Review Comments

Draft Staff Report to Support a Proposed Basin Plan Amendment to Establish and Implement Salinity Water Quality Objectives in the Lower San Joaquin River

This review focuses on three components of the basin plan amendment for salinity water quality objectives. In addition, some general comments on the overall draft document are provided.

1. Data generated by the WARMF watershed modeling tool was appropriate to:

- **Evaluate water quality changes in the LSJR under different implementation management actions.**
- **Predict the attainment of the proposed WQOs with the implementation of the planned management actions**
- **Identify the potential for lower salinity concentrations (the proposed Performance Goal) with the implementation of the planned management actions for certain seasonal and water year types**

The WARMF model is a reasonable tool to evaluate the above objectives. However, the model has great uncertainty in being able to capture the complexity of such a large and diverse watershed area. Thus, while an appropriate tool, it must be qualified as having great uncertainty and any application of the model results must take into account a realistic level of uncertainty. As presented, it is very difficult to <u>quantitatively</u> assess the level of uncertainty associated with the model results. While the WARMF model provides a realistic representation of baseline conditions for both hydrology and EC (salt load), its ability to accurately forecast responses to watershed management/treatment actions is not demonstrated in the documentation provided. This is not to say that the forecasted EC conditions are inherently wrong, but they could either over- or under-estimate future conditions by a significant amount due to model uncertainties.

There are many sources of uncertainty in hydro-biogeochemical models such as WARMF including:

1) limitations or lack of important meteorological, irrigation, stream and ground water monitoring, water quality and geospatial datasets;
2) limitations in our understanding of the complexity of environmental processes affecting water quality and/or scaling issues associated with large complex basins (such as the SJR basin);
3) limitations of the modeling approach in numerically representing the complex, integrated environmental processes accurately;
4) accurately <u>predicting</u> future management/treatment actions, changes in land use, climate change, etc. for use as model simulations;
5) limitations in <u>formulating/applying</u> management/treatment interactions in models; and
6) extrapolating model predictions to conditions outside the range of baseline calibration.

The uncertainty associated with use of the WARMF model in this study is not rigorously <u>quantified</u> making the reliability of model predictions difficult to assess. The application of the WARMF model to the salinity/B WQOs lacks sufficient uncertainty analysis to truly evaluate its abilities to predict future management/treatment scenarios and support the WQO. For example, it would be very useful to place confidence limits on the modeling results such as an 80% C.L.

illustrated in the graph below. By adding confidence bands to model output, it would be possible to evaluate an EC criterion value with an associated level of confidence, such as stating that there is an 80 or 95% chance of being met. This would be the ideal scenario.

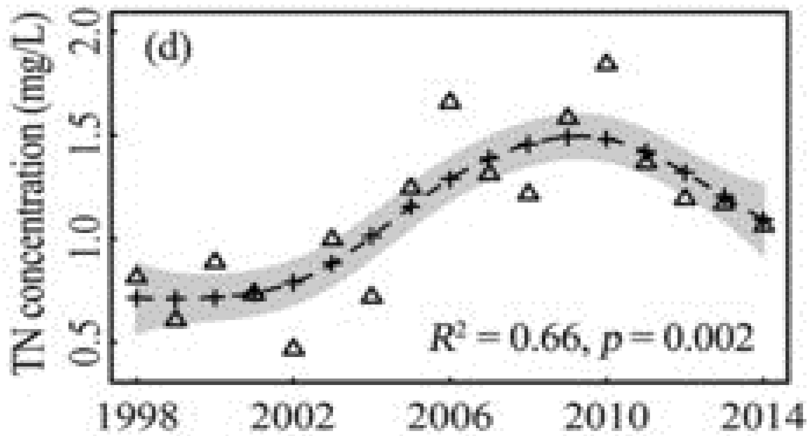

Figure: Example of 80% Confidence Limit (gray shading) around the model prediction (dashed line) and measured data (triangle points).

Based on the modeling data provided for EC (Figures 5-7, 5-8 & 5-9), it appears that EC values have a plus/minus ~20% deviation at 1550 µS/m giving an absolute error value of ±310 µS/m. It would be nice to be able to support this eye-ball observation with quantitative uncertainty analysis. Then, you could put a confidence limit on the ability to attain a target WQO.

In terms of modeled vs measured EC values (Figures 5-7, 5-8 & 5-9), the R^2 values reflecting the variance explained by the model simulations are 0.62, 0.49 and 0.53 for Maze, Patterson and Crows Landing, respectively. This indicates that roughly 50% of the variance is explained by the model simulations, which does not provide a high level of confidence in the ability of the model to accurately simulate past or future EC levels.

The only error statistics that I found in the documentation is Table 12 shown below. It would be useful to break these data into various time frames (e.g., 5 year segments) to see if the model fit is changing over time and into wet/dry year comparisons to determine if there is a bias toward wet vs dry years. The error analysis presented in Table 12 is on the high side for a baseline calibration scenario. The errors are likely to <u>increase</u> substantially when using the baseline calibration to forecast future management/treatment conditions that are outside of the model's calibration range.

Table 12: Error Statistics of WARMF Baseline Simulation, San Joaquin River at Crows Landing (October 1995-September 2013)

	Relative Error		Absolute Error	
Flow	-330 cfs	-16%	412 cfs	21%
EC	-89 µs/cm	-9%	254 µs/cm	25%

Table 11 (below) provides valuable qualitative information on data quality, model sensitivity, and effect on model uncertainty with regard to various WARMF model inputs available for the lower San Joaquin River. In particular, the diversions/discharges and groundwater components have low data quality and high model sensitivity. Rather than a qualitative assessment of model uncertainty, it would be useful to provide a Monte Carlo type assessment of those input parameters to quantitatively assess the potential uncertainty associated with these parameters. Monte Carlo simulation generates random values of stochastic parameters from their corresponding probability distribution to determine an uncertainty range for modeling results.

Table 11: WARMF Model Time Series Inputs

Model Input	Data Quality	Model Sensitivity	Effect on Model Uncertainty
Meteorology	High	High	Low
Air & Rain Chemistry	Moderate	Low	Low
Boundary Inflows	High	High	Low
Point Sources	Moderate	Low	Low
Deliveries from DMC	High	High	Low
Diversions from SJR	Low	High	High
Irrigation Usage	Moderate	High	Moderate
Groundwater Recharge	Low	High	High
Groundwater Flow	Low	High	High
Groundwater Quality	Low	High	High

Concerns about using the WARMF model for predicting future EC/B trends

1. Model results provide limited uncertainty analyses commonly reported for rigorous model output (e.g., 95% C.L., Standard Errors, mean square errors, Monte Carlo uncertainty analysis, Nash–Sutcliffe efficiency). Only the R^2 of modeled vs measured is provided; no level of significance (p-values) was associated with the R^2 values. It is not possible to assess treatment effects without considering the uncertainty associated with the results.

2. WARMF modeling of stream water flows appears to be satisfactory for the purposes of assessing management/treatment simulations based on the resulting R^2 (>0.90) of modeled vs measured streamflows. However, uncertainty analysis should be provided to fully assess the confidence range in the predicted water flows. The relative and absolute errors associated with water flow in Table 12 (above) appear larger than those apparent in Figures 5-4, 5-5 & 5-6.

3. Changing future irrigation practices may change surface vs ground water dynamics from agricultural fields, which might add increased uncertainty to the existing baseline calibrations. The change from gravity irrigation with tailwater exports to the SJR to drip/sprinkler irrigation with leaching of salts to groundwater flowpaths will likely change the dominant hydrologic flowpath from surface water to groundwater. Tailwaters affect SJR WQ relatively immediately while groundwater flowpaths have a significant lag time in reaching the river. Thus, salts transiently stored along the soil-vadose zone-groundwater-river flowpath will reduce salt exports to the river for some time period after which the salt load may increase once the groundwater lag time is exceeded. I found no discussion of possible lag effects associated with the modeling effort; does WARMF adequately capture the lag-time dynamics. Lag times and transient storage have been reported to range from several months to several decades. Lag time has been implicated as the reason for the slow response of riverine nutrient loads to considerable implementation of nutrient BMPs within a given watershed.

Example of references discussing lag time effects:

Hamilton, S. K. Biogeochemical time lags may delay responses of streams to ecological restoration. Freshwater Biol. 2012, 57, 43−57.

Bouraoui, F.; Grizzetti, B. Modelling mitigation options to reduce diffuse nitrogen water pollution from agriculture. Sci. Total Environ. 2014, 468−469, 1267−1277.

Meals, D. W.; Dressing, S. A.; Davenport, T. E. Lag time in water quality response to best management practices: A review. J. Environ. Qual. 2010, 39 (1), 85−96.

Sanford, W. E.; Pope, J. P. Quantifying groundwater's role in delaying improvements to Chesapeake Bay water quality. Environ. Sci. Technol. 2013, 47 (23), 13330−13338.

Sebilo, M.; Mayer, B.; Nicolardot, B.; Pinay, G.; Mariotti, A. Long-term fate of nitrate fertilizer in agricultural soils. Proc. Natl. Acad. Sci. U.S.A. 2013, 110 (45), 18185−18189.

Chen D.; Huang H.; Hu M.; Dahlgren R.A. Influence of lag effect, soil release, and climate change on watershed anthropogenic nitrogen inputs and riverine export dynamics. Environ. Sci. Tech. 2014, 48:5683–5690.

4. WARMF modeling result reliability: *"When the Planned Bundle pre-processed WARMF model results at Crows Landing are adjusted to match the timing and magnitude of historical EC levels, modeled results for all water-year types again fall below 1,550 µS/cm "*. This statement suggests that the WARMF model is not fully reliable in matching the actual riverine EC patterns (i.e., the results need to be adjusted). If this is true, then the model results have a higher uncertainty than acknowledged with respect to forecasting EC/B.

5. Is it possible to effectively simulate all management/treatment actions for salt reduction in the WARMF model accurately in time and space? Again, there is no uncertainty analysis associated with these management/treatment actions.

6. Does the model incorporate the >100 diversions and >100 discharge sites in the SJR (Kratzer and Shelton, 1998; Zamora et al. 2013)? While inflows from the discharge sites might not be large, they might have high salt concentrations and contribute a disproportionate amount of salt relative to their discharge volume. This may, in part, explain the lack of a better modeled vs measured EC relationship, especially in the vicinity of Crows Landing.

References discussing diversions/discharges along the lower SJR:

Kratzer, C.R., and Shelton, J.L., 1998, Water quality assessment of the San Joaquin-Tulare basins, California: Analysis of available data on nutrients and suspended sediment in surface water, 1972–1990: U.S. Geological Survey Professional Paper 1587, 92 p.

Zamora, Celia, Dahlgren, R.A., Kratzer, C.R., Downing, B.D., Russell, A.D., Dileanis, P.D., Bergamaschi, B.A., and Phillips, S.P., 2013, Groundwater contributions of flow, nitrate, and dissolved organic carbon to the lower San Joaquin River, California, 2006–08, U.S. Geological Survey Scientific Investigations Report 2013–5151, 105 p.
< https://pubs.er.usgs.gov/publication/sir20135151>

7. What assumptions were made about groundwater flows and chemistry?

Appendix A statement**: *Because WARMF calculates near-surface groundwater flow and chemistry as a function of watershed characteristics and model inputs, <u>groundwater data are not needed by WARMF and are not included in its database</u>.***

I interpret this to say that no measured groundwater chemistry and data-supported discharge/recharge rates were used in the WARMF simulations to estimate salt inputs from groundwater beneath the river channel. Rigorous spatial data are available from Zamora et al. (2013) who found dissolved inorganic N and DOC inputs from groundwater to represent 7 and 9% of instream loads, respectively. A digital dataset for EC, B and major cations/anions is available online from the Zamora et al. Prop 50 project. MODFLOW simulations estimated groundwater inputs of ~1 cfs per mile along the SJR. Given the often very high EC values (>5 dS/m) measured in shallow groundwater beneath the river channel it might be a significant source of salt/B. Several distinct salt/B hotspots were identified within various river reaches. Since the groundwater component has high model sensitivity resulting in high model output uncertainty, having the best available information for the groundwater component is warranted.

Zamora, Celia, Dahlgren, R.A., Kratzer, C.R., Downing, B.D., Russell, A.D., Dileanis, P.D., Bergamaschi, B.A., and Phillips, S.P., 2013, Groundwater contributions of flow, nitrate, and dissolved organic carbon to the lower San Joaquin River, California, 2006–08, U.S. Geological Survey Scientific Investigations Report 2013–5151, 105 p.
< https://pubs.er.usgs.gov/publication/sir20135151>

8. The EC of the DMC is likely to increase with an increase in the EC WQO as the SJR provides a significant portion of the salt load to the DMC waters. Has this potential increased in EC been incorporated into the model simulations? The model is highly sensitive to the salt concentrations in the DMC.

In sum, the WARMF model as applied has significant uncertainty in precisely supporting attainment of the EC WQO and in simulating the effects of management/treatment actions on riverine EC levels in Reach 83. However, the expected trends in riverine EC response from the management/treatment actions (based on a mass balance approach) are consistent with the model results.

2. It was appropriate to utilize the conservative, steady-state soil salinity Hoffman Model to calculate ranges of protective salinity criteria for irrigated agriculture in the Lower San Joaquin River Basin and work with local irrigators to determine appropriate parameter inputs to the model.

The steady-state soil salinity Hoffman Model is fundamentally sound for the purposes used in setting the agriculture-use salinity WQO. Crop yield salinity response is based on data relevant to the geographical area. Real-world leaching fractions were available from the EC of irrigation source waters and various subsurface drainages waters. The leaching fraction of 0.15 used in setting the WQO is relatively conservative compared to grower standard practices. Using almonds, a relatively salt sensitive crop, adds a further conservative aspect when applied to other common agricultural crops in the lower SJR Valley. The model development utilized a rigorous assessment of the literature and the existing data validate overall modeling results. The results obtained appear consistent with grower experiences.

The Extended Drought Criteria is a very good practical approach to deal with issues related to irrigation water availability in drought years. It provides reasonable flexibility with adequate protection for the environment, agricultural operations, and other potential beneficial uses. Survival of perennial crops is more important than loss of yield under these circumstances. The definition of extended drought conditions is rigorously defined to minimize controversy as to when these alternative criteria should be employed.

The modeling approach may demonstrate some uncertainties across different soil types. For example, soils with preferential flowpaths or impeded drainage characteristics may be more or less affected by the salinity of the irrigation source waters. These are site specific conditions that will need to be recognized and adjusted for by the grower.

In sum, the use of the steady-state soil salinity Hoffman Model is well supported by the documentation provided. It provides a defensible approach toward establishing the EC WQO for irrigation waters in the lower San Joaquin River basin.

3. Based on recent trend data, it is reasonable to expect that the proposed EC WQOs will be protective of the boron WQOs in the Lower San Joaquin River and that proposed implementation provisions will ensure long-term attainment of the boron WQOs.

Given simple mass balance calculations of B inputs from the San Luis Drain via Mud Slough, it would be expected that B concentrations should continue to fall and remain below the WQO for Reach 83. EC is an appropriate measure for the salinity WQO and it provides a reasonable surrogate for B with periodic confirmation that the relationship between EC and B is not substantially changed with management/treatment changes in the watershed. EC is easily measured in a continuous fashion at low expense and it should be possible to estimate B concentrations from established EC vs B ratios with reasonable accuracy.

There should be more verbiage on B throughout Section 5 of the main report; B information is relegated to Appendix C. The WQO values are provided in section 5, but it would be nice to see how the B WQO compares to simulated B values predicted by EC estimates from the WARMF modeled and/or historical results on a time series graphic. You are asking the reader to believe that there is no real concern for meeting the B WQO without providing the minimum data necessary in the main document for the reader to make an assessment. I suggest taking some of the graphical materials from Appendix C and placing them in Section 5 to support the discussion for B in the report's section 5.

EC has historically been a good predictor of B concentrations at a given monitoring site. However, these relationships may change with implementation of salt reduction strategies, especially removal of drainage waters from the Grasslands Bypass Project (GBP). As the correlation between EC and B at Crows Landing has been substantially decreased in recent years, there is a critical need to continue regular measurements of B across Reach 83 to verify the efficacy of using EC to predict B. Thus, a robust set of EC vs B measurements should be acquired as part of the early monitoring program (e.g., following elimination of inputs from the GBP). Appendix C recommends that B be measured throughout Reach 83 rather than just weekly at Crows Landing; I agree with this suggestion.

Monitoring efforts need to provide boundary conditions for Reach 83 (i.e., inputs and outputs). Thus, EC/B should be collected regularly above the Merced River (e.g., Hills Ferry) and at Vernalis to document inputs and outputs. It would be warranted to determine B on a weekly basis during the first year of implementation. If the EC vs B relationships are strong, sampling for B could be triggered by a threshold EC value that is expected to have B levels of potential concern. Implementing collection of samples for B only after a B WQO-exceedance has been detected at Crows Landing would delay collection of downstream samples by weeks (i.e., waiting for analyses to be reported) preventing documentation of the propagation of the B spike downstream from Crows Landing. Thus, I recommend B be collected at a weekly basis at all sites until reliable EC vs B relationships have been established, after which samples for B analysis could be collected only when EC values exceed a critical threshold of concern for B.

General comments related to the LSJR Draft Staff Report

I believe it is important to state what other water quality impairments (303D list) occur in Reach 83 of the SJR. Some additional context would be helpful in the introduction to indicated how the proposed salinity/B WQOs might relate to activities regarding Se, DO, nutrients, pesticides and other water quality impairments of concern in this river reach. Is it predicted that all water quality impairments will be beneficially affected by the management/treatment scenarios modeled in this document? It is necessary to state that other potential TMDLs are not in conflict with the salinity/B efforts. For example, higher EC waters (from the current 700/1000 µS/cm standard) may result in changes in nutrient concentrations (N, P) and less upstream flows (from GBP) might increase residence times affecting algal growth and related downstream DO issues. Less dilution may result in other pollutants becoming more concentrated resulting in enhanced aquatic toxicity issues.

Similarly, are the proposed salinity/B standards for Reach 83 fully compatible with standards for downstream Southern Delta Agricultural? The previous standards (700/1000 µS/cm) at Vernalis were set to be protective of Southern Delta Agriculture. Will a near doubling of the salinity WQO at Vernalis adversely affect Southern Delta Agriculture? A statement should be provided.

Please be consistent with use of µS/cm, mS/cm, S/m and dS/m throughout the document. It can be very confusing to constantly have to convert the units to make relevant comparisons. There might be a few errors in the units used; please verify bottom of page 40 – should be mS/m or dS/m?? & page 159 & 161 should be mS/cm or dS/m??

Section: 5.4.2.6 – Should the 2270 µS/cm value be 2470 µS/cm?

Section: 5.5 Selection of Preferred Alternative – *"... provide the greatest operational flexibility to export salts out of the basin while promoting the best possible water quality for the protection of both the AGR and the MUN beneficial uses…"*. The term "while promoting best possible" seems misleading here; you could certainly provide even better water quality for protection of AGR and MUN beneficial uses with additional management/treatment practices. I suggest replacing with the phrase "while providing acceptable water quality".

The Real Time Management Program (RTMP) is an important aspect and insurance policy for meeting the WQO at Vernalis. It also provides an excellent data set for salt moving through Reach 83 and the potential upstream sources. An integrated water quality monitoring program will all the relevant partners would provide substantial cost savings. It seems like most of the EC monitoring infrastructure is already in place.

Section 8 (Economic) - In addition to providing the total cost of various actions, it would be helpful to provide an estimate of cost per ton of salt removal as the cost per ton of salt removal may be very different among various actions (cost:benefit analysis). A high cost is warranted if it results in removal of a large salt load. This analysis also provides a cost estimate for trading "salt credits". In addition, actions such as reverse osmosis will remove other potential pollutants (e.g., nutrients, pesticides) that provides added value for these actions.