Steiner
Walter Bourez
Yung-Hsin Sun
Anna Fock

Oral Commenters

John Mills
Russ Brown
Jack Keller
Speck Rosekrans
Peter Vorster

Date: July 8, 2005

To: K.T. Shum, review@cwemf.org

From: Alex Hildebrand
South Delta Water Agency

Cc Paul Hutton
Dan Steiner
John Herrick

RE: CALSIM II Science Review

We are writing in regard to the Science Review on August 4 in Modesto of the "new San Joaquin River Valley Representations in CALSIM II". The development of this model and its modification to reflect future conditions that will exist when it is used "for planning and management of the State Water Project and Federal Central Valley Project" is of great importance in assuring that measures to protect the South Delta are adequate to protect the in-channel water supply from impacts of those projects. These considerations are also important when the model is used for the SWRCB's triennial review.

We are suggesting questions and considerations that the review team should include in determining whether the model optimally reflects the flows and salinities that would occur in different months of different years with the present level of development and present water management. Furthermore, the model is being used to plan water management measures that will be adequate when and after the permanent South Delta barriers and increased export rates are functioning. We therefore urge the reviewers and the developers of the model to revise the model when used for that purpose to reflect a range of likely changes in current conditions during that time frame. Some changes are already planned and others are likely as discussion herein. Even for current conditions it may be more realistic to have the model present a range of probable results rather than a single determination of flow and quality at any given time and place.

Please forward our comments both to the reviewers and to the developers of the model. It is our intent to be constructive, not critical.

Considerations relating to current conditions

1) What does the model assume regarding operation of the Environmental Water Account, EWA? What are EWA's current and future plans and how may EWA alter the time and salinity of flow?

2) The Exchange Contractors are selling the portion of their DMC entitlement that exceeds their needs. What does the model assume regarding to whom it is sold and how this affects drainage timing and salinity into the river? How firm are these assumptions?

3) What does the model assume regarding surface and subsurface accretions to the lower Stanislaus River below Goodwin Dam? The South San Joaquin Irrigation District, SSJID, started this year to export water from Goodwin Dam out of the Stanislaus watershed to Lathrop and Tracy. This water was previously largely applied in the watershed. This export may therefore reduce the accretion to the lower Stanislaus River.

4) The model assumes that adequate New Melones releases to the San Joaquin River are available for salinity control and other purposes. Are these releases sustainably available on a multiyear basis?

<u>Considerations relating to use of the model for future planning</u>

1) It is our understanding that the model assumes that river water is available from unidentified sources. It would be risky to assume that this water will continue to be available during the planning horizon if we don't know its source.

2) The Bay Area is planning to increase diversions from the Tuolumne River by about 14%, and to increase export conveyance capability by about one third. Future planning should recognize this change.

3) It is our understanding that the model assumes continuation of the present drainage volume and salinity to the river from parties who receive DMC water. There are plans to substantially reduce part of the agricultural drainage (SJ Rip) within five years, and eliminate that portion of the agricultural drainage soon thereafter. However, the total elimination of this drainage is less certain to happen within the planning period, so we should know how to cope with a long interim period.

4) There is an on-going increase in consumptive use of water in the watershed, and no expectation of an increase in watershed yield during the planning period. The model should be capable of reflecting the consequence of a plausible range of increased consumptive use of water.

We look forward to answering any questions on the above discussions, and to a careful evaluation of the model and its alteration when used to depict future conditions.

From: Hutton,Paul H [phutton@mwdh2o.com]
Sent: Monday, July 25, 2005 12:28 PM
To: review@cwemf.org
Subject: Questions/Comments for CWEMF CALSIM Peer Review

The following questions and comments are offered for consideration by the review committee:

1. I have noticed small but significant discrepancies in the magnitude of New Melones water quality releases as provided in the CALSIM baseline and as computed in the SANMAN model. I am interested in exploring the CALSIM developers' confidence in the current CALSIM calculations for New Melones water quality release.

2. I am interested in seeing a presentation on how the CALSIM baseline distributes Vernalis flow and salinity to the various upstream sources by month and water year type, how this distribution compares with others' work, and the mechanics and significance of the flow and salinity closure terms.

3. I suggest a dynamic linkage between DMC water quality and West side drainage water quality in future installments of CALSIM.

Thank you for your consideration.

Paul Hutton, Ph.D., P.E.
Senior Engineer
Water Resources Management Group
Metropolitan Water District of Southern California
1121 L Street, Suite 900
Sacramento CA 95814-3974
Phone 916.650.2620 FAX 916.650.2625

July 30, 2005

To: K.T. Shum

From: Alex Hildebrand hildfarm@gte.net

cc John Herrick, Dennis Majors

The July 29 meeting notice for the 8/4 review of CALSIM II refers to the intended use of CALSIM II for “planning and management of the State Water Project and the federal Central Valley Project”. It is already being used for the SDIP, the DIP, the SWRCB triennial review, and other proposals that will not be implemented for five or ten years or more.

The CEQA/NEPA and equivalent documents relating to these plans must be based on current hydrology, levels of development, and water management at the time that those plans are implemented, and not on conditions at some previous historical time. The hydrology, level of development and water management are continually changing. We therefore need a basic CALSIM II that correctly depicts the performance that each future proposal would provide if basic conditions continued to be as they were in 2002 or some other date. But we also need an established method of updating this basic model for the conditions that will be current at the time that any specific proposal would be implemented.

I urge the reviewers and model developers to establish this method of modifying the basic model so that it will provide evaluations that are current at the time that is relevant to each proposed change in water management.

August 3, 2005

To: Jay Lund

From: Alex Hildebrand

Re: CALSIM II

I urge that the review team clearly identify the historic conditions reflected by CALSIM II. The model was apparently verified by comparing model output to river flow and salinity measurements that were made over an extended period of years. Most of those measurements were made prior to changes that include:

- Exchange Contractor sales of their surplus DMC entitlement to parties that then consume most of the water;
- DMC deliveries to wildlife refuges;
- current levels of control of westside agricultural drainage to the river;
- alterations of flow by the EWA;
- VAMP;
- alterations in time of eastside tributary releases per the CVPIA;
- b2 and other commitments that over commit New Melones yield;
- export of Stanislaus water from the watershed to Tracy and Lathrop

Those who use CALSIM II should be given a clear understanding of the conditions that are, or are not, reflected by the model.

Thanks

ENVIRONMENTAL DEFENSE
finding the ways that work

August 5, 2005

Science Review Panel
San Joaquin River Valley Representations in CALSIM II

These comments relate to the recent work refining the San Joaquin River watershed component of the State-federal CALSIM II water planning model. Yesterday's workshop was well-organized and informative. Environmental Defense appreciates the hard work of the model developers and the review panel in this important effort to develop the best possible water planning tool possible.

The commitment to documentation is an obvious improvement in CALSIM II. Understanding the model's input and output data has been a challenge. When one accesses data pertaining to any particular node, it would be useful if at least a short description of that data was available. For many variables, it is not at all clear what the data represent. The entire model should be documented, not just the newly enhanced San Joaquin River watershed portion.

CALSIM II includes an impressive state-of-the art graphical user interface that makes model inputs and outputs readily accessible. Unfortunately, it is difficult to run studies using the model, making it impractical and/or expensive for most stakeholders to investigate their own alternatives. In this respect, CALSIM II is a step backward compared to its predecessors, DWRSIM, Prosim, Stanmod and Sanjasm. If the model were more accessible, more stakeholders would run the model and be able to suggest improvements. It is unfortunate that though many people know the system well, few can run the model.

The most obvious use of water supply operations models is to test "what if" scenarios. There was little discussion yesterday of the model's suitability for examining changes to the San Joaquin system. Any substantive review of the model's enhancements ought to include its ability to model system changes, whether in hydrology, operating practice or infrastructure. In particular, the model's ability to measure the effects of the following potential significant changes in the San Joaquin River watershed ought to be considered:

- **Increased groundwater development** – More than 5,000,000 acre-feet of groundwater storage has been developed in California the last 15 years. Significant potential exists at many locations in the San Joaquin basin. Is

CALSIM II poised to examine the costs and benefits of developing groundwater at these locations so that we can make informed decisions?

- **Potential San Joaquin River flows** – There is an ongoing dispute about whether releases to sustain a fishery below Friant Dam must, as a matter of law, be made. Is CALSIM II suited to investigate how releases to support the fishery would affect water supply operations or downstream water quality?
- **Restoration of Hetch Hetchy Valley in Yosemite National Park** - The upper Tuolumne watershed is perhaps the biggest 'black box" in CALSIM II. Nowhere does the system recognize the existence of Hetch Hetchy, Cherry and Eleanor Reservoirs, which together hold more than 650,000 acre-feet and from which more than 200,000 acre-feet are diverted annually. Why does CALSIM II not include any representation of these resources, so that the public can better understand their role in providing water to the San Francisco Bay Area, especially at a time when elected officials have proposed that restoration of Hetch Hetchy Valley in Yosemite National Park be considered?

Thank your for the opportunity to comment.

Spreck Rosekrans
Senior Analyst

Anonymous comments **8 August 2005**

According to the documentation on the web, the motivation for doing this upgrade to CALSIM is:

“ (a) response to perceived gaps between CALSIM II capabilities and ongoing planning questions, and (b) anticipation of future planning questions that will need to be served by CALSIM II with functionality beyond the current model. Both of these factors motivated redevelopment of CALSIM II’s hydrology representation on the Eastside San Joaquin River Basin.”

Given the motivation for the upgrade,

1. What specific planning questions (scenarios) in the San Joaquin Valley and Delta region is CALSIM 2 being used to address now and are anticipated to be addressed in the future.

2. Given the admitted limitations of the model such as not modeling surface water–groundwater interactions, not encompassing the entire CVP service area (i.e. the Tulare Basin is not represented), and contract driven demand on the west side, are the scenarios that it is trying to analyze adequately served by the representations and level of detail of the San Joaquin Valley system.

3. How will water supply and water quality management scenarios that involve reallocation of water supplies, recirculation, groundwater banking, changes in groundwater pumping, coordinated reservoir operations, retirement of drainage impacted lands, demand management etc. be represented and analyzed.

4. What time and resources would be required to include simple representations of the groundwater mass balance in selected regions.

5. The written documentation states on P.70 "The San Joaquin River reach between Gravelly Ford and Mendota Pool was estimated to lose up to 200 cfs of the available flow at Gravelly Ford. This estimate is consistent with information acquired from pilot projects recently performed on the San Joaquin River." Could this assumption be elaborated. Does it mean that the first 200 cfs of flow at Gravelly Ford is assumed to be a seepage depletion. Explain how the information from the Pilot Projects was used to support that conclusion.

From: John S. Mills
To: CALSIM II Review Panel
Re: Questions and observations regarding presentation of 8/4/05
Date: August 11, 2005

I have a series of questions for the Review Panel to consider relative to the CALSIM II Model presentation in Modesto on 8/4/05. I want to thank the Panel and the people working on the CALSIM II Model, in advance, for all the effort and thought put into making this a useful tool in dealing with the watershed's resource challenges.

Questions:
1. Land Use Based Demands (LBD) are referenced as being included in the model and highlighted as an improvement since they are based on DWR aerials. For future projections does the LBD utilize the same estimates from Bulletin 160-05? If not, are Department of Finance estimates used, or are Urban Water Plans, in combination with irrigation demands to achieve a total estimate for an area? If Bulletin 160-05 estimates are used, shouldn't the CALSIM II data sets be updated as Bulletin 160-10 (Regional estimates) numbers become available?

2. As a follow up to number 1, what role do/should land use plans (General Plans) and their land based density estimates have in projecting future use?

3. Why were Hetch Hetch, Cherry Lake and Lake Eleanor (all on the upper Tuolumne system) not included in the model?

4. Given the relationship between ground water sources and total water use in the San Joaquin watershed can CALSIM II capture this interaction, absent a ground water component (other than the existing estimate approach)? How do you propose to deal with the significant ground water overdraft in the watershed in attempting to make use of the Model?

5. When is it reasonable to hope that West side diversion (from the Delta) return flows will be incorporated into the Model? In light of the significance of this resource, as well as refuge return flows, in impacting San Joaquin water quality (salinity) as recently documented by the San Joaquin River Technical Work Group's efforts, can CALSIM II be a useful tool in answering questions regarding San Joaquin river operations (which to a great extent are being driven by quality factors)?

6. Can the model, in its present construct, be used to accurately estimate the water quality and management consequences of pending Friant Dam releases related to the Friant/NRDC case?

7. Could the model be used to estimate opportunities and constraints of creating new surface or ground water storage within the San Joaquin watershed?

Date: August 9, 2005
To: Jay Lund
From: Alex Hildebrand
Re: CALSIM II

This e-mail first repeats the suggestions I handed you in hard copy on August 4, and then adds additional comments.

I urge that the review team clearly identify the historic conditions reflected by CALSIM II. The model was apparently verified by comparing model output to river flow and salinity measurements that were made over an extended period of years. Most of those measurements were made prior to changes that include:

- Exchange Contractor sales of their surplus DMC entitlement to parties that then consume most of the water;
- DMC deliveries to wildlife refuges;
- current levels of control of westside agricultural drainage to the river;
- alterations of flow by the EWA;
- VAMP;
- alterations in time of eastside tributary releases per the CVPIA;
- b2 and other commitments that over commit New Melones yield;
- export of Stanislaus water from the watershed to Tracy and Lathrop.

Those who use CALSIM II should be given a clear understanding of the conditions that are, or are not, reflected by the model.

The model is already being used in connection with numerous analyses. The review team could consider whether the model output could be modified to be more appropriate for these uses. The model only purports to be a monthly model. However, monthly outputs are often inadequate and misleading as regards consequences that result from extreme rather than average condition. Could the average outputs be accompanied by a probable range of variations above and below the average?

For example, the CVP and SWP must not be allowed to cause a reduction in water level and depth in shallow South Delta channels that make it impossible to maintain local diversions that are needed for irrigation. The rate of these diversions fluctuates, but must be sustained as needed continuously every hour of every day. These diversions are from channels that are all tidal channels. Export pumping substantially reduces the natural tidal depth in these channels in order to draw water toward the pumps. This then reduces the ability of proposed tidal barriers to capture water during high tides for use during low tides. This deficit in water availability is proposed to be provided from inflow at Vernalis. The inflow needed fluctuates substantially. This then requires evaluation of the availability of that flow on a daily rather than a typical average monthly basis.

The water salinity standards in the South Delta are unfortunately based on 30 day running averages. However, a farmer must consider the risk involved if he may have to irrigate salt sensitive seedlings with water having salinity considerably above the 30 day average. The 30 day average salinity was only designed to be marginally adequate.

Grassland Water District
22759 S. Mercey Springs Road
Los Banos, CA 93635
Telephone (209) 826-5188
Fax (209) 826-4984

August 12, 2005

Email Memo: Jay Lund, review@cwemf.org
California Water and Environmental Modeling Forum

Dear Mr. Lund,

The Grassland Water District in conjunction with the U. S. Fish & Wildlife Service and the California Department of Fish and Game, representing the managed wetlands located in the western portion of Merced County, would like to convey our comments regarding the science review of the CALSIM II modeling. The three agencies, representing the Managed Wetlands, feel that it is imperative that any future modeling that may be added to the present CALSIM II model will accurately portray the present and future practices of managed wetlands. These irrigation and drainage practices differ greatly from those of agriculture or municipalities. There has been only one rough attempt to model the managed wetlands to our knowledge. That model has been tagged WETMANSIM. Over the past year we have noticed that many distortions of that model have surfaced in attempts to represent the drainage patterns of the managed wetlands. We are deeply concerned since these distortions grossly misrepresent the actual drainage patterns of our areas.

At the present time we are working with the Bureau of Reclamation to secure funding to advance the WETMANSIM model to a more reliable and acceptable tool for inclusion into the CALSIM II model. We are asking that any attempts to model the managed wetlands would directly include the three agencies to insure accuracy and acceptability with the model.

Respectfully submitted,
Scott Lower,
Assistant General Manager

From: Wilbur_Huang@URSCorp.com
Sent: Monday, October 03, 2005 3:20 PM
To: Jay Lund
Subject: RE: Comment for CalSim II Science Review Panel Comment Draft

Dear Professor. Lund,

When I review a study or a project with results from an hydraulic model, I would actually go through the modeler's thinking trail and run the hydraulic model using the modeler's assumption and data. I would see if I could derive the same results as the modeler. Also, I would invest some time to see if the result of the model would support the modeler's conclusion. By not running the model, one would totally trust the modeler's modeling skill and interpretation, hoping that what he writes down on the document is the same as you would get from the model.

The usage of CALSIM model has been very limited to some modelers within the DWR and BR as well as some contractors that had experience with these two agencies. The larger public shareholders have been left outside of the usage of the model. Why? Because the model is written in such computer scripts that today's "window WYSIWYG" users would have real difficulties to even understand. The documentation (such as user manual, example application and technical reference) of the model is very poor. Even many accomplished hydraulic and hydrology engineers and professional, that have been through the CALSIM training, would not be able to apply some simple application using such difficultly operating model.

The review panel is an accomplished group of people who would have supper understanding of the system and great experience of testing the model's result. If you are able to run the same data as the modeler and get the same conclusion, that is the most simple way to test the model's accuracy. But if you can not run the model, or, your conclusion is different, then you have to ask a deeper question. Is the model to complex for common usage? Can it be simplified or advanced to such common public can use it. Are the input data really applicable? Is the result really means what the writer (DWR or BR) intents to simulate? Will common user get the same conclusion besides the government agencies.

It is up to the panel charge to scrutinize the model for its usage and accuracy. Just reading the government and its contractors' document would not do it. If the experienced panel can not run the model and interpolate the result, how does DWR or BR expects other common public professional to do it? That is what I mean "Tasting the icecream". If the penal CAN run the model and get the same conclusion, then we, the public, will have deeper faith in the panel and the model. The testing application can be very simple one. It does not have to be a complex application, as long as it can demonstrate the panel understands the model and can follow its modeling logic. I guarantee that you will appreciate the meaning of operating the model and your panel's questions would not stop at just the data and the assumptions of the documents.

The above are my two cents.

Wilbur Huang
Tel: (916) 679-2260

California Water and Environmental Modeling Forum
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CALFED Science Program and California Water and Environmental Modeling Forum

Science Review of the new San Joaquin River Valley Representations in CALSIM II

August 4, 2005

Technical comments for consideration by the Review Panel: Questions for Walter

Regarding Ag Demands – (1) where is it assumed that non-recoverable losses go and is there empirical data to support 10% of CUAW?

(2) – Does the model have the ability to adjust to account for land use/crop changes?

Urban Demands – (3) what per-capita use is assumed? (3a) Is it the same for all areas?

(4) – How are treated wastewater return to groundwater dealt with?

Would you like to make a brief oral comment during the public comment period at 3:30? No

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

- ☐ Project Operations
- ☐ Water Demand
- ☐ Salinity
- ☐ Input Data
- ☐ Model Formulation
- ☐ Others

Name: Steve Ottemoeller Affliation: URS
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Comments could also be sent by email to rewview@cwemf.org

Details on the review are posted on http://science.calwater.ca.gov/workshop/calsim_05.shtml and will be updated regularly.

California Water and Environmental Modeling Forum

Promoting Excellence and Consensus in Water and Environmental Modeling

P.O. Box 488, Sacramento, CA 95812 ◆ 916-607-0435 ◆ cwemf@cwemf.org ◆ www.cwemf.org

CALFED Science Program and California Water and Environmental Modeling Forum

Science Review of the new San Joaquin River Valley Representations in CALSIM II

August 4, 2005

Technical comments for consideration by the Review Panel:

- What % of Groundwater flows is Est.?
- What is the relationship between Deep Percolation & Pumping?
- How accurate is the model for the smallest module? Farm?
- Precipitation vs snow melt?
- Discuss accuracy of urban Area - Runoff / Water Quality?
- Some processes are 2nd order with river/flow or temperature will the model adjust?

Would you like to make a brief oral comment during the public comment period at 3:30? OK ~2 min

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

- ☐ Project Operations
- ☐ Water Demand
- ☒ Salinity
- ☒ Input Data
- ☐ Model Formulation
- ☐ Others

Boundary Conditions

Name: Richard Gardner Affliation: SCWD

Email: Capopalm@hotmail.com Phone: 949 240-4804

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Technical comments for consideration by the Review Panel:

① It is not obvious that the eastside CALSIM EC model matches Maze salinity and load any better than the original Fortran eqns. How well does the new model results match recent historical EC & salt load? Where did the flow term estimates for recent years come from? How much of salt load at Maze is contained in the residual salt load estimates? It seems that historical EC & flow data are used to estimate model terms — so it is not surprising that the 'simulated' results match historical. Isn't this circular?

Would you like to make a brief oral comment during the public comment period at 3:30? _______

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

☐ Project Operations ☐ Water Demand ☒ Salinity

☐ Input Data ☐ Model Formulation ☐ Others

Name: Russ Brown Affliation: Jones & Stokes

Email: rbrown@jsanet.com Phone: 916 739 3032

Comments could also be sent by email to rewview@cwemf.org

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Technical comments for consideration by the Review Panel:

① The major achievement of the new CALSIM appears to be the data gathering and analysis required to estimate the historical operations of each water district. We should be spending more time reviewing this work by Dan Steiner & Walter Bourez. What is gained by putting all these fixed historical inputs into CALSIM eastside - the model appears to only give one time sequence of operations.
② Why is there a reluctance to simulate the historical development of SJR district's landuse and reservoirs? If we can't reproduce these historical incremental operations, why are we expecting the model to give reliable estimates of future management or facility changes?

Would you like to make a brief oral comment during the public comment period at 3:30? ________

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

- ☐ Project Operations
- ☐ Water Demand
- ☐ Salinity
- ☒ Input Data
- ☐ Model Formulation
- ☐ Others

Name: Russ Brown Affliation: Jones & Stokes

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Technical comments for consideration by the Review Panel:

The input data for the computation of actual CROP WATER use and unrecoverable evaporation losses could be greatly improved by using remote sensing. What is the prospect and payoff for employing this tool.

Would you like to make a brief oral comment during the public comment period at 3:30? ______

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

- ☐ Project Operations
- ☑ Water Demand
- ☐ Salinity
- ☑ Input Data
- ☐ Model Formulation
- ☐ Others

Name: JACK KELLER Affliation: CBDA / ISB & WMSB
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Details on the review are posted on http://science.calwater.ca.gov/workshop/calsim_05.shtml and will be updated regularly.

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August 4, 2005

Technical comments for consideration by the Review Panel:

Topic: Demand Development - RD usage

The Representation is based on the input of each RD Water usage, as told by this morning's speaker. Are these water usages are on Written document, ~~agre~~ legal agreement and strictly followed ed? In an other word, how valid are these usages assumptions? When it (RD) changes in the future, will the model still valid?

Would you like to make a brief oral comment during the public comment period at 3:30? No

If you do, which of the area(s) will you comment on? (This is for the purpose of determining the order of presentations.)

- □ Project Operations
- □ Water Demand
- □ Salinity
- □ Input Data
- □ Model Formulation
- □ Others

Name: Wilbur Huang Affliation: UR

Email: Wilbur_huang@urscorp.com Phone: 916-679-2260

Comments could also be sent by email to rewview@cwemf.org

Details on the review are posted on http://science.calwater.ca.gov/workshop/calsim_05.shtml and will be updated regularly.

Date: 12/1/2005

To: Jay Lund

cc: Paul Hutton
John Herrick

From: Alex Hildebrand

I have been pleased to review the 11/18 draft review Panel Report, San Joaquin River Valley CALSIM II Model Review. You indicated that further comments would be welcome. The Panel Members deserve commendation for having made a very careful, competent, and extensive review of CALSIM II.

They point out that the model has much merit, but that it also has some weaknesses. For example, on page 5 they state "In absolute terms the new presentation systematically underestimates (San Joaquin River) salinity", and "This underestimate of salinity causes underestimates of releases from New Melones Reservoir that in turn leads to overestimated water availability to entities dependent on New Melones storage".

The focus of the review was on San Joaquin River salinity. However, the model also estimates flow at Vernalis. It would be helpful to have the reviewers comment more directly on the probable accuracy of these flow estimates. Vernalis flows have a substantial affect on water quality and water supply and water depth in South Delta channels.

The purpose of a water model is as a tool in managing water and developing better ways to do so. CALSIM II output is already being used without modification for purposes including analyzing the future viability of the South Delta Improvement Program, and analyses by the San Joaquin Salinity Group, and in forecasts of future San Joaquin River flow submitted to the State Water Resources Control Board. As you point out, conditions and available data change so that the model will not reflect future conditions unless it is modified to reflect those future conditions. No one can prevent misuse of the model. However, you could perhaps propose that there be a "users guide" that would define the hydraulic conditions that are or are not reflected by the model (2001 or a longer calibration period?) the guide could call attention to changes affecting flow and quality that have already occurred since those reflected in the model, and other changes that are already planned such as increased exports from the Tuolumne, shifts in flow timing by EWA, exports out of the Stanislaus watershed, etc.

It would also be helpful to have in the guide some estimate of the range of probably accuracy of outputs; i.e., instead of showing an output of x cfs, show x +/- cfs.
This uncertainty is discussed on page 11 of the draft review. The reviewers also discussed the limitations resulting from using monthly averages. For some purposes, such as maintaining adequate depth for local diversions, it is important to know what the range of fluctuations may be within the month.

A model user's guide should also call attention to the reviewers' caution on page 40. The reviewers discuss the lack of probabilistic model results. They state that "absent such probabilistic model results, the model is best used only for comparative purposes--". Lack of probabilistic model results severely limits the ability of decision makers to rely on this model to make informed long-term planning and policy decisions".

The guide should also include the caution on page 42, item 7, against relying on the model for assessing low-flow conditions. The model was not calibrated for those conditions.

Thank you for the opportunity to make suggestions.

Date: December 2, 2005

To: Jay Lund, Rich Satkowski

From: Paul Hutton

Subject: Comments on 11/18/05 Draft SJR CalSim II Model Review

The following comments are submitted in response to Rich Satkowski's November 22, 2005 email requesting comments on the subject document. These comments reflect my own professional views and do not necessarily represent those of Metropolitan Water District.

I commend the external review panel members for the thoroughness of their review and the clarity of the draft document they produced. I also wish to commend those members of CWEMF and the CALFED Science Program who are overseeing the review process. I believe that this model review will not only advance the development of CalSim II, but that it will also advance the California water community's ability to effectively conduct subsequent external reviews.

I am encouraged that the reviewers recognize the pressing need for systematic data development for the San Joaquin Valley. The ability to provide decision support on issues related to the San Joaquin River will continue to be limited until more comprehensive water volume and constituent balances are developed for the river. I am also encouraged that the reviewers recommended that longer-term model development focus on groundwater and Westside components.

However, for this document and external review process to function as envisioned, the final draft MUST provide a bold, prominent statement on the overall merit of the new model representation relative to the old model representation. Is the new representation a more useful decision support tool than the old representation? This question MUST be answered with an unequivocal "yes" or "no". The answer to this question could be qualified with recommendations for immediate action and longer-term action (as no model of a complex system will ever be perfect), but it must be answered. I strongly believe the success of this review, as well as the success of future model reviews, hinges on the willingness of panel members to provide an answer to this question. If this question is not answered boldly and prominently in the final document, the external review will not contribute to the immediate decision-making environment and could be counter-productive.

Thank you for the opportunity to comment on the document.

From: Peter Vorster [vorster@bay.org]
Sent: Friday, December 16, 2005 9:47 AM

COMMENTS ON EXPERT REVIEW OF SAN JOAQUIN RIVER VALLEY CALSIM 2 MODEL

I agree that the Review Report provides a better understanding of model reliability for different applications; such an understanding will be enhanced by conducting an error analysis study in the near term. Given the widespread use of this model, it would be helpful if the review panel could identify those applications for which it is better suited and those applications for which it should be used with more caution. Some of the planning scenarios it will be used for, such as those with year round flow in all the reaches of the main-stem San Joaquin River, could significantly change the accretion/depletion relationships and the model should be used with caution.

I also agree that the documentation of the model assumptions is much improved over previous efforts but that there is an immediate need to improve the documentation of key assumptions. One area of documentation that was not addressed by this review is the existence or lack thereof of a ³users guide² for this version of CALSIM 2. A good users guide is needed so that a larger arena of people can feel comfortable using the model. Hopefully a guide can be developed so that a person who is moderately knowledgeable about models and the Central Valley water resource system can use it and does not have to take a week-long workshop or be intimately involved with the model development.

Specific comments:

P. 16 - Friant diversions- in addition to noting that the model under-predicts peak canal diversions in recent years, it should also note that the model also over-predicts canal diversions in very wet years such as 1983, 1995, 1998. This could be in part due to the abundant alternative sources of supply that is not fully captured by the model¹s Tulare Basin index.

P. 25 - Documentation of Gravelly Ford to Mendota Losses – “ever month” should be “every month”. This reach is a good example of how losses will be significantly different from the assumed loss if scenarios are run in which water is assumed to be in the San Joaquin River more often than under existing baseline conditions. Gage data and data from pilot projects are available that would indicate different values should be used.

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United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY REFER TO:
MP-700
PRJ-1.10

DEC 30 2005

VIA ELECTRONIC MAIL

Professor Jay R. Lund, Ph.D.
Chair, San Joaquin River Valley
CalSim-II Model Review Panel
Department of Civil and Environmental Engineering
University of California, Davis
Davis, California 95616

Subject: Draft Review Panel Report, CalSim-II San Joaquin River

Dear Dr. Lund:

Reclamation thanks the CALFED Science Review Program, California Water and Environmental Modeling Forum, the Review Panel, participants of the CalSim-II technical team, and the public for their interest and support of the peer review process. As part of our joint mission with the California Department of Water Resources, we strive to develop, maintain, and advocate CalSim-II as the simulation model of the State Water Project and Central Valley Project, which best represents the two projects for planning and management studies. Our goal is to develop and maintain the best available technical tools for planning and management studies.

The CalSim-II San Joaquin River representation is the result of a three-year development effort to improve the representation of project and non-project operations, demands, hydrology, and water quality in the region. We will continue to implement model refinements in the next phase of San Joaquin River development. Thank you for your praise of our effort to improve and forge a new standard for model documentation.

We have reviewed the Draft Review Panel Report and will respond to the Review Panel's findings in a timely fashion through additional improvements to the model. We are currently pursuing sensitivity and uncertainty analyses as recommended by the Review Panel.

Again, our goal is to continually improve and provide the best tools available for planning and management studies. We are disappointed that the Draft Review Panel Report does not discuss two important items. First, the Review Panel did not state if the new representation is as good as or better than the old model. Second, the Draft Review Panel Report did not identify if any other tool exists that is more functional or has received greater cooperation and coordination from interested parties, than the San Joaquin River CalSim-II model. We request the Review Panel address these two items prior to finalizing the Draft Review Panel Report. Without an answer to this request, we believe you have not responded completely to the purpose of the review.

The Draft Review Panel Report compliments our planning and management model, mission and goal. We look forward to working with those interested in the CalSim-II San Joaquin River model in the future. If you would like further information, please contact Lloyd Peterson at lpeterson@mp.usbr.gov or 916-979-0258.

Sincerely,

William Rohwer

William P. Rohwer
Deputy Regional Planning Officer

cc: review@cwemf.org

APPENDIX F - Panel Qualifications

Jay R. Lund (Chair) (http://cee.engr.ucdavis.edu/faculty/lund/) is a professor in the Civil and Environmental Engineering Department at the University of California, Davis. His expertise is in the areas of operations modeling and water demand theory and practice. He has analyzed California's water supply and is the principal developer of the model CALVIN. Prof. Lund conducted the first phase of the previous CALFED CALSIM II review in 2003, and served on the external Review Panel.

David Ford is the Principal at David Ford Consulting Engineers, Inc., (http://www.ford-consulting.com/), a firm with over 25 years of experience in hydrologic engineering, water resources planning, flood warning, and decision support systems. He has extensive experience with water supply operations modeling for field problems, and has unusually good knowledge of the San Joaquin River system for someone not involved in the work being reviewed.

Les Grober is a Senior Land and Water Use Scientist at the California Regional Water Quality Control Board, Central Valley Region. He has extensive experience in the drainage and water quality of the San Joaquin River Valley, and has worked on numerous modeling and management issues.

Tom Harmon (https://ucmeng.net/FacultyBio/tharmon) is an associate professor in the School of Engineering at the University of California, Merced. His expertise is in the areas of contaminant transport in aquatic systems, soil and groundwater remediation, development and use of environmental sensors. He has become involved in San Joaquin Valley water quality problems.

Daene C. McKinney (http://www.ce.utexas.edu/prof/mckinney/mckinney.html) is a professor in the Department of Civil Engineering at the University of Texas, Austin. He is an expert in developing and applying numerical methods for simulation, optimization, and uncertainty analysis of environmental and water resource management problems, and in decision support tools for trans-boundary water resources management problems. He is a member of the CALFED Water Management Science Board and a member of the previous CALFED CALSIM II external Review Panel.

APPENDIX G - Acronyms

CALAG	California Agricultural model
CU model	Consumptive Use model
CUAW	consumptive use of applied water
CVGSM	Central Valley Groundwater – Surface Water Simulation Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
CWEMF	California Water and Environmental Modeling Forum
CDWR	California Department of Water Resources
DPLA	Division of Planning and Local Assistance, DWR
DSM2-SJR	Delta Simulation Model 2 – San Joaquin River
DWR	Department of Water Resources
DMC	Delta Mendota Canal
EC	Electrical Conductivity
GIS	geographic information system
ID	Irrigation District
LP	Linear Programming
MWDSC	Metropolitan Water District of Southern California
OCAP	Operations Criteria and Plan
OID	Oakdale Irrigation District
Reclamation	U.S. Bureau of Reclamation
RWQCB-CVR	Regional Water Quality Control Board, Central Valley Region
SANJASM	San Joaquin Area Simulation model
SJR	San Joaquin River
SJRIO	San Joaquin River Input-Output model
SJVWYI	San Joaquin Valley Water Year Index
SWAP	Soil Water Atmosphere Plant model
SWRCB	State Water Resource Control Board
VAMP	Vernalis Adaptive Management Program
WD	Water District
WETMANSIM	Wetland Management Simulator
WQ	Water Quality
WWTP	wastewater treatment plant