

**KNOWLEDGE GAINED SUBCOMMITTEE
TECHNICAL REVIEW OF SALT AND NITRATE SOURCE STUDY APPROACHES**

Technical Criterion	Source Study		
	EKI Spreadsheet Model	SNPS WARMF and MODFLOW Models	Bureau of Reclamation WARMF and Spreadsheet Models
1. Does the study provide a basic conceptual model that describes salt/nitrate sources, sinks, salt/nitrate paths of movement from source to sink, and areas of salt/nitrate accumulation?	<p>The spreadsheet model provides a conceptual model that describes salt sources and sinks within the Turlock Sub-basin. Nitrate sources and sinks are not considered. The spreadsheet model could be adapted to include nitrate sources/sinks but a means of accounting for nitrate formation and loss would need to be developed because nitrate is not conserved to the same degree as salt.</p> <p>The approach to mineral dissolution in the spreadsheet model is highly simplified and does not attempt to simulate actual processes (e.g., ion exchange, mineral precipitation, microbial mediated reactions) that may be occurring in subsurface.</p>	<p>SNPS provides a conceptual model that describes both salt and nitrate sources and sinks for each of the three pilot study areas (e.g., Yolo, Modesto, and Tule River). The SNPS also models the movement of salt and nitrate from sources to sinks, and the locations where these constituents are accumulating.</p> <p>Many of the parameters used in SNPS modeling are default or assumed values (e.g., nitrification and denitrification rates, atmospheric deposition, sorption rates, hydraulic conductivity, soil moisture, mineralization rate). Parameters were adjusted until discrepancies were minimized between flow and water quality monitoring data and modeled values. As WARMF and MODFLOW may yield non-unique solutions, SNPS indicates that a sensitivity analysis should be performed whereby the ranges of expected values of physical and process parameters are entered into the models to judge their effects on the allocations of salt/nitrate among sources and sinks.</p>	<p>The Bureau of Reclamation intends to conduct a salt and nitrate source study of the Westside Salt Assessment Area using WARMF. The WARMF will be checked by applying a spreadsheet model to subregions of the study area. The results of the source study are not yet available.</p>
2. Does the conceptual model include a regional water budget that describes source quantity, quality and timing, and supply demand patterns (by timing and use); characterize fate and transport of water; and list critical influences on regional water management?	<p>The spreadsheet model presents a regional water balance based upon average flows. Average TDS concentrations reported in the flows are used to describe salinity conditions. Temporal variations in quantity and quality are not reflected in the model.</p>	<p>Water balances were performed on the three pilot study areas, but the report does not include tables summarizing individual flow rates or salinity and nitrate concentrations in the various water flows that comprise the water balance. However, the modeling approach could be modified to clearly illustrate the regional water budget.</p>	

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3. Do the regional water budget and total salt/nitrate mass loads individually balance and are the results clearly communicated?	The spreadsheet model includes tables that summarize the manner in which the water budget and salt mass loads balance. The study did not examine nitrate mass loads.	SNPS includes tables and figures that summarize the manner in which salt/nitrate mass loads balance. Similar tables and figures for the regional water balance are not included but could be added.	
4. Does the conceptual model employ a clearly defined control volume to accomplish the regional water budget and salt/nitrate load balances?	The control volume corresponds to DWR sub-basin boundaries and DWR estimated volume of fresh groundwater in the sub-basin. Study presentation could be improved by including land use maps, and locations of drains, canals, and creeks that enter and exit the control volume boundaries.	Control volume boundaries of the pilot study areas encompass one or more DWR watersheds, and groundwater basins or sub-basins. The control volumes employed in WARMF and MODFLOW appear to differ, which complicates understanding of the salt/nitrate load balances. For example, WARMF includes salt/nitrate contributed by surface water originating from areas west of the San Joaquin River, which are outside the Modesto Study Pilot Area, but MODFLOW does not consider salt/nitrate that may be conveyed in groundwater from these same areas. SNPS presentation could be improved by accomplishing the regional water and salt/nitrate mass load balances according to DWR boundaries so the findings are more easily comparable with agency reports that rely upon such boundaries.	

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5. Is the regional water budget used to examine salt and nitrate concentrations through the water supply chain?	The spreadsheet model does not evaluate the effects of diversions and discharges on salinity/nitrate concentrations through the water supply chain. The spreadsheet model could be adapted to model the effects provided adequate flow rate and water quality data pertaining to the diversions and discharges are available.	WARMF modeled the flow and water quality at selected surface water monitoring stations within the three pilot study areas. Good agreement between model results and available data was obtained for monitoring stations upstream of agricultural areas. Agreement was not as good for monitoring stations influenced by agricultural return flow and irrigation drainage possibly because these flows are largely unmeasured and the areas tributary to specific agricultural drains and canals are difficult to discern.	
6. Are regulatory requirements, beneficial uses, and local planning objectives pertaining to salinity and nitrate within the region identified and considered in the implementation of the study?	Water quality management goals were not considered in the spreadsheet model but should be incorporated into future studies. An understanding of regulatory requirements, beneficial uses, and local planning objectives is important to identifying significant sources, and surface water bodies and portions of the groundwater basin or sub-basin that need to be protected. In particular, salinity/nitrate concentrations of sources need to be compared with water quality management goals to establish if predicted concentrations are sufficiently precise to be meaningful. For instance, if the variability of a predicted concentration is so large that it cannot be determined that the concentration is less than or greater than an applicable goal then further study may be warranted.	SNPS does not include water quality management goals, but such goals should be considered in future studies for the reasons described under the spreadsheet model.	

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7. Does the study determine the salt/nitrate mass loading rates of each source and clearly present a written and graphical comparison of source loads?	The spreadsheet model describes the salt mass loading rates originating from each source category within the sub-basin and percentages of the total mass loads to surface water and groundwater each source category represents. Study presentation could be improved by including graphical summaries.	SNPS describes salt/nitrate mass loading rates and provides tabular and graphical summaries. Future studies could be improved by organizing salt/nitrate mass loading rates according to source categories that coincide with existing regulatory programs, such as irrigated lands, CAFOs, POTWs, and food processors.	
8. Are historical and projected salt/nitrate loads for each source quantified sufficiently to conduct trend analyses?	The spreadsheet model projects the trend in average TDS concentration in sub-basin groundwater to assess the reasonableness of salt mass loading estimates. The spreadsheet model is not sufficiently refined to predict salinity/nitrate concentration trends at specific locations.	SNPS estimated trends of average chloride, nitrate, and TDS concentrations in shallow groundwater beneath certain catchments in the Yolo Pilot Study Area to assess the reasonableness of the WARMF output. SNPS performed preliminary MODFLOW groundwater simulations for the Tule River Pilot Study Area and concluded that available data and the spatial resolution of the model are not sufficient to make reliable trend predictions.	
9. If salt/nitrate is accumulating within the region, does the study determine the locations and rates of accumulation?	The spreadsheet model aggregates the individual entities that comprise a specific source category. The spreadsheet model could be modified to estimate salt/nitrate mass loadings attributable to each entity and linked to GIS to display the locations of these entities. However, assessing the locations and rates of salt/nitrate accumulation in the subsurface would require fate and transport modeling.	WARMF and MODFLOW are capable of describing the locations and rates of salt/nitrate accumulation in groundwater. The ability of modeling to accomplish this criterion is variable depending upon the amount of data that are available to calibrate the models. Fairly good agreement of modeled values with measured chloride, nitrate, and TDS concentrations in shallow groundwater in the Yolo Pilot Study were obtained. Poorer agreement was achieved for the Modesto and Tule River Pilot Study Areas due to sparser input data.	

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11. Are the salt/nitrate mass loading rates translated into corresponding water flow volumes and salinity/nitrate concentrations so the loading rates can be put into a regional context to allow prioritization of management options?	The spreadsheet model translates the salt/nitrate mass loadings of the sources into water flow volumes and salinity/nitrate concentrations, such that the relative effects of the source categories on water quality objectives can be judged. The spreadsheet model does not resolve the mass loadings into water flow volumes and salinity/nitrate concentrations by the individual entities that comprise each source. The results of the spreadsheet model coupled with mapping of available surface water and groundwater data could be used to prioritize sources and areas within a given region for more detailed study and implementation of management options.	SNPS presents modeled water flow volumes and salinity/nitrate concentrations for selected surface water streams in the Pilot Study Areas. Source category salt/nitrate mass loading rates are not similarly translated. The modeling approach could be modified to estimate the water quantity and quality characteristics of individual entities that comprise each source category. However, the reliability of the estimations depends upon the accuracy and completeness of data needed for model input. Insufficient input data could lead to non-unique solutions. SNPS notes multiple ways may exist for model simulations to match observed measurements if a lack of input data prevents the models from being sufficiently constrained.	
12. Does the study determine salt/nitrate assimilative capacities of groundwater and surface water bodies within the region?	No.	No.	

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13. Are salt/nitrate loadings characterized in sufficient detail to inform control strategies?	<p>The spreadsheet model quantifies salt mass loadings associated with general source categories (e.g., CAFOs, irrigated agriculture, municipalities, food processors, septic tank systems, mineral dissolution), which allow these sources to be ordered by their mass loading rates.</p> <p>The spreadsheet model does not describe temporal or spatial variations in mass loadings that are attributable to the entities that comprise these source categories. Therefore, the study results cannot be used to identify specific entities or locations within the sub-basin that require control strategies to maintain or achieve water quality management goals.</p>	<p>SNPS quantifies salt and nitrate mass loadings associated with general source categories and attempts to characterize the distributions and trends of salinity and nitrate concentrations in groundwater. The study also makes efforts to model temporal variations in salinity and nitrate concentrations in surface water flows. However, the accuracy and reliability of SNPS modeling results are hampered by limitations in the data that must be input into the WARMF and MODFLOW models.</p>	

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14. Does the study clearly describe the methodology used to conduct the study?	<p>The spreadsheet model describes the methodology used to perform the study. The methodology essentially consists of accomplishing water balances for the sub-basin unsaturated and saturated zones. Each water flow was then multiplied by the estimated representative TDS concentration of the flow to derive the flow's associated salt mass. Salt mass balances were completed by considering dissolved salts resulting from mineral dissolution.</p>	<p>SNPS clearly describes that WARMF and MODFLOW were used to model salt/nitrate mass loading rates. The manner in which these models are coupled could be more fully explained and documented. For example, groundwater recharge rates and salinity/nitrate concentrations of extracted groundwater from MODFLOW are input to WARMF. SNPS does not explain how effects due to changes in land use, fertilizer application, or other factors modeled by WARMF in turn influence groundwater conditions predicted by MODFLOW.</p> <p>Salt/nitrate mass loading rates associated with atmospheric deposition includes wet and dry deposition, and plant and soil respiration. Plant and soil respiration are not typically considered part of atmospheric deposition. The methodology for calculating salt formed through plant and soil respiration should be explained in detail given the magnitude of salt mass loads that WARMF predicts is due to these processes.</p>	
15. Is the methodology sound and transferrable to other regions?	<p>The spreadsheet model is simply a means by which to conduct mass balances on water, salt, and nitrate in a given region. These mass balances must be completed as part of any modeling approach.</p>	<p>WARMF and MODFLOW are sound modeling techniques. The primary advantages of these models are they can be used to examine the fate and transport of salt and nitrate, and identify not only significant sources, but the pathways from sources to sinks. The predictive capabilities of the models depend greatly on the input data available to describe physical conditions of the region being modeled.</p>	

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16. Are data gaps identified?	Limited groundwater elevation data lead to an incomplete understanding of groundwater flow in the sub-basin and results in uncertainty in the regional water balance. In addition, the salt mass loads balance could be refined by performing detailed water and salinity mass balances at representative food processors, CAFOs, and municipalities, conducting mineral dissolution studies to quantify the effects of local soil and water types on salt loadings and concentrations, and more accurately establishing local salt contributions of fertilizers and soil amendments.	SNPS notes data gaps exist with regards to soil processes, quantities and quality of groundwater that discharge to surface water, groundwater levels, groundwater salinity and nitrate concentrations, agricultural well pumping rates, agricultural return flow rates (i.e., tailwater), and well construction records. Most flow and water quality data were obtained from state and federal agencies. Data completeness could be enhanced by developing data sharing protocols with water districts, municipalities, and other local agencies. For instance, SNPS states that only 1 of 21 irrigation districts provided requested groundwater quality data for the Tule River Pilot Study Area.	
17. Is the data validated? How?	Data were validated using procedures similar to those employed in the SNPS.	Data were compiled from various agencies, references, and studies. Reported values for the same flow, salinity concentration, land area, or other parameter were cross checked against one another. Consistency among reported values provides an indication of data accuracy.	

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18. Are the data relied upon in the study sufficient and of high enough quality to answer the above questions with an acceptable degree of confidence?	<p>Available data are insufficient to credibly answer all of the above questions on a groundwater basin or sub-basin scale. Due to its simplicity, the spreadsheet model is less affected by data limitations than other modeling approaches. Thus, compared with more sophisticated modeling techniques, the spreadsheet model can be applied more readily on a groundwater basin or sub-basin scale to determine the salt/nitrate mass loadings and associated water flows, and salinity and nitrate concentrations of various source categories. The spreadsheet model also can be applied on a smaller scale, such as a single facility, to identify practices contributing to the salt/nitrate being emitted from the facility and to evaluate actions for control of salt/nitrate from the facility.</p> <p>The spreadsheet model cannot be easily adapted to describe spatial and temporal variations in salinity and nitrate concentrations in surface water and groundwater within a basin or sub-basin.</p>	<p>SNPS concludes that available data are not sufficiently complete to adequately model each of the three pilot study areas. Therefore, future salt/nitrate studies would benefit from conducting an initial evaluation on a basin or sub-basin scale to identify significant salt/nitrate sources, and surface water bodies, and portions of the groundwater basin or sub-basin that have higher risks of impairment.</p> <p>The results of such an evaluation could be used to prioritize sources, surface water bodies, and portions of the basin or sub-basin for further study. Data completeness also could be determined. WARMF, MODFLOW, or other modeling techniques may prove important in conducting more detailed study, and implementing and assessing the effectiveness of salt/nitrate control strategies.</p>	
19. Is the data storage and management system compatible with the system that will be used for the entire project?	<p>Data storage and management were accomplished in electronic spreadsheets. The data storage and management system needs to be defined for the reasons cited under the SNPS.</p>	<p>The data storage and management system needs to be defined before conducting further studies to avoid conflicts and redundancies between databases.</p>	