Peer Review of the San Joaquin River Restoration Program's Seepage Management Plan

Independent Peer Review Panel:

- Jason J. Gurdak, Ph.D., P.H.
- Joel Kimmelshue, Ph.D., CPSS
- Daniel Munk, M.S.
- Nigel Quinn, Ph.D., P.E., D.WRE
- Mark Roberson, Ph.D.
- Albert Steele, P.G., C.H.G.
- Stuart Styles, D.E., P.E., D.WRE

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Acronyms

CCID	Central California Irrigation District
CDEC	California Data Exchange Center
CF	capillary fringe
CVHM	Central Valley Hydrologic Model
DMC	Delta-Mendota Canal
DPPC	Dual Pathway Parallel Conductance
DWR	California Department of Water Resources
EC	electrical conductivity
ECe	saturated soil paste extract
EM	electromagnetic
ENSO	El Niño/Southern Oscillation
ET	evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GCMs	global circulation models
GPS	global positioning system
IDW	inverse distance weighting
LOCs	levels of concern
NAIP	National Agriculture Inventory Program
NWIS	National Water Information System
ORP	oxidation reduction potential
PRP	Peer Review Panel
QA/QC	quality assurance/quality control
RS imagery	remotely sensed imagery
RSSD	Response Surface Sampling Design
SCTFG	Seepage and Conveyance Technical Feedback Group
SJR	San Joaquin River
SJRRP	San Joaquin River Restoration Program
SJRRPGW	San Joaquin Restoration Program Groundwater Model
SMP	Seepage Management Plan
SPH	Seepage Project Handbook
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSEL	River bed water surface elevation

Preamble

Seepage along the San Joaquin River (SJR), the Chowchilla Bypass, and the Eastside Bypass is a known problem that creates high groundwater level conditions in several locations when significant flows occur along reaches of these watercourses. It has been recognized that expected flows for the San Joaquin River Restoration Program (SJRRP) will cause shallow groundwater conditions that impact farming operations. The U.S. Bureau of Reclamation (Reclamation) has prepared a Seepage Management Plan (SMP) that works to address this problem (Draft SMP, dated August 31, 2012). In August 2012, a Peer Review Panel (PRP) was assembled to review and provide comments on the SMP between September and November 2012. The PRP is comprised of experts in the fields of agriculture, drainage, groundwater, water quality, and hydrologic modeling. The objective of this PRP is to: (a) provide Reclamation with an assessment of the processes described in the SMP; (b) to provide guidance on revisions to the document to increase the document's technical accuracy; and (c) to suggest strategies for maximizing the conveyance of Interim and Restoration flows while reducing or avoiding material adverse effects due to groundwater seepage. Additionally, the PRP was charged with the task of delivering a single report that answers five questions outlined in the following section and provides an explanation of those findings.

It was the opinion of the PRP that the Draft SMP presents a balanced approach by providing various methods and guidance that will be used to address any material adverse seepage impacts caused by Interim and Restoration Flows associated with the SJRRP. The plan provides for quick identification of seepage problems through monitoring, modeling, and stakeholder (landowner) involvement. Appendices to the plan provide details regarding seepage effects of concerns, areas vulnerable to seepage, historic groundwater levels, sediment texture, monitoring networks, soil salinity and groundwater level thresholds, and groundwater modeling. A landowner claims process is described, and a Seepage Project Handbook (SPH) is included. The SMP and SPH will be very useful, especially during the Interim Flow stages of the SJRRP. The SMP may prove to be nearly 100 percent effective in avoiding seepage impacts during the Interim Flow stages because the SMP includes flow modification up to and including complete flow stoppage if material adverse impacts are experienced or predicted. The Seepage Hotline and real-time monitoring will provide valuable information that will be used to implement the plan.

Once the Restoration Flow portion of the SJRRP begins, it will be more difficult to protect against seepage impacts, as it may not be feasible to interrupt river flows on short notice. The SMP leaves open the flexibility of management to modify river flows needed to limit impacts to agricultural productivity and identifies a range of projects, including slurry walls, seepage berms, field drainage systems, drainage ditches, interceptor lines, groundwater pumping, and building up of low lying areas which can be used to mitigate seepage problems. Real estate actions such as easements, license agreements, and land acquisition are also considered viable options to address seepage issues. Design and construction time lines and preliminary cost estimates for some of these remedies are provided. It should be noted that many of these actions would require multiple years to implement due to the extensive nature of the projects, environmental concerns, and seasonal limitations on when the work can be performed.

Overall, Reclamation and collaborating organizations on the SMP should be commended for their considerable effort in developing a reasonable and generally effective plan to address material adverse impacts. The following sections of this report provide detailed comments and recommendations by the PRP as to the reasonableness and effectiveness of the SMP, including specific areas of the SMP where more information is needed or problems should be addressed.

Questions Summary

Objective

The objective of the SMP Peer Review is to provide Reclamation with an assessment of the 12/10/2012processes described in the SMP and, where appropriate, guidance on revisions to increase the document's technical accuracy in maximizing the conveyance of Interim and Restoration flows while reducing or avoiding material adverse effects due to seepage.

The questions listed below are intended to highlight known areas of concern regarding seepage of Interim and/or Restoration Flows from the SJR and its impact to adjacent lands as part of the SJRRP. Peer reviewers should answer the primary questions in their report and answer secondary questions as time and reviewer agreement permits. Please provide specific modifications to the SMP where possible.

Questions

1. Do the operational practices use reasonable predictors and are the methods of sufficient accuracy? Please consider:
    a. Types of monitoring (e.g., wells, EM38®, laboratory testing, gaging stations, staff gages, etc.)
    b. Resolution of monitoring (e.g., spacing, frequency, reporting, etc.)
    c. Travel time and flow attenuation
    d. Flow Bench Evaluation steps
    e. Groundwater level prediction for flow bench evaluations using a one-to-one initial approach
    f. Field corrections to flow bench evaluation groundwater levels including a ground surface adjustment and gradient adjustment where known
    g. Use of the drainage method for Flow Bench Evaluations if irrigation is occurring

2. Do the agricultural thresholds provide a reasonable amount of protection when setting a threshold?
    a. Are the estimates of root zone reasonable and are there practical ways to refine the values?
    b. Are the estimates of capillary rise reasonable and are there practical ways to refine the values?
    c. Are the estimates for the irrigation/leaching buffer reasonable and are there practical ways to refine the values?

3. How do we reasonably account for historical conditions that may impair groundwater even in the absence of SJRRP flows?
    a. Are the estimates of historical groundwater levels reasonable and are there practical ways to refine values?
    b. Is the use of historical groundwater levels a reasonable approach to setting thresholds where known?

   c. Is the use of historical groundwater levels on fields exceeding agricultural thresholds overly conservative?
   d. How should the SJRRP incorporate historical soil texture conditions such as hardpan adjacent to the Eastside Bypass that could inhibit drainage after flood releases have been shut off?

4. Are there missing components or other refinements to the SMP necessary to achieve the goals of releasing and conveying Interim and Restoration flows while avoiding material adverse effects due to groundwater seepage?

5. Overall, does the SMP maximize release of flows to the River for furtherance of the Restoration Goal while providing reasonable measures to avoid material adverse impacts from groundwater seepage? Please consider:
   a. Does the SMP describe the significant material adverse effects due to groundwater seepage or are there other effects to consider?
   b. Will the SMP avoid the identified material adverse effects? If not, what revisions would avoid the material adverse effects?
   c. Is the SMP overly restrictive on the release of flows? If so, would revisions allow for increases in flows while avoiding material adverse effects?

1. Do the operational practices use reasonable predictors and are the methods of sufficient accuracy?

The operational practices review includes the development and interpretation of appropriate systems monitoring, the use of modes as a predictive tool and the development of initial system flows necessary to identify reach areas affected by a range of possible restoration flows. The review focuses on the evaluations and actions developed in the SMP's Appendix E and the monitoring networks identified in Appendix F. The PRP worked to develop language supporting the reasons for collecting certain types of data and explaining our inclination on how to improve the existing plan. However the review generally fell short of providing specific values related to recommended changes. This was intended to allow the Bureau and those directly involved in the operational practices and monitoring phases to maintain a level of flexibility that corresponded to the changing needs of the plan and project activity.

1.1 Summary PRP Recommendations

The following summary of the PRP recommendations is supported by the discussion in each of the following sections 1.2 to 1.8.

1.1.1 Types of Monitoring

Observation Wells

- It is recommended to increase the number of monitoring wells where necessary to improve recognition and reporting of seepage problems. As a general guideline, these should be spaced at approximately one-mile intervals along both sides of the River in reaches 2B, 3, 4A, and 4B targeted at areas where seepage is expected to be a problem. The additional monitoring wells should be as close to the river as possible.
- The observation wells for the SJRRP should be submitted to the California Department of Water Resources (DWR) for inclusion in their labeling system since this is a long-term evaluation project. Once assigned a DWR label, the label should be used for all future reference.
- The use of data loggers and telemetry is encouraged on all wells in the program that are used in decision making for the Flow Bench Evaluation. All of the strategic monitoring wells should be equipped with data loggers. The Program will need to invest in an enterprise-level hydrological data management system for data acquisition, data processing and data quality assurance analysis to ensure provision of timely data. Manually reading wells is not a viable long-term solution especially once restoration flows commence in the River given available staff resources. The PRP recommends that Reclamation utilize the California Data Exchange Center (CDEC) system to the extent possible for real-time monitoring until they have an equivalent website available for real-time data access.

Soil Salinity

- Salinity monitoring activities need to have a refined protocol with realistic expectations of the outcome of the evaluation. The use of the EM-38 for salinity evaluation as presented in the SMP is problematic. Note that the changes in salinity may take time to be recognized. It is recommended that additional details be provided on the protocol to be used to evaluate the assessment of increased soil salinity.

Laboratory Testing

- The PRP suggests the inclusion of multispectral imagery remote sensing to the operational practices of the SMP in order to help document long-term impacts to the area due to seepage. The impact area as shown in the SMP documents seems to be very narrow. It is recommended that the area of evaluation extend least 1 mile from the River on areas upslope from the River water surface and 5 miles for the fields that are downslope. These evaluations could be focused on flood years to show the areas impacted by high water tables.

Cropping Patterns and Productivity

- Establish control sites for crop productivity monitoring. Coupling multispectral imagery remote sensing with control sites can be used to establish production impacts from elevated groundwater and salinity. Control sites can range from pristine locations with good drainage and low salinity groundwater to well characterized poorly producing lands. Historical imagery can be used to establish baseline biomass productivity. Statistics can be used to show how areas believed to be impacted by river flows compare with surrounding areas, by hydraulic flow lines, measured groundwater levels, other areas in the same field, other fields, by irrigation type or by crop type.
- Develop a method for determining crop risks associated with seepage and link those risks to crop selection categories favoring the selection of crops more tolerant to salinity and shallow water table conditions in high risk areas.
- Outline a more specific land reclamation plan following salinization events that addresses the variable nature of the problem including the potential need for additional water and soil amendments.

Water Quality

- The PRP recommends that irrigation water quality should be reported by source where available. The two major surface-water sources, the Delta-Mendota Canal (DMC) and the SJR, are currently monitored and posted to multiple databases. Local groundwater quality should be characterized.

1.1.2 Resolution of Monitoring

- Similar to 1.1.1, it is recommended to increase the number of monitoring wells where necessary to improve the evaluation of the travel time as the releases are made down the River. As a general guideline, these should be spaced at approximately one-mile intervals along both sides of the River in reaches 2B, 3, 4A, and 4B targeted at areas where seepage is expected to be a problem. The new wells should be located as close to the river as possible.

- It wasn't clear in the SMP if there is a formal Quality Assurance/Quality Control (QA/QC) protocol for monitoring data collection? If so, we suggest including that QA/QC protocol in the SMP. If not, we suggest developing a formal QA/QC plan. Similarly, what is the QA/QC protocol for the telemetry data that is uploaded to the CDEC, presumably in "real-time"? Is there a program that checks for data problems and accuracy, and/or do you have personnel to spot-check the data prior to upload on the CDEC?
- The SMP report is deficient in its plan for long-term data acquisition, data management and data quality assurance. An enterprise-level hydrologic data management system will eventually be needed as the program transitions from the more experimental interim flow event response paradigm to fully operational status.

1.1.3 Travel Time and Flow Attenuation

- The use of HEC-RAS is appropriate for estimation of travel time and flow attenuation when flows are diminished in the San Joaquin River. However, the SMP doesn't clearly describe how the travel times or flow attenuation were verified and the steps taken to calibrate and tune the HEC-RAS model. It is recommended this extra information be added with a brief explanation in the SMP.
- In the Flow Bench report, the graphs generated by the HEC-RAS data should be standardized. Currently, they have different scales reported on both the x-axis and the y-axis. Since these graphs are a key indicator for the Flow Bench Evaluation, it is also recommended that some additional descriptive graphics be added to this section of the report.

1.1.4 Flow Bench Evaluation Reports

- The Flow Bench Evaluation Reports could be expanded and more informative. The PRP found it difficult to decipher all of the information in the reports especially in relation to the interpretation of the data. For example, a summary map would be helpful showing the key locations identified in the text. Currently there are six pages of HEC-RAS rating curves for the SJR but not an overall map.
- Specific changes to the report format and graphics are also recommended.

1.1.5 Groundwater Level Prediction

- The level of detail in the SMP and SHB as well as the responses to the innumerable questions and comments has been extraordinary. The review of this SMP portion of the SJRRP has demonstrated that a tremendous amount of high quality work has been done. It is strongly recommended that as the program increases flows to the SJR, Reclamation uses an independent, peer review team to help evaluate the operational practices again in the future.

1.1.6 Field Corrections to Flow Bench Evaluation Groundwater Levels

- The PRP agrees with the method used to correct the field groundwater levels based on the flow bench evaluations. In the future, additional wells and operational knowledge will reduce the need for the field corrections.

1.1.7 Use of the Drainage Method for Flow Bench Evaluations if Irrigation is Occurring

- The visual representation of what is happening during the drainage flow condition from a field is missing from the SMP and Flow B*e*nch Evaluation reports. It is recommended that a new schematic be used to describe the drainage method.

1.2 Types of Monitoring

1.2.1 Observation Wells

In general, the well monitoring network is reasonable and the associated methods outlined in the SMP appear sufficiently accurate. The PRP agrees with the SMP statement that "high-quality data inform determining, understanding, and documenting the effects of these flows of groundwater levels, root-zone salinity, levees, and crop health conditions in the vicinity of the SJR/bypass system" (see page F-1). As such, the SMP outlines a flexible and comprehensive plan for monitoring groundwater levels using wells, which is a critically important component of the SMP.

The use of drive-point wells is just one example of the flexibility of the SMP. Drive-point wells can be installed relatively quickly to collect water levels in areas of potential concern for seepage effects.

On page F-2, line 12, the text reads that Figure F-1 "shows locations of all SJRRP and stakeholder monitoring wells, including drive-point wells installed thus far". This reference should be changed to Figure F-2.

The Priority Well network (see page F-2) appears adequately spaced along the length of the study area and located in close proximity to the SJR. The weekly water-level measurements at the Priority Wells in most cases are of sufficient temporal resolution to be appropriate in most scenarios for informing the Flow Bench Evaluations or Daily Seepage Evaluations. However, the weekly water-level measurements may not be of sufficient temporal resolution under some rapidly changing conditions in flow of the San Joaquin and thus may not be sufficiently accurate given the timing of a nearby Daily Seepage Evaluation. With that said, most groundwater levels do NOT rapidly change over the course of days, thus a weekly measurement of water levels at the Priority Wells should be sufficiently accurate for most Flow Bench or Daily Seepage Evaluations.

Additionally, it appears the cross-river transects (see page F-4) are of adequate design to characterize horizontal and vertical hydraulic gradients along various reaches of the San Joaquin River.

Although there are many positive aspects to the well monitoring network, the PRP offers additional recommendations to improve monitoring well data reliability and accuracy: Given the importance of accurate and reliable groundwater levels to the success of the SMP, clear data collection and reporting protocols should be established and adhered to. These could include standard methods by the U.S. Geological Survey (USGS) and/or DWR.

Wells used in the SMP appear to use a numbering system without any apparent geographic notation or significance. The PRP recommends that all monitoring wells and piezometers use the California State Well Numbering System. In this system wells are numbered using Township, Range, Section, Quarter-Quarter Section, (40 acre plot), and a sequential number. The local district office of the California DWR assigns the well numbers. For this project the DWR office would be the South Central Regional Office in Fresno. Using this system will ensure that each well will have a unique number and will allow for the data collected to be stored in the DWR Water Data Library.

The PRP suggests that the quantity of monitoring wells may be insufficient to perform adequate modeling of the areas subject to seepage impacts and to develop an optimal decision support strategy. The PRP recommends adding monitoring wells on an approximate one-mile spacing with wells being targeted at the toe of the levees in the key areas that are suspected to have seepage issues (Reaches 2B, 3, 4A, and 4B). The scope of this project demands that there be a greater reliance on actual data and less reliance on the assumptions currently being used for groundwater movement. Although it is clear that the Restoration Program has worked well with stakeholders to make sure that current wells are strategically placed, the current network may be insufficient to be able to calibrate local scale models that are detailed enough to be able to simulate the efficacy of installing drains and other seepage management options. Modeling the potential impacts of these seepage management strategies ahead of their design and installation will help to optimize their effectiveness and contain the cost of implementation.

One useful strategy may be to use the data from the existing monitoring network to help select a smaller number of sentinel wells which would become the “canaries in the coal mine” for local seepage problems. The Central California Irrigation District (CCID) has adopted a similar approach for monitoring local subsidence along the Delta Mendota Canal and in the vicinity of its delivery canals. If these sentinel wells are chosen well, with the cooperation and with collaboration from local landowners, it will help to winnow down the number of wells requiring telemetry and that need to report “real-time” to the Restoration Program project website. It will also be easier for local landowners to access the information and over-time become comfortable with the level of protection provided by the data obtained from these sites.

The use of data loggers should be required on all wells in the program. A data logger that has been successfully used on other projects is the Telog unit. This unit has proven to be robust and reliable. Manually reading wells monthly appears to be cumbersome and is not adequate. As previously noted those sentinel wells chosen from among the well network ought to have both dataloggers and telemetry systems and report directly to the Restoration Program data website.

1.2.2 Soil Salinity

Soil salinity is being monitored to protect crops from the impacts of elevated concentration of salt in the soil. The primary sources of salinity are the inherently saline soils, shallow groundwater and irrigation water containing dissolved salts. Fluctuations in the shallow water table have definite impact on the movements of these soil salts and their potential to accumulate in the root zone. It is reasonable and appropriate to develop a soil salinity monitoring and mapping program that works to document the changes in root zone salinity levels over time and particularly those areas where water table levels are thought to be influenced by restoration flows.

Soil salinity mapping using electromagnetic (EM) devices has become a common practice in precision agriculture to map spatial distribution of soil salinity and assess the effects of alkalinity on crop productivity. The EM38®®, developed by Geonics Ltd, together with analytical software, based on the Dual Pathway Parallel Conductance (DPPC) model developed by James Rhoades et al. (1989), has been proven to be effective and accurate in the prediction of soil salinity across vast landscapes in agricultural settings (Corwin and Lesch 2003, 2005a, and 2005b, Isla *et al*. 2003, Lesch and Corwin 2003, Lesch *et al.* 2005, Cassel 2007). Readings obtained by the EM38® instrument can be affected by factors such as soil texture and taxonomy, soil moisture, topography, vegetation and litter cover, which all affect electromagnetic response (Hanson and Kaita 1997, Suddeth *et al*. 2005, Brevik *et al*. 2006). The most significant factors determined by Corwin *et al.* (2003b) in a west-side San Joaquin Valley cotton field (Broadview Water District, Fresno County) were the electrical conductivity (EC) of a saturated soil paste extract (ECe), gravimetric water content, and texture.

The EM38® utilizes dual coil electromagnetic induction in order to obtain soil salinity measurements employing non-invasive methods where the strength of the magnetic flux is proportional to the bulk conductance of the soil. Data from the EM38® and a backpack global positioning system (GPS) are typically recorded on a rugged, hand-held PC, suited for fieldwork. Data logging software designed for this application is TrackMaker®, which plots the person conducting the survey's current GPS location on the hand-held device while retaining the previous survey locations as a continuous line of closely spaced sample points.

The ESAP software package was created by the USDA Salinity Laboratories to correlate EM38® *xyz* (apparent EC) data to actual EC. Within the program is a Response Surface Sampling Design (RSSD) that uses the raw ECa *xyz* data to design a sampling strategy to calibrate the EM38® instrument against actual soil EC values. For each field, the RSSD software selects 12 sample locations based on even-increment sampling of a frequency distribution of values from which to collect soil samples for analysis.

The EM38® MK1 can be used in two different orientations; vertically or horizontally. Figures 1-A and 1-B (McNeill 1980) illustrate the nature of the EM38® MK1 response in both the vertical and horizontal orientations. Figure 1-A, displaying the cumulative signal response, illustrates that the maximum depth of the horizontal and vertical orientations, representing 75% of the response signal, are roughly 1m and 2m respectively. The 75/25 response pattern was considered to be the maximum reading depth by McNeill *et al.* (1980) based on their theory and field trials.

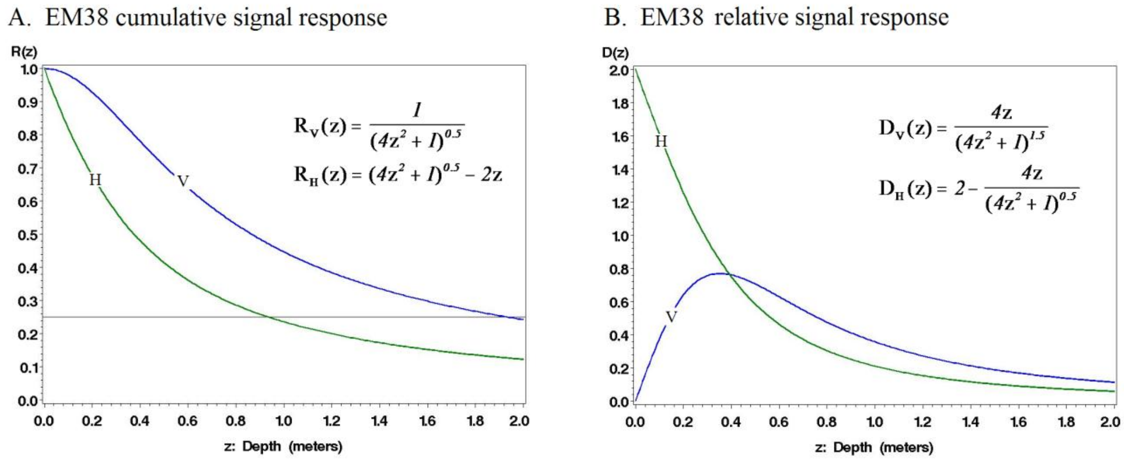


Figure 1. EM38® cumulative and relative signal responses where H is horizontal orientation and V is vertical orientation (McNeill 1980).

The suggested operating procedure for using ECa in precision agriculture includes four steps (Corwin and Lesch, 2003): (i) an initial intensive ECa survey, (ii) a soil sample design based on the intensive ECa survey, (iii) a stochastic or deterministic calibration of ECa to soil sample–determined ECe, and (iv) a determination of the dominant soil properties influencing the ECa measure at the site of interest. Although this procedure is for precision agriculture it applies to the SJRRP because landscape-sized areas are being monitored for salinity changes.

The current procedure as described by Joe Brummer (personal communication) is to calibrate the EM38® meter at the site specific locations identified in the Plan. Although this will provide good information for the selected site, it does not appear to meet the requirements as a monitoring tool on a landscape scale. Moving from the point measurements to a landscape level will require considerable time. Another measure that could be suitable for determining soil salinity is the use of existing water quality information. Empirical information shows a predictable relationship between the soil salinity that develops over time for a given irrigation water quality and crop leaching fractions (Ayers and Westcott, 1986). The relationship is as follows: ECe = ECw * X, where X varies from 3.2 at a leaching fraction of 5% to 0.6 at a leaching fraction of 80%.

Using a DMC water quality of either 0.3 dS/m (USBR 2011) or 0.5 dS/m (DWR 2009) and the equation provided by Ayers and Westcott (1986) the required leaching fraction for the trigger crop types in the three reaches identified in the Plan are as follows:

Reach	Trigger Crop	ECe Threshold (dS/m)	Leaching with DMC @ 0.3 dS/m (USBR 2011)	Leaching with DMC @ 0.5 dS/m (DWR 2009)
2b	Almond	1.5	<5%	~6%
3	Corn	1.7	<5%	~7%
4A & 4B	Alfalfa	2.0	<5%	~5%

Under this approach, all leaching fractions are readily obtainable through current irrigation systems. The monitoring of leaching activity could be conducted through the use of the existing network of monitoring wells. For example, at San Juan Ranch, the groundwater level handout provided on September 13, 2012 covering April 2010 through the present showed that the water table is shallower after irrigation events in the wells further from the River (MW-10-92 & 93).

Also, the EC of the water (grower-provided values at field site) in these wells (2.4 dS/m), is more saline than the riverside well MW-10-91 (1.8 dS/m). Although this is only one measurement, it indicates that the groundwater salinity further from the River is greater than areas closer to the river. In addition, assuming conservation of mass, the leaching fraction in the area near the River (MW-10-91) is 0.5/1.8 = 27% and the others are 21%. It should be noted that the ITRC (2010) reviewed groundwater levels from April-August 2010 on the same property and found that groundwater was moving away from the River (from wells 91-93). Using data presented in Table 3 by ITRC (2010) in the same locations in 2010 indicate that the leaching fractions were 44% in 91, 13% in 92 and 11% in 93. Given that the required leaching fractions are obtainable, the primary issue appears to be a lack of drainage.

The SMP PRP endorses selection of the EM38® by the SJRRP for assessing soil salinity changes over time in affected fields. However, the PRP notes the following deficiencies in the SMP document with respect to EM38® surveys:

- There is no written protocol provided in the SMP for conducting the EM38® surveys. As noted above, these are useful instruments but require careful calibration, well-controlled selection of field soil samples to obtain a valid model assessing soil salinity changes, and appropriate soil moisture conditions in order to result in an accurate analysis of soil salinity. The PRP cannot assess whether these surveys were conducted with sufficient rigor from the information provided in the report.
- Even with valid EM38® surveys, it isn't clear how useful the EM38® survey will be as a decision support tool for the large areas potentially affected by seepage. For example, it may take two people an entire day to survey, collect and prepare soil samples, and run through the ESAP software to first design the soil sampling regime for a 40-acre tract. It would take a second day to develop the model relating EM38® reading, and a third to provide a map of soil salinity. This seems a very onerous task when considering that the affected area may cover hundreds if not thousands of acres.
- There are no maps provided for review in the SMP document; it isn't clear just how many of these surveys have been completed or how the SJRRP is using these maps to make decisions. What criteria have been developed to classify affected lands according to the results from these EM surveys? Is an average salinity over the field sufficient or is the SJRRP more interested in "hot spots" in the field, used to trigger an exceedance in soil salinity criteria? The SMP needs to address this deficiency in how the EM38® surveys fit into a general water table and salinity management strategy.

1.2.3 Laboratory Testing

In the Handbook and the SMP, lab testing procedures appear to be acceptable but it is not clear that this is the best use of resources for monitoring. Soil analysis for SAR, EC, pH etc provide good information but given that the primary issues appears to be drainage, laboratory monitoring of these components may not always be warranted. In addition, some basic salinity information can be obtained from soil surveys. However, when a project is developed it may be necessary to perform targeted soil and water quality analyses.

Salts and boron in the region comes from irrigation water delivered through the DMC that subsequently evapoconcentrates yielding a shallow groundwater elevated in both constituents. Salts, boron, and selenium are also found in groundwater beneath soils derived from sediments eroded from the Coast Range and deposited within the Panoche Creek and Little Panoche Creek alluvial fans. Most selenium is found in the groundwater as a result of leaching of these alluvial sediments. Other trace elements such as mercury and uranium that are similarly associated with certain shale formations such as the Kreyenhagen and Moreno and eroded from the Coast can also be found in shallow groundwater. The depositional environment and location of the property relative to the extent of the west-side alluvial fans can provide a guide to groundwater quality and the need for Laboratory testing. Local groundwater should be characterized, but ongoing monitoring should not be required.

1.2.4 Gaging Stations and Staff Gages

The USGS and CDEC gaging stations currently used appear to be adequate and are available on CDEC. As the project progresses, all newly constructed conveyance structures should be added to the CDEC system. The current gaging structures in the reaches of primary seepage concern exist at Mendota Pool, Sack Dam, and Washington Avenue. These gaging sites are operated and maintained by USGS and DWR. They are good sites and have been utilized to evaluate the seepage characteristics in this portion of the River (about 30 miles). It is strongly recommended that a seepage protocol based on the gaging stations be incorporated into the SMP.

River gaging stations are typically located at bridge overcrossings, which provide relatively stable cross-section profiles and minimize the requirement for frequent cross-section surveys. Most river stations are operated either by DWR or the USGS (under contract with Reclamation or other water agencies). Reclamation operates several of its own stations along the San Joaquin River between Friant Dam and Mendota Pool. DWR publishes preliminary flow information on CDEC; Reclamation sends its telemetered data to CDEC as well. The USGS publishes preliminary data on its National Water Information System (NWIS) web server. The gaging stations currently used appear to be adequate and all available bridge overcrossings are in service as monitoring stations. CDEC has been very accommodating by allowing their server to share flow and water quality data even when it has no direct bearing on flood hydrology. NWIS is only able to serve data produced by the USGS.

1.2.5 Cropping Patterns and Productivity

Determining what crop to grow is a complex decision carried out by the grower, who weighs key factors such as cropping history, soil and water quality, commodity price, water availability and pricing, irrigation and equipment infrastructure. Producers farming the land adjacent to the San Joaquin River have generally grown a large diversity of crop types including cotton, alfalfa, corn, and other forages in addition to sugar beets, processing tomatoes and a few other annual crops. In recent decades crop diversity has been enhanced with some acreage that includes additional fresh and processing vegetables as well as increasing acreages of permanent crops that generally have higher total returns. Increases in the acreages of almonds, grapes, pistachios, and pomegranates have enhanced grower returns and helped growers in the region to remain profitable while some crops in the grower portfolio have experienced market downturns. The long-term viability of area farms will in part depend on the growers' capacity to continue to plant a diversity of crops that are both stable and profitable in the marketplace.

Implementation of a successful SJRRP will need to consider the future needs of growers to continue to maintain diverse cropping systems. These systems must be flexible and profitable in most years as well as be able to recover from periodic production issues that may be encountered during restoration flow periods. But because each crop has unique sensitivities to perturbations caused by water table level changes near the soil surface, there will be limitations to the flexibility of crop types being planted in areas frequently impacted by the presence of shallow water tables, increased surface soil salinity, and increases in anaerobic soil conditions. For instance, it will be difficult to expect some permanent crops such almonds, grapes, stone fruit and other salt sensitive crops to grow in areas that are regularly or periodically impacted by water table level rises into the root zone. More flexibility, on the other hand, can be given to crops that have a higher salinity threshold and at least temporarily tolerate anoxic soil conditions. Annual cropping systems that include crops such as cotton, alfalfa, small grains and some vegetable, while generally having lower per-acre returns, will be better suited cropping choices in areas more acutely impacted by shallow water table conditions. But regardless of crop selection, even crops that are better adapted to shallow water tables or the effects of soil salinity will be impacted by the presence of very shallow water tables and even brief periods of inundation.

Within each crop type there is considerable variation in yield regardless of whether salinity or shallow water tables exist. Crop productivity in cotton, for instance, can be affected by planting date, row spacing, plant population, irrigation and nutrient regime, and can be adversely impacted by elevated pest populations including insects, diseases, and weeds. Because of cotton's high seasonal heat unit requirements and relatively warm soil conditions required for germination, cool spring conditions can delay planting to the point that yield potential suffers. High heat during the bloom set period can also adversely affect boll set and reduce the opportunity to achieve top yields. In some years yield benefits have been achieved by increasing planting density or migrating to 30-inch bed systems (as opposed to the historical 40-inch bed configuration). Cotton growers benefit from timely pest management practices that start by regularly monitoring insect pest populations, weed populations, and the occurrence of disease in their fields as each can have a significant impact on productivity.

Routine crop and soil monitoring are also observed to determine the need for plant nutrients and timely irrigation management decisions. Irrigating a cotton crop too soon, for instance, results in the cooling of the soil and can set back crop development by reducing crop development and vigor, while irrigating too late in the season risks developing water stress that limits canopy expansion and therefore the capacity of the plant to capture light in a limited season environment. Field optimization of each of these crop management parameters plays an important role in maintaining consistently high yields that result in profitable farm operations and vary from crop to crop.

Farm production systems impacted by shallow water tables, increased salinity and reduced aeration are generally managed differently from more well-drained field conditions. To improve yields in poorly drained fields, growers have changed in-season management practices that accommodate these fields, thereby improving opportunities to maximize yield. In some cases growers have benefited from earlier and more frequent irrigation events that can offset the osmotic and specific ion effects of salts in the root zone. More frequent irrigation can lead to increased early season crop vigor that can in turn improve vegetative production and increased fruit set. Alternatively, changing irrigation practices from furrow or flood to sprinkler and drip irrigation has been successful in some, but not all shallow water table systems by maintaining a downward leaching of salts with reduced concern for over-irrigation and the problems it can cause in further elevating local water table levels.

One further complication in crop production fields impacted by shallow water tables is that rarely are the problems uniform throughout the field, including the depth to water table. Small changes in the depth to water table can have a significant impact on the depth to salts residing above the capillary fringe and directly impacting crop growth. Although the grower may have good field history of the site and understand the variable nature of the field, it remains problematic in how to apply uniform or non-uniform practices in dealing with the non-uniform nature of salinity and drainage problems from an agronomic standpoint. In some cases it may make sense to divide the field into smaller units and change irrigation management practices such that they reflect optimum management for each contrasting soil condition. However, this is often not the case due to the fact that most management occurs in one orientation down the length of the rows which is generally preset to optimize other production system elements. And while growers do work to adopt irrigation and other field management practices that optimize the whole field, many decisions are optimized by implementing practices that are a compromise between the field extremes.

Fields that have been exposed to transient rises in groundwater levels have the problem of retaining much of their salt content in the root zone following a subsequent decline in water table levels. Growers have generally managed these salts by applying an additional leaching fraction during pre-plant irrigation periods or during in-season irrigation events. The additional water required to move these salts to areas deep in the soil profile would not be necessary if shallow water table rises caused by increased river flows are minimized. In some cases fields have benefited from the application of gypsum or acidic amendments that have worked to improve the field's internal drainage. Outlining a more specific reclamation plan that addresses the variable nature of the problem and includes the need for additional water and potentially soil amendments would be useful added elements to the SMP.

A primary element of the SJRRP is to maintain the productivity of the low lying agricultural areas that are more susceptible to the influences of rising water table levels caused by restoration flows while preserving productive farmland. To achieve this goal it will be necessary to recognize the limitations of future cropping system choices. For example, it may not be practical to establish new plantings of salt sensitive crops into areas most impacted by a combination of high soil salinity levels and restoration flows. The PRP suggests that a method be developed in the plan that outlines crop selection components be matched with the corresponding level of risk associated with the areas historically impacted by shallow water tables and their impacts on crop productivity. The discussion under multispectral imagery suggests that remote sensing could be useful in establishing pre-project cropping patterns and help maximize crop productivity. Groundwater threshold levels described in Appendix H can be useful in establishing risk level to future plantings provided the local data be used where possible and updated to match geographic regions hydrology to cropping system selections.

1.2.6 Remote Sensing

Remotely sensed optical digital imagery acquired by satellite or airborne sensors (RS imagery) captures the spectral reflectance values of land cover features. Spectral reflectance values are unique to a land cover feature within a specific environmental condition. By leveraging any one or multiple RS imagery sources, limited ground verification survey data, and current advanced image analysis algorithms, it is efficiently possible to perform large-area feature classifications, such as vegetation type discrimination, habitat mapping, agricultural yield estimation, biomass mapping, multi-temporal change detection of any such classifications, to name a few applications. Analysis of RS imagery to quantify land cover characteristics has multiple benefits. Compared to traditional vegetation survey techniques, RS imagery requires significantly less time and labor, while covering a larger area. Rather than the exhaustive on-going field effort that would be required to survey a large area such as the seepage affected area outlined by the SJRRP staff in their briefings, field work is limited to the time necessary to provide calibration data for the image analysis effort, thus allowing a proportionally-representative population of field data to be used to “train” an algorithm to cluster common land features for the entire area covered by an imagery source.

While satellite imagery can be used effectively to map small areas, it becomes increasingly cost effective for larger study sites. Additionally, for larger study areas this need for limited field data allows for an inventory to represent a discrete time-frame with RS imagery, and field data collected is able to represent a specific temporal window. Satellite imagery is also a flexible technology. Depending on the variables of interest, image collection can be timed to capture different features throughout the growing season. Through tracking the changes in multi-temporal imagery and correlating changes with previously made management decisions, impacts may be assigned to various land use activities (Holland, 1986, Fredrickson, 1991). Satellite imagery is also an unbiased and consistent data source, which both reduces concerns of consistency between teams of surveyors, or drifts in field methodology and nomenclature during the field season. It also creates the potential for study sites to be viewed in a broader context, both regionally and worldwide. Finally, the imagery provides an archival data source, which after its initial use continues to be available as a historical reference, and can be used in later studies.

In addition to RS imagery mentioned above, which involves optical and passive detection sensors, there is also recent significant advancement in "active" sensors such as LiDAR and RADAR. Active sensors transmit and return signal attributes that vary depending on the sensor type. LiDAR is primarily used for capturing highly-detailed terrain data. RADAR data has many deviations but offers the opportunity to quantify any characteristic ranging from canopy structure classification, soil moisture, and centimeter-level land disturbances between dates, among a myriad of other applications.

Seepage monitoring may be accomplished through a combination of data and analysis methods. Through the use of RS imagery crop/vegetation mapping may be accomplished, resulting in discrimination of vegetation types and subsequently a root zone depth grouping by vegetation type. Monitoring vegetation impacts through time would be optimally performed based on vegetation classes as related to root-zone impacts or other effects. RS imagery analysis allows for this multi-temporal, multi-year vegetation impact analysis. Orchard crops, once delineated through RS means, offer a relatively constant managed environment which could be tracked for vegetative stress through spectrally-based vegetative indices and canopy density features, all able to be determined through RS imagery analysis.

The SJRRP study area has available a large selection of RS imagery products, both historical and current. A rich inventory of National Agriculture Inventory Program (NAIP) imagery offers a high-resolution (1m spatial resolution) photographic record of the study area (4 complete inventories in the last 8 years). For moderate-resolution applications, the USGS maintains a 30-year archive of Landsat imagery (30 m spatial resolution), providing a consistent and uninterrupted imagery source covering the study area, in addition to much of the world. For example, the USDA NRDS NASS (http://nassgeodata.gmu.edu/CropScape/) uses an algorithm to estimate vegetation type based on LandSAT band combinations. Utilizing such imagery archives allow multi-year change detection, both major vegetative change and subtle vegetative stress monitoring that can be directly related to monitoring station data, flow rates, rainfall, soil surveys, and other vegetative moisture impacts.

In 2008, the majority of the SJRRP project area had multi-return LiDAR acquired. LiDAR data may provide information ranging from bare earth terrain models that denote depressions and areas. These areas may be more impacted by higher water tables to vegetative height and in some cases canopy complexity, which provide insight into both supporting a RS imagery analysis event but also provide auxiliary information to a vegetative inventory. In areas devoid of vegetation, multi-temporal radar imagery may be a cost-effective method to quantify elevation change or terrain disturbance such as land subsidence.

RS imagery is frequently used simply as a visual reference. The valuable tool and imagery archive offered by Google Earth has been used to good effect by the SJRRP to help locate the various monitoring wells and delineate the seepage problem areas relative to the channel geometry and bathymetry of the San Joaquin River. The detail and resolution of these images are very effective in providing the reviewer with information on local influences and other factors that could impact seepage. It is also instructive to observe the location of monitoring stations both for surface flow and groundwater level within each parcel map. The GIS overlays of shallow water tables and areas of inundation are also effective – though some of the flow inundation maps were difficult to analyze or draw meaningful conclusions from.

To date, very little use is made of other remote sensing techniques such as multispectral analysis, which can be used under the right conditions to perform change detection studies for moisture conditions and salinity build up. There is mention in the SMP of remote sensing being used to identify sand stringers; however, no results are presented of this analysis or description of how the information gained from imagery was used.

Provided proper field data is presented for calibration, it is certainly feasible to classify surface types along a channel or other exposed soil areas. High resolution imagery and appropriate algorithm application can help discriminate fine to coarse materials in other project areas. Leverage of the multiple data sources already collected for this project and being collected in an ongoing manner offers the ability to establish obscure land feature relationships. For example, utilizing RS imagery, multi-return LiDAR, and EM38® survey data offers the opportunity to explore potential correlations across a large region, based on a relatively small sampling of survey data.

Remote sensing might be most appropriately combined with the EM38® surveys to establish a rapid appraisal technique for assessing seepage impacts and damage beyond what can be obtained from the EM38® surveys alone. This can certainly be performed at considerable savings in time and cost using RS. Investigation of multiple uses of RS along this approximately 150-mile reach of the San Joaquin River is recommended since it can provide multi-benefit results, not only for seepage management, but also vegetation surveys, crop classification, tracking wetness evaluations, etc.

The procedures using RS might look like the following:

- Select wet years in the past where high flows down the SJ have occurred
- Select dry and normal years where crops were similar in the same area
- Make sure that these years influenced the water table (higher on wet, lower on dry and normal)
- Use an evapotranspiration (ET) evaluation tool such as METRIC to assess actual evapotranspiration for the whole year for each year selected.
- Select fields that had the same crop (check that the age of perennial crops was not significantly different)
- Make sure there was a high water table during the wet year for these fields. The amount of water applied on the fields was the same each year.
- See if there was a measurable impact on the seasonal average crop coefficient (ETo will vary so Kc should be the comparison).
- Evaluate the variability in ET between years in each of the fields.

1.2.7 *Water Quality*

Relatively little information about water quality is presented in the SMP. The PRP recommends that irrigation water quality should be reported by source where available. The two major surface-water sources, the DMC and the SJR, are currently monitored and posted to multiple databases. It is recognized that the water districts have much of this information that is used for day-to-day operations. However, the quality of groundwater utilized for irrigation is currently NOT being monitored by the SJRRP.

The collection of water quality information will support water resource management by potentially reducing salinity impacts to crops. For example, higher quality water should be used in the spring (higher Delta flows should provide higher spring water quality in the DMC) to reduce impacts from salinity on seedlings. In addition, given that the water table generally decreases as the summer progresses, this could increase soil profile management options that allow leaching and the use of lower quality water.

The region, like all areas in the Central Valley, is under the Central Valley Regional Water Quality Control Board's Agricultural Waiver Program. This program requires landowners to comply with surface and groundwater quality discharge requirements. This program is designed so that agricultural discharges do not adversely impact surface and groundwater quality particularly for nutrients, salts and pesticides. The Board has orders that are regionally specific so they should be considered during project implementation.

Another water quality parameter that could potentially be monitored and characterized is the oxidation-reduction potential (ORP). This inexpensive, simple measurement indicates the level of electron activity in an aqueous phase. Assuming an ambient pH of around 6.5-8, when the electron (pE) activity is low there is plenty of oxygen in the system for respiration. When the electron potential is high, oxidized components in the soil water system are rapidly reduced. This process causes anoxia leading to the inactivity of primary root function in most crops and the possibility of root diseases developing. Although there is good general data on the range of ORP in soils and corresponding impacts on some crops, there is very little data on how specific ORP levels at depth might impact the many crop types being grown under local soil and climatic conditions. The utility of monitoring either the ORP or dissolved oxygen content is that water table levels could be manipulated such that drainage pumps could be activated when the anoxia becomes an issue.

1.3 Resolution of Monitoring

The SMP PRP assessment of monitoring spatial and temporal resolution is generally favorable. The SJRRP has installed a very large number of shallow monitoring wells, which would appear to provide adequate resolution for characterizing the nature and extent of the seepage problems. The SJRRP apparently has not restricted itself to a finite number of wells at each location; rather, the SMP appears to have provided a sufficient number to address any unique circumstances encountered at individual sites. It is a real strength of the SMP to allow for additional monitoring wells to be installed as needed to supplement existing datasets.

The temporal resolution of data collection from the groundwater monitoring network is likely sufficient to meet most needs of the SMP. The collection of hourly water levels using pressure transducers in some wells to supplement the spatial coverage of manual (monthly) water levels is an appropriate use of technology. The use of telemetry and real-time posting of water levels at key wells is also a very positive aspect of the SMP that may be used as a possible early-warning alert before adverse material seepage effects actually occur. It isn't stated in the SMP, but we recommend evaluating the potential time and costs savings of converting additional manually collected wells to pressure transducers that can collect hourly data, particularly at known and anticipated trouble spots of material seepage effects.

Local growers know their fields very well and are in a good position to note heterogeneities in soil texture or anomalies of groundwater levels given their long history farming each field. Being able to take advantage of this local knowledge can save a lot of unnecessary expenditure and reduce the amount of data that needs to be collected and analyzed. This is a credit to the Program.

The PRP recommends that the SMP add a clearer description of the degree of correspondence between the approximately "2,800 wells within the 5 mile of the SJRRP study that are available in a database" (Appendix C: Historical Groundwater Levels) and the wells currently used in the monitoring network (see Appendix F: Monitoring Network).

It wasn't clear in the SMP if a formal QA/QC protocol for monitoring data collection exists? If so, we suggest including that QA/QC protocol in the SMP. If not, we suggest developing a formal QA/QC plan. Similarly, what is the QA/QC protocol for the telemetry data that is uploaded to the CDEC, presumably in "real-time" (see page F-6)? It is recommended that descriptive language be added to the SMP that references a method for checking the accuracy of data prior to upload on the CDEC.

Improvements in the characterization of seepage resulting from high river stage can always be improved by increasing the number of shallow water table monitoring wells. Factors that need to be weighed against increasing the number of monitoring wells and similar sensing technologies deployed in the field are the personnel and data management costs associated with the additional monitoring. The choice between deployment of in-situ loggers versus real-time telemetry may ultimately be decided by the number of field personnel available to visit field sites and the hydrologic data management software available to store the data and perform basic quality assurance analysis. Data quality assurance is a significant constraint to both monitoring approaches since the data will be used to guide decisions and provide the fast response expected by landowners using the Project hotline.

The SMP report is deficient in its plan for long-term data acquisition, data management and data quality assurance. An enterprise-level hydrologic data management system will eventually be needed as the program transitions from the more experimental interim flow event response paradigm to fully operational status. Computer programs such as Kisters HYDSTRA or WISKI are good candidates for this task. DWR staff working on the Restoration Program is currently using HYDSTRA for maintaining river gaging station ratings and calculating rating shifts. Both software programs are owned by the same company and are equivalent in functionality although they employ slightly different data structures. They are, however, interoperable and data is easily moved from one system to the other.

1.4 Travel Times and Flow Attenuation

The use of HEC-RAS is appropriate for estimation of travel time and flow attenuation for the San Joaquin River. However, the SMP doesn't clearly describe how the travel times or flow attenuation were verified and the steps taken to calibrate and tune the HEC-RAS model. It is recommended this extra information be added with a brief explanation to the SMP.

In the Flow Bench report, the graphs generated by the HEC-RAS data should be standardized. Currently, they have different scales reported on both the x-axis and the y-axis. Since these graphs are a key indicator for the Flow Bench Evaluation, it also recommended that some additional graphics be added to this section of the report.

Although logistically challenging, another possible future technique that can be used to good effect is the "dye study", such as the fluorometric dye rhodamine WT, to estimate river travel times under different flow regimes. An ideal dye study would be conducted under a range of conditions along the hydrograph to develop relations between travel time [*Gurdak et al., 2002*] and discharge and to estimate longitudinal-dispersion coefficients that could benefit future distributed surface-water modeling of the SJR with benefits for the SMP. There was no mention of this or other types of studies being conducted in support of the HEC-RAS model.

1.5 Flow Bench Evaluations

Based on background information on protocols used by the USBR, USGS, and DWR the flow rates, groundwater data, and analysis performed in the Flow Bench Evaluations is of sufficient accuracy to develop an initial estimate of where thresholds were exceeded or triggers initiated that result in adverse impacts to landowners. It is recommended to continue clear lines of communications with the growers and the water districts on the impacts of seepage.

It is the opinion of the PRP that the Flow Bench Evaluation reports could be expanded and more informative. The PRP found it difficult to decipher all of the information in the reports especially in relation to the interpretation of the data. For example, a summary map would be helpful showing the key locations identified in the text. Currently there are six pages of HEC-RAS rating curves for the SJR but not an overall map.

The following are specific recommendations for the Flow Bench Report format:

1. Clearly list the nine key monitoring criteria for decision making. For example, the following is an example from an existing SJRRP Flow Bench Report.

   "Operations calls identified a concern regarding the amount of exchangeable demand available in Mendota Pool."

   The suggested change to this type of reporting is to make the information a little less cryptic to a person not familiar with the details:

Operation Conference Call: The weekly call (Mondays at 9:15am) with SJRRP staff and the district managers/water masters resulted in a concern on the exchangeable demand in the Mendota Pool. There were no concerns listed for maintenance activities, increased flows, or water quality.

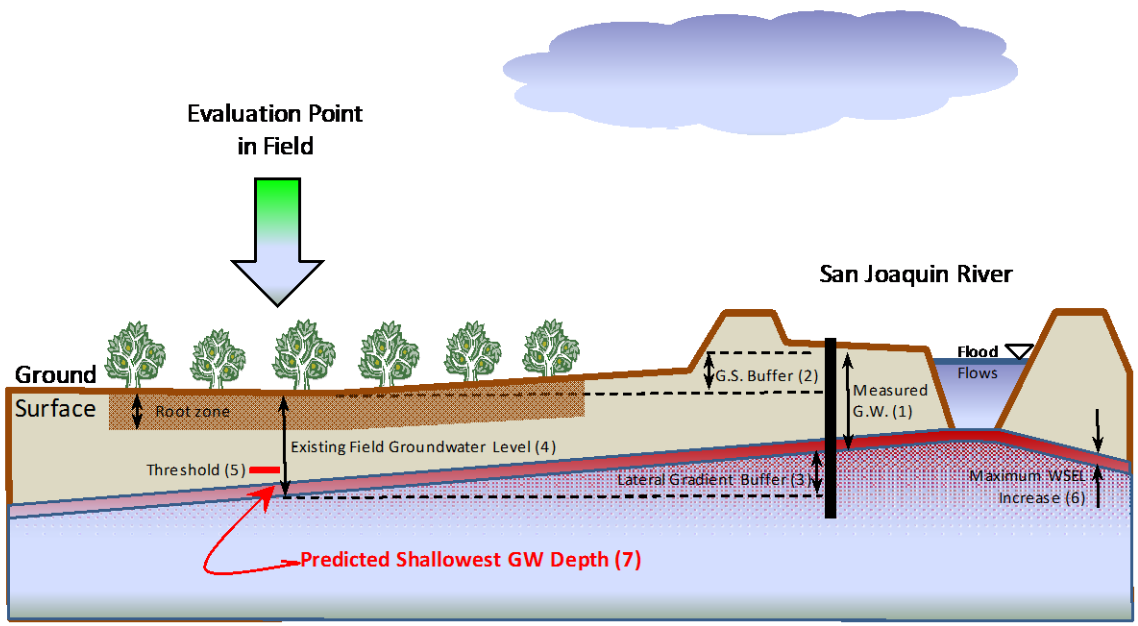
2. All of the tables in the report need to have column headings such as 1, 2, 3… with a description of each of the columns at the bottom of the table. Especially, the columns that require some simple math interaction with the previous columns.

3. The tables should have a footer that delineates the wells that are within the levee system as compared to zones that are located outside of the levee (Wells FA-9, MW-09-47, MA-4, and MW-09-49B are all located within the SJR levee).

1.6 Groundwater Level Prediction

The current practice of assuming a 1 ft increase in the River bed water surface (WSEL) equating to a 1 ft rise in a nearby observation well is overly conservative. Even in instances where significant hydraulic communication is evident, there is typically a time lag between the river rise and the water table response. As discussed earlier, this is an area that could be improved with an increased density of wells. In particular, the number of wells along the toe of the SJR levee should be increased. The key problem is the variability of timing of the groundwater movement. Although in many instances the groundwater response time is a function of the rate of porous flow through the connecting aquifer layer, the response can be more rapid in situations where elevated river stage blocks regional groundwater flow. In the valley trough where there is a considerable area of bottom land bordering the river, the impact of drainage impedance can occur rapidly and be extensive. The affected aerial extent has been appropriately mapped by the Restoration Program and in some instances extends several miles west of the River along reaches 3, 4A, and 4B.

Although it may be clear to those within the SJRRP, the simple maps used to show the impact of an increase in the river stage are not very clear. It is recommended that the following figure be used to better describe the impact of a change in the river elevation.



Proposed new figure for "Increase in Stage" Method

Note: The values 1-7 reference columns in the new Flow Bench report format.

1.7 Field Corrections to Flow Bench Evaluation Groundwater Levels

The PRP agrees with the method used to correct the field groundwater levels based on the flow bench evaluations. In the future, additional wells and operational knowledge will reduce the need for the field corrections.

1.8 Use of Drainage Method for Flow Bench Evaluations if Irrigation is Occurring

It is the feeling of the PRP that the key to making the two "methods" more reasonable and accurate for the evaluation is to increase the number of monitoring wells. It may also lead to the conclusion that drainage that is currently occurring to the SJR will be impacted for significant areas. These areas may need drainage relief prior to starting the full-scale delivery of flows to the SJR.

Since it was not very clear, the PRP solicited from Katrina Harrison (Reclamation) the following clarification on the difference between the standard method and the drainage method:

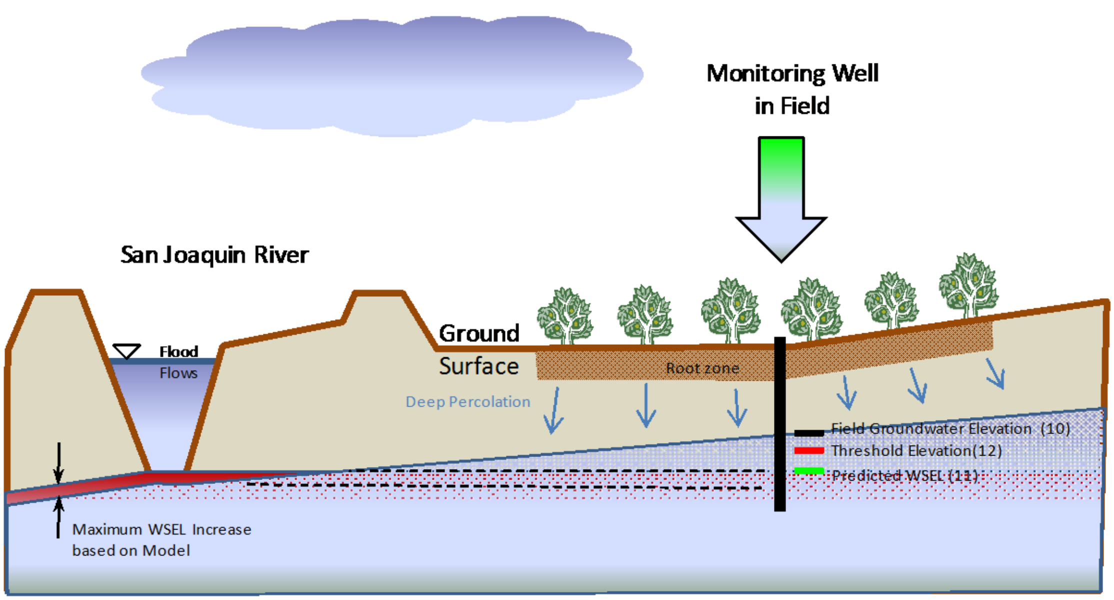
The standard method (or "increase in stage method") is calculated as follows:

- Measured depth of the water table below ground surface in the well, converted to a depth bgs (below ground surface) in the field by applying the difference between field and well ground surface elevation (if any)
- Calculated water surface elevation from HEC-RAS at the future flow level, minus the elevation at the existing flow level (i.e., delta h)
- Measured depth bgs in the field, + delta h = predicted depth bgs in the field at the future flow level

Thus, this standard method is sensitive to the most recent measurements, but can result in a predicted groundwater elevation that is greater than the WSEL in the River.

The drainage method is a comparison of elevations regardless of the most recent groundwater level. One of the key assumptions in the drainage method is that a rise in the river level (WSEL) will not cause a rise at the observation well that is already draining towards the river. This needs to be evaluated in the future with additional site data.

The visual representation of what is happening during the drainage flow condition from a field is missing from the SMP and Flow Bench Evaluation reports. It is strongly recommended that a new schematic be used to describe the drainage method.



Proposed new figure for "Drainage" Method

Thresholds were set when the SMP was developed back in fall 2010/spring 2011, and were put together by a group of people, with input from landowners. The agricultural thresholds were initially researched by Reclamation, some of it from the original SMP in 2009 (developed by Reclamation, consultants, and the USGS), and then updated by Reclamation with additional research in January 2011 to expand the crop root zone table and incorporate the most recent capillary fringe measurements from soil salinity boreholes. The Seepage and Conveyance Technical Feedback Group (SCTFG) was presented with draft thresholds in January and February 2011. Landowners and district managers provided input and so several thresholds changed (tomatoes and almonds were the main ones). These thresholds were then memorialized in the March 2011 SMP, and haven't changed to the version being reviewed. Thresholds are set in two different ways: agricultural (root zone + capillary fringe), and historical (more or less the shallowest historical groundwater level not in a wet year).

2. Do the agricultural thresholds provide a reasonable amount of protection when setting a threshold?

The following review of the SMP includes comments on Appendix H, which contains the results of the Development of Groundwater-Level Thresholds, and comments on Appendix G, which contains soil salinity thresholds and soil salinity monitoring approaches. Specifically, this review focuses on agronomic components of the Agricultural Practices Method, used to estimate root zones or crop root depth for pertinent crops to allow for leaching.

2.1 Summary PRP Recommendations

The accuracy and clarity of results in Appendix H and Appendix G would be improved by the following revisions and recommendations found below.

It should be noted that all natural systems are different and can vary even within a production field, let alone over 150 miles of agricultural land along a river system. Soil types, crop types, irrigation methods, groundwater levels, farm management, etc., all change and provide various challenges when protecting a cropping system from impacts such as seepage and high water tables. Therefore, it should be clearly stated that the information provided below related to crop root zones, capillary rise, etc., all come from known and accepted resources, but are not local conditions specific to the agricultural environment along the San Joaquin River. As a result, site specific monitoring and accurate interpretation should be used in lieu of literature or other academic values whenever possible.

2.1.1 Groundwater-Level Thresholds

Crop Root Zones

- It is recommended that a complete "effective" root zone be used (and are provided below) for all crops rather than "maximum" root zones. Distinguishing between the two is important to establish a truly representative and reasonable root zone for plant growth. Therefore, both should be considered; however, the "effective" root zone should be used when determining the Groundwater-Level Thresholds. For the purposes of this document, report either maximum effective root depth and/or maximum root depth consistently.
- It is recommended that "effective" root depths be presented and initially used for unrestricted root growth only. Actual restrictive conditions (e.g., hard pans, dense clay layers, etc.) should be investigated and considered when possible.
- It is recommended that the SMP provide more explanation and clarification on the limitations that varying irrigation practices and management have on individual crops and that these differences are considered when establishing the root zone depths for each crop.

Capillary Rise

It is recommended that the accuracy of capillary rise estimates (particularly for medium- to fine-textured soils) be improved by increasing the number of field observations on which estimates are based, or by providing supporting documentation. An initial starting point is provided (by soil texture) below; however, again, actual field conditions can increase or decrease these estimates.

Irrigation Buffer

It is likely not necessary to provide an irrigation buffer component to the overall depth of unsaturated soil required for crop growth above the water table. This is not a common component for this type evaluation, and limited references/examples were provided to justify this additional depth of soil.

Other

Due to the extensive variability and overall distance in question along the San Joaquin River, the PRP recommends remote sensing techniques be considered as a method to not only assess potential impacts to crop production, but also to evaluate seepage conditions in fallow fields, native vegetation areas and other land use areas.

2.1.2 Crop Salinity Thresholds

The following recommendations should be considered for crop salinity thresholds:

- Provide data from more than one source for crop salinity thresholds; ideally include regional data.
- Refine the salinity thresholds for pistachio, pomegranate and safflower using data from scientific literature rather than selecting a point within the range that corresponds to its salinity ranking.
- Revise root zone salinity levels of concern for river reaches according to the most salt-sensitive crop that is grown in the study area and perhaps even the most salt-sensitive crop that "could" be grown in that area.
- Revise plow layer salinity levels of concern for the most salt-sensitive crop grown in the study area.
- Clarify and emphasize that crop symptoms are likely not timely indicators of soil salinization beyond crop thresholds.

2.2 Development of Groundwater-Level Thresholds (Appendix H)

2.2.1 Crop Root Zones

The SMP states that the purpose of establishing a root zone for each crop is to provide an unsaturated zone to avoid waterlogging. The objectives of this modeling effort stated in the SMP are as follows:

- Identify different root zones based on crop type to expand on the existing crop root zones in the 2009 Seepage Monitoring and Management Plan.
- Include multiple root zones for each crop based on young and mature crops if information is available.

Approach

The approach in the SMP proposes that crop, soil texture, irrigation practices, and depth to groundwater affect crop root depth. Additionally, it states that poorly drained and fine-textured soils can restrict crop root growth, while irrigation practices can change root distribution and depth. The following three comments pertain to the approach and assumptions used to determine and report root depths for crops.

Root Zone – Maximum and Effective Zones

The term root zone should be specifically defined. Crops have a maximum root depth, which is the depth to which roots of a particular crop can penetrate in unrestricted soils with no physical impediments such as hard pan, poorly aerated zones or compacted soil layers. However, roots are typically concentrated in the upper layers of soil; even in crops that are deep-rooted, 60 to 70 percent of root mass usually lies within the top few feet of soil (Erie et al., 1982), and in some cases within the top 6 inches (Hanaway and Larson, 2004). It is in this zone that most of the metabolic activity of the root takes place as well as the majority of water and nutrients taken up. For this reason, *effective* root depths are sometimes reported, though the meaning of "effective" is not as definitive as "maximum". Other values reported include "average" root depth, which refers to the weighted average of root mass by depth.

It is unclear if maximum root depths, effective root depths, or some other depth such as "typical" root depths (difficult to define) are reported in Table H-1 of the SMP. The values do not correspond consistently to maximum or effective root depth, though the concept of effective root depth is mentioned in one of the footnotes to the table. Values from the Food and Agriculture Organization of the United Nations (FAO) are implied as maximum root depths when in fact they are effective root depths.

The title "Crop Root Depths" does not indicate which depth is reported, though it is apparent from the notes that maximum root depth is implied. If this is the case, several of the reported values may be too shallow. For example, alfalfa is documented to root beyond 12 feet (Hall et al., 2004; Hanaway and Larson, 2004; Samac, 2007). The other indication that maximum root depth and effective root depth are mixed in the table is the ranges given for crops. For example, the maximum root depth for almonds is 2 to 12 feet. Though it is likely that effective root depth could be 2 feet or more, it is unlikely that 2 feet would be considered maximum root depth for almonds. Whether maximum or maximum effective root depth was intended, it should be specified and consistently reported as such.

Soil Texture and Root Depth

The concept that fine-textured soils restrict root growth and coarse-textured soils promote root growth does not necessarily hold true for all crops. For example, no correlation has been found between root depth and soil texture in grapes (Smart et al., 2006). This may be the reason that different values are not reported for grapes in Table H-1 for different textures of soil. However, this should be stated and reported more accurately. Reporting root depths for somewhat restrictive, fine-textured soils is questionable (described in more detail below) because root depths are typically only provided for unimpeded root zones, regardless of soil texture.

Irrigation Practices and Root Depth

The approach notes that root zone results do not account for the differences in root depth caused by different irrigation practices. However, an assumption is made that optimum irrigation decreases average root depth while less than optimum irrigation increases average root depth. While this is true for alfalfa (Abdul-Jabbar et al., 1982; Blaylock, undated), it is not true for cotton (McMichael et al., 2011), which implies that the effect of irrigation on root depth is crop-specific. It is likely that site-specific evaluations need to be considered to fully evaluate these unique conditions under certain affected crops and soil conditions. The effort to investigate the effect of irrigation on root depths for all crops would be substantial and not called for in this review; however, it is important to note that irrigation has an important and variable influence on root depth.

Though the limitation of not accounting for irrigation-induced differences in root depth is acknowledged in the approach, the assumption that the effect of irrigation is similar across all crop types is potentially problematic for two reasons. First, the assumption may represent too much variability to omit from the approach. Second, it implies that the results provided could be modified in a certain way to reflect this assumption, which would be erroneous for some crops.

In summary, the approach would be improved by implementing the following recommendations:

- Reporting either maximum effective root depth and/or maximum root depth consistently
- Reporting root depth for unrestricted root growth only
- Providing more explanation and clarification on the limitations of not accounting for the effect that varying irrigation practices has on individual crops

Presentation of Results

Some inconsistencies and points of clarification were noted in Table H-1 of the SMP that provides the root zone results for relevant crops, as follows:

- The crop type "spring wheat winter" is unusual and should be clarified. It implies hard red spring wheat that is planted during the winter growing season, but clarification is needed.
- Root depths are listed for late season (no soil type indicated), for fine-textured soils, and late season for coarse-textured soils. It is unclear if the root depth for "late season" refers to moderately-textured soils, or contains values that encompass the range of both fine and coarse soil data.
- The relevance of the distinction between root depth in fine-textured soils and coarse-textured soils is questionable, as evidenced by the low values reported in

the fine-textured soil column (three out of a possible 15 crop types), for two reasons. First, as described above, the correlation between soil texture and root depth may not hold for all crops. Second, root depths are usually not reported for restricted root zones because there are many variables other than soil texture that can impede root growth. For example, root depth could be restricted by various amounts of clay, salt lenses, soil structure, compaction, stoniness, and calcified or hard-pans. The impacts of these factors on root growth cannot be quantified in a general fashion.

- Therefore, maximum root depths are typically reported under the assumption that crops are growing in well-drained soils without impediments. Under different conditions, root depth would differ on a site by site basis, and is likely the reason that root depths are typically not reported for fine-textured soils. Root depth is more accurate when it is reported in a manner that is consistent with published scientific articles – citing maximum root depth for deep, unrestricted soils. Reporting a different root depth for fine-textured soils is questionable because of the low availability of data, and because of the lack of correlation between soil texture and some crops as explained above.
- It is unclear how early season root depth applies to grapes (a value of 5 feet is listed) and other permanent crops. If it doesn't apply, the table should indicate that it is not applicable; currently there is no distinction between categories that don't apply to the crop, and categories for which there is no data.
- It is unclear why sugarcane is listed as a relevant crop. Sugarcane is not referenced in the final results in Appendix H.

Results

As discussed above, the values in Table H-1 in the SMP appear to be inconsistent, and may represent maximum root depths in some cases and effective root depths in other cases. Table 1 provides a comparison of values listed in Table H-1, FAO values for effective root depth, values for the effective and maximum root depths found in other sources of literature, and maximum root depths.

As indicated above, many of the values reported as root depths may be too shallow if they are intended as maximum root depths, likely because these values actually refer to effective root depth. For example, the root depth listed in Table H-1 for grape, pistachio, lima beans, barley, cotton, corn and wheat are very similar to the effective root depths listed by FAO. For these crops, the maximum root depth is necessarily higher than the values reported in Table H-1. The range of root depth provided for alfalfa appears to correspond to maximum root depth, but likely does not reach the top of the actual range.

At least five sources cite alfalfa root depths beyond 12 feet in unrestricted soils. The almond root depth is likely reasonable at the top end of the range (12 feet) but is likely too low at the bottom end of the range (2 feet) as discussed previously. Melon root depth is reasonable according to other various other reported sources. The upper range of root depth for safflower (15 feet) was not corroborated by other sources. Ten to 12 feet is likely a more reasonable upper limit. The range of root depth for sugar beet is similar to other reports. Tomato root depth may be up to 6 feet but that has not been verified by other sources.

FAO is a well-documented and accepted source of agronomic information. The effective root depths reported by this source are likely good estimates and the upper ranges of these are recommended if an effective root zone is sought. Reviewing these values is also one method to evaluate maximum crop root depths. Because many of the values for maximum root depth in Table H-1 may be low or otherwise inaccurate, Table 1 includes a maximum root depth for each crop, rounded to the nearest half-foot. These values are based on scientific literature cited in Table 1; however, these references represent only a cursory review. A more in-depth review would likely benefit the accuracy of root depths.

For the purpose of modeling, the SMP approach used the following root zone depths for categorized crops:

- Cotton, alfalfa, other annual crops and unknown – 4 feet
- Grape, pistachio and pomegranate – 6 feet
- Almond – 9 feet
- Tomato, bean, melon and corn – 3 feet

Again, if these are intended to be maximum root zones, they are likely too shallow for all categories. If they are intended to be effective root zones, the values for annual field crops and vegetables is probably reasonable, but too deep for the tree species listed. Clarification of the root zone intended would improve the interpretation of these results.

Table 1. Maximum Root Depth And Maximum Effective Root Depth of Crops Included in SMP

Crop	Maximum Root Depth listed in Table H-1 of SMP	Effective Root Depth (feet) Reported by FAO (date)	Effective Root Depth (feet) Reported by Various Sources	Maximum Root Depth (feet) in Unrestricted Soils Reported by Various Sources	Recommended Maximum Root Depth (feet) in Unrestricted Soils	Rationale
			Permanent Semi-permanent and Perennial Crops			
Alfalfa	3-12	3.3-6.6	5 – Scherer, 2007	>12 - Kizer, 2007; Weaver, 1926 >15 – Hall et al., 2004 30 – Hanaway and Larson, 2004 60 – Samac et al., 2007	15	Several sources indicate that value of 12 is too low. Highest values are unique in literature.
Almonds	2-12	3.3-6.6	2.5 – Almond Board of California, Undated	13 – Catlin, 1996	12	Value in Table H-1 reasonable as corroborated by similar data in other sources.
Grape	3-6	3.3-6.6	2 – South Jersey RC&D Council, Undated	19.7 – Smart et al., 2006	20	Value provided in Table H-1 is effective root depth; maximum root depth is necessarily higher.
Pistachio	3-5	3.3-4.9	No other sources found	7 – Herrera, 1997 8.25 – Spiegel et al. 1977	8	Value provided in Table H-1 is effective root depth; maximum root depth is necessarily higher.
			Annual Crops			
Barley	3-5	3.3-4.9	3.5 - Scherer, 2007	4.4 – Weaver, 1926 6.9 – Hanaway and Larson, 2004 7 – Hackett, 1969	7	Value provided in Table H-1 is effective root depth; maximum root depth is necessarily higher.
Lima Beans	2-4	2.6-3.9	No other sources found	5.5 – Weaver, 1926	5.5	Value provided in Table H-1 is effective root depth; maximum root depth is necessarily higher.
Cotton	3-6	3.3-5.6	No other sources found	9 – McMichael, 2011	9	Value provided in Table H-1 is effective root depth; maximum root depth is necessarily higher.
Corn	3	3.3-5.6 (sweet) 2.6-3.9 (field)	4- Scherer, 2007	8 – Weaver, 1926	6	Value provided in Table H-1 is effective root depth; recommend value is rounded from effective zone.
Melon	2-6	2.6-4.9	2 - South Jersey RC&D Council, Undated	3.75 – Weaver, 1926	6	Not corroborated by other sources but reasonable in view of effective root zone.

Table 1. Maximum Root Depth And Maximum Effective Root Depth of Crops Included in SMP

Crop	Maximum Root Depth listed in Table H-1 of SMP	Effective Root Depth (feet) Reported by FAO (date)	Effective Root Depth (feet) Reported by Various Sources	Maximum Root Depth (feet) in Unrestricted Soils Reported by Various Sources	Recommended Maximum Root Depth (feet) in Unrestricted Soils	Rationale
Safflower	3-15	3.3-6.6	No other sources found.	10 – Oelke et al., 2012; Lyon et al., 2007; Berglund et al., 2007 11.5 – FAO Water Undated-a At least 12 – Henderson, 1962 12 – Kaffka and Kearney, 1998	12	Value in Table H-1 not corroborated by other sources. Several sources indicate shallower root depth.
Wheat (fall planted)	4	3.3-4.9	2 – Weaver, 1926 2 - South Jersey RC&D Council, Undated	4.6 4.8 – Weaver, 1926	5	Value in Table H-1 within effective root zone.
Sugar Beet	6	2.3-3.9	4 - Scherer, 2007 3.3 – Carlson and Bauder, 2005	>6 -Franzen et al., Undated 6 – Reddy et al., 2007 8 – Cattanach et al., 1991 >9 – Biancardi et al., 1998	7	Maximum root depth is likely at least 6 feet.
Sugarcane	5	Not listed	4 - Gosnell and Thompson, 1965	6 – Weaver, 1926 12 – Gosnell and Thompson, 1965 16.5 – FAO Water Undated-b	6	Root depth in FAO reference cited in Table H-1 is listed as 5 feet, with caveat that roots to 16.5 feet are possible.
Tomato	2-6	2.3-4.9	2- South Jersey RC&D Council, Undated	4.3 – Weaver, 1926 5.0 FAO Water. Undated-c	5	Value in Table H-1 within effective root zone.
Wheat (spring planted)	3-5	3.3-4.9	3.5 - Scherer, 2007 2 – Weaver, 1926 2- South Jersey RC&D Council, Undated	4.8 – Weaver, 1926	5	Range in Table H-1 within effective root zone.

2.2.2 Capillary Rise

The SMP implies that the purpose of including a capillary fringe (CF) buffer is to prevent crop roots from intersecting the anoxic portion of the capillary fringe. The thickness of the capillary fringe depends on the water retention curve and can be approximated by the air-entry matric head (Table 2).

Table 2. Soil Water Parameters of Saturated Soils

Soil Type	Saturated Hydraulic Conductivity (cm/hr)	Total Porosity (cm^3/cm^3)	Air-entry Matric Head (cm)	Estimated Capillary Rise (inches)	Microscopic Capillary Length (cm)
Sand	21.00	0.437	-16.0	6.4	2.83×10^{-2}
Loamy sand	6.11	0.437	-20.6	8.24	2.06×10^{-2}
Sandy loam	2.59	0.453	-30.2	12.08	9.92×10^{-3}
Sandy clay loam	0.43	0.398	-59.4	23.76	4.63×10^{-3}
Loam	1.32	0.463	-40.1	16.04	1.11×10^{-3}
Silt loam	0.68	0.501	-50.9	20.36	5.83×10^{-3}
Clay loam	0.23	0.464	-56.4	22.56	4.50×10^{-3}
Sandy clay	0.12	0.430	-79.5	31.8	3.84×10^{-3}
Silty clay loam	0.15	0.471	-70.3	28.12	3.31×10^{-3}
Silty clay	0.09	0.479	-76.5	30.6	3.02×10^{-3}
Clay	0.06	0.475	-85.6	34.24	2.77×10^{-3}

Source: Handbook of Soil Science. Ed. Sumner. 2000. CRC Press LLC, Boca Raton, FL

The values in Table 2 provide a comparison for the data presented in Table H-6 of the SMP, which includes observed capillary rise data from different types of soils in the field. As indicated by the relatively wide 95% confidence ranges in Table H-6, the empirical data varies considerably, and the average values derived from this data are less meaningful than those that could be derived from data with low variability or more observations in the field. For example, the average rise for Category 2 soils (sandy loam and loamy fine sand) is based on only four observations and has a 95% confidence range that is half as large as the entire range of data. However, the average capillary rise value for this category (13.75 inches) is similar to the value for similar soils in Table 2 (12.0 inches for sandy loam). Brady and Weil (2007) advise that capillary rise in sand can be as high as 15 inches.

Table 2 indicates that capillary rise in soils of vastly different textures ranges (on average) from 6.4 inches to just over 34 inches. The values for capillary rise in Table H-6 show that the range for different soils found in the study area range from 6.9 to 18.3 inches. For comparison, Brady and Weill (2007) cite capillary rise in clay loam at 22 inches, and loamy sand at 26 inches. This increase in capillary rise in a coarser-textured soil is inconsistent with the values provided by Sumner (2000) and is explained by both rate and duration of capillary rise. According to all of these sources, however, the estimates of capillary rise for medium- and fine-textured soils in the SMP are likely reasonable but may be at the low end of the range that occurs in field soils throughout the season.

The rationale provided for using field analyses as indicators of capillary rise is that capillary rise depends not only on soil texture, but also on depth to water table, evaporative demand, and land use. The SMP also states: "*The field setting can present a different capillary fringe than a theoretical or laboratory experiment under uniform controlled conditions. Thus, measurements made in the field are the basis for this analysis*." While this is undisputed, the wide variability in field conditions necessitates more observations that are provided here on which to base a reliable estimate of capillary rise.

The capillary rise values of 12 inches and 6 inches assumed for medium- to fine-textured soils and coarse-textured soils respectively are based on limited field data that is not compared to or supported by other sources. The results of this approach would benefit from additional supporting documentation. While the estimate of capillary rise for coarse-textured soils is likely accurate, the estimate of capillary rise for medium- to fine-textured soils should likely be interpreted at the low end of the range that occurs in the field.

2.2.3 Irrigation Buffer

The SMP states that the purpose of the leaching buffer is to allow for leaching irrigation, if needed, to remove accumulated salts in the soil from irrigation or groundwater. The irrigation buffer is not intended to prevent the temporary several-foot rise of the water table, but rather to allow the water table to recede by allowing for drainage.

The following comments apply to the description of how the irrigation buffer was developed.

- The SMP describes the leaching fraction as the amount of irrigation water that passes through the root zone to carry salts below the root zone where they will not harm crops. The SMP then states "*This leaching fraction, with salts in a reduced volume and proportionately increased concentration, could dissolve additional salts from the underlying soil.*" Depending on the constituents and concentration in irrigation water, salts may precipitate out of the soil solution or salts in the soil may be dissolved by irrigation water as it passed through the profile. Therefore the amount of salt leached below the root zone may be less or more than that applied over a long period depending on whether salts precipitate or dissolve in the crop root zone
- Table H-4 lists water duties for three crops. It is unclear if these are typically applied or recommended amounts. To corroborate these values and complete the table, it would be beneficial to consult more than one source. Consulting more than one reliable source would likely result in a range of values that would be more representative of actual irrigation practices.
- In Table H-4, it is unclear what the blank cells in the "wheat and small grains (furrow)" mean; they could indicate that there is no data or they could indicate that there is no pre-irrigation. These cells should be populated or if not, an explanation should be provided.

- In Table H-4 there are only four crops listed, while several more crops are listed in other sections of this appendix. It is unclear why a different list of crops is used for each approach (i.e., root zone, vs. irrigation buffer).
- The SMP states, "*Immediately following a 6-inch furrow irrigation, the water can rise up to a couple of feet, however it should recede fairly rapidly with natural drainage or functioning artificial drains*." This statement should be explained and referenced, or, if it is a judgment, then that should be stated.
- The SMP states, "*A leaching application of 1 foot of water may cause a 3 foot or more rise in the water table temporarily, but would not be expected to move salts upward and the water table would recede*." The rationale for this statement should also be referenced.
- Table H-5 does not include the value of the leaching buffer, though it appears that was intended.

The document states several times (e.g., A.2.2) that water in a saturated soil is anoxic. Although anoxia frequently occurs in saturated soil it is the consumption of oxygen typically by plant root activity that results in anoxia. Although roots can extract oxygen from water for respiration, the diffusion of oxygen into water is much slower than in the air space in an unsaturated soil. Provided aeration, plants can do well in saturated conditions (e.g., hydroponics). The text should be reworded to properly reflect this concept. In addition, anoxia could be monitored through ORP readings in areas thought to be most affected by anoxic shallow water conditions.

The use of soil water by plants and the salinity impacts associated with this use have been extensively researched but are not fully understood. Soil factors that contribute to where soil water is extracted include texture (hydraulic conductivity), aeration, temperature, and fertility. Plant factors include type of plant, age, and root distribution. Wallender et al., 1979 showed that a cotton crop, grown on a loam soil in the San Joaquin Valley, with a water table at 6-8 feet obtained 60% of its water from the shallow groundwater with an EC of 6 dS/m. As less irrigation water was applied, the amount of groundwater used for ET increased but the yield decreased. Gardner and Fireman (1958), using soil columns found that due to capillary rise, lowering the depth of groundwater to only three feet below the surface was of little use with saline water. However, when the depth was lowered below three feet they found that hydraulic properties limit the upflow. In another experiment by Hutmacher et al., 1987 cotton grown in lysimeters was not affected by water quality at a depth of 3.9 feet until the salinity was in excess of 16dS/m. Likewise with sugar beets, they were not affected until the salinity was 11 dS/m. Maas and Hoffman (1987) threshold guidelines for these crops are 7.7 and 7.0 dS/m respectively. These experiments suggest that there is potential to allow elevated salinity levels in the lower reaches of the profile provided the quality of the irrigation water is comparable to the DMC.

As an example, Imperial Valley is an area with heavy clay soils, that are extensively tiled, and there is shallow groundwater that is very saline. The typical installation depth of relief drainage tile is about five feet (personal knowledge). Irrigation water in the Imperial Valley is about 1.2 dS/m and the average drainage water is about 4 dS/m. Due to the heavy clay soils in the Imperial Valley, tile lines drain slowly leaving elevated groundwater tables with elevated salinity levels for several days after an irrigation event. Crop production in the Imperial Valley is considered comparable with the Central Valley.

Due to the complexities and uncertainties in the contribution of saline shallow groundwater to crop yield decline, monitoring of the capillary rise and rooting depths in these specific soils and agricultural systems should be conducted. For the interim only, the information presented previously on rooting depths and capillary rise can be used as a guide. To ensure that there is sufficient leaching there should be monitoring of both irrigation and drainage water quality including ORP. In addition, crop productivity monitoring can provide information about the impact of elevated saline groundwater on yield.

2.2.4 Yield/Control Site

Yield control sites should be a component of remote sensing described under the triggers section. Remote sensing can be used to monitor vegetation indices, and plant stress due to salinity (Pinter 2003). Yields can be mapped on a temporal basis sufficient to capture seasonal progress. In addition, historical images can be used to establish a baseline value.

The resolution of the remote sensing imagery should be equivalent to what is shown for the groundwater table depth in section C. The biomass, salinity stress, and vegetative index values can be compared on a landscape and a groundwater contour basis. In addition, the areas that are potentially vulnerable to seepage effects, found in section B should be monitored along with the cropping record.

2.2.5 Crop Selection

Cropping patterns should be based on historical cropping patterns coupled with yield data. Cropping patterns and production should be developed using concepts presented under the Yield/Control Site discussion. The threshold for crop selection should be based on the limiting factor, which appears to be drainage.

See 1.1.5 for further discussion of cropping selection, including cropping patterns and productivity.

2.2.6 Irrigation Water Quality

It is not clear whether there are water quality based limitations on crop production with the surface water used for irrigation. There may be some limitations in areas where only poor quality groundwater is used; however, groundwater quality information was not presented in the SMP so this is an unknown.

An approach for establishing a relationship between water quality and yield could be based on a crop yield baseline that is established using remotely sensed vegetation indices and other information obtained from historical images along with records of historical cropping patterns. This will likely vary by water year type and will probably be most correlated to the regional shallow groundwater level. The scale at which to use remote sensing should be equivalent to what is shown for the groundwater table depths by year type as shown in section C of the Plan. Salinity stress, and vegetation indices can be readily compared along the established contour lines.

2.3 Development of Soil Salinity Thresholds (Appendix G)

2.3.1 Approach

The approach used in the SMP to develop soil salinity thresholds is not directly explained as is the approach in developing groundwater thresholds and root zones in Appendix H of the SMP. The authors listed common crop salt tolerance data and then apparently developed levels of concern (LOCs) for the root zone and plow layer based on these data. However, it is unclear how the LOCs are derived from the crop tolerance data (addressed below). Clarification of the approach would improve the interpretation of the information in Appendix G.

2.3.2 Presentation of Results

The common crop salt tolerance data listed in Table G-1 is from one source published by the FAO. These data should be regarded as reliable and regarded as general guidelines that provide information about the relative salt tolerance of common crops. Though this source is used globally to reference crop salinity thresholds, the location and amount of experimentation that generated these data varies widely by crop.

The location of the salinity threshold studies is important because different varieties of one crop are often associated with different regions, and these varieties may have significantly different tolerances to salinity. For example, many of the Mediterranean crops grown in California are also grown in parts of southern Europe and North Africa, but the varieties of choice in each region may be different. On the other hand, a great deal of research on salinity has been done in other countries with environments similar to that of California, and the resulting data should not be ignored, but should be interpreted with California-specific cropping practices and common varieties in mind.

Also, crop salinity thresholds are not absolute because of the complicated nature of how salts affect plant physiology. Some crops are more susceptible to the more general impact of salts (called the osmotic effect) while others are affected more readily by specific ions (termed specific ion toxicity). For example, safflower, which is considered a moderately salt tolerant crop, is particularly tolerant to sodium salts, and is in fact stimulated by a certain amount of salinity during early growth stages (Agriculture and Agri-Food Canada, 2004). Other crops might be particularly sensitive to sodium salts.

Therefore, a search of the scientific literature, in the case of most crops, leads to other sources with more specific salt tolerance information, and these should be considered in compiling crop salinity thresholds. Regional information is considered more relevant than general guidelines.

Assumed Thresholds

For the reasons explained above, salinity thresholds for pistachio, pomegranate, and safflower need not be qualitatively assessed based on their salt tolerance rankings, as noted in Table G-1. Selecting a mid-point in the range associated with the crops' respective rankings is unnecessary, unclear in its derivation (ranges associated with rankings are not provided in the SMP), and may not be representative.

Pistachio

Most sources indicate that pistachio is considered a relatively salt-tolerant crop and provide salinity thresholds between EC_e 4 and 9 dS/m. Ferguson et al. (2011) documented pistachio yields of 100 percent at EC_e 4 dS/m and 50 percent at 11 dS/m during a rootstock trial in California. Another study in California documented significant decreased growth only at EC_{iw} 12 dS/m (Ferguson et al, 2002). One study used irrigation water with an EC of 5.4 dS/m that did not affect growth of young pistachios (Sanden et al., 2008). These authors referenced previous studies that indicated that pistachio could tolerate an EC_e up to 9.4 dS/m. Therefore, the assumed salinity threshold of 2.5 in Table G-1 is likely too low and should be raised to 5.4 dS/m as a conservative estimate.

Pomegranate

The information on pomegranate salt tolerance is conflicting. Research from the Middle East, Australia, and Spain indicate that it is relatively salt tolerant, though varieties may vary widely in salt tolerance. Okhovatian-Ardakani et al. (2010) found that the most salt-tolerant varieties tolerated 4 to 7 dS/m of salt in irrigation water. This study was done in pots which were leached; however drainage water was not tested for salinity so it is unclear if and how salts concentrated in the soil.

Another source cites pomegranates grown in salt marshes and irrigated with water with an ECiw of more than 4 dS/m (Moreno, undated). An Australian source indicates that ECe should ideally be between 3.6 and 5.4 dS/m (Government of Australia, 2008); however pomegranates can tolerate soil salinity over 7 dS/m (likely for short periods that do not occur during sensitive and/or critical growth stages such as germination). The main variety grown in Australia (Wonderful) is also commonly grown in California.

However, Bhantana and Lazarovitch (2010) found in their orchard study that the salinity threshold of the pomegranate varieties they studied was 1 dS/m, and suggested that the moderately tolerant ranking of pomegranate may be too high; moderately sensitive might be more appropriate if these results hold on a large scale. This study also included the variety "Wonderful" that is commonly grown in California. There was no specific information found on salinity thresholds of this variety.

The salinity threshold of 5.0 dS/m assumed for pomegranate is likely representative of pomegranate varieties overall, but may be inaccurate for certain individual varieties. In this case, information on pomegranate varieties grown in the area may be useful in refining the salinity threshold.

Safflower

The salinity threshold assumed for safflower and listed in Table G-1 is likely lower than its actual salt tolerance. It is considered to be more tolerant than wheat (6 dS/m) and similar to but likely not as salt tolerant as barley (8 dS/m) (Oelke et al., 2012; Agriculture and Agri-Food Canada, 2004). Two sources indicate that safflower growth begins to decline at a salinity of 7 dS/m (Francois and Bernstein, 1964; Agriculture and Agri-Food Canada, 2004). From his research, Mohammed (2010) estimated that salt tolerance of safflower is 6.4 dS/m. Therefore, the EC_e threshold for safflower is likely between 6 and 7 dS/m.

2.3.3 Results

Preliminary salinity thresholds in the SMP are expressed as LOCs for the active root zone (0-30 inches) and the plow layer (0-12 inches). Active root zone LOCs were developed according to three river reaches, whereas only one LOC was developed for the plow layer. The rationale for these two different approaches was not explained in the SMP and should be included

Levels of Concern for the Active Root Zone by River Reach

For Reach 2B, the salinity threshold of the least tolerant crops (grapes and almonds) was chosen as the LOC. A similar approach was used for Reach 3; field corn has the lowest tolerance to salt and its salinity threshold was considered the LOC for this reach. For Reaches 4A and 4B, however, the salinity threshold for tomatoes was selected as the LOC, even though alfalfa has a lower salt tolerance (2.0 compared to 2.5 for tomatoes) and even though the SMP states that alfalfa is the most common crop in these reaches. The reason for this inconsistent approach and result is unclear and should be clarified.

In addition it should be completely ruled out that the most salt-tolerant crop will not/cannot be grown in certain reached before shifting to the next most limiting crop.

Levels of Concern for the Plow Layer

The SMP states that germination and stand establishment are critical for field crops and implies that a separate LOC for the plow layer should be considered for this reason. However, only one LOC, 2.0 dS/m, was developed for this purpose. This LOC corresponds to the salinity threshold for alfalfa, which is the most common crop in the area; however, almonds and grapes have an even lower salinity threshold (1.5 dS/m). It seems reasonable that if only one LOC is to be considered and used as an indicator to increase soil salinity monitoring, it should correspond to the most sensitive crops in the area, even if they are not the most common crops.

Other Indicators of Increasing Soil Salinity

The SMP lists seven additional indicators (other than LOCs discussed above) that would indicate a need to increase soil salinity monitoring.

The first indicator listed is "significant (95% confidence level) increases in measured soil salinity at monitoring sites." It is unclear if this refers to significant differences between consecutive sampling events or significant differences between baseline results and any subsequent sampling event results. In either case, this indicator should be regarded with caution; soil salinity usually increases gradually, and increasing EC over a sampling period, even though not statistically significant (which depends on the power of the test chosen) should be investigated especially if it approaches the salinity threshold of the crops grown on that sampled soil. Soil salinity also consistently has seasonal fluctuations and this too, should be considered. The proximity of the soil salinity sampling result to the crop salinity threshold is more important than whether differences in EC between sampling events are statistically significant.

Other indicators listed in the SMP that may or may not necessarily be useful include the following:

- Landowners and grower observations of reduced crop vigor
- The appearance of poor or weak spots in fields
- Decrease in crop yields compared to prior years
- Increasing electricity use at drainage sump pumps

First, these signs of declining crop health could be caused by myriad factors. It is only in combination with soil sampling that the causes of reduced crop health can be determined. Increasing monitoring because of these indicators alone would not necessarily be efficient.

Second, and most importantly, if crops are showing signs of distress from salinity, the soil has likely already been salinized. In other words, soil sampling will likely show increased salinity before crop damage from salinity becomes apparent. In most cases, crops can tolerate adverse conditions if they are short lived; however, symptoms of declining crop health begin to show after internal physiological damage begins to occur. Therefore, these indicators may indeed be indicators of soil salinization, but they won’t necessarily be timely enough to prevent soil salinization or crop damage by increased monitoring and action.

3. How do we reasonably account for historical conditions that may impair groundwater even in the absence of SJRRP flows?

To help answer this question the PRP considered the existing information in the SMP, including Appendix C and attachment. We evaluated the groundwater level database, hydrographs, stream flow gage measurements and other available data to assess the historical record efforts.

3.1 Summary PRP Recommendations

The following summary of PRP recommendations is supported by additional details, comments, and specific recommendations in each of the following sections 3.2 to 3.4.

3.1.1 Are historical groundwater levels reasonable?

- In general, the historical groundwater level maps (SMP Figures 1-12, pages C-2 to C-13) are scientifically sound and reasonable estimates of actual groundwater levels for most areas during the selected years. We note, however, that the historical water levels are not reasonable and could be refined in some specific areas (often upstream and north of the SJR) and for some historical years (most notably for Spring 2006).
- We recommend refining the historical groundwater level maps by addressing possible human errors, the spatial density of water level measurements, and the interpolation techniques that were used to create the maps.
- To provide a more quantifiable and scientifically defensible map, we recommend adopting a reasonable threshold or guideline for the minimum spatial density of wells that will be used to construct maps of historical water levels.
- We recommend that Reclamation consult the historical published reports and maps on predevelopment water levels, soil surveys, and observed historical seepage issues.
- See additional detailed recommendations in section 3.2.

3.1.2 Using historical groundwater levels to set thresholds?

- Although the historical water table maps are a valuable component of the SMP, they don't clearly address the magnitude and scope of the seepage problem without additional context and explanation. We recommend that Reclamation develop and present a diagram(s) in the SMP that articulates their conceptual model of how, why, when, and where the groundwater flow system and corresponding changes in the water table have evolved over space and time.
- We recommend developing maps that delineate the magnitude of historical groundwater levels exceeding current SMP thresholds. Such maps may help Reclamation predict locations and forecast water years that will have seepage problems.
- See additional detailed recommendations in section 3.3.

3.1.3 Are historical groundwater levels overly conservative?

- In general, historical groundwater levels provide a reasonable first approximation to help set SMP thresholds. However, we note that depending on the water year type (i.e., wet, above normal, below normal, dry, critical), historical groundwater levels could be overly conservative and will limit the ability to release flows. Therefore, we recommend establishing a baseline groundwater level and/or map that are based on a water year-type index, which will help Reclamation evaluate whether agricultural thresholds are overly conservative or not.
- See additional detailed recommendations in section 3.4.

3.2 Are the estimates of historical groundwater levels reasonable and are there practical ways to refine values?

In general, the maps of historical depths to groundwater (Figures 1-12, pages C-2 to C-13) are likely reasonable estimates of actual groundwater levels during the selected years of 1965, 1981, 1983, 1988, 1991, 1994, 1999, 2006 (Spring and Fall), 2007, and 2008 (Spring and Fall). These maps were developed by using actual water level measurements at (presumably) all available historical monitoring well locations and using inverse distance weighting (IDW) to extrapolate water levels in locations between measurement locations. We endorse this general approach as the best and most practical way to estimate historical groundwater levels across an aquifer. The PRP is not aware of any other general approach to estimate historical depths to groundwater across an aquifer.

In terms of refining the estimates of historical depths to groundwater, there are at least major 3 potential sources of errors that may contribute to uncertainty in the estimates of historical groundwater levels that could be addressed.

The first potential source of error is from human errors associated with accurate measurements of water levels and possibly misidentifying/misreporting the well screen depth. The PRP makes the following specific recommendations:

- Although, there are no practical means to address possible human error in historical water level measurements, it might be worth re-examining that all the wells are in fact screened in the same hydrogeologic unit of interest.
- Water levels from wells screened in deeper hydrogeologic units should probably NOT be included in the IDW with the majority of wells that are screened in the near-surface hydrogeologic unit that most affects groundwater-surface interactions with the SJR.

The second potential source of error is attributed to the spatial density of the wells and associated historical water level measurements. The PRP makes the following specific recommendations:

- The accuracy of the IDW-based depth to groundwater maps is a function of the spatial density of water level measurements. Areas with low density or no water level measurements will have a larger error between estimated water levels determined by IDW and actual historical water levels. The only practical way to address this source of error for historical water levels is to find and use additional wells and historical water levels measurements in those parts of the aquifer that have low spatial density.

- For example, we question the value of the depth to groundwater map from Spring 2006 (Figure 8) that was built using virtually no wells in reaches 1A, 1B, 2A, and 2B. There are also very few wells on the north side of the San Joaquin River over the entire study area. Additionally, Figure 8 also shows some of the highest water levels of any year, even though 2006 was apparently a normal year in terms of the water year type designation. What is the purpose of showing Figure 8, especially in light of the lack of data used for the IDW?
- Approximately 6 months later in Fall 2006 (Figure 9), water levels on the north side of the San Joaquin River are 55 to 60 feet deeper than what is shown in Figure 8. The apparent and substantial swing in water table depths between Figure 8 and 9 is likely a function of the spatial coverage of wells used in the IDW and not representative of actual, field conditions, particularly in Spring 2006 (Figure 8). We recommend either removing Figure 8 or providing considerable more explanation in the SMP that addresses some of these issues.
- The PRP recommends adopting a reasonable threshold or guideline for the minimum spatial density of wells that can be used to construct maps of historical depths to groundwater. The guideline could be classified as wells per square mile or minimum number of wells per reach (1A to 5). Such a guideline may help to provide a more quantifiable and defensible method of the development and use of historical water table maps.

The third potential source of errors is attributed to the interpolation and geographic information system (GIS) mapping techniques. The PRP provides the following comments and specific recommendations:

- IDW is a reasonable interpolation technique to create the maps of historical depths to groundwater (Figures 1 to 12, pages C-2 to C-13).
- Kriging is another commonly used and reasonable interpolation technique that might produce more accurate interpolated depths to groundwater in some cases. IDW and Kriging each have distinct advantages and disadvantages. For example, IDW tends to create more “bulls-eye” looking patterns whereas Kriging tends to create smoother surfaces (depending on the spatial density of the wells), and Kriging can produce a standard error estimate of the interpolation.
- However, neither IDW nor Kriging will result in accurate depth to groundwater in areas of low spatial density of wells.
- The PRP recommends that Reclamation review the maps of historical depth to groundwater critically evaluate the use of IDW versus Kriging.
- What is the grid cell size on the IDW rasters used to make the depth to groundwater maps (Figures 1 to 12, pages C-2 to C-13)? Is it 500 feet, 0.25 mile, 0.5 mile, etc.? This information would be worth mentioning in the SMP section that describes these water table maps. The resolution of water table depth (and change in water table over time as shown in the series of maps in Figure 1 to 12) is a function of the grid cell size. For example, if the grid cell size is 0.25 mile, then the maps indicate that the water table is the same value everywhere in that 0.25 mile by 0.25 mile grid cell size. There are practical limits to the grid cell size, but the PRP recommends making them as small as possible to delineate small scale differences in the depth to water, especially near the San Joaquin River to help identify seepage problems.
- Why do all the Figures 1 to 12 (pages C-2 to C-13) have depth categories that start at 0.876020968 to 5 feet? Why isn’t 0 to 0.876020968 feet shown on the maps? What

does 0.876020968 feet represent? If you keep this as a category threshold, please consider the number of significant figures and round down to something more reasonable, such as 0.88 feet.

- We suggest using a depth category on Figure 1 to 12 (pages C-2 to C-13) that has finer resolution and thus is more consistent with other aspects of the SMP. For example, we recommend showing categories 0 to 1 ft, >1 to 2, >2 to 3, >3 to 4, > 4 to 5, and then show >5 to 10, >10 to 15, etc.
- There is some discussion of the limitations of IDW in Appendix H. We recommend that the discussion of IDW and associated limitations should be presented with the first appearance of the depth to water maps (either in Appendix B or C).

As a general comment, the presentation of depth to water maps in Appendices B, C, and H is confusing and needs improvement. Therefore, the PRP provides the following comments and specific recommendations:

- It was NOT immediately clear to the PRP that 3 of the maps of historical depth to groundwater from Appendix C were used to develop the groundwater thresholds that are presented in Appendix H.
- Page C-1, lines 3-5: The SMP states that the "maps of depth to the water table presented in Appendix B, and for various analyses and model calibration." This paragraph needs to clearly state that maps of depth to groundwater from Fall 1999, Spring 2008, and Fall 2008 that are presented in Appendix C are used to develop the groundwater thresholds, which is discussed in Appendix H. The current phrase of "…for various analyses and model calibration" is not sufficient.
- Page C-1, lines 23-24: The sentence reads "Maps of depth to the water table were developed using GIS and…". As written, this sentence makes it seem like Reclamation made the depth to water maps in Appendix C. However, Appendix H (page H-27, line 12) states that "the USGS developed maps of DTW for various years from the 1960s to present…" Is it correct that the USGS developed the maps presented in Appendix C? If so, page C-1, lines 23-24 should be written "the USGS developed maps of depth to water using GIS…".
- Page C-2 has the bulleted list of years: 1965, 1981, 1983, 1988, 1991, 1994, 1999, and 2006, but is apparently missing 2007 and 2008? Maps for 2007 and 2008 are shown in Figures 10, 11, and 12. Please add 2007 and 2008 to the bullet list on page C-2 or explain in the SMP why they are not included in the list.
- Why doesn't Appendix B show the maps of depth to groundwater for Fall 2007, Spring 2008, or Fall 2008?
- Please include the units (feet) on the explanation of the maps in Appendix H (H-10 to H-15).

Additional comments and specific recommendations include:

As the SJRRP eventually restores San Joaquin River flows to allow for healthy fish (salmon) populations, it is likely that other aspects of the natural system will be restored to some degree of historical conditions, including groundwater levels.

- Therefore, it would be helpful for the SMP to consult and possibly include some of the historical published reports on predevelopment water levels and observed historical seepage issues. Such reports should include Soil Surveys published by the NRCS (formerly SCS), and early USGS publications. Historic soil surveys for the area include, Fresno Area 1914, Madera Area 1910 and 1962, Los Banos Area 1952, Merced Area

1916 and 1962, Mendota Area 1956, and Lower San Joaquin Valley Reconnaissance 1918. These soil surveys show areas of poor drainage, shallow groundwater, and saline-alkali conditions. One of the first groundwater reports on the area by the USGS is Ground Waters of the San Joaquin Valley, California by Walter C. Mendenhall, dated 1908. This report contains an excellent map of groundwater levels and areas of artesian conditions.

The historical water table maps (Figures 1 to 12) are valuable in the SMP, but don't clearly address the magnitude and scope of the seepage problem without additional context and explanation. Therefore, the PRP offers the following specific recommendation:

- The SMP would benefit if Reclamation develop and present a conceptual model that articulates how the groundwater system has evolved over a reasonable historical context (such as the last 40 or 50 years) that is important for the SMP. Such a conceptual model would describe how, why, when, and where the groundwater flow system and corresponding changes in the water table have evolved over space and time. The historical snapshots of depth to water (Figures 1 to 12) begin to address the *when* and *where* of changes in the flow system and depth to water, but don't conceptualize *how* and *why* with specific implications for localized seepage along the San Joaquin River. We recommend that Reclamation develop a single diagram, image, or map and accompanying text that describe your conceptual model and provide the context and linkage between Figures 1 to 12.

3.3 Is the use of historical groundwater levels a reasonable approach to setting thresholds where known?

In general, we agree that the use of historical groundwater levels represents a reasonable approach to setting thresholds. However, some historical water level maps may represent an overly conservative level. It is likely a reasonable approach to start off conservatively and refine expected groundwater levels based on monitoring and operational observations. Therefore, we make the following specific recommendations:

- We generally endorse the decision to use historical groundwater levels as the threshold when the computed threshold is deeper than historical water levels (see page H-3 of SMP).
- Moreover, we endorse the logic to first rely on wells with long-term groundwater level records to establish the threshold, then to rely on nearby wells with long-term records, and finally to use the maps of historical water levels in nearby wells where long-term water levels are not available (see page H-3 of SMP). This order places the greatest value on actual water levels at the point of interest and places the least value on interpolated historical water levels that are subject to varying degrees of uncertainty, as we described in section 3.1.
- On page H-24, the SMP states that the "31 percent cutoff was based on the number of wet years (9) that occurred during the period of record…". The decision to select 31 percent is not clearly described here. Because the decision to use 31 percent is so critical to the development of the historical threshold, we strongly recommend a concise, but more detailed description of the rationale for choosing 31 percent.

- The biggest question and concern related to historical groundwater levels is which historical year the SMP should use to establish the threshold. What is the baseline year to represent historical conditions? We recommend establishing an agreed upon baseline groundwater level based on a water year-type index because historical water levels have varied over space and year types.

The PRP agrees that developing and presenting maps of historical groundwater levels in the SMP is valuable because of the need for SMP personnel to have an understanding of absolute depths to water at specific locations and the relative change in depth to water over various spatial and temporal scales. However, the presentation of a series of historical water table maps (Figure 1 to 12, pages C-2 to C-13) doesn't completely address the important question of where and when groundwater levels may pose seepage problems.

- Therefore, we recommend exploring other ways to display the data in Figures 1 to 12 to better address the question of seepage. Such maps may show locations of historical groundwater levels that exceeded SMP thresholds and the magnitude of those exceedences. These new maps may be used in a similar way that Figures B-15 to B-25.

3.4 Is the use of historical groundwater levels on fields exceeding agricultural thresholds overly conservative?

Similar to the recommendations in section 3.3, we recommend establishing a baseline groundwater level and/or map based on a water year-type index to use when evaluating whether agricultural thresholds are overly conservative or not. We note that depending on the year type selected, historical groundwater levels will limit the ability to release flows. Historical groundwater levels (i.e., pre-2009) were based on a complex interaction between antecedent hydrology and irrigation. In a wet year, such as 1997, the shallow groundwater would fill and there would be limited ability to lower the water table without relief drains and a means to move the water into other surface drains. Conversely, in drier years such as 1989 there is adequate regional drainage such that the water table would be low enough to plant without impact.

Although the last water year (2011-2012) was a drier year there were no flow releases because of exceedances of the trigger levels. One thought conveyed at the September 13, 2012 kick-off meeting is that the elevated groundwater level is due to antecedent flood water from the 2010-2011 water year. Because of the hydrologic events this condition could be considered a baseline condition where existing groundwater levels are due to flood flows and not flow releases. This situation again points to the need to establish a baseline groundwater level using a water year-type index approach (see section 5.3.1 for details on the water year-type index).

4. Are there missing components or other refinements to the SMP necessary to achieve the goals of releasing and conveying Interim and Restoration flows while avoiding material adverse effects due to groundwater seepage?

The PRP considered a wide range of potential missing components and refinements and identified a few primary changes and challenges that could assist the existing SMP, as well as provided more certainty for its future success. The PRP also developed a specific list related to document language clarification and improved definition of statements in the SMP.

4.1 Summary PRP Recommendations

4.1.1 Climate Change

The SMP does not directly mention climate variability or change. Given the importance that climate variability and change will likely have on natural processes and human activities that will affect water resources in the SJR watershed and underlying Central Valley aquifer, we recommend that the SMP eventually include some evaluation of the potential implications of climate variability and change. Some potential scenarios to consider in the SMP might include the following:

- Climate variability (i.e., ENSO or PDO) induced wet periods could result in flooding (> 4,500 cfs restoration flows) of the San Joaquin River, which is beyond the scope of the SMP and requirements of the larger Restoration Program. However, such wet periods could result in prolonged increases in the water table, that last well beyond the period of flooding in the San Joaquin River.
- Following such prolonged wet periods, there could be a considerable temporal delay until restoration flows are possible because of the increased risk of seepage effects due to the raised water table.
- Conversely, climate variability and change could result in prolonged dry periods (i.e., during the negative phase of ENSO and PDO). Such prolonged dry periods could potentially benefit the SMP goals because the water table would likely drop due to increased groundwater pumping to meet irrigated agricultural demands and from reduced recharge rates.

- Additionally, the SJRRPGW groundwater model could eventually be used to evaluate climate variability and change effects on seepage and be used to help evaluate implications for the SMP. However, this may not be possible until a "temporally refined regional-scale model of surface water and groundwater flow" is available.

4.1.2 Surface Water Modeling

- Provide more detail on modeling tools and address model integration issues. How will these tools be combined in an operational decision support system?

4.1.3 Groundwater Modeling

- The current SJRRP GW model lacks the spatial and temporal resolution necessary to be effective as a management tool. This model can be used to provide boundary conditions for more detailed models that operate on a daily timestep with a more refined model mesh of suggested cell size of 30-50 meters. This resolution is necessary to be able to simulate benefits of various tile drainage and impermeable barrier seepage management options.
- The Model needs to include the drainage package and simulate drainage options explicitly if it is to have utility as a decision tool.

4.1.4 Subsidence

- Land subsidence appears to be a major problem in some areas close to the San Joaquin River. The first step in addressing subsidence impacts is determining where subsidence is occurring, and the current rate of land deformation..
- A working group should be established to coordinate efforts to document subsidence, and seek additional funding to safely and effectively manage the transmission of water through the subsidence areas.

4.2 Climate Variability and Change

4.2.1 Background

Although not directly called out by the SJRRP in their set of questions for the PRP, the PRP nevertheless agrees that there ought to be some consideration of the fact that future climate and Basin hydrology may differ substantially from that which has occurred in the past. Since long-term solutions to current seepage management problems are being sought, tacit recognition of this uncertainty ought to be built into contingency planning strategies for dealing with droughts and sustained high flow events along the San Joaquin River. The following section provides a brief overview of climate variability and change, outlining some processes that may have implications for the SMP.

Climate variability generally refers to interannual to multidecadal (or longer) changes in climate that is largely the result of naturally occurring oceanic-atmospheric phenomenon that includes the well-known El Niño/Southern Oscillation (ENSO), which has a characteristic 2- to 7-year quasiperiodic oscillation between the El Niño and La Niña phases of variability [*Gurdak et al., 2009*]. It is well established that ENSO and other climate forcings on interannual to multidecadal` variations in pressure, temperature, and precipitation patterns throughout the U.S. [*Wolter and Timlin*, 1993, 1998]. During the positive ENSO (El Niño) phase, much of California and other parts of the U.S. have increased precipitation, particularly in the winter months of December to February [*Ropelewski and Halpert*, 1986]. In California, extreme precipitation events (sometimes defined as a 50-year return interval of approximately 150 mm per day) are strongly correlated with the El Niño phase, and conversely, the risk of precipitation extremes is reduced during the negative ENSO (La Niña) phase [*Shang et al.*, 2011].

A number of recent studies have shown that climate change will affect California's water resources and flood risk through changes in the snow line, snowpack, evapotranspiration, and other processes [*Pierce et al., 2012*]. For example, Pierce et al. [2012] used 16 global circulation models (GCMs) to develop probabilistic projections of temperature and precipitation changes across California by the 2060s. By the 2060s in the San Joaquin valley, Pierce et al. [2012] predict an average seasonal temperature increase of 1.8 to 2.9 deg C, a 1 to 7 % increase in seasonal precipitation during DJF and JJA, and an 8 to 19% decrease in seasonal precipitation during SON and MAM. It is possible that such long-term trends in average seasonal temperature and precipitation may affect the operation of Friant Dam and spatiotemporal patterns in groundwater withdrawals, among other factors, that may have implications for the SMP.

4.3 Surface Modeling

Surface water models are the core elements of the decision support system, used to manage reservoir releases from Friant Dam to meet downstream flow and temperature objectives and to estimate river stage as a result of flow releases along defined reaches of the San Joaquin River. River stage and the duration of sustained flow events will directly affect the incidence and severity of seepage problems experienced on agricultural land either side of the San Joaquin River alignment. Two models – one a Riverware model application which simulates Friant Dam operations and manages surface water allocation down the San Joaquin River; and a second HEC-RAS model application which provides surface water profiles along the San Joaquin River at different flow releases.

However, the SMP provides no details on these models, how they were developed, how they are being used and current limitations of each model. Integration of these models will be important for the formulation of a decision support system to fine-tune management of flow down the River to conjunctively sustain an anadromous fish population while providing reasonable protection to landowners potentially impacted by Restoration flows. Because of the importance of these models to the long-term success of the Program, we recommend additional details in future versions of the SMP and/or in a stand-alone, but SMP-cited, technical report or document.

4.4 Groundwater Modeling

It is a substantial challenge to develop decision-support tools that reflect regional conditions, have sufficient detail to provide realistic responses at the field scale, are easy to use, and can return output quickly and efficiently. There are no existing tools that meet all of these requirements. However, the SJRRP team has attempted to address the groundwater management decision support task by utilizing the San Joaquin Restoration Program Groundwater model (SJRRPGW), which is a modified version of the published USGS Central Valley Hydrologic Model (CVHM) (Faunt et al., 2009), and extracting from the model a subset of cells that provides a five-mile buffer along the alignment of the San Joaquin River on the Valley floor. This was a good choice of model on three accounts:

- The CVHM model has undergone significant internal and external peer review within the USGS and by cooperating agencies.

- Model development time is minimized – allowing effort to be devoted to improving model calibration by incorporating data from field monitoring and special studies.
- CVHM can be used to provide basin scale boundary conditions supporting spatial and temporal model refinement.

This particular approach lends itself to the use of telescoping 3-D numerical model meshes, which allows the formulation of more refined and detailed local scale models that obtain their flow boundary conditions from more regional models. Although somewhat complicated to implement on a large scale planning and implementation program such as the SJRRP, it is perhaps the most cost-effective and timely approach to develop relevant a groundwater modeling toolbox.

In the opinion of the PRP, the current SJRRPGW model lacks the spatial and temporal resolution to be effective as a management tool and largely fulfills the basin-scale component of a future telescoping groundwater numerical modeling systems approach to addressing decision support needs. The one mile model mesh is too coarse to recognize local conditions that are important as support to the flow bench step evaluation studies that are central to monitoring seepage problems and designing custom solutions to address them. A grid cell size in the order of 30-50 meters might be more appropriate. The monthly time step currently utilized in the model is also too coarse for simulating river stage-induced seepage events, which with the high permeability characteristics of the shallow aquifer, can lead to rapid water table response in farmer's fields to a short term high flow event in the River. A minimum of a daily timestep is needed for modeling these short term flow events in the San Joaquin River for both pre-restoration and restoration flows. The use of a daily timestep would have the added benefit of being at the same temporal resolution as the RiverWare model. If possible, we suggest that these concerns be addressed in the forthcoming (fall, 2012) USGS report describing the SJRRPGW model, as indicated in J.2.5 Next Steps (see page J-13).

In the groundwater modeling section write-up it isn't clear if the new groundwater model derived from CVHM simulates tile drainage. There is an inadequate description of the model to make this determination. If the model does not utilize the MODFLOW drainage package it will be difficult to use the model to simulate the impact of most of the suggested seepage remedies (various types of relief and interceptor drains).

An alternative approach would be to use another model that has been designed to fulfill more of a decision support function. One of the limitations of MODFLOW that its data structures are somewhat primitive and there are no current graphical user interfaces that work with both MODFLOW and the Farm Process Package utilized in the current model. A user interface could be developed using the ArcGIS toolbox which might go some way to addressing this current deficiency.

4.5 Subsidence

In the SMP there is no mention of Land Subsidence. Land Subsidence caused by withdrawal of groundwater is a known and serious problem along reaches 2 through 5 of the San Joaquin River. The problem is historic and ongoing. Historic subsidence has been documented by the USGS at over 28 feet up to 1972. More recent subsidence has been documented by CCID (information supplied by Chris White, CCID Manager, September 13, 2012). Problems of aquifer subsidence were discussed during the orientation session and demonstrated quite dramatically near Sack Dam during the field trip. According to Mr. White subsidence in the last year has approached a rate of one foot per year in some areas. This new subsidence is due to increased groundwater withdrawals east of the San Joaquin River and the Bypass system.

The effects of subsidence on water conveyance facilities are profound. As the land surface elevations are lowered, water flows into lowered reaches of the rivers, canals, and other channels, and must rise to the elevation beyond the depressed area in order to continue flowing. This results in decreased channel capacity, increased flooding, decreased levee stability, and increased seepage. Subsidence can affect flow in the San Joaquin River reducing the channel gradient in certain reaches and causing the River stage to increase upstream in order to pass the same volume of water. The net effect of subsidence for existing levees is to force raising levee height to allow the same flow to pass. Since adjacent farmland is most likely subsiding at a similar or even greater rate than the River channel. This problem results in increased groundwater gradients from the losing river and exacerbates current seepage rates. This could rapidly eliminate the ability of the land parcels adjacent to the River alignment to support deep rooted and salt sensitive crops.

The SJRRP will not contribute to increased or accelerated subsidence; however, the operation of the program will have to deal with the subsidence impacts if it is to be successful. This includes but is not limited to seepage issues. Reclamation and the SJRRP should not be expected to solve or mitigate subsidence impacts on their own. Other agencies such as local irrigation districts, canal companies, levee districts, DWR, the USGS, National Geodetic Survey, and the local counties should all be part of the solution. The first step in mitigating subsidence impacts is determining where subsidence is occurring, and to what extent. It is suggested that a working group be established to coordinate efforts to document subsidence, and seek additional funding to safely and effectively manage the transmission of water through the subsidence areas.

4.6 Editorial Comments

Other specific comments related to the Groundwater Modeling Appendix in the SMP include:

Page Appendix J-2, line 35-36: This sentence is somewhat vague and trails off. "…as the model calculates" what?

Page Appendix J-2, line 29-32: The description here of the loose coupling between the RiverWare and SJRRPGW model indicates that the "maximum flow simulated in RiverWare for any given month was assigned as the flow for the entire month in the SJRRPGW". Given the duration of maximum simulated stream flows, the gaining/losing nature of individual stream reaches, the local hydraulic gradient between stream water and groundwater, and other factors, the modeling assumption to apply the maximum RiverWare flow for the entire month in the SJRRPGW may be overly conservative in the sense that the maximum impacts to groundwater levels may not be reflective of actual, field conditions. As describe above, changing the timestep of the SJRRPGW may help to address this concern. Alternatively, would it be possible to adjust the FORTRAN tool (see Page Appendix J-2, line 32) to assign other flow values, such as median or 75% percentile flows that are not as conservative as maximum flows?

Page Appendix J-2, line 36-38: Please consider additional details describing the rationale behind "…river inflows should be set at four locations…". Does this mean that there are only 4 locations in the study area where RiverWare flow is used as input to the SJRRPGW? If so, is 4 locations adequate?

Page Appendix J-3, line 29: What is the rationale for 30%?

Page Appendix J-3, line 38: What is the rationale for 30%?

Page Appendix J-4 to J-5, Figures J-1 to J-3: These plots of Riverware and SJRRPGW flows (cfs) look nearly identical, possibly due to the thickness of the lines. It might be more instructive to plot the difference between Riverware and SJRRPGW flows, either as cfs or as a percentage of the Riverware flows.

Figures J-4 to J-6: How do the simulated depth to water maps compared to observed water levels at monitoring wells? Such a comparison would be a valuable indicator of the predictive ability of the model and may help to assess limitations of the spatial and temporal resolution. These details may be available in the forthcoming USGS report?

Page Appendix J-13, Line 21: Suggest changing sentence to "The relative effects of precipitation on the water table and high river flows are unknown…". It is confusing as written.

5. Overall, does the Plan maximize the release of flows to the River for the furtherance of the Restoration Goal while providing reasonable measures to avoid material adverse impacts from groundwater seepage?

The SMP provides reasonable measures to avoid the material adverse impacts from groundwater seepage but does not maximize the opportunities to release flows to the River. The triggers provided in the SMP may not maximize the furtherance of the restoration goal because they do not fully consider pre-project conditions. Pre-project conditions that are not fully considered include year-type and critical period groundwater level variations, cropping patterns, and crop productivity. Including pre-project conditions should allow more opportunities to release restoration flows.

In addition to providing responses and recommendations to the questions, this section also provides commentary on the project types, along with the proposed project scoring matrix that are listed in the Handbook. The projects in the SMP provide a diverse array of actions that can be used to reduce impacts from groundwater seepage. The implementation of the projects will provide the agricultural community with infrastructure or compensation to ensure that their agricultural operations are comparable with pre-project conditions.

5.1 Does the Plan describe the significant material adverse effects due to groundwater seepage or are there other effects to consider?

The SMP describes the adverse effects due to elevated groundwater; however, the plan does not adequately describe the potential effects of groundwater seepage on either cropping patterns or crop productivity. Cropping patterns and productivity are outcomes of the management of physical, biological, and chemical practices as well as external economics. It is recommended that the Plan include the following;

- Pre-project cropping patterns need to be identified so that growers have historical guidance on what could have been planted in a given year-type without the impact of restoration flows.
- Crop productivity is necessary so that there is a baseline for the amount of production that could have been achieved in a given year-type without the impact of restoration flows.

Developing baseline cropping patterns and productivity can be achieved through the use of historic remote sensing data and historic cropping patterns as discussed under the monitoring section.

- Establish control sites for crop productivity monitoring. Coupling remotely sensed multispectral imagery with control sites can be used to establish production impacts from elevated groundwater and salinity. Control sites should range from pristine locations that are irrigated with high quality water, have good drainage to lands impacted by seepage that are irrigated with low quality water. Statistics can be used to show how areas impacted by river flows compare against several variables including non-impacted areas, hydraulic flow lines, groundwater levels, other areas in the same field, other fields, by irrigation type or by crop type.

5.2 Will the Plan avoid the identified material adverse effects? If not, what revisions would avoid the material effects?

Using the established triggers, the plan will avoid the identified material adverse effects of elevated groundwater; however, without a baseline and monitoring program of cropping patterns and productivity it is not known if adverse impacts will occur to either cropping patterns or crop productivity.

5.3 Is the Plan overly restrictive on the release flows? If so, would revisions allow for increases in flows while avoiding material adverse effects?

In response to the question posed, the corollary is "relative to what condition?". The PRP agreed that the Program has taken a very conservative approach to protect the ability to continue agricultural operations. This approach indicates to the landowners that Reclamation understands their livelihood and will strive to not impact their current operations. Although this is a sound strategy, not all are satisfied and not all are participating. However, the high level of interaction between Reclamation and the affected stakeholders appears to have created a fair amount of common understanding and goodwill and this will be of great benefit as the Program starts ratcheting up flows and addressing seepage in problem areas. With no release flows in the River, Reclamation is clearly not maximizing flow but with the long-term strategy of working with affected landowners, it may get to the goal of maximizing flow while minimizing impacts to the affected agricultural community.

The criteria selected for the establishment of the triggers (e.g., rooting depth, salinity tolerance, historic water table level) are appropriate metrics for planning purposes; however, the values selected restrict the release of flows. The groundwater threshold values selected to establish flow level triggers appear to be fully protective of crop production but they do not fully represent the range of fluctuating groundwater levels that were present pre-project. For example, CCID monitoring wells 191 and 188a shown in Figures H-7 & 9 have threshold levels that do not include historic high water levels. Without the inclusion of historic high water levels the threshold value for these locations is lower than pre-project conditions. The impact of excluding non-wet years is that there is less ability to meet restoration flows. Wet years are part of the historic cycle and should be included.

In order to determine the incremental impacts of increased flows and to be more representative of pre-project conditions, the triggers should include a year-type component that considers antecedent hydrology. For example 2010 was a wet-year and 2011 was a below-normal year. Therefore, the 2012 trigger should be based on the pre-project period of record that best matches these conditions. The development of the year-type trigger will require the analysis of cropping records (historic remote sensing data) and year-type surface and groundwater hydrology. The utility of a year-type trigger is that it provides clear guidance on how the shallow groundwater conditions change with year-type. Also, the knowledge of shallow groundwater conditions supports a grower's consideration of what crops are suited for the available rooting depth. For example, a grower would know if under pre-project conditions there was sufficient root zone availability for almonds. Knowledge of long-term rooting depth could also be used to determine cost-share on mitigation projects.

5.3.1 Initial Actions

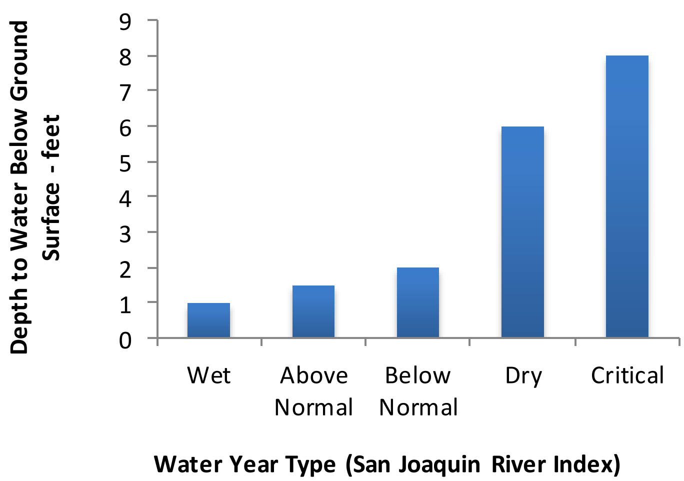
The Plan should take initial actions to establish an increase in the opportunities to release flows by refining the triggers and implementing projects. It is recommended that the Plan include the following;

Implement Seepage Projects

At the September 13, 2012 team meeting in Los Banos Chris White, of CCID presented a proposal to construct interceptor drains. This project should be implemented and monitored to determine the effectiveness at reducing seepage impacts and the associated costs. Several other projects designed to reduce seepage impacts and gather further knowledge should be considered. Early projects may be considered pilots and cost-sharing for these should rely more heavily on Reclamation; however, as information improves cost-sharing should be proportionally lean toward the beneficiary as defined under a pre-project baseline.

<u>1. Establish a year-type sensitive baseline for groundwater levels</u>

Considering that in 2012 there was no flow released because the groundwater triggers were exceeded suggests that there is a disconnect between the established triggers and pre-project watershed conditions. Groundwater level triggers should be based on pre-project conditions that span the year-type variations that occur in the watershed. Data for establishing this information has been collected for the project. The following illustrates the concept of establishing a year-type baseline for depth to groundwater.



In this illustration, the depth to groundwater varies based on the year-type index. When it is a wet year the ground water level naturally increases and when it is a dry or critical year the depth to groundwater increases. Because of the lag time between surface and groundwater hydrology there will not be a perfect match between year-type and groundwater level. Therefore, it will be necessary to review data on a time-series (seasonal and year) and use professional judgment to best match groundwater levels to surface water conditions.

When constructing the baseline, all pre-project data, including wet year data must be used. Spatial refinement to the groundwater observation well grid, along with improved modeling tools, both of which are included as near-term recommendations, should improve the spatial resolution for impacted areas.

Included with the baseline, the PRP recommends that Reclamation develop and present a conceptual model in the SMP that articulates how the groundwater system has evolved over a reasonable historical context (such as the last 40 or 50 years) that is important for the SMP. Such a conceptual model would describe how, why, when, and where the groundwater flow system and corresponding changes in the water table have evolved over space and time. The historical snapshots of depth to water (Figures 1 to 12 in the Plan) begin to address the when and where of changes in the flow system and depth to water, but don't conceptualize how and why with specific implications for localized seepage along the San Joaquin River. We recommend that Reclamation develop a single diagram, image, or map and accompanying text that describe your conceptual model and provide the context and linkage between Figures 1 to 12.

Another component that could potentially improve the ability to release flows to the River includes an analysis of the time duration of impacts. For example, if a fall pulse flow increases the groundwater level above the trigger but outside of cropping season or during a non-critical period of a cropping or cultivation period then there may be additional opportunities to release flows. Therefore, the inclusion of a critical and non-critical trigger level by season would improve the ability to release flows.

2. Suspend the use of Method 1 to trigger groundwater thresholds until a sufficient amount data has been collected and analyzed.

Trigger Method 1 requires additional information to be effective. The mechanistic approach of adding irrigation buffer, capillary rise, and rooting depth should be supported by information on crop productivity. Therefore it is recommended that the PRP recommendations in question 1 be implemented but that Method 1 be revisited.

3. Improve the monitoring network

These recommendations are provided to increase the both the spatial and temporal resolution of information to be used for decision making. Consistent with the recommendations in question 1, we reiterate the need to:

a) Increase the number of monitoring wells along the toe of the levee where necessary to improve recognition and reporting of seepage problems. These should be spaced at approximately 1 mile intervals along both sides of the River in reaches 2B, 3, 4A, and 4B targeted at areas where seepage is expected to be a problem.

b) Increase the use of data loggers and telemetry on all wells in the program that are used in decision making. All wells should be equipped with data loggers. The Program will need to invest in an enterprise-level hydrological data management system for data acquisition, data processing and data quality assurance analysis to ensure provision of timely data. Manually reading wells is not a viable long-term solution especially once restoration flows commence in the River given available staff resources. The PRP recommends that Reclamation utilize CDEC system to the extent possible for real-time monitoring until they have an equivalent website available for real-time data access.
c) Refine salinity monitoring needs protocol with realistic expectations of the outcome of the evaluation. Note that the changes in salinity may take time to be recognized.
d) Improve the analytical tools used for decision making.

The current SJRRP GWundwater model lacks the spatial and temporal resolution to be effective as a management tool. This model can be used to develop the boundary conditions for more detailed models that operate on a daily time-step with a more refined model mesh of suggested cell size of 30 – 50 meters. This will increase the accuracy of the analytical models to predict groundwater levels, travel-time, and attenuation. This resolution is necessary to be able to simulate benefits of various tile drainage and impermeable barrier seepage management options. In addition the model needs to include the drainage package and simulate drainage options explicitly if it is to have utility as a decision tool.

Improve the reporting of decision-making

These recommendations are provided to increase the understanding what information and data is being used for decision-making.

Flow Bench Evaluation Reports identified in question 1should be expanded to include better explanations of the data reported. For example, a clear definition between the drainage method and the standard method should be described. Another example is to add text to clearly define where there has been a threshold issue of a monitoring well.

The addition of monitoring wells will aid in the evaluation of the Flow Bench Evaluation Reports. At this point, the SMP appears to be a long-term research project. There need to be some additional components that will ensure the decision makers are not just relying on models.

Suggest using a depth category on Figure 1 to 12 (pages C-2 to C-13) that has finer resolution and thus is more consistent with other aspects of the SMP. For example, we recommend showing categories 0 to 1 ft, >1 to 2, >2 to 3, >3 to 4, > 4 to 5, and then show >5 to 10, >10 to 15, etc.

Recommend exploring other ways to display the data in Figures 1 to 12 to better address the question of seepage. Such maps may show locations of historical groundwater levels that exceeded SMP triggers and thresholds and the magnitude of those exceedences.

5.4 Potential Projects

The SMP works to avoid impacts to agricultural fields using a series of physical improvements and agreements that work to limit and reduce, but are not expected to eliminate adverse effects. The Plan lists several potential project categories that contain drainage solutions, physical changes to the landscape, and legal arrangements to allow restoration flows. Based on the review of the Handbook, each project is reviewed for its ability to enable or constrain restoration flows, to consider implementation feasibility, and to consider relative cost.

An issue that is threaded throughout the potential projects is the determination of what baseline condition to use to compare a proposed project against. A baseline is necessary so that the incremental effects of the restoration flows can be determined and to appropriately share project costs and benefits. A discussion of the baseline is provided in the monitoring section of this report.

Following the implementation of the SJRRP there are expected to be numerous low-lying areas where seepage effects will be apparent. The SPH outlines a process and approach to deal with seepage impacts in an effort to avoid and reduce affected agricultural lands while ensuring environmental compliance. It is not apparent that a clear method has been developed to identify priority projects that consider weighing regional impact benefits with project costs. In addition to the site prioritization and evaluation approach discussed in the SPH, a method for identifying projects that have a large acreage impact should be considered over those that are geographically more limited. More specific geographic assessment criteria should be integrated into the site evaluation activity to better support the project prioritization process. The process of final project approval and the timing of project implementation is unclear. Additional language clarifying the project selection and implementation phases will be helpful. Please consider:

- Does the project have positive effects on adjacent fields and what are the projected effects to surrounding areas?
- With budget constraints likely to limit future seepage project activity, how will project funding priorities affect this process early on?
- How will the process avoid the problem of placing a high priority on the first projects submitted and avoid low project competition?
- Are there specific river reaches that are more critical to successful plan implementation and therefore require a higher priority?

The remainder of this section provides a brief qualitative review each of the proposed project types with respect to effectiveness, cost, and ability to be implemented.

5.4.1 Interceptor Drains

- Interceptor drains are subsurface tile drains typically installed at right angles to seepage flow paths. They are commonly constructed at the toe of a levee, along canals with high leakage rates, or to provide drainage relief in areas where the presence of a conveyance canal creates a barrier to regional drainage. Interceptor drains are typically easy and relatively quick to install and do not cause too much disruption to agricultural activities. In addition, their operation and maintenance requirements are typically low requiring only a shallow lift sump-pump and a periodic line flushing. Chris White of CCID advocates this approach and presented it as a potential solution along Reach (4A) at the review team meeting on September 13, 2012. A drawback with this approach is that the intercepted water needs to be disposed of in some manner.
- Reusing the water as a supply source is an option; however, there may be water rights considerations that must be resolved prior to proceeding with this option. For example, reusing the intercepted water on non-drainage affected upslope lands may not be a

viable option if it constitutes a loss to the River and could be seen as an indirect water supply delivery of riparian water. Returning this water to the River also has impediments. If the intercepted water is of good quality, similar to the ambient quality (including temperature) of the River, then returning it may be an option. If water quality is sufficiently degraded that it constituted a point source of waste loading it would require monitoring and worked into a potential waste discharge requirement.

5.4.2 Relief Drains

- Relief drains are typically subsurface tile drains that are installed to relieve locally high water tables. Most often they are installed to address an area within a field that suffers poor yield owing to a change in soil type (higher clay content) or due to local perching where an area is underlain by a clay lens that impedes drainage. As with interceptor drains, relief drains have similar disposal issues. However, unlike interceptor drains, relief drains are typically installed on-farm thereby increasing the complexity of supply and quality issues and distinguishing between controlling seepage from the River (benefits to the program) and providing drainage service (benefits to the grower). Without appropriate legal authorities, relief drains may create greater long-term liability for the SJRRP.

5.4.3 Drainage Ditches

- Drainage ditches are surface drainage facilities that convey accumulated seepage from the impacted area. These ditches can be configured to act as either interceptor or relief drains. They tend to be less popular because they are more disruptive of farming operations, require greater maintenance and are not as effective since they cannot be configured as deep or with the same flexibility of function as subsurface tile drains. For instance if a subsurface tile drain provides insufficient relief of a high water table condition a second tile line can be installed deeper and along the same alignment to intercept more water. If there is a localized sand stringer or lens of highly permeable aquifer material that surfaces well into a field, a second tile line can be installed to intercept this flow. This is not easily accomplished with drainage ditches. As with interceptor and relief drains the collected water requires disposal and this creates the same issues described for other drainage approaches.

5.4.4 Shallow Groundwater Pumping

- Shallow groundwater pumping is a less cost-effective technology for achieving the same result as drainage approaches. Shallow groundwater pumping wells need to be installed deeper than drains to achieve the same effect and need to be spaced close enough to capture enough water to have an impact on water levels. Aquifer tests (page 2-8 of Appendix K) will be valuable to determine drawdown-time and drawdown-distance curves to optimize the spatial density of shallow groundwater pumping wells and pumping rates. Additionally, the location of shallow groundwater pumping wells with respect to hydrogeologic boundaries, particularly the distance to the River or other un-lined canals or streams that may act as recharge boundaries, may limit drawdown in between the well and recharge boundary. Thus, identifying no-flow or recharge boundaries within the cone of depression is an importance factor in the effectiveness of the pumping strategy. Also, an ideal well placement may be limited by landowner or farming constraints, in which case, shallow groundwater pumping with new or existing wells may not be an ideal or sole solution to site-specific adverse material effects due to seepage.

- Additional practical considerations such as the proximity of electrical lines for powering the groundwater pump may limit the use of shallow groundwater pumping in some locations. The operation and maintenance of a well field and the associated energy costs of pumping make this a less attractive option than the passive drainage collection methods. In addition, the effectiveness of the shallow groundwater pumping to lower the water table and mitigate material adverse effects is limited by the ability to transport, store, and dispose of the water.
- Considering the above approaches to lowering the water table caused by the restoration flows the most cost-effective, controllable, and potentially easiest to implement are interceptor drains.

5.4.5 Slurry or Cutoff Walls

- Slurry or cutoff walls require deep trenching close to the toe of levees and the filling of the open trench with a low permeability material that severely impedes passage of water. These walls could prevent water from moving from the River to the groundwater system underlying adjacent farmland or from the farm field to the River. The wall needs to be set deep enough such that the head drop along the new flow lines under the slurry wall exceeds the difference in head between river surface and the localized groundwater table. These walls are expensive and take considerable time to install. Properly designed and installed they do offer a permanent solution. They can eliminate most river seepage; however, they may cause drainage problems on the non-river side where because the flow path to the River will be effectively eliminated.

5.4.6 Buildup of Low-Lying Areas

- This approach raises the land surface such that there is sufficient profile to allow drainage. Unlike drainage projects there are no water quality or operational issues to consider. However, raising the land surface requires borrow sites (existing channel debris), extensive grading, and potential changes to both on-farm and district irrigation infrastructure. Finally, given extensive landscape scale changes determining the benefits to the program against benefits to the grower will be challenging. This appears to be an expensive solution.

5.4.7 Channel Conveyance Improvements

Channel conveyance improvements are designated in the settlement agreement for known critical areas in the River. However, at this point there is insufficient understanding by the review team to contemplate additional channel conveyance improvements.

5.4.8 License Agreements and Easements

These provide structured agreements to allow impacts to occur on farmlands. Flood easements are commonplace in other reaches of the River. Under these agreements the landowner is compensated for impacts based on agreed to conditions. These types of arrangements are very effective because they give both parties an assurance on the outcome of actions.

Creating the agreement will require extensive analysis of baseline hydrologic, water quality and cropping conditions that have yet to be established.

5.4.9 Acquisition

In essence this is an extension of the license agreement and easements. However the government would acquire all land along with any potential unforeseen impacts associated with the acquisition. For example, upslope growers may claim that by allowing a property to be impacted resulted in an elevated water table in their area. Therefore, prior to either easements or acquisitions there must be a rigorous analysis of related impacts.

Creating the agreement for acquisition will require extensive analysis of baseline hydrologic, water quality and cropping conditions that have yet to be established.

5.4.10 Changes to Cropping Pattern

Land use changes are a form of easement where cropping patterns are adjusted such that the substituted crop is acceptable for the given conditions.

Creating the agreement for changes to cropping pattern will require extensive analysis of baseline hydrologic, water quality and cropping conditions that have yet to be established.

5.4.11 Partnerships

Partnerships appear to be similar to easements and cropping pattern changes where there is an agreed upon arrangement between two parties.

Creating the agreement for partnerships will require extensive analysis of baseline hydrologic, water quality and cropping conditions that have yet to be established.

5.5 Project Scoring

Project scoring provides a metric to compare one project against another. In the Handbook the criteria has points for various aspects of any selected project. For example one point is added to a projects score if the project aligns with a regional plan or a project loses a point for each 0.5 ppb increase in selenium. In addition to the criteria there is a weighting factor whether the project ranks high or medium. Because no sample projects were included in the Handbook it is not possible to comment on the robustness of the criteria; however, based on a cursory review it seems like most elements are in place but it is unknown if the point system is effective in providing sufficient discrimination between projects. In addition to adding a few more criteria it would be helpful if several projects are analyzed for how they score.

Additional criteria that may improve the analysis of the various projects include the following:

- Year-type viability – Does the project improve the ability to release flows?
- Seasonal viability – Does the project improve the ability to release flows during specific portions of the year?
- Cost-share – How is the landowner and Reclamation project cost share split?
- Geographic susceptibility – Does the project location fall within defined boundaries that distinguish between impact levels? This would require Reclamation, to develop contour

maps, using groundwater threshold levels that define several priority areas. Projects are then awarded more points if they are entirely within a higher priority region. The contour maps will be both year type and seasonally sensitive.

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