Regional Water Quality Control Board
Central Valley Region
Board Meeting – 31 May/1 June 2018

Response to Peer Review Comments on Proposed Amendments to Incorporate a Salt and Nitrate Control Program Into the Water Quality Control Plans for the Sacramento and San Joaquin River Basins and the Tulare Lake Basin

An external peer review is a legal requirement of the Basin Planning process for scientific findings, conclusions or assumptions that establish a regulatory standard for the protection of public health or the environment. The peer review panel is made up of independent scientific experts.

This document presents responses to the comments received from two peer reviewers on the Central Valley-wide Salt and Nitrate Management Plan (SNMP) which served as the technical basis for the proposed Salt and Nitrate Control Program Basin Plan Amendment and its associated Draft Staff Report. The conclusions being evaluated were based on seven scientific reports and three additional reports that documented models used to develop the SNMP. The main conclusions and their supporting minor conclusions were:

1. Annual salt accumulation must be addressed with an Out-of-Valley solution.

    a. Data generated by the Watershed Analysis Risk Management Framework (WARMF) watershed modeling tool used in conjunction with the USGS Central Valley Hydrologic Model (CVHM) was appropriate to evaluate ambient groundwater quality and changes in groundwater quality within the Central Valley and resulted in assumptions regarding import and export of salt that were reasonable estimates for the Central Valley.

    b. The management options identified to treat and dispose of the annual salt accumulation included a reasonable range of feasible treatment and disposal measures that can be implemented in the Central Valley.

    c. A brine line is the most reasonable alternative to remove excess salt accumulation in the Central Valley.

2. Nitrate contamination in some locations may not be reasonably treated to achieve drinking water quality. Geology and nitrate concentrations in some locations are conducive to restoration. Reduction of nitrate levels in groundwater is possible in certain geologic settings (sandy soil conditions and relatively shallow groundwater levels). However, even with significant restoration activities, it may take 40 to 70 years to achieve drinking water standards in groundwater, and in some cases, even longer.

In addition to the review of these conclusions, the reviewers were invited to provide general comments on the reports.

The peer reviewers are listed here:

- Dr. Vijay Singh, Distinguished Professor[1], Department of Biological and Agricultural Engineering, Texas A & M University
    - Responded to all main conclusions and supporting minor conclusions
    - Provided general comments

- Dr. Thomas Harmon, Professor, School of Engineering, University of California Merced
    - Responded to 1 main conclusion and 2 of 3 sub-conclusions and supporting minor conclusions
    - Provided general comments and document review comments.

Direct quotes from a reviewer's comments are provided in "*italics".*

Comments and Responses on Main Conclusions and Supporting Minor Conclusions

Comments on Conclusion #1: Salt Accumulation must be Addressed with an Out-of-Valley Solution.

Dr. Singh indicated that, "*based on the documents provided, this conclusion seems reasonable. However, In-Valley solutions must not be discarded outright. The In-Valley solutions may include reducing the influx of chemicals in agriculture as well as reducing the sources of salts coming to the valley. Reducing the salt through wastewater and other sources is admirably discussed in the report. However, greater emphasis and effort must be put in to stem the flow of salt at the source itself. Likewise, greater use of organic manure, such as compost, can significantly reduce the use of chemical fertilizers in agriculture. The use of organic manure is already on the rise. There can be other others to reduce the sources of salt. In other words, in the long run it will pay rich dividends to solve the problem at the source rather than creating it in the first place and then solving it."*

> Response: Support of the main conclusion noted, and staff appreciates that Dr. Singh recognizes the need to address salt sources. The largest influx of salt into the Central Valley comes from the consumptive use of imported surface water for agricultural irrigation use. This consumptive use cannot be completely stopped without significant impact to the sustainability of agriculture within the Central Valley. However, improved irrigation efficiency and reuse is recognized as part of overall salt management for the valley and one critical component of source control. The proposed Salt Control Program's measures to address salt accumulation include both Out-of-Valley solutions as well as In-Valley measures such as source control, reduction in use of synthetic chemicals through implementation of best management practices, sequestering of salt in salt management areas, etc. However, based on initial analyses, In-Valley options can only address a portion of the salt necessary to be managed to bring balance within the Central Valley. An Out-of-Valley solution is therefore necessary to handle the remainder.

Dr. Harmon made no direct comment on Conclusion #1, but commented on minor conclusions #1.a. and #1.c., and supported the minor conclusions.

[1] Dr. Singh also holds the following titles: Regents Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, President, FARA, President, G.B.S. Board, Editor-in-Chief, Water Science and Technology Library Bookseries, Editor-in-Chief, Global Water Resources Book Series, Editor-in-Chief, Journal of Ground Water Research and Editor-in-Chief, Open Agriculture and Editor, Journal of Agricultural Research

Comments on Minor Conclusion #1a: Models utilized provided reasonable estimates of ambient groundwater quality, trends and flux.

Dr. Singh stated that, "*Data generated by the WARMF watershed modeling tool used in conjunction with the USGS CVHM and SWAT model was appropriate to evaluate ambient groundwater quality and changes in groundwater quality within the Central Valley and resulted in assumptions regarding import and export of salt that were reasonable estimates for the Central Valley."*

Response: Support of Conclusion 1a noted.

Dr. Harmon concluded, "*... the WARMF-CVHM approach was appropriate for estimating the salt and nitrate balance in the Central Valley, and that the simulated data produced by this modeling approach provides an appropriate approximation to the Central Valley horizontal and vertical variability in groundwater quality."* Dr. Harmon did note that both the CVHM and WARMF models have uncertainty that varies spatially in the Central Valley and that the integrated modeling product is likely more uncertain than either of the model simulations individually. He also indicated that while, the combined modeling product was not rigorously calibrated nor validated, rigorous calibration is probably not possible given the variability and uncertainty in historical groundwater quality data, and therefore validation is not possible. However, because there was a reasonable effort to compare simulated salinity (TDS) and nitrate with historical observations, and these produced reasonable outcomes for TDS, a conservative solute, but not so much for nitrate, a reactive solute (as he would expect), he concluded that the WARMF-CVHM approach was appropriate for estimating the salt and nitrate balance in the Central Valley.

Dr. Harmon made two recommendations:

- *"As suggested in the reports, it would be preferable to create the dedicated modeling tools necessary to avoid the need of integrating results from different models that were created for different regions and perhaps different spatial resolutions. The SWAT-CVHM-MT3DMS modeling approach is a good step in that direction.*

- *Defining the capacity and strength of the salinity and nitrate sources in the vadose zone is central to the modeling effort, but also challenging. In general, estimates of groundwater restoration times will be very sensitive to source zone characteristics. That issue is true for the ICM case, and adds significant (possibly large) uncertainty to the modeling scenarios. At this time, I do not have a good idea for how to efficiently characterize and model these vadose zone source at a meaningful scale for the modeling approach used, but I believe it is possible and important to identify some field tests and modeling approaches to do so."*

  Response: Support of conclusion 1a noted. Dr. Harmon's comments regarding uncertainty are correct, but, as he noted, rigorous calibration of the integrated models may not be possible due to the variability and uncertainty of the historical data and therefore validation is not possible. However, as he also noted, there was reasonable effort in comparing simulated TDS concentrations to observed TDS date with reasonable outcomes, but nitrate simulated data were poor in comparison, which was to be expected due to TDS being a conservative solute that doesn't change in transport, while nitrate is a reactive solute that undergoes transformation during transport.

Dr. Harmon's recommendations will be considered in future studies within the Priority and Optimization Study, as well as in the periodic re-assessment of groundwater quality within the Central Valley that is required in the proposed Surveillance and Monitoring Program. However, vadose zone influences may not be able to be reasonably ascertained due to significant spatial and temporal variability.

Comments on Minor Conclusion #1b: Reasonable range of management options were identified to treat and dispose of annual salt accumulation.

Dr. Singh stated that, "*[t]he management options identified to treat and dispose of the annual salt accumulation included a reasonable range of feasible treatment and disposal measures that can be implemented in the Central Valley."*

He also indicated that the management options employed in the studies encompass a broad range and are quite comprehensive in that they cover a viable range of practical treatment and disposal measures and that it is hard to think of other measures than what is already included in the plan.

Dr. Harmon did not review the documents describing various alternatives.

Response: Dr. Singh's comment supporting Conclusion 1b noted.

Comments on Minor Conclusion #1c: A regulated brine line is the most reasonable alternative to remove excess salt accumulation.

Dr. Singh stated that, "*[t]his conclusion seems reasonable but there can be other alternatives that do not permit the accumulation of salt in the first place. Such alternatives should be explored. Until then, the conclusion is acceptable."*

Response: Support of Conclusion 1c noted. As part of the Salinity Control Program, a Priority and Optimization Study (P&O Study) is to be carried out during the first 10-year phase of the program. During this study work, additional salt management alternatives, such as alternatives that can prevent the accumulation of salt, will be evaluated as components of the final overall salt management implementation plan. (See also response to main Conclusion 1.)

Dr. Harmon stated that, "*[b]ased on Task 5 and Tasks 7 & 8 Reports, I was able to understand the sustainability problem stemming from the Central Valley's historical salt balance. If the plan is to sustain the Central Valley land use and land management practices as they stand today, then I agree that a brine line is likely to be the most reasonable alternative*."

Dr. Harmon recommended:

- *"If the SNMP is to serve California for the next 50-100 years, a more comprehensive study is more appropriate, one that employs a broader systems approach, extending to least to all of California (including coastal waters) but preferably expanding to a global perspective. There are several reasons why an expanded approach makes sense:*
    - *The Central Valley population will be increasing over the next several decades, and the resulting water demands and land use changes are likely to be substantial and important to consider;*

- *Environmental costs of engineered solutions (such as a brine line) can be better considered using a systems approach, including costs that may need to be passed along to state agencies, agricultural producers, and consumers; and*
- *A still broader perspective (international) considers markets for Central Valley products (and the water footprint they represent), including potential markets for salt-based products."*

Response: Support of Conclusion 1c noted. As Dr. Harmon indicated, the proposed Salt Control Program is designed to address sustainability within the Central Valley at the current level of land use and management practice implementation. However, as the overall program is to be an adaptable program, the program is to be periodically reviewed and adjusted, if necessary. Dr. Harmon's recommendations could be considered at the future reviews, should land use and management practices change significantly from the current levels. In addition, the propose Salt and Nitrate Control Program includes recommendations to other agencies throughout California to encourage broader engagement in the overall effort including equitable distribution of costs and evaluation of market based solutions.

Comments on Main Conclusion #2: Nitrate Contamination in some Locations may not be Reasonably Treated to Achieve Drinking Water Quality and Restoration is a Long-Term Venture.

Dr. Singh stated that, "*[g]eology and nitrate concentrations in some locations are conducive to restoration. Reduction of nitrate levels in groundwater is possible in certain geologic settings (sandy soil conditions and relatively shallow groundwater levels). However, even with significant restoration activities, it may take 40 to 70 years to achieve drinking water standards in groundwater, and in some cases, even longer. This conclusion is very reasonable and is based on sound geological considerations and can be accepted without dispute."*

Response: Support of conclusion noted.

Dr. Harmon stated that, *"[t]he Aggressive Restoration modeling scenarios demonstrated that aquifer restoration in the Central Valley is a long-term venture in most cases. I believe that the simulations clearly demonstrated this but, it is worth noting, large-scale aquifer restoration such as is addresses in these reports is always a long-term venture. Chemicals which have been given many decades to enter and disperse in the subsurface require many decades to extract. Given this general observation, the following points are intended to address the issue of groundwater nitrate restoration more directly.*

- *In some cases, it may be possible to restore and maintain drinking water quality in the aquifer. However, as noted above with respect to vadose zone source zones, restoration potential and duration is strongly connected to the continued irrigation and fertilization practices. This issue was evidenced by the steady-state nitrate concentrations that resulted in many of the aggressive restoration simulations. In these simulation, nitrate-contaminated groundwater is extracted and treated, but "replacement" nitrate leaches from the soil to the aquifer or moves from the upper to lower aquifer layers. The long-term result is steady nitrate concentrations in the aquifer. Ideally, modified fertilization practices would reduce the loading on groundwater and result in either acceptable steady-state or even decreasing nitrate levels.*

- *Some interesting outcomes of the aggressive restoration scenarios had to do with providing a reliable drinking water supply for DUCs and DACs in the Central Valley. While some cost estimates were provided, it was not clear if they were considered manageable or excessive. From this perspective, if the costs are manageable then perhaps some form of the pump, treat, and serve option is the best with respect to Goal 1 (safe drinking water). With this goal met, attention could focus on Goals 2 and 3. In connection to a broader systems approach, planning for population increases in regions where it is may reduce long-term costs by providing economy of scale in what are otherwise relatively small-scale treatment systems.*

- *Again in the context of drinking water treatment costs, it would be interesting and informative to know if there were alternative cost-sharing models that would make various alternatives more or less competitive. For example, could treatment costs be shared by agricultural producers, suppliers, and consumers (i.e., inclusion of environmental costs of food, water, energy)."*

  Response: Dr. Harmon supports the conclusion that restoration is a long-term venture and notes that restoration is a long-term process that is closely tied to the levels of loading to the groundwater that is occurring during the restoration activities – including loading from ongoing fertilization as well as residual loading from the vadose zone. The SNMP and resulting Salt and Nitrate Control Program acknowledge this by incorporating Goal 2 of the overall program, to balance salt and nitrate loading to groundwater, so that it does not continue to contribute to the problem. This goal is implemented through the permitting of non-point source dischargers through the ILRP and its Nitrogen Management Plan program, and through the issuance of Waste Discharge requirements for point-source dischargers. These programs are designed to minimize discharges to a level that can be sustainably managed, while being protective of groundwater beneficial uses and taking the first step toward restoration (Goal 3).

  Where applicable, groundwater restoration activities may include pump treat and serve in conjunction with reductions in salt and nitrate mass loading to groundwater through implementation of the ILRP and WDR programs. Restoration activities will be based on local geologic conditions, as well as what makes technological and economic sense in terms of safe drinking water supply for impacted communities and individuals, including DACs and DUCs.

  With regards to cost, the currently proposed Nitrate Control Program, using Management Zones, is designed to allow for pooling of resources and for sharing of costs among the involved dischargers for providing safe drinking water to impacted users and implementing long-term restoration activities where feasible, reasonable and practicable.

General Comments and Responses

Dr. Singh's General Comments.

"All things considered, the work reported in the seven scientific studies is quite comprehensive and is based on solid science. The models used are state-of-the art and the analyses, including cost estimates, reported are commendable. Conclusions reached are acceptable. However, alternatives for mitigation of salt and nitrate loading which do not permit salt accumulation and

nitrate loading in the first place should be explored. Until such alternatives become feasible, the proposed measures seem viable. Overall, the work is well done."

> Response: Support noted. As indicated previously, additional salt and nitrate management alternatives shall be further developed and evaluated during the P&O Study, including potential alternatives that prevent salt accumulation and nitrate loading of groundwater, as source control must be a component of the overall long-term salt and nitrate management strategy for the Central Valley.

Dr. Harmon's General Comments

"The study is based on sound scientific knowledge, methods, and practices for the study area (i.e., the engineering control volume) as defined. The results indicate that groundwater restoration in the Central Valley is a challenging and long-term prospect, at best, and infeasible without substantial reductions in salt and nitrate loading or major investments (such as treatment facilities and brine lines). The study appears to be premised on the need to sustain the current land use and land management practices in the Central Valley. In short, the study's "big picture" question is whether we need to re-engineer the Central Valley's salt balance to maintain the region's current agricultural enterprise. Based on the resulting appraisal of the Central Valley's salt and nitrate balances, I agree that the answer is yes.

Given that a broader study would require a larger and more costly effort, a more sound scientific approach would address the greater system. Such a "bigger picture" perspective would enable California to consider if re-engineering the Central Valley's salt balance is sufficient and if it is desirable or whether it might lead to other major problems. This would require identifying an SNMP (a more complex socio-environmental problem) that is technically feasible as well as food-water-energy smart, economically beneficial, and socio-culturally acceptable. This is obviously a much more challenging problem that will require a broader, multiple objective approach focused on optimizing state natural resources and their services to a broad range of Californians. Tackling such a problem will require envisioning changes in agricultural technology, climate, population and demographics, land use, and more."

> Response: Dr. Harmon agrees that the overall study is based on sound scientific knowledge, methods and practices. His agreement is noted. As for the conducting of a larger and broader study, the CV-SALTS initiative to develop the SNMP and the resultant Salt and Nitrate Control Program was designed to be a broad study that envisions changes in agricultural technology, climate, population demographics and land use. The developed programs are to be dynamic, with periodic reviews to assess new technologies, changes in land use, climate, population demographics and program effectiveness in order to sustain a strong agricultural economy, while ensuring safe drinking water supply, protecting current and future groundwater and surface water beneficial uses and, where feasible, reasonable and practicable, restoring impacted groundwater supplies. The proposed amendments recognize the need to engage stakeholders throughout California to collaborate in any long-range management solutions and have included recommendations to other federal, state and local agencies including recommendations to the California State Legislature.

Additional Recommendations

In general, both reviewers agreed that, based on the existing data available for the foundational analyses performed in support of the SNMP and the resulting Salt and Nitrate Control Program,

the conclusions were reasonable and based on sound science methods, practices and principals. Additional report-specific comments were submitted by Dr. Harmon regarding future work that should be considered to further strengthen the foundational analyses and modeling as the program moves forward. His comments are presented with staff responses in Table 1 below. These comments will be provided to the third party conducting future studies relating to the Salt and Nitrate Control Program.

Table 1 – Additional - Comments on Technical Reports to Support Future Activities (Dr. Harmon)

Comment	Staff Response
ICM TASK 5 REPORT	
Section 1, Page 1	
The goal of Task 5 is to describe the Initial Conceptual Model (ICM) methodologies for assessing water, salt, and nitrate balances throughout the Central Valley. The resulting ICM will support Phase 2 work which will provide "refined, interconnected spatial detail" in subsequent modeling and planning efforts. This phased approach is a reasonable, and the resulting ICM appears to be based on input from relevant stakeholders intimately familiar with the problem.	Comment noted.
The ICM is relatively detailed and quantitative for a conceptual approach, and the details are difficult to appreciate in a concentrated review period. What is apparent is that outputs from several complex, spatially distributed models are to be integrated in the resulting ICM. From a hydrologic and mass balance perspective, the approach is reasonable. However, the section would benefit from some assurances as to how the ICM approach is going to be validated (or "reality-checked"/tested in the event that rigorous validation is not possible) would help to solidify this section by setting a target in addition to the scope (such as in reference to section 4.3).	As noted in overview comments, submitted 18 April 2018, validation of the modeling in a study area as broad and diverse as the Central Valley is difficult, if not impossible. Additionally, the ICM was used as a broad, initial review. A subsequent High Resolution groundwater analysis, performed on a DWR basin/subbasin basis, was ultimately utilized for prioritization of the Nitrate Control Program and for spatial analysis of ambient groundwater salinity for the Salt Control Program.
Section 1, Page 2	
"…on a 30,000-foot level" is a vague expression that is used repeatedly and likely has some specific contextual meaning to the report authors. Yet the ICM is a fairly detailed approach, so it would be good to define what is meant by this expression.	A 30,000-foot level means a high level conceptual overview, not a detailed plan.
The significance of the selected 20-year evaluation period is not clear to the reader at this point, and a brief explanation would improve this introductory material.	Comment noted. The 20-year evaluation period was selected to represent a general planning horizon that most County General Plans adhere to.

Section 2.2, Page 7	
Methods of detecting bias is an important part of the methodology and several relevant and potentially important sources of bias are described. Were issues encountered and addressed regarding method detection limits and historical changes in same? This issue is addressed in Tasks 7 & 8 (p 4-4) but should be included in the list of potential sources of bias.	Duplicate data were removed during the QA/QC process (see ICM Final Report, Page 3-9, which details the thousands of duplicate data points removed from the analysis). Many different laboratories and data sources reported various detection limits for the same analyte, sometimes not reporting a detection limit at all. Over time, the detection limits sometimes decreased for certain constituents. In order to still utilize non-detected values in the analysis of ambient groundwater quality, a value of 0.1 mg/L NO3-N and 10 mg/L TDS were used. In a later study, an analysis of historical groundwater data was performed to assess current ambient groundwater quality within the Central Valley in order to prioritize where to first implement the Salt and Nitrate Control Program. Prioritization of where to implement the control program, specifically the Nitrate Control Program, utilized a later, high resolution analysis that evaluated ambient nitrate concentrations in groundwater for each of 43 groundwater basins/sub-basins within the Central Valley (Department of Water Resources defined basins/sub-basins). Breakpoints for the basin/sub-basin prioritization ranking were above 1 mg/L nitrate, so the bias associated with the use of the 0.1 mg/L nitrate detection limit for non-detect data points did not affect the overall prioritization work.
Table 1	
The Data/Decision matrix is a good idea that supports objective sorting of the model outcomes.	Comment noted.

Section 4, Page 19	
"…a net mass recharge to groundwater is determined." Recharge may not be the correct word choice. Recharge pertains to water flow/flux to groundwater, not nitrate or salts, which is more often referred to as mass loading.	Comment noted.
Section 4.1.1, Page 20	
If I follow the method, then the vertical groundwater velocity is estimated using Darcy's Law, with the vertical hydraulic conductivity estimated from CVHM material properties. This is an important aspect of the water, salt, and nitrate balance calculations. I am not an expert on CVHM, but I recall that the material property distribution is texture-based, and a geostatistical realization based on many borehole logs (and possibly other hydrogeologic data). In this context, the realization may be optimized with respect to the overall groundwater dynamics in the Valley, and may be more/less consistent with local values in different regions of the Valley. Was this considered in the method development? For instance, it seems that the 20-year travel zone estimates could easily be off by a factor of 1.5 or 2 based on the difference between the geostatistical conductivity field and an estimate based solely on local values.	Due to the large regional scale of this analysis, the texture-based spatial distribution of vertical hydraulic conductivity was determined to be sufficient for estimating the vertical 20-year travel distance. Using the texture-based approach allowed for spatial variability in the estimated 20-year travel distance (and therefore mixing zones) within each IAZ (in other words, the bottom of the 20-year zone for each IAZ was not uniform), which takes into consideration both regional patterns and local patterns in textural variability. Additionally, the 20-Year Travel time was not carried forward into final Salt and Nitrate Control Program. The 20-year time frame was superseded by the use of ambient nitrate concentrations for prioritization of the nitrate permitting strategy implementation and ambient salt concentrations for the conceptual salt management strategy, estimated in a subsequent, higher resolution groundwater analysis based in DWR basins and sub-basins.
Section 4.1, Water Balance	
With CVHM as the hydrologic driver, it would be valuable to incorporate its uncertainty into the ICM methodology. For instance, Figure C17 from Flaunt et al. (2009) suggests that there would be significant uncertainty in the lithology and hydrogeological properties (as would be expected with any such modeling effort). This may be beyond the scope of the ICM, but the subject may merit some discussion with regard to sources of error or uncertainty in this effort.	Comment noted. Although utilized for the high-level evaluations, continued effort on validation and uncertainty associated with this analysis were some of the reasons why the project moved in a different direction in the final phases of this effort (use of the High Resolution Groundwater Analysis to prioritize implementation of the control programs.).

Section 4.1, Page 29	
As the report states, WARMF model domain assumes zero leakage from stream segments (except for some segments of the San Joaquin R), and it is assumed that CVHM stream leakage is correct. Given the connection between WARMF and CVHM in the ICM approach, it would be good to call out potential discrepancies like this with regard to their potential impact on the ensuing calculations.	Comment noted. The ICM results were developed to represent a high level conceptual view. The Prioritization & Optimization Study component of the proposed Salt and Nitrate Control Program will be developing a more detailed conceptual design for managing accumulating salt, including a more refined salt accumulation estimate.
"The quality of this recharge is likely similar to other stream recharge and would likely tend to be more concentrated…" Please explain or provide a reference for this statement.	The assumption is that a gaining, open interceptor drain-type stream would be more concentrated in salts and nitrates than the groundwater it overlies due to the stream receiving direct ag drainage, which is influenced by evapotranspiration and any applied soil amendments, resulting in higher concentrations of salt and nitrate compared to underlying groundwater that has been diluted by the aquifer body. This is further compounded by the effect of groundwater, which typically contains more salt and nitrate than storm water, leaking into the drain (attribution), the drains already higher salinity and nitrate concentration (due to the interception of agricultural drainage) and evapo-concentration of the drain waters. This scenario occurs in broad areas of the Central Valley, in particular, the northern part of the valley and was utilized where appropriate.
"For the IAZs where this is relevant, this effect will be noted as one for the approximations in the current salt and nitrate balances." This sentence needs attention. An effect should not be described as an approximation – perhaps "assumption" or "source of uncertainty."	Comment noted. We agree, “source of uncertainty” is probably a better representation of the meaning of this sentence.
Section 4.2, Page 36	
As the report states, there is no accounting for vadose zone thickness and recharge simply applies the salt and nitrate loads directly to the shallow aquifer. The report also appropriately points out that this could be an issue where depth to groundwater is very large. I few more sentences would be good here to point out potential regions in the model where this might be the case.	Comment noted, and comment will be provided to the entity tasked to perform the future Prioritization and Optimization Study.
Section 4.3.2, Page 44	
These paragraphs a largely redundant with earlier discussion of nitrogen reactive transport and could be compressed.	Comment noted.

ICM TASK 7 & 8 REPORT	
Section 4.2, Page 4-4	
The large spike of log(C) for nitrate (Figure 4-3) points to bias by the detection limit assignment of 0.1 to many concentrations.	Comment noted. In a subsequent high-resolution analysis, the median value for wells were averaged within 1 square mile sections and then utilized to calculate a volume weighted average for each of 43 Central Valley, DWR-defined, basins and sub-basins. This work was utilized to prioritize implementation of the Nitrate Control Program; therefore, the bias doesn't affect the overall results. See response to comment on ICM Task 5 Report, Section 2.2, Page 7
Section 4.2, Page 4-7	
For CVHM model regions that demonstrate upward pressure gradients, and is there well data supporting this (from prior work)? It would be good to point this out in support of CVHM, which is being accepted as the flow driver in the ICM effort.	Comment noted.
Figure 4-4, Table 4-1	
The trend analysis outcomes reported in Table 4-1 would be more meaningful if the statistical criteria for the descriptors (R^2, p-value). For statistically significant trends, a comparison of slopes might provide additional information about whether rates of change are similar in different regions of the Valley.	Future trend analyses will be conducted as part of project evaluation and the comments noted here will be considered.
Were observed groundwater quality data trends tested on subsets of the timeframe, such as during drier and wetter periods? This might also yield additional information about water quality and hydroclimatic conditions.	This was not the goal of this effort – the study period for which the average hydraulic conditions were developed contained drier and wetter periods, but the large-scale overall movement of water, salt, and nitrate were the focus of the IAZ analysis. Groundwater quality trends were determined and estimated in a later effort with the High Resolution work report, where groundwater quality was evaluated on a 1 mile x 1 mile spatial grid, including decadal summaries, but not necessarily focusing on wet or dry climatic periods.
Section 4.2	
Were the groundwater quality data tested for spatial correlation, or were the wells overly clustered to allow for this type of analysis?	Yes, the data were declustered spatially and temporally.

Section 5, Sample Calculation and Figures 5-5 and 5-6	
The mass apportioning mechanism is a key aspect of the CVHM-WARMF model connection. An example calculation is used to demonstrate that salt mass is conserved when apportioning mass from WARMF to CVHM. There is a substantial difference in the hydrology with CVHM producing much larger recharge rates compared to WARMF. Thus, the same salt mass results in a concentration (TDS) that is about 3 times lower in the mass re-apportioned model. If we believe WARMF salt mass estimates and take CVHM as a more complete hydrologic model, then the lower estimates would seem to be a more accurate depiction of reality. The report would be improved if there was some validation of this point using observed salt levels. However, I recognize that the groundwater quality data may be too uncertain to support this type of validation.	Due to the high-level conceptual nature of this work, and, as pointed out, the uncertainty of the groundwater quality data, validation of the salt mass to modeling results was not able to be accurately determined and as noted may not be reasonably possible.
Section 5, Page 5-15 & Section 8.2	
"The groundwater recharge flows used in the WARMF-CVHM linkage were higher than the correct flows show in Figure 5-5…" The errors introduced by this issue are presented in section 8.2 (Table 8-3) for most of the IAZs. How were excess salt and nitrate masses estimated, and why not show all the IAZs? Were subsequent analyses corrected based on these error estimates?	The effort at the Central Valley scale was unprecedented at the time of this work to understand salt and nitrate balances at that scale. As with the groundwater flow models at the Central Valley scale (such as CVHM and C2VSim), a local model provides superior resolution and understanding of the physical system and hydrology. Therefore, for the P&O study, local models will help provide the needed higher resolution for salt management purposes.
S**ection 6, Page 6-1**	
The beginning of section 6 states that "specific analyses were added to the originally planned work to bracket uncertainty…" but the scope of these analyses were difficult to identify in the remainder of the section. It would be good to clarify where uncertainty was being addressed, such as where ranges of values were tested or multipliers were employed.	The current report has been finalized. However, future work will consider this recommendation.

Section 7, Figure 7-2, Page 7-1	
The results here focus on the 20-year modeling period. Has there been analysis of the results with respect to inter-annual variation or seasonal? It may be good to identify key climatic conditions when the groundwater is more/less vulnerable to salts/nitrate.	The IAZ water, salt, and nitrate balance calculations were performed on a quarterly basis for a 20-year period for each of the 22 IAZs. This would contain seasonal variability in all flux components (recharge, lateral flow, pumping, surface water deliveries, etc.). Climatic conditions were not the focus of this analysis, because overall trends and a determination of historical and future salt and nitrate trends and fluxes between IAZs were of greater importance on such a large scale. Additionally, while originally considered, data was too limited in much of the Central Valley to refine to seasonal variations. The concept may be revisited as the project moves forward with expanded data set (P & O Study and SAMP).
Section 7, Figure 7-3, 7-4 and 7-5	
The "track the mass" figures are quite informative, and should provide good ICM-level support for more refined modeling efforts	Comment noted.
Section 7, Figure 7-6	
As with Figure 7-2, it would may be informative to examine temporal behavior of various mass in/outflow terms.	Comment noted. See response above
Section 7, Figures 7-7 and 7-8	
The shallow groundwater quality estimates are highly sensitive to the loading scenarios. These issue is also connected with differences between WARMF and CVHM recharge values, as well as with neglecting vadose zone effects on mass loading. Are the loading scenarios intended to address all of these uncertainties?	The purpose of the nitrogen and TDS loading scenarios is to address ranges of the uncertainties and provide “book-end” estimates. Nitrate loading scenarios were meant to reflect anticipated reduction in nitrate loading to groundwater through implementation of the Irrigated lands regulatory program's nitrogen management plan program. The scenarios were not able to account for legacy nitrate within the vadose zone.
Section 7.4	
The starting and final masses of TDS and nitrate would be interesting to compare with historical changes in observed values	Comment noted.
Section 7, Figures 7-19 and 7-20	
These figures seem to be very important, but are difficult to read and interpret. The report does not provide much in the way of conclusions regarding these figures. Is the general conclusion that the groundwater quality data is too variable for meaningful comparison with the IAZ-level simulated values?	Yes, the data was too variable. These figures were used to look at various loading scenarios based on nitrate uptake efficiencies for nitrate and 200% of assumed TDS loading, assumed TDS loading and 50% of assumed TDS loading versus median shallow groundwater concentrations to see what scenarios most closely matched the median concentrations in the IAZs groundwater. Nothing seemed to correlate very well for any of the IAZs.

Section 7, Figures 7-24 and 7-25	
The prioritization outcomes appear to be reasonable for the ICM and ambient data.	Comment noted.
Section 7.7	
The conclusions that the IAZ-scale analyses are inadequate for characterizing large scale and local scale salt and nitrate conditions, and for supporting detailed local salt and nitrate management activities is consistent with the results presented. However, the ICM effort does represent a useful, high level approximation of Central Valley conditions, and can be refined with modest model developments and regular groundwater monitoring efforts.	Comment noted.
Figures 9-15 and 9-16	
The agreement between simulated and observed concentrations for the refined Modesto area model was quite poor. Results in Appendix H are more promising, but point to the lack of water quality data for validating such models. Do subsequent work plans include regular groundwater quality monitoring (perhaps on a quarterly basis), or do budgets not allow for this?	The program was to utilize existing data only. Limited data was noted throughout the project, but future efforts will include new data through the Surveillance and Monitoring Program data.
Section 10.2	
The development of post processing databases is a major advancement and laudable accomplishment in this Phase I effort.	Comment noted.
The IAZ approach adds value to the current salt and nitrate problem in the Central Valley by creating a relatively objective approach to identifying hotspots and assimilative capacity in the Valley groundwater.	Comment noted. This was the initial analysis step, but ultimately the project needed to go to the more detailed High Resolution analysis that assessed groundwater quality in Department of Water Resources (DWR) defined basins and sub-basins within the Central Valley.
Nitrate Implementation Measures Study (NIMS)	
Goal 1	
The stated most immediate management goal appears to be achievable in the short-term through treatment of nitrate-impacted groundwater. As subsequent analyses point out, pump-and-treat will not restore groundwater quality quickly, or ever if land application of nitrogen continues unabated. However, pump-and-treat can provide drinking water to local entities, thereby achieving Goal 1. Why not achieve Goal 1 first, then worry about groundwater remediation after the legacy and land application management problems have been addressed?	The three goals of the SNMP and resulting Salt and Nitrate Control Program include all three, and are prioritized in the order noted. Safe drinking water is the highest priority, but balancing loading and restoration are still necessary to protect current and future beneficial uses and to move toward restoration of impacted areas (where feasible, reasonable and practicable).

General Observation	
While the approach is systematic, it is relatively simplistic (probably due to timelines and budgets). More detailed approaches will be executed at the IAZ (more local) scale. This may be fine as long as a regional plan is in effect. How will a collection of local solutions be checked for their regional synergy (as opposed to interference)?	Part of the Nitrate Permitting Strategy requires coordination among Management Zones within the same basin/sub-basin, with Groundwater Sustainability Agencies (GSAs) within the basin/sub-basin and with entity responsible for the Salt and Nitrate Control Program's Surveillance and Monitoring Program. Regular reviews on a sub-basin scale are also required.
Alternative Scenarios	
One alternative not mentioned in the report is providing drinking water from surface water sources. Was this considered or was it ruled out due to clear treatment cost differentials (e.g., filtration, chlorination)?	This alternative was not considered as the report was focused on groundwater restoration. The purpose of the referenced section was not to identify and evaluate alternatives for obtaining safe drinking water. The purpose was to evaluate alternatives to restore groundwater in the Pilot Study area to 10 mg/L. The analysis included using the treated groundwater for beneficial use. There are other studies looking at this alternative through other agencies and programs, such as the State Water Resources Control Board's Division of Drinking Water.
Section 5.1, Page 5-1	
"Nitrate is higher on the east side…principally from agricultural practices." Soil types and lithology also contribute to these circumstances. Given this, and given the long-term perspective of the CV-SALTS effort, is it worthwhile to consider some type of land use policies that might "rearrange" the Central Valley activities to maintain productivity in a more sustainable manner?	The SNMP recognizes that land use planning will be a major component for long-term solutions, however, land use is outside of the Regional Boards authorities. We can make recommendations to the Counties, but ultimately the Counties have land use authority. Where Management Zones are utilized for permit compliance, agencies with land planning authority are to be engaged in the overall implementation planning.
Section 5.1, Page 5-3	
Regarding the volume of contaminated groundwater to be hypothetically treated, it is stated that the remediation analyses do not account for legacy nitrate in the vadose zone or continued flux of nitrate from other sources (most importantly from irrigated agricultural fertilization practices). These would seem to be key nitrate sources and their absence suggests that the pumping time estimates for the different scenarios are not very meaningful. How do these results relate to the Aggressive Restoration model simulations (SWAT + CVHM + MT3D-MS), which appear to address loading through the vadose zone and fertilization practices?	NIMS was an initial analysis to look at what measures could be implemented to treat nitrate in groundwater and to provide a rough estimate of the minimum timeframes involved to reduce nitrate concentrations to below the 10 mg/L water quality objective. This analysis utilized ambient groundwater concentrations from the AID archetype project and excluded nitrate loading from agriculture, and legacy nitrate in the vadose zone and used a simple mass balance model to estimate how long it would take to reduce nitrate concentrations based on a pump treat and re-inject scenario – injecting treated groundwater with a 1 mg/L nitrate concentration. The Aggressive Restoration project also did not include legacy vadose zone nitrate concentrations in the analysis, just loading of nitrate from agriculture using the SWAT model and assuming that what goes past

	the root zone goes directly into groundwater with no transformation. It is recognized that by not including loading from the vadose zones, the results likely under-estimate required restoration times.
Given Goal 1 as a priority, is pumping time required to reduce groundwater nitrate concentrations a relevant criterion. Also, is it likely that pump-and-treat times will be longer than the life cycle of the treatment facilities? Given these issues, should the cost analyses be less concerned with remediation progress and focus more on capital, O&M, followed by capital replacement costs.	These were conceptual costs. More detailed cost estimates would be calculated for the actual projects and would most likely include these costs. Pumping time to reduce nitrate concentrations is a relative criterion, given the purpose of NIMS was to evaluate alternatives to restore groundwater and achieve the MCL. The purpose of the project was not an evaluation of how to achieve Goal 1 but how to achieve Goals 2 and 3. We agree that the pump and treat times will likely be longer than the life cycle of the treatment facilities and it is correct that the analysis only is missing the replacement costs. As for remediation progress vs. costs as relevant criteria, both are important.
Section 5.2, Page 5-3	
Regarding DACs and DUCs, how have stakeholder preferences been incorporated into the analyses or conclusions? It would be good to include this in the discussion to support institutional memory.	There was a subcommittee overseeing the NIMS project which included representatives from the EJ community and regular updates were provided to the CV-SALTS Executive Committee, of which the EJ Communities are members. EJ stakeholder input regarding DACs and DUCs have been considered and included throughout the process.
Section 5.3, Page 5-4	
Given that irrigated agriculture is the largest contributor to groundwater nitrogen loading, it seems imperative to incorporate this nitrogen loading (along with mitigation goals, such as targeted NUEs) in any temporal estimates of groundwater remediation. Unfortunately, of the four nitrate-limiting practices noted, only the last one (pump and fertilize) is discussed further.	NIMS modeling utilized ambient groundwater quality and did not account for continued loading of nitrate from on-going agricultural operations. Modeling in NIMS utilized a simple mass balance model that did not account for legacy nitrate in the vadose zone nor for current nitrate loading. The purpose of this modeling was to simply show that remediation timeframes are long. Reduction in Nitrate as nitrogen loading goals are part of another Regional Board Program, the Irrigated Lands Regulatory Program (ILRP), where farmers are required to account for net nitrogen use taking into consideration applied nitrogen, nitrogen in the irrigation water and nitrogen removed through plant uptake, plant sequestering of nitrogen and removal of nitrogen through crop harvesting.

Section 5.4, Page 5-5	
Recharge of high quality water (stormwater) is an interesting suggestion that does not receive much attention in the report. This would be consistent with a more systems level approach, whereby groundwater recharge is being maximized while groundwater pollutants are being diluted. This issue is also tied to potential for enhanced leaching of TDS and nitrate from the vadose zone, but presumably this loading would be reduced after a few flushes.	Stormwater recharge is one of the measures that is to be considered in mitigation/restoration activities proposed as part of the Nitrate Permitting Strategy.
Section 5.5.1, Page 5-5	
Pump and fertilizer is an appealing concept. How much might this practice tend to reduce normal fertilizer application? If it is not a substantial change, then the effect of this approach is likely to be minimal.	The current study did not calculate specific potential offsets to fertilizer use by utilizing groundwater with elevated concentrations. However, accounting for nitrate in irrigation water is required under the ILRP Nitrogen Management Plan program and should result in information on reduced application of fertilizer pound per acre, depending on the mass of nitrate in the irrigation water.
Section 5.5.1, Page 5-7	
The report recommends irrigation and nitrogen management planning specific to each grower and management unit. This sounds like a good approach, but it would be good to add a few examples of what such plans might look like.	As discussed above, the ILRP already includes this in their Nitrogen Management Plan program for which templates exist.
Section 5.5.2.1, Page 5-9	
The salt brine approach is presented briefly. A brine line is a major undertaking with major environmental implications. Would such a recommendation point to the need for regional and coastal analyses as to the costs and benefits of transferring salt from on part of California to another (or to the ocean). Should there be discussion in this report on the topic?	Yes, any project on the scale of a regional regulated brine line where require full review under the California Environmental Quality Act and include an economic analysis. The SSALTS report discusses the needed review in detail. Additionally, the P&O Study of the first phase of the Salt Management Strategy is designed to develop a framework for addressing these analyses.
Section 5.5.3	
Very little is said about in situ treatment of nitrate as an alternative, other than to explain it. Are there "waste-to-substrate" approaches associated with food processing, etc. in the Central Valley that could be used as a carbon source?	NIMS nitrate measures were only examples of potential measures to be utilized and in no way limit the potential nitrate related measures that can be used. Use of in-situ treatment is one of the restoration or mitigation measures that could be utilized where appropriate and some exploration of accepting manure and compositing has occurred, but the measures must be balanced against importing more salt.

Section 5.5.4.2	
The remediation scenarios and costs of treatment seem overly simplistic, even given the limited scope of this project. For example, in comparing scenarios 1a and 1b, the simple mass balance approach points to half the timeframe when you double the pumping rate. This is extremely rough. Doubling the pumping rate will change the groundwater "capture zone" alter the balance between clean and contaminated water being pumped. It will also alter the groundwater velocity field and therefore the mixing of contaminated zones and clean zones. Therefore, I would not put a lot of weight on the timeframes resulting from these calculations.	Comment noted. This report was to assess at a high level what measures could potentially be utilized to address nitrate impacts. Timelines were not utilized from this report. A following study, the Aggressive Restoration Study, was utilized to estimate restoration timelines.
Table 5-6	
Do the costs here consider variable groundwater concentrations? Concentrations will affect treatment consumables and therefore O&M costs.	NIMS looked at starting concentrations in groundwater and the timeframe it would take to meet the water quality objective, but did not evaluate what restoration costs would be at different concentrations. These were conceptual level costs for typical treatment systems. More detailed cost estimates will be calculated for actual projects and will most likely consideration of nitrate concentrations. The more detailed Aggressive Restoration Study did evaluate different initial groundwater concentrations.
Aggressive Restoration Report	
Introduction Section, Page 1	
A brief description of some aspects of the modeling approach would have been useful and I recommend adding them in reference to Figure 1 (or in the next relevant report). Specifically, it was difficult to connect CVHM, MT3D-MS, and SWAT until eventually I found more details in report appendices (but these appendices were not called out in the report).	Comment is noted for future efforts.
Methodology Section, Page 5	
The goal of the Aggressive Restoration pump, treat, and reinject approach is to observe decreases in nitrate in ambient groundwater within 10 to 20 years. Is this goal feasible given continued nitrogen loading in the area, or was the notion here that aggressive pumping might overcome the continued loading?	Reduction of nitrate loading is anticipated through the ILRP Nutrient Management Plans. The scenarios in the study include nitrate loading at various levels (including levels reduced from today's rates and a zero Ag [no load] rate scenario) and simulate groundwater quality responses due to the pumping, treatment and reinjecting of treated groundwater at realistic pumping rates, so the combination of pumping and reinjecting overcomes the loading over time.

Methodology Section, Page 7	
In Plan C, the potential issue of "short-circuiting of clean water" was raised in the context of increasing pumping rates as opposed to increasing the number of injection and extraction wells. For Plan C and other simulations, were flow fields generated by CVHM checked to see whether simulated decreasing nitrate concentrations were due to efficient nitrate extraction or dilution due to the capture of clean water?	Flow fields were generated from MODFLOW output (not CVHM) to look at the influence of hydraulic gradient versus number of injection/extraction wells. Simulation results indicated that the effects of the pump and treat system of injection/extraction essentially “turns over” (removes nitrate and adds clean water back to the groundwater system) on a very local scale, indicating that the decrease of nitrate concentrations only occurred in small areas around the injection/extraction wells due to a combination of removal of nitrate from extraction wells and clean water being injected into the system.
On-Farm Recharge Simulation Results Section, Page 11	
Flushing of shallow groundwater chemicals into deeper layers during winter time recharge is interpreted as a negative side effect. If pump, treat, and serve is the technology of choice, then do the benefits of recharge outweigh the cost of pushing contamination downward? Will they ultimately be pushed deeper in the absence of winter time recharge activity?	On-farm recharge, if continued over the long-term, will ultimately reduce contaminant concentrations in the deeper aquifer zones. Absence of winter recharge reduces the flushing of contaminants into the deeper aquifer zones, but it still does occur, but a slower rate.
AID Simulation Results Section, Page 12	
There is a tendency to accept that the Production Zone should remain unchanged, and perhaps this is justified by the cost of production wells. Nevertheless, is it worthwhile to consider restoration of the upper zone and vadose zone as a early goal, and addressing the Production Zone after nitrogen source strength has been reduced? Or there may be other approaches--I guess what I'm suggesting is that this is a multi-objective problem, and there may be other more optimal approaches from a systems perspective.	Different regions will require different approaches based on local ambient groundwater quality, the availability of clean water for recharge projects, the availability of funding to sponsor pump/treat/reinject projects, etc. If restoration is the goal, creative solutions will have to be tailored to each area that will likely combine many different management measures. As indicated in the Aggressive Restoration report, restoration is likely not practical or feasible in all circumstances, and it will be important to utilize approaches and resources that have the highest benefit to maintain and/or improve groundwater quality within a region. Exploring the option to change screening depth on production wells as the upper zone improves, is one option that can be explored.
Conclusions and Lessons Learned Section	
That a targeted approach for restoration works better in smaller geographic settings seems subjective. It is important to the Central Valley and the state of California that the local targeted approaches are not only locally beneficial but enhance the sustainability of water resources regionally.	Comment noted, however due to the diversity of the region, the report noted that restoration may in some cases be restricted to those areas where the geology is conducive to the technologies available for restoration. The targeted approach is based on this principle.
While I agree with the second bullet point, what is meant by "rural/urban/domestic pumping stresses," and where was this featured in the simulations?	All agricultural pumping was removed from the simulation, but drinking water to provide farm houses, urban residences, and domestic wells were left in the simulation.

Similar to the previous comment, the third bullet points to where on-farm recharge effects might appear and how they might be affected by nearby pumping stress, yet the report did not seem to address these issues. I assume this was gleaned from the simulation output, but it would be more typical to point to those results if they are to be part of the main conclusions.	Comment noted. Figures that show the change in nitrate concentration over time, and spatial distribution of nitrate after a certain number of years help illustrate this point. Groundwater pumping is ubiquitous in the Central Valley, and along with the inherent hydrostratigraphy of the subsurface, can help shape the local movement of on-farm recharge that seeps past the water table.
I agree that pump, treat, and serve has good potential to provide clean, reliable drinking water to local communities. I do not see its shortcomings in terms of aquifer restoration as surprising--pumping cannot restore the aquifer while active sources and loading remain. The approach alone depletes the aquifer (as noted), but it was not clear from the report how significant this would be over time. And, could this depletion be balanced by on-farm recharge?	The pump/treat and serve option may not deplete the aquifer if it is done on a sustainable level. On-farm recharge can help to alleviate some of the depletion from the pump/treat/serve option; it takes a much longer time for on-farm recharge to enter into the greater aquifer system than it does to extract water from a well. Also, the on-farm recharge provides a local mound of groundwater, and this may not help water levels or provide cleaner water to the location where the additional pumping is occurring. On-farm recharge may also mobilize poorer groundwater that is located in the shallow upper aquifer down toward deeper aquifer units that are tapped by other wells potentially not equipped with treatment systems. Therefore, on-farm recharge would only be able to be utilized where the geology and water quality conditions are conducive. As it has limited areas of use, it may not be able to fully offset the volume of groundwater removed by pump, treat and serve.
Regarding the final bullet point, I found it difficult to judge whether restoration is feasible on the scale of the Central Valley. Aquifer restoration activities that require decades or even 50 years are the norm in most major subsurface restoration scenarios. Costly yes, but infeasible no. I do agree with the bullet if land management practices with respect to nitrogen loading remain unchanged.	Comment noted. The study showed that restoration would be possible (i.e. feasible) given enough time, however, the Regional Board has to consider not only the time required for restoration, but also the costs of restoration, as well as balancing safe drinking water supply while maintaining economic vitality of the agricultural industry within the Central Valley.