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Executive Summary

Previous to this Task 5.1-5.2 Report (Report), CV-SALTS' Executive Committee determined that narrative salinity objectives are appropriate to protect irrigated agricultural beneficial use (AGR). Protection criteria were also developed defining major crops to be protected, unacceptable levels of yield reduction due to salinity, and the driest years in which such protection need be afforded. A technical approach to regulating salinity sources to effect such protection was developed, along with the numerous data layers that were listed in the Task 5 Workplan (Workplan) previously submitted to CV-SALTS, and that are necessary or helpful to implement the suggested method. The Workplan envisioned that the work would be done in three main parts:

- Task 5.1 – Compilation of crop, soil, management, water district,hydrographic, and climatic data;
- Task 5.2 – Delineation of crop sensitivity zones (CSZs); and,
- Task 5.3 – Determination of crop sensitivity (salinity concentration) targets.

Many other general technical approaches are possible, and may yet be considered outside of this final report (Report) by CV-SALTS. For example, it could be assumed that, since crop yield reduction due to excessively saline water is generally rare, that protection of existing irrigation supply water quality is a sufficient guideline for some areas. While these approaches may have merit, they are not the subject of this Report.

The first two steps are the subject of this Report. In addition, extensive crop sensitivity data has been gathered and analyzed in a preliminary manner. This work and an a priori delineation of the CSZs were necessary to identify sensitive major crops (SMCs), which are defined based on their proportion of irrigated land in each CSZ. While not in direct conflict with the Workplan, this unavoidable work sequencing nuance had not been identified in the Workplan, but rather was discovered as the actual work proceeded. A flow chart was developed as part of the Workplan to facilitate understanding of the anticipated methodology. Many data themes were named, as were steps required to determine CSZs, SMCs, and crop sensitivity targets.

Upon completion of the final draft of this Report, the concepts and results were reviewed at a workshop attended by, among others, the primary agricultural stakeholders involved in the CV-SALTS process. This workshop was recommended after review of the Report by the CV-SALTS Project Committee. The principal outcomes from discussion during this workshop included the following:

1. A priori, set “zone” boundaries as required by the CV-SALTS GIS Task 5 Workplan (Workplan) and as described in the Report are not desirable. Rather, a statistical approach to calculating crop frequency to define SMCs should be considered for development. When applying crop sensitivity thresholds to interpret narrative AGR standards, consider replacing the fixed zone concept with concepts listed in items 2 and 3 (below).
2. Recharge areas for applied water (whether surface water or groundwater) are the waters that require protection, and to which AGR thresholds should apply.
3. When applying thresholds, mixing and dilution in the watershed should be considered, perhaps by considering the area of influence of discharges.
4. The statistical definition of major crops, for which two alternatives are presented in the Report, requires further discussion.

Items 2 and 3 (above) are addressed by the methodology presented here. Item 1, a newly developed alternative to CSZ’s, remains to be explored by CV-SALTS during potential future investigations. These workshop outcomes currently frame the path forward on this topic. Information from the workshop has been included in an Addendum to this Report.

A large introductory section of this Report was devoted to conceptual description and documentation of the methodology employed, as well as to describing the strong functional connection to the intended end-use of the work and to the Workplan. In that section, a flow chart was developed to capture the additional knowledge and steps as they were executed, with the correspondence of each element to elements of the Workplan noted and discussed. This flow chart shows how, in finalizing the work approach, end use of results was carefully considered, resulting in a method that should be useful for the intended purpose of guiding protection of crops from excessive concentration of salinity in irrigation supply. The method is described in lesser detail in this Executive Summary, and in greater detail in the main body of the methods section (Sections 1 and 3). These three sections tell the same basic story in three different ways, with the hope of accommodating the needs of readers with varying levels of desire and need for detail.

The preliminary determination of crop sensitivity levels was developed based on literature classifications and functions relating water quality to soil conditions and yield impacts. An estimate of irrigation water quality required to avoid unacceptable yield impacts to 96 crops was developed, and crop sensitivity classes were identified for an additional 86 crops. As part of the Workplan, a more thorough assessment of salinity targets, based on not only crop types, but also on soil and climatic conditions (for example, per Hoffman (2010) is planned as part of Task 5.3. However, Task 5.2 could only be completed if the locations of sensitive crops are already mapped.

To protect irrigated crops as intended, areas recharging irrigation water supply to sensitive crops need to be known. Locating areas where sensitive crops are likely to be grown is a first step. Two options exist:

- Method 1: Develop a theoretical map based on analysis of multiple factors influencing planting decisions (water availability and quality, soil and drainage conditions, climate, flood risk, infrastructure [irrigation, transportation, crop processing, and artificial drainage systems], pest pressure, market conditions, grower culture, and regulatory conditions).
- Method 2: A phenomenological map based on what farmers, who integrate these factors when making planting decisions, have chosen to do.

Method 2 has the disadvantage of being tied to the timeframe of the observation, after which some of the driving factors and the planting patterns that they determine may shift. However, it is very difficult to model farmer decisions (Method 1) with anywhere near the precision required to predict future planting decisions at the required level of detail, and in any case the development of such a model is beyond the scope of the current work. Therefore, Method 2 was employed, recognizing that observed cropping patterns would likely shift somewhat over time, and that these shifts would need to be taken into account once known, perhaps by adjusting narrative AGR objectives in the future.

Locations of sensitive crops were mapped based on the most recent available irrigated crop mapping by the California Department of Water Resources (DWR). These maps showed many geographic concentrations of particular crops into localized groupings of fields. Recharge areas for these groupings of fields were observed to be relatively restricted in many cases, suggesting that protection of their water supply might naturally focus on fairly defined areas, some smaller than those envisioned in the Workplan (which estimated 25 CSZs in the whole Central Valley). It became evident that these relatively large CSZs would be most useful if primarily defined by hydrographic boundaries. This way, the main recharge areas for sensitive crop irrigation waters would be more likely to fall within the CSZ within which the crops occur, even if futher subdivision might prove necessary. Preliminary CSZ boundaries used to identify SMCs that followed hydrographic boundaries were thus retained as final boundaries of 22 CSZs.

The same process applies to lands irrigated partly or predominantly with groundwater, although subsurface hydrographic network data are needed to implement this approach. No convenient Central Valley-wide data layer of subsurface flow networks exists, and subsurface hydrography was not mentioned in the Workplan. Nevertheless, the physical existence of subsurface hydrography is acknowledged, and conceptually included as part of this methodology. Where SMCs are primarily irrigated with groundwater, subsurface hydrography will need to be investigated and folded into the analysis. However, this work is expected to be site-specific, sometimes quite intensive, and only needed for a subset of Central Valley irrigated lands.

Other data themes listed in the Workplan as potentially affecting CSZ boundaries would then be primarily employed for their other intended purposes:

- Crop data in conjunction with soil, climate, and management: These data were compiled in 5.1 (this Report) for use per Hoffman in Task 5.3 to develop refined crop sensitivity targets. The stage is thus set for Task 5.3, which cannot be performed without these inputs. The implied multivariate determination of CSZ boundaries (including several of these variables as inputs) was found to be inconsistent with the broader goal of defining a usable method to inform water quality criteria in narrative AGR objectives, and was thus not pursued further. The reasons for this are those described in the preceding paragraphs.
- Irrigation and drainage districts, and drainage basins: The intended purpose of these data was to understand the routing of water to sensitive crops. Hydrographic data are more precise and appropriate for this purpose. Nevertheless, these data were collected and mapped as part of Task 5.1 (this Report), per the Workplan, and are available for use. Drainage basin boundaries were compared to the CSZs, and found to be generally similar.

Prologue

The purpose of this prologue is to orient the reader to the process by which this Report evolved to its current form, and to outcomes of the work that do not appear explicitly in the remainder of the Report.

An addendum to this Report contains a response to comments table, along with materials presented during a workshop in which the Report was reviewed with agricultural stakeholders in the presence of Report reviewers and a number of other CV-SALTS participants. Reviewers had several alternative approaches to configuring crop sensitivity zones (CSZs) relative to the approach developed in this Report. Examples of alternative approaches that were suggested include the following:

- Use the boundaries of irrigation districts, since these are a guide to how water is really managed and delivered to farmers.
- Use boundaries of drainage basins delineated by the Central Valley Regional Water Quality Control Board, since these align with the flow of discharges.
- Base CSZs on a spatial analysis of data for themes such as land cover (cropping patterns), climatic, and soils data, since these determine the sensitivity of the crops that need to be protected. This was the approach most strongly implied by the CV-SALTS GIS Task 5 Workpan (Workplan).

While the concept of static CSZ boundaries was initially attractive, it poses several practical challenges described in the Report. First, CSZ configurations influence the identification of major crops too strongly and in ways that may not be intended; since this calculation depends on the proportion of a crop within a CSZ delineation, the result depends strongly on the form of the delineation. Second, the Report demonstrated that the large CSZs specified in the Workplan, and perhaps any CSZ specified a-priori, would likely require subdivision to focus narrative AGR interpretations on sources of irrigation supply to sensitive major crops (SMCs), particularly where SMC fields occur in localized clusters (as they do in most of the Central Valley).

The Report presents two alternative statistical definitions of major crops. One is developed and used in mapping throughout the Report, and the alternative is described in Attachment B. Such a definition is a policy question that affects the range of crops influencing interpretation of narrative AGR standards.

Materials from the workshop complement the Report. Included are explanatory figures, summary of the main Report elements, and an example illustrating how the CSZ concept in the Report would be applied to a portion of the Central Valley.

The principal outcomes from discussion during this workshop included the following:

1. A priori, set “zone” boundaries as required by the Workplan and as described in the Report are not desirable. Rather, a statistical approach to calculating crop frequency to define SMCs should be considered for development. When applying crop sensitivity thresholds to interpret narrative AGR standards, consider replacing the fixed zone concept with concepts listed in items 2 and 3 (below).
2. Recharge areas for applied water (whether surface water or groundwater) are the waters that require protection, and to which AGR thresholds should apply.
3. When applying thresholds, mixing and dilution in the watershed should be considered, perhaps by considering the area of influence of discharges.
4. The statistical definition of major crops, for which two alternatives are presented in the Report, requires further discussion.

Workshop participants recommended that CV-SALTS consider implementing additional work to evaluate alternatives consistent with the workshop outcomes but do so only in one or two pilot areas, making sure to check in with the same stakeholder group at frequent intervals.

At the time of writing, plans for this potential followup work remain in development.

Please see the Addendum to this Report to review the cited materials.

1. Introduction

The objective of the Geographic Information System (GIS) Technical Services (GIS project) is to continue development of a GIS database for the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)[1]. As a result of the GIS project, data and information pertaining to the beneficial uses, water quality objectives, and water quality of surface water and groundwater within the Central Valley[2] are being organized into a comprehensive database. A comprehensive database and GIS tools are central to the utilization of these data in analyzing water, land-use, and water quality information and for identifying areas of concern and assessing management alternatives.

The GIS project is being conducted in a collaborative setting with stakeholders and regulatory and partner agencies. One application of the database is to assist with the Initial Conceptual Model (ICM) work effort that, in turn, supports the development of a Central Valley Salt and Nitrate Management Plan (CV-SNMP). The knowledge base, technical analyses and associated documentation will support development of amendments to the Water Quality Control Plans for the Sacramento River and San Joaquin River Basins and Tulare Lake Basin (i.e. Basin Plan Amendments or BPAs).

The *GIS Technical Services Workplan* (Workplan) describes the approach, milestones, and deliverables to be completed as part of the GIS project. The primary technical tasks include:

- Task 3 – Address Identified Data Gaps in Existing Beneficial Use Objectives Study (BUOS) System;
- Task 4 – Incorporate Additional GIS Map Layers into Existing System; and
- Task 5 – Develop Map Layers and Identify Crop Sensitivity Zones.

This Report covers part of the work planned under Task 5, subtasks 5.1 and 5.2. Introductory sections (immediately below) describe the following:

- The elements of Task 5 that are addressed in this Report;
- The organization of the Report; and
- How the Task 5 Workplan was implemented.

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[1] This project builds off of the Phase I Beneficial Use Objectives Study (BUOS) GIS data gathering effort that has already incorporated much data pertaining to water quality objectives and beneficial uses.

[2] The GIS project is being completed for the area within the jurisdictional boundary of the Central Valley Regional Water Quality Control Board (Region 5).

1.1 Description of GIS Task 5 – Develop Map Layers and Identify Crop Sensitivity Zones

The main purpose of Task 5 is to develop a Crop Sensitivity Tool Set (CST), which is intended to provide a method to analyze GIS layers to produce results that inform AGR (beneficial use of water for agricultural irrigation) designations and implementation. For this beneficial use, one of the main potential water quality impairments is elevated salinity. Less frequently, specific ions might also be considered impairments for this use. The focus of this work is to provide a robust manner in which to quantitatively relate the quality (salinity) of irrigation water to the potential for the water to cause reductions in crop yield. As such, the locations of sensitive crops, the sources of their irrigation water, and the quality of that water must be considered together. These elements are addressed in Tasks 5.1 and 5.2 (described below), and are the subject of this Report. The Workplan, the manner in which it was implemented, and the processes and datasets that were developed, are elements of the CST. Additional elements will be developed under Task 5.3. A portion of the 5.3 work has been deferred, and only a pilot element was slated to be performed under the currently authorized budget (Phase 1). The Task 5.3 work is not addressed in this Report, but this work provides helpful data and process for Task 5.3. Based on input from workshop participants, it appears that any additional work will focus on pilot application of the workshop outcomes, rather than proceeding with Task 5.3 as described in the original Workplan.

The Task 5 work effort comprised three tasks that are briefly described below.

- Task 5.1: Research and Develop Map Layers

  This task involved development of GIS data layers to form the basis for analysis under Tasks 5.2 and 5.3. Task 5.1 was a data gathering effort for the Central Valley, employing readily available datasets to develop GIS layers characterizing conditions related to soils, climate, cropping patterns, drainage basins, irrigation and drainage districts, and applied water quality. As part of this effort, an irrigation water quality data request was generated and data received to date were also mapped. Maps and summary tables were produced, including available data on soils, crop coverage, crop sensitivity, climate, irrigation management, and applied water quality throughout most irrigated areas of the Central Valley.

- Task 5.2: Identify Crop Sensitivity Zones (CSZs)

  This task involved delineating up to 25 CSZs. The delineation methodology (described later) was performed in such a way as to facilitate later development of protective AGR criteria, and the recharge zones in which they would be most critical. Crops were screened based on soil water salinity thresholds to identify Sensitive Major Crops (SMCs). The SMCs were identified and mapped. Summary tables of crop sensitivity thresholds were prepared. Data layers developed under Task 5.1 were mapped within the CSZs.

- <u>Task 5.3: Determine Applied Water Sensitivity Thresholds (the subject of a forthcoming report)</u>

  This task was conceived to use the GIS data layers from Task 5.1 and the CSZs and the major crops identified from Task 5.2 to estimate tolerable maximum irrigation water salinity for areas that recharge water used to irrigate SMCs. During the currently authorized phase of this work (Phase 1), this would have been performed for one pilot CSZ, probably in an area where a detailed study has already been performed (see below). However, extensive review and development of the 5.2 methodology with CV-SALTS was a higher priority, and needed to be completed before proceeding with Task 5.3. Thus, the project team was directed to participate in a workshop to review the Tasks 5.1 and 5.2 work, in lieu of proceeding with any work related to Task 5.3. Thus, participation in the workshop and finalization of this Report serve to complete Phase 1. Based on input from workshop participants, it now appears likely that a pilot implementation of the workshop outcomes will constitute the next activities related to these topics. Estimates of maximum tolerable irrigation water salinity for other areas will await the completion of that work, which is not currently authorized. When Task 5.3 is undertaken, three detailed studies of AGR thresholds exist, for Yolo County (Grattan and Isidoro, 2006), the South Delta (Hoffman, 2010), and the Lower San Joaquin River (Montgomery, 2010) areas. Among these three detailed analyses, one area may be selected for focused study in consultation with CV-SALTS, and the results of Task 5.3 could be compared with results previously obtained for that area. After evaluation of the results of this work, the CST might be applied in other locales to estimate maximum tolerable irrigation water salinity levels.

Many other general technical approaches are possible, and may yet be considered outside of this Report by CV-SALTS. For example, it could be assumed that, since crop yield reduction due to excessively saline water is generally rare, that protection of existing irrigation supply water quality is a sufficient guideline for some areas. Also, broad frameworks for implementing narrative AGR standards are being developed in the CV-SALTS policy process at this time. These tend to simplify implementation wherever possible, focusing detailed analysis (such as that described in this Report) into areas where it can be most helpful. While these approaches may have merit, they are not the subject of this Report, which focuses on the development of data needed to inform such analyses, and an approach to spatial aspects of AGR implementation, including the delineation of up to 25 CSZs.

The purpose of this Report is to discuss the data collected, data sources used for developing the foundational GIS data layers (Task 5.1), the methodology used to delineate the CSZs, and the nature of the CSZs themselves (Task 5.2). **Table 1** lists the elements of the Workplan, and where each is provided in the Report. It also lists items provided that were not explicitly called for in the Workplan, but that were developed and included due to their utility in completing the work.

As such, this Report, submitted by the LWA Team[3], fulfills the requirement of the Task 5 Workplan[4] for Tasks 5.1 and 5.2. The Agricultural Stakeholder's workshop and related materials (provided in Addendum), along with this completed Report, satisfy the balance of the LWA Team's commitments under Task 5. One outcome of the Task 5.2 stakeholder workshop was that Phase 2 should initially focus on pilot of the methodology described in this report, with several specific modifications. This work is currently in the planning stages. As such, Task 5.3 activities remain on hold, and may be modified as a result of this work. To date, no Phase 2 work has been authorized by CV-SALTS.

1.2 Report Organization

This Report includes the following sections pertinent to GIS Tasks 5.1 and 5.2:

- Section 1 – Introduction

  Provides a brief background on the GIS project and Task 5 objectives.

- Section 2 – Data Sources and Types

  Provides an overview of data sources and types that were used in the development of the GIS data layers and the delineation of the CSZs.

- Section 3 – Crop Sensitivity Zone Delineation and Sensitivity Crop Locations

  Describes the methodology used to delineate the CSZs and to identify the SMCs.

- Section 4 – Other CSZ Properties Related to Crop Sensitivity

  Presents the GIS maps showing the spatial distribution of the soils, cropping patterns, climatic conditions, drainage basins, and applied water quality, along with summary tables of soils and cropping patterns, across all of the CSZs.

- Section 5 – Conclusions and Recommendations

  Describes progress to date, recommendations, and data limitations of the CSZs for estimating the applied water sensitivity thresholds.

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[3] The LWA Team consists of the following firms: Larry Walker Associates, Luhdorff and Scalmanini Consulting Engineers, Kennedy/Jenks Consultants, PlanTierra, Systech Water Resources, and Carollo Engineers.

[4] The Task 5 Workplan for the development of the agricultural zoning map layers was submitted separately on February 7 2013 and authorized for Phase 1 of the effort.

Table 1 Summary of Task 5 GIS Data Layers and Deliverables

GIS Data Layers Requested in the Task 5 Workplan	Task/Subtask No.	Figures Corresponding to Data Layers	Report Sections	Description
GIS Layers Developed Pursuant to Task 5 Workplan				
Political or Other Boundaries and Base Map Information	Subtask 5.1.1	Figures 2a and 3	Section 2.2.1	GIS layers cover the requested data layers pursuant to the Task 5 Workplan and include the county boundaries used as the base map; Region 5 jurisdiction boundary; irrigation, water, and reclamation district boundaries; and IAZ boundaries.
General (Statsgo2) and Order 2 (SURRGO) Soil Mapping	Subtask 5.1.2	Figures 12, 13, 14, 15, 16a, and 16b	Sections 2.2.2 and 4.1.1	GIS layers cover the requested soil database pursuant to the Task 5 Workplan and include the map of the EC; SAR; drainage classes; depth to water table; available water supply at 0-25 cm soil depth; available water supply at 0-100 cm soil depth.
Irrigation Water Supply Sources and Quality	Subtasks 5.1.3 and 5.1.4	Figures 18, and 19	Sections 2.2.3 and 4.1.2	GIS layers cover the requested database based on available data and include applied water data from KRCD; and applied water quality from WARMF.
Agricultural Beneficial Use Listings	Subtask 5.1.5	NR	NR	GIS layer was completed under Task 3 of the GIS Project and will be used in Phase 2 of Task 5, pursuant to the Task 5 Workplan.
Current Crops Grown	Subtask 5.1.6	Figure 7a	Sections 2.2.5 and 3.2	GIS layers cover the requested data pursuant to the Task 5 Workplan and include the crop cover based on available DWR land use survey.
Current and Historic Value of the Crops Grown	Subtask 5.1.7	NR	NR	GIS data layer is not applicable and not included pursuant to the Task 5 Workplan.
Other Constraints Limiting Growth of Crops: Climate and Crop Yield Reduction Data	Subtask 5.1.8	Figures 9, 21, 22, 23, 24, 26, 27, 28, 29,	Sections 2.2.7, 4.1.3, and 4.1.4	GIS layers cover the requested database pursuant to the Task 5 Workplan and include various climate data; crop sensitivity data; and crop yield reduction.
Delineation of CSZs	Task 5.2	Figure 6 (CSZs are shown in all GIS layers developed)	Section 3.1	GIS layer covers the requested data layer pursuant to the Task 5 Workplan. Task 5.2 involved delineating up to 25 CSZs in the entire Central Valley.
Draft GIS layers and other calculations (databases, workbooks) associated with analysis inputs and outputs for one of the three CSZs (Yolo County, the Lower San Joaquin River, and South Delta areas)[5] One (1) Draft Technical Memorandum 5.3 for methods of applied water sensitivity threshold[5]	Task 5.3	No deliverables provided as part of this Report. Upon completion of the draft Task 5.1-5.2 Report, it was recognized that it would be more beneficial for CV-SALTS to review crop sensitivity zone concepts with stakeholders in a workshop. Accordingly, at the request of CV-SALTS, workshop preparation, participation, and follow-up were substituted for this Phase 1 activity as the appropriate deliverables to complete Phase 1, and to set the stage for Phase 2. While the Task 5 Workplan originally called for draft maps and CSZs as part of Phase 1, CV-SALTS has asked that the original Phase 2 effort be paused while the methodology described in this report, as altered by requests from CV-SALTS that are documented in the Addendum, be pursued next. As part of this effort, a revised or alternative approach to CSZs may emerge. Thus, finalization of CSZs is premature, until that work is completed.		
Additional GIS Layers Developed				
Hydrologic Units	NR	Figure 3	Section 2.2	GIS layer was prepared in support of the CSZ delineation.
Drainage Basin Boundaries	NR	Figure 3	Section 2.2	GIS layer was prepared in support of the CSZ delineation.
Groundwater Basins	NR	Figure 2b	Section 2.2	GIS layer was prepared during the completion of Task 5 in response to the CV-SALTS stakeholder review.
Sensitive Crop Locations	NR	Figures 7b, 8a, 8b, 11a, 11b, and 11c	Section 3.2	GIS layer was prepared in support of the CSZ delineation.
Sensitive Crops and Surface Recharge Network	NR	Figures 11d and 11e	Section 3.2	GIS layer was prepared in support of the CSZ delineation.
Preliminary Threshold Applied Water Salinity for 95 Percent Maximum Crop Yield	NR	Figure 10	Section 4.1.2	GIS layer was prepared in support of the CSZ delineation.
Difference between Applied Water Salinity and preliminary	NR	Figure 19a	Section 4.1.2	GIS layer was prepared in support of the CSZ delineation.
Groundwater Quality Data in total dissolved solids (TDS)	NR	Figure 17	Section 4.1.2	GIS data layer developed with groundwater TDS based on readily available data completed under the GIS Task 4.
Irrigation Water Sources	NR	Figure 30	Section 4.1.5	GIS layer was prepared in support of the CSZ delineation.
Irrigation Type	NR	Figure 31	Section 4.1.5	GIS layer was prepared in support of the CSZ delineation.

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[5] Pursuant to the Task 5 Workplan, only the draft Task 5.3 GIS maps and draft TM are part of Phase 1 effort and final TM and GIS layers are intended to be part of Phase 3 deliverables.

Note: “NR” defines not required by the Task 5 Workplan, but developed and furnished as part of the geodatabase.

1.3 How the Task 5 Workplan was Implemented

The CST is intended to contain and facilitate analysis of spatial data for cropping patterns, climate, soil, management, water delivery, and water drainage, to identify:

- SMCs grown;
- Locations of the SMCs and waters requiring protection; and,
- Irrigation water salinity that will not cause unacceptable yield reductions to SMCs.

The CST will help to establish a technical (not policy) linkage between agricultural water quality needs on one hand, and actual water quality on the other, identifying areas where use and quality are most likely to conflict. Crop Sensitivity Zones, the main focus of this Report, need to be configured to facilitate foreseen application of the CST, as well as the use of criteria produced by the CST to inform the regulatory process.

This section contains a brief discussion of the following considerations that were key to deciding exactly how to implement the Workplan:

- How the Task 5 work is likely to be employed to inform AGR beneficial use criteria; and
- Implications of implementation considerations for CSZ delineation methodology.

This discussion is placed here, at the end of the Report's introduction, for the sake of clarity, since it is fundamental to the details of how the methodology in the Workplan was actually implemented. Development of this section was requested for clarification during reviews of previous drafts of this Report. Additional methodological details are presented later in the Report.

The GIS Task 5 Workplan calls for analysis of spatial data (cropping patterns, soils, climate, and management) to delineate CSZs, and then to identify the most SMCs grown in each CSZ and the irrigation water quality required to produce those crops without unacceptable yield reductions due to salinity. It also identifies drainage areas, as well as irrigation and water districts, as considerations in delineating CSZs. However, the exact manner in which all of these data themes would be combined to determine the boundaries of CSZs was not described, implying that the data themselves, and other considerations, might provide useful insights as to the best approach, and that this would occur during the actual execution of the work. This is exactly how the work proceeded.

As a first step in executing this work, a process connecting protection of water quality for use to irrigate agricultural crops to underlying data was explored. The purpose of this step was to ensure that data organization and analysis would be focused, and would produce a usable body of work. The step proved helpful in organizing the order and manner in which data inputs listed in the Workplan were employed to delineate the CSZs. Process steps leading to the desired outcome (protection of SMCs from undesired yield reductions due to poor irrigation water quality), are primarily driven by two key elements:

1. Sensitive Major Crops. These inform the process as follows:
    - Identification of locations in which SMCs tend to be grown.
    - Identification of water quality criteria (particularly the concentration of salinity) that protect SMCs grown in a locale from undesirable yield reductions due to poor water quality.
2. Hydrography. This informs the process by showing where the irrigation water in question comes from. This is important for two reasons:
    - Impairments of irrigation water quality can only happen upstream from the point at which irrigation water is applied. Therefore, water supply recharge areas need to be identified.
    - Practically speaking, lands that are not upstream of waters applied to SMCs cannot reasonably affect water applied to those crops. Therefore, protection of waters beyond the recharge areas for SMC irrigation water might reasonably be determined by other criteria.

When considered in this manner, the elements in **Figure 1** from the Workplan take a slightly different order from that originally envisioned, as follows:

1. The definition of CSZs becomes predominantly a matter of hydrography to facilitate linkage of water supplies and their recharge areas to areas of SMCs that they affect. It is also evident that CSZs might require later subdivision when applying quantitative water quality criteria to avoid incorporation of areas that have no effect on SMCs, since there is no guarantee that SMCs will always be situated at the downstream terminus of an SMC. Also, the CSZ must be delineated before SMCs can even be defined, since major crops' areas must exceed a threshold proportion of the area's total acreage (and total acreage can only be determined for a known area). As such, the CSZ delineation occurs earlier in the process than was originally recognized. The same process applies whether lands are irrigated partly or predominantly with groundwater, or solely with surface water. However, to apply the process to subsurface hydrographic networks, information on the geographic nature of these networks would be needed. Unfortunately, no convenient Valley-wide data layer of subsurface flow networks exists. If it did, major recharge areas for specific locations would generally be smaller, and might often lie within the boundaries of the major surface hydrographic recharge areas. Consideration of subsurface hydrography was also not described in the Workplan. While the importance of subsurface hydrography is acknowledged and included as part of this methodology at a conceptual level, hydrography in the CST at this point is based on surface water, since data on this network is readily available. Where SMCs occur and where groundwater is a significant proportion of applied water, subsurface hydrography will need to be investigated and folded into the analysis at a later stage. This work is expected to be site-specific, sometimes quite intensive, and necessary for a subset of Central Valley irrigated lands.

2. A preliminary identification of sensitive crops from the literature, and simplified calculation of irrigation water salinity (ECw) thresholds, can be utilized for purposes of prioritization, before running the Hoffman model or its equivalent. Areas with concentrations of sensitive crops can be mapped quickly within the CSZs and linked to their water source areas. These preliminary thresholds are not suitable for application in Task 5.3, or any other final determination of quantitative salinity thresholds related to interpretation of narrative AGR standards.
3. Model inputs such as soils, climate, and management data can be mapped for these areas, and models can be run to provide refined ECw thresholds.
4. Applied water quality in sensitive crop areas can be estimated and compared to thresholds to identify potential problem areas.
5. Actual or anticipated use of specific surface waters and/or groundwaters to grow sensitive crops can be more readily assessed by evaluating the hydrographic network to help focus management and regulatory attention into areas where they can feasibly have the desired protective effect.
6. Specific waters and their recharge areas can be more readily connected due to the hydrographic basis of CSZs.

This process is illustrated in a modified flow chart in **Figure 1b** of this Report. The new flow chart fits the Task 5.2 analysis into a broader, implementation-oriented context, with all of the elements of the Workplan retained. In **Figure 1b**, each process step was colored either green or blue, indicating whether it contained mainly crop (green) or hydrographic (blue) information. Steps where crop and hydrographic information are combined were colored similarly (but more lightly), according to the most dominant factor. A version of **Figure 1** from the Workplan, in which the process elements are numbered, is provided for reference in **Figure 1a**. The elements of **Figure 1a** are referenced by number (in parentheses) in the related elements of **Figure 1b**. In addition to the changes to the order in which input data are employed, **Figure 1b** takes a broader view that considers the end use of outputs to protect beneficial uses. As such, there are steps for which no Workplan element is cited. These steps have been added to more fully express the process points just listed. Some of the new elements are beyond the scope of this work, but are nevertheless recognized to illustrate practical connections to the regulatory process.

For the purpose of this discussion, it is useful to follow the illustrated process upstream, from the end use (on the right-hand end of **Figure 1b**), through preceding process steps (working leftward). What emerges is a picture of how crop and hydrographic information can be used together to spatially focus SMC investigations to most effectively inform AGR beneficial use narrative objectives. Steps referenced are the numbers at the beginning of the text in each process box of **Figure 1b**.

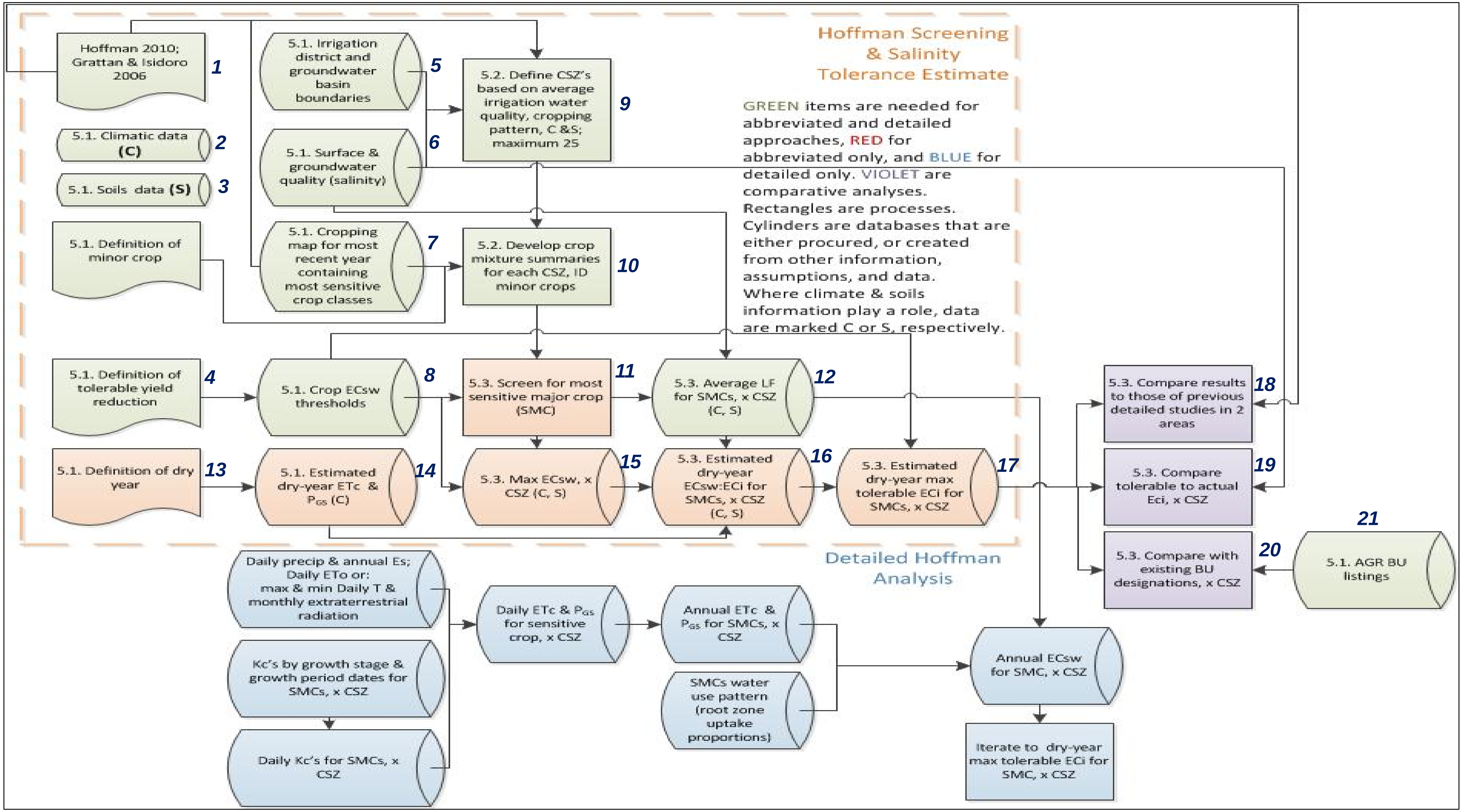
- Protection of SMCs by setting the objective for AGR uses in specific waters (steps 17-21, informed by steps 6 and 7): For the reasons previously described, these steps focus on the water applied to SMCs, and are thus essentially hydrographic.

- Locate SMCs based on crop data (step 4): Water applied to these crops would have the most stringent target quality (salinity). Why are land cover data used here? Observed cropping patterns express decisions by thousands of individual agricultural producers, each decision being the product of an integrated weighing of controlling factors (water availability and quality, soil and drainage conditions, climate, flood risk, infrastructure [irrigation, transportation, crop processing, and artificial drainage systems], pest pressure, market conditions, grower culture, and regulatory conditions) that affect crop production/yield and therefore profitability. Cropping patterns are thus a phenomenon in which, from the standpoint of crop location, farmer behavior has practically integrated data we can only analyze in the abstract. This fact can be used to quickly and confidently define an area where sensitive crops are likely to be grown in the future. As will be shown later, SMCs tend to be found in spatial groupings (clumps), perhaps due to a discovery by farmers that in those areas, you can find combinations of controlling factors that favor production of SMCs. These areas would be subject to change as the spatial distribution of controlling factors evolve. Data layers from Task 5.1 might be employed to assess the potential for such shifts.
- Preliminary delineation of CSZs (step 3): The CSZ delineation is required at the outset, so that the proportion of irrigated acreage for sensitive crops may be evaluated, allowing distinction between major and minor crops within each CSZ. It would be best if this delineation had a basis that would come in handy later in the process. What is a reasonable basis for such a delineation? Although surface water is the predominant applied water source in most areas, groundwater is also widely used. Recharge zones for groundwater are more localized, and not extensively mapped. Irrigation and drainage districts and drainage basins were discussed in the Workplan, primarily as factors that might be helpful in placing CSZ boundaries to align with surface hydrographic boundaries. However, Central Valley surface water networks themselves have been extensively mapped and this mapping was incorporated into CV-SALTS' geographic databases as part of previous GIS tasks. This mapping is a more direct, robust, and accurate way to delineate hydrographic networks and boundaries than referencing district and approximate basin boundaries. Hydrographic boundaries will be the most salient factor when seeking to encompass surface water recharge areas that feed SMC areas. Therefore, surface hydrographic data were primarily employed to determine the CSZ boundaries throughout most irrigated areas of the Central Valley, resulting in 22 CSZs. It is fully anticipated that, while the CSZ boundaries are a helpful starting point, actual recharge areas will often lie within only a part of a CSZ. In other cases, they may (despite the hydrographic basis of CSZ boundaries) extend into a neighboring CSZ. It is hoped, however, that because of the manner in which the CSZs have been delineated, the most important water supply recharge areas will frequently be found within the same CSZ.
- Preliminary identification of water quality thresholds (steps 1, 2, and 5): Salt concentrations that might cause yields to be unacceptably affected by a given crop can in most cases be estimated from research results for that crop. These thresholds do not take into account all of the factors that a Hoffman or similar analysis do, but

they are useful in ranking the relative sensitivity of crops so that SMCs can be identified for mapping purposes.

- Determine water quality targets based on actual water use and crop sensitivity (steps 13 and 16): The targets are determined by the sensitivity of the crop in question, when grown in the specific environment of the area in question, with irrigation practices defined as accurately as practicable for that area and crop. This is accomplished by the method developed by Hoffman, or by an analogous method.
- Compile and analyze foundation data to inform water quality target (Hoffman or similar) analysis (steps 11, 12, 14, and 15).
- Analyze water supply sources, including mixed use of surface water and groundwater, in SMC areas (steps 8-10).

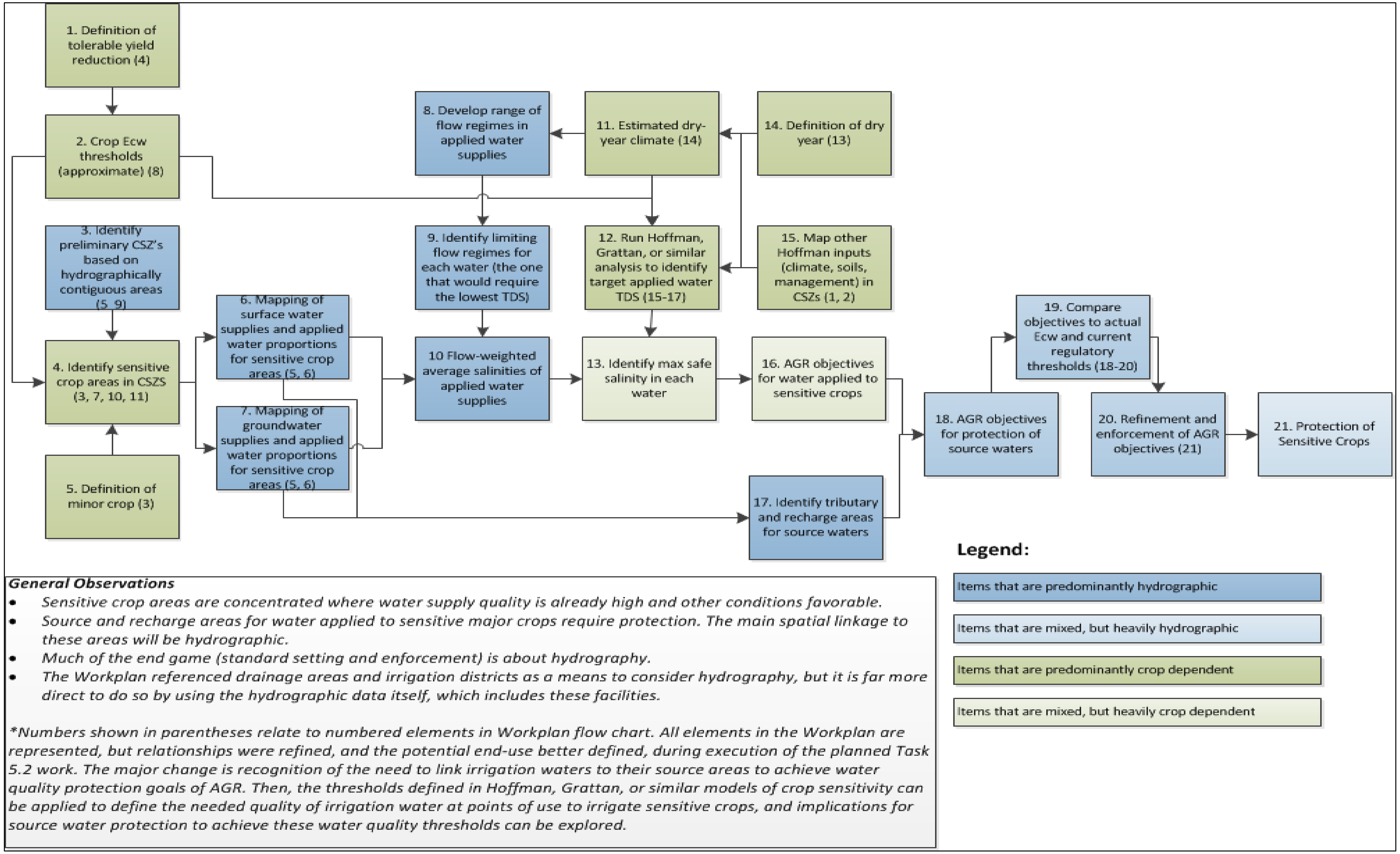
Again, this summary of how the multiple data themes were considered, prioritized, and employed in this work is intended to orient readers by clarifying the logical connections to the Workplan, and explaining why the work should be suitable to inform the AGR objective setting process. Additional description of the methods employed, and the results of the work, are contained in later sections.



GREEN items are needed for abbreviated and detailed approaches, RED for abbreviated only, and BLUE for detailed only. VIOLET are comparative analyses. Rectangles are processes. Cylinders are databases that are either procured, or created from other information, assumptions, and data. Where climate & soils information play a role, data are marked C or S, respectively.

Note: Figure 1a shows the schematic of Task 5.2 analysis, as presented in the Workplan, with element numbering added. Numbers are referenced in Figure 1b to relate elements in the two charts.

Figure 1a Schematic of Task 5 Analysis as Presented in the Workplan



General Observations

- *Sensitive crop areas are concentrated where water supply quality is already high and other conditions favorable.*
- *Source and recharge areas for water applied to sensitive major crops require protection. The main spatial linkage to these areas will be hydrographic.*
- *Much of the end game (standard setting and enforcement) is about hydrography.*
- *The Workplan referenced drainage areas and irrigation districts as a means to consider hydrography, but it is far more direct to do so by using the hydrographic data itself, which includes these facilities.*

**Numbers shown in parentheses relate to numbered elements in Workplan flow chart. All elements in the Workplan are represented, but relationships were refined, and the potential end-use better defined, during execution of the planned Task 5.2 work. The major change is recognition of the need to link irrigation waters to their source areas to achieve water quality protection goals of AGR. Then, the thresholds defined in Hoffman, Grattan, or similar models of crop sensitivity can be applied to define the needed quality of irrigation water at points of use to irrigate sensitive crops, and implications for source water protection to achieve these water quality thresholds can be explored.*

Note: This illustrates alignment of technical data development with needed regulatory inputs and protection of AGR beneficial uses.

Figure 1b Schematic of Hypothetical AGR Implementation

2. Data Sources and Types

This section describes the main data sources and types that were used for the development of the individual GIS data layers for Task 5.1.

2.1 Data Sources

This data collection effort consisted of compilation of readily available data from multiple sources. Data Source Matrix presented in the GIS Task 5 Workplan was developed at the time of the GIS project scope preparation to highlight potential data sources that could be useful for the GIS project data needs, including Task 5. These potential data sources were used as a guideline for Task 5.1 data layers (Subtasks 5.1.1 through 5.1.8). During the actual execution of the work, the focus was on datasets that were most pertinent to the Task 5.1 layers and Task 5.2 analysis. In addition, other datasets that were generated as part of the previous GIS project (e.g., Tasks 3 and 4) and the ICM project were considered and included for Task 5, as described below. The major sources of data that were selected for Tasks 5.1 and 5.2 included the followings:

- Teale GIS Solutions Group;
- Environmental Systems Research Institute, Inc. (ESRI);
- U.S. Bureau of Reclamation (USBR);
- Central Valley Regional Water Quality Control Board (CVRWQCB) or Region 5;
- U.S. Geological Survey (USGS);
- U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS);
- California Department of Water Resources (DWR);
- Kings River Conservation District (KRCD, 2013) and references they suggested (Page and LeBlanc, 1969);
- Luhdorff & Scalmanini (2003);
- Hanson et al. (2006); and
- Specific Watershed Analysis Risk Management Framework (WARMF) model runs and underlying data.

Table 2 summarizes the major data sources and types analyzed for preparing the Task 5.1 data layers (Subtasks 5.1.1 through 5.1.8) and presents individual data sources used to complete each layer.

Table 2 Data Sources and Types

Data Source	Data Types	Purpose of Data	Description of Data Source
Teale GIS Solutions Group	CVRWQCB (Region 5) boundary	Subtask 5.1.1	Region 5 boundary generated by Teale GIS Solutions Group was incorporated into the GIS layers.
ICM Project	Initial Analysis Zone (IAZ) boundaries	Subtask 5.1.1	IAZs established for the ICM project
ESRI	Political boundaries (e.g., counties and cities)	Subtask 5.1.1	ESRI 2010 Datasets
USBR and DWR	Federal, State, and private irrigation and water districts	Subtask 5.1.1	USBR Mid-Pacific regional office (MP), MPGIS Service Center in coordination with DWR.
CVRWQC	Drainage basin boundaries	Subtask 5.1.1	Drainage basin boundaries in the Central Valley were digitized for Task 5.1 from the CVRWQCB Staff Report (1992) that was prepared as part of the Inland Surface Waters Plan (ISWP) (CVRWQB, 1992).
USGS	Hydrologic Unit	Subtask 5.1.1	California Spatial Information Library (published on 11/18/2004).
	National Hydrography Dataset (NHD)	Subtask 5.1.5	USGS (http://nhd.usgs.goc/data.html). Beneficial Use mapping was prepared under GIS Task 3 (This data layer will be included in the Phase 1 of Task 5.3 and will be compared with results for one of the CSZs).
	Water quality	Subtasks 5.1.3 and 5.1.4	Fresno Area Groundwater Report by Page and LeBlanc (1969).

Table 2 (Continued) Data Sources and Types

Data Source	Data Types	Purpose of Data	Description of Data Source
USDA NRCS	Soil survey data: electrical conductivity (EC), sodium adsorption ratio (SAR), drainage classes, depth to water table, and available water supply (AWS)	Subtask 5.1.2	NRCS website (http://soildatamart.nrcs.usda.gov/)
KRCD	Irrigation water quality	Subtasks 5.1.3 and 5.1.4	Surface water quality was gathered for the KRCD area in response to the irrigation water quality request, and used to map salinity of applied water.
WARMF	Applied water quality	Subtasks 5.1.3 and 5.1.4	Applied water quality established from existing WARMF runs.
DWR	Crop cover	Subtasks 5.1.6	http://www.water.ca.gov/landwateruse/lusrvymain.cfm
	Water quality (TDS) from agricultural wells	Subtasks 5.1.3 and 5.1.4	Groundwater quality dataset that is being developed under GIS Task 4 was incorporated into Task 5.1 data layers. Data are based on the DWR Water Data Library (WDL).
	Agroclimate data: evapotranspiration (ET), precipitation, and applied water (AW)	Subtask 5.1.8	http://www.water.ca.gov/landwateruse/anlwuest.cfm
Luhdorff & Scalmanini	Water quality	Subtasks 5.1.3 and 5.1.4	Monitoring Program Report, Mendota Pool Group (Fresno Slough Report, dated 2003).
Hanson et al. (2006)	Crop sensitivity data	Subtask 5.1.8	Salinity threshold of crops were compiled from literature and joined with DWR cropping pattern data.

2.2 Task 5.1 Overview of GIS Data Layers

Data compiled from each of the major data sources are described below. Data sources are grouped according to the eight data layers prepared under the Subtasks 5.1.1 through 5.1.8. Data layers for Subtask 5.1.1 are associated with the jurisdictional boundaries and they are presented in this section. In addition to the jurisdictional boundaries, a number of datasets for soils, irrigation water sources and quality, climatic, crop distribution and sensitivity, and management were utilized and analyzed for Task 5.1. The data layers associated with these datasets are described below under Subtasks 5.1.2 through 5.1.8 and the resulting GIS data layers are presented in Sections 3 and 4.

2.2.1 Subtask 5.1.1 – Political or Other Boundaries and Base Map Information

This GIS layer builds off the Task 3 baseline map layers and adds other boundaries that are geographically pertinent to the CST. The Subtask 5.1.1 includes the jurisdictional boundaries as outlined in the Task 5 Workplan. These boundaries include the political boundaries (counties and cities), CVWRQB jurisdiction (Region 5) boundary, irrigation, water, and reclamation district boundaries as well as the IAZs from the ICM project. In addition, during the analysis of Task 5.1, other boundaries that were considered pertinent to the CST were analyzed and incorporated into Task 5.1 layers. These additional boundaries include the Hydrologic Unit boundaries by the USGS and the drainage basin boundaries defined by the CVRWQCB. **Figure 2a** shows the irrigation and water district boundaries within the Region 5 boundary. **Figure 2b** shows the groundwater basins, as defined by DWR Bulletin 118. **Figure 3** shows the Hydrologic Unit boundaries together with the drainage basin boundaries and the IAZs. Each of the boundaries included in the Subtask 5.1.1 are briefly described below. Among the boundaries shown in **Figures 2a, 2b,** and **3**, the political boundaries (e.g., counties and cities) and the Region 5 boundary serve as the base maps for Task 5 and they appear on the majority of the Task 5.1 maps.

- Political boundaries include the country and city boundaries and used on the base map for Task 5 (**Figure 2a**).
- The Region 5 jurisdiction boundary was generated by Teale GIS Solutions Group and is on the base map for Task 5 (also for GIS Tasks 3 and 4) (**Figure 2b**).
- Irrigation, water, and reclamation district boundaries are based on the data from the USBR and DWR (**Figure 2a**).
- Groundwater basin boundaries are based on DWR Bulletin 118 (DWR, 2003; **Figure 2b**).
- IAZ boundaries employed in the ICM project are shown on **Figure 3** for reference.
- Hydrologic Units are based on the USGS NHD (**Figure 3**). They delineate water bodies (major rivers) and represent the various drainage basins at the watershed level. Each Hydrologic Unit is progressively subdivided into smaller levels called Hydrologic Areas that represent the major tributaries. These standardized watershed delineations tend to

group common surface water supplies. **Figure 3** represents the Hydrologic Unit boundaries and the numbers associated with each Hydrologic Unit.

- Drainage basin boundaries in the Central Valley were digitized from the CVRWQCB Staff Report (1992) that was prepared to report on the Inland Surface Waters Plan (ISWP). These drainage basins represent areas of similar hydrology and common discharge locations. As part of the ISWP, CVRWQCB identified the water bodies dominated by agricultural drainage and constructed agricultural drains in Region 5. Information was gathered from over 340 water, reclamation, and drainage entities that cover over 90 percent of the Region 5's irrigated area. For developing the drainage basins, the Region 5 was initially divided between foothills and the valley floor. The valley floor was then divided into four distinct areas with boundaries similar to those of Basin Plan 5A (Sacramento River Basin), 5B (Sacramento-San Joaquin Delta), 5C (San Joaquin River), and 5D (Tulare Lake). The four valley zones were further subdivided into the drainage basins that are shown on **Figure 3**.

2.2.2 Subtask 5.1.2 – Soil Mapping

Soil data were employed to characterize soils on which crops are grown in the CSZs. Soil survey information from the NRCS' SSURGO database are available in GIS (shape file) format, and can be linked to extensive data associated with unique mapping units through the use of a structured Microsoft Access database template, and an ArcGIS extension called "Soil Data Viewer". Mapping units are the basic units of soil survey, characterizing soil profiles as they occur on the landscape, and with which soil properties (such as those that affect crop susceptibility to salinity in irrigation water) have been defined. A given mapping unit is named for a local landmark, and contains basic information. Thus, a Sacramento sandy loam, 0 to 2 percent slope, would have been originally mapped in or near capital of California, occur on land less than 2 percent in slope, and have a sandy loam surface texture. Normally a great deal of other data about this mapping unit would also be described, all of which is contained in the SSURGO database. The shape files delineate polygons with which mapping units are associated, and by this association, all of mapping unit characteristics are also associated with polygons bearing the mapping unit's name. This is the most common and standard format in which soil survey are digitally accessed and analyzed in the United States at this time. Additional information about SSURGO data and their use can be found at http://soils.usda.gov/survey/geography/ssurgo/description.html.

Soils data were acquired from the NRCS Soil Data Mart. Data were downloaded for a total of 29 survey areas, covering the majority of the irrigated land in the Central Valley. Tabular and spatial data were downloaded, analyzed, and used in mapping. Tabular data were first imported into the Microsoft Access database and then spatially analyzed in ArcGIS. Data analyzed in GIS include those that could be of interest in assessing the influence of saline irrigation water on sensitive crops. These were electrical conductivity (EC), sodium adsorption ratio (SAR), drainage classes, depth to water table, and available water supply (AWS) at two different depth intervals: 0 to 20 centimeters (cm) [about 0 to 8 inches] and 0 to 100 cm [about 0 to 40 inches].

A separate GIS layer was prepared for each of these five soil properties. The resulting GIS data layers are presented later.

2.2.3 Subtasks 5.1.3 and 5.1.4 – Irrigation Supply Water Sources and Quality

Irrigation water quality (salinity) can be used during the development of the CST for conducting comparisons to salinity thresholds that will be performed as part of Phase 1 of Task 5.3 in a selected area. However, representative irrigation water quality data are currently lacking for many geographic areas in Region 5. The following data collection efforts were completed, including a data request from CV-SALTS to stakeholders, as well as compiling other sources that are being developed as part of the ICM and GIS projects. The water quality data gathering effort focused on salinity (TDS), as Task 5 focuses on salinity effects on irrigated agriculture.

Applied Water Data Request from CV-SALTS to Stakeholders

A data request was developed by the LWA Team to facilitate compilation of readily available irrigation water quality data from CV-SALTS stakeholders. The data request was submitted in April 2013 with the main intent to correctly represent the characteristics of irrigation source water in areas of the purveyors of irrigation water. Data requested included estimated average annual salinity of applied surface water and groundwater, the primary sources of surface water applied to crops, and the approximate ratio of groundwater to surface water applied.

In response to the data request, the KRCD was the one, high-priority area (for which little data were already in hand, and on which a detailed salt and nutrient balance was being developed as part of the ICM project) that provided data. Key references were KRCD (2013), Page and LeBlanc (1969), and LSCE (2003). Estimates were for the flow-weighted average applied water quality, in this case at a very fine scale of one square mile. Methods for development of these applied water quality estimates are documented in the CV-SALTS ICM Task 8 report. Similar data for other areas may be forthcoming in the future, but are not currently available. The data request is in **Attachment A**, along with a table documenting the data request activities to date. This effort was completed with no additional water quality data from stakeholders by the time of this Report.

Applied Water Quality Data from WARMF

Applied water quality (salinity) data available from existing WARMF model runs were compiled in an effort to develop a representative applied water quality (in the form of TDS). TDS was calculated within the WARMF domain based on individual estimates of applied surface water and groundwater depth (inches per year) and quality. The sum of applied, dissolved ions' masses was divided by the sum of the applied water volumes, yielding the applied water TDS concentration estimate.

Groundwater Quality Data from Agricultural Wells

Groundwater quality data are currently being developed as part of GIS Task 4 (Kennedy/Jenks, 2013a). As part of Task 5, salinity (TDS) of agricultural wells was mapped, based on data available from DWR Water Data Library (WDL). Additional datasets were added based on data available from the RWQCB Waste Discharge Requirements (WDR) Dairy Data[6] and data compiled from the National Water Quality Monitoring Council (MWQMC). RWQCB WDR Dairy Data includes TDS from monitoring wells with data spanning from 1999 to 2008. NWQMC dataset provides groundwater TDS but no information on well types was available. Although the RWQCB WDR Dairy Data provide data from monitoring wells and NWQMC dataset does not identify well types, these two datasets were included to help infer groundwater quality from non-agricultural wells. For the three datasets, the most recent values were presented to show the current conditions of groundwater quality for TDS. A more detailed explanation of these datasets is provided in the GIS Task 4 Report.

2.2.4 Subtask 5.1.5 – Agriculture Beneficial Use Listings

This data layer was completed under Task 3 of the GIS project. The GIS map layer and the geodatabase were submitted to CV-SALTS in April 2013 (Kennedy/Jenks, 2013b). Under Task 3, beneficial uses and water quality objectives for the existing waters, including AGR, were linked to the updated NHD 2012 dataset.

2.2.5 Subtask 5.1.6 – Crops Grown

When the scope for Task 5 was prepared, potential sources for cropping patterns were identified, including land cover layers from DWR, WARMF, and Central Valley Hydrologic Model (CVHM). Upon further review of these three sources, the DWR dataset was selected for the Task 5 analysis as it provides a complete coverage of cropping patterns at the field scale. The DWR dataset is also the basis for WARMF and CVHM land coverage (which contain less information), and contains the most recent mapping from DWR. Certain land cover classes, such as dairy land application, urban classes, and native cover classes, are not mapped in detail by DWR. However, none of these areas of relatively lower detail relate to the SMCs and irrigated land acreages that are the focus of this work. DWR mapping, on the other hand, maps these crop cover classes quite well.

Periodically DWR maps irrigated crops grown in fields within a county. The most recent of these data were merged and employed for the Central Valley counties to determine the locations of crops. Due to crop rotation, changes will occur year-to-year for particular fields. However, cropping patterns and proportions within regions should remain generally similar over the short

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[6] RWQCB WDR Dairy Data are data solely for dairies that fall under the RWQCB's General Order (WDR General Order R5-2007-0035) from 2007 for existing milk cow dairies. These data were received by special request for a different project conducted by the LWA team in 2009 for Dairy CARES. With agreement from dairies, this readily available dataset was made available in support of the GIS project (also for the ICM).

term (5 to 10 years). Over the longer term, factors controlling farmer's planting decisions will evolve, and concentrations of particular crops may shift more significantly, and these shifts may require revised interpretations of narrative AGR water quality standards. Nevertheless, crops will continue to be found where conditions are favorable for their profitable cultivation.

Crop locations were based on the DWR land cover data. For each CSZ, crops were screened based on sensitivity to irrigation water salinity to identify the SMCs (see crop sensitivity discussion below). Major crops were defined as those occupying more than five percent of the irrigated land within a CSZ. An alternative approach to defining major crops is described in **Attachment B**. This definition is a policy consideration that is beyond the scope of this technical report. While CST results will be sensitive to the definition, the methods can be applied in conjunction with any major crop definition that is in current use.

2.2.6 Subtask 5.1.7 – Current and Historic Value of Crops Grown

This parameter has been de-emphasized based on stakeholder input. It is not anticipated that it will inform the development of AGR regulatory targets, and thus no crop value data were collected. This is consistent with the Workplan.

2.2.7 Subtask 5.1.8 – Other Factors Related to Salt Sensitivity

The main constraints to crop growth other than climate and soils would be quality of the existing water supply, the type of crop (irrigation) management, and intrinsic limitations (crop and cultivar yield potential under favorable conditions). Irrigation water quality data were just discussed. Other factors discussed below include climate, crop sensitivity, and irrigation management related factors. The most efficient way to assess multi-factorial questions of which crops can and will be grown where is to locate where farmers have historically elected to grow the crop, to study the reasons for these choices, and then to project that knowledge into areas or timeframes of interest. This type of land use forecast, while conceivable, is beyond the scope of the current work.

Climate Data

CV-Salts has provisionally defined the driest year for which crops need to be protected for AGR beneficial uses (as they pertain to salinity) as a 95th percentile drought year. This threshold is used throughout this report to define "drought".

Climate conditions for statistically average and drought years were developed comprehensively for the Central Valley. The estimates are regional and useful for larger-scale planning purposes; they should be replaced with data from local meteorological stations for more site-specific evaluations.

Agroclimatic variables for crops have been summarized by DWR for each detailed analysis unit (DAU) throughout the Central Valley. A similar climatic summary of the region would be quite labor intensive if developed from basic CIMIS data; such an analysis is beyond the scope of the current work.

Climatic and crop parameters can be used to estimate reference evapotranspiration (ETo), effective precipitation (EP), and an index of applied water (AW). To do this, data for alfalfa are particularly handy, since this crop grows nearly year-round, and is cultivated in most areas of the Central Valley. Its ET is therefore a reasonable approximation of ETo, and EP for it reflects the maximum precipitation that might infiltrate the soil. These parameters are only reported for a 4-year data period, 1998 through 2001. CIMIS data from four of the oldest (at least 1983-2012) stations in the Central Valley (Kettleman City, Five Points, Davis, and Gerber, running from south to north) were analyzed to relate 1998-2001 means of reference ET, precipitation, and a calculated estimate of applied water (all from the CIMIS data record) to the median and 95th percentile drought year for these three parameters. These relationships were used in conjunction with the alfalfa agroclimatic parameters to estimate regional long-term median and drought parameters for each DAU.

Again, while the regional climatic data will be helpful at the general level, site-specific studies should be based on the best available local (CIMIS or comparable) data. Also, in irrigated systems, the severity of actual drought stress in a crop may depend more greatly on operational, infrastructure, regulatory, and institutional limits to irrigation water availability, than on the length of climatic dry spells. Most of these non-climatic factors, while important, are also beyond the scope of the current work.

Crop Sensitivity Data

CV-SALTS has provisionally defined 95 percent of maximum relative yield as the threshold of protection for the AGR beneficial use. This threshold is employed throughout the current work.

The main focus with respect to crop sensitivity was salinity, which can be measured and expressed as either electrical conductivity (EC) or TDS. Most of the data referenced in this Report were measured in TDS. Much of the crop work was performed in EC. Crop applied water salinity (ECw) targets were converted to TDS for purposes of comparability to water quality data. Where necessary, a standard conversion of 640 milligrams per liter (mg/L) TDS = 1 deciSiemens per meter (dS/m) ECw (salinity of applied water) was employed. For more site-specific work, conversions based on local water quality conditions may prove more appropriate. Soil salinity levels (ECe), on the other hand, are not converted to TDS, as there is no meaningful way to do this.

The main reference for crop sensitivity data was Hanson et al. (2006), especially Tables 2 through 5. These were linked to DWR land cover classes so that crop sensitivity levels could be mapped. The methodology for assigning crop sensitivity is documented by many, including Maas (1990) and Ayers and Westcot (1985). Crop sensitivity data of the type shown in **Figure 4a** for Common Bean were developed under Task 5.1 to identify the SMCs in each CSZ. These functions relate soil salinity levels to relative crop yields, and vary widely depending on the level of the plant specie's physiological salt tolerance. In addition to quantitative functions, crops are assigned to four narrative classes, ranging from Sensitive to Tolerant. These functions were used to develop a screening-level list of applied water targets, based on a simplistic version of the Hoffman calculations. These concentrations represent the relative sensitivities of crop species in a quantitative manner, but are intended only for use in the mapping and screening work of this Report. They are not suitable for direct use in interpreting narrative AGR standards.

Leaching fraction is the ratio of the depth of applied water leached to the total depth that infiltrates. This fraction, along with other factors, determines the quantitative relationship of the average root zone salinity (again, ECe) to salinity in applied water (again, ECw; see **Figure 4b**). A commonly assumed and recommended leaching fraction is 0.15 (shown in red on **Figure 4b**). Assuming this leaching fraction and the water uptake distribution shown on **Figure 4b**, the maximum ECw required to produce 95 percent maximum relative yield of each crop shown in **Figure 4c** was calculated, and converted to TDS. Maximum target applied water salinity in TDS ranges from less than 600 to over 6000 mg/L. Major crops in the more sensitive range (shown in the expanded plot in the right-hand half of **Figure 4c**) are the most important in the CST. Due to the simplicity of this calculation, site-specific and climatic and management data that can be considered in Hoffman or similar analyses have not been fully considered. Therefore again, these maxima, while helpful in quantitatively ranking crop sensitivity, are unsuitable for use in determining final AGR target concentrations.

There are a number of crops for which no quantitative salinity function has been defined. These crops are listed, along with their salinity tolerance classes in **Table 3**.

Irrigation Management

In California as elsewhere, management factors do vary. They are extremely difficult to assess quantitatively at a broad scale due to lack of data. DWR spatial land use datasets contain information on water sources used and irrigation type that pertain to irrigation management. Both datasets were mapped separately under Task 5.1. As management factors go, these are informative, since irrigation water source and irrigation method can affect the actual yield impact of a given level of ECw.

Table 3 Crops for which Coefficients have not been Measured

Sensitive	Moderately Sensitive	Moderately Tolerant	Tolerant
Okra	Brussels sprouts	Fig	Jojoba
Parsnip	Cauliflower	Jujube	Kenaf
Apple	Kale	Papaya	Millet, channel
Avocado	Kohlrabi	Pineapple	Oat
Cherimoya	Pumpkin	Pistacio	Alkali grass, nuttall
Cherry, sweet	Watermelon	Pomegranate	Alkali sacaton
Cherry, sand	Castorbean	Safflower	Kallar grass
Currant	Bentgrass	Brome, mountain	Kikuyagrass
Gooseberry	Bluestem, Angleton	Canary grass, reed	Oat (forage)
Lime	Brome, smooth	Clover, Hubam	Paspalum, Polo
Loquat	Buffelgrass	Clover, sweet	Salt grass, desert
Mango	Burnet	Dhaincha	Wild rye, Altai
Passion fruit	Clover, white Dutch	Fescue, meadow	Wild rye, Russian
Pear	Dallis grass	Guinea grass	
Persimmon	Glycine	Panicgrass, blue	
Pummelo	Grama, blue	Paspalum	
Raspberry	Milkvetch, cicer	Rape	
Rose apple	Millet, Foxtail	Rescue grass	
Sapote, white	Oatgrass, tall	Rhodes grass	
Tangerine	Sirato	Ryegrass, Italian	
Sesame	Eucalyptus	Trefoil, broadleaf bird's foot	
Walnut	Timothy	Wheat grass, intermediate	
Nursery		Wheat grass, slender	
		Wheat grass, western	
		Wild rye, Canadian	
		Kiwi	

3. Crop Sensitivity Zone Delineation and Sensitive Crop Locations

This section describes the methodologies used for the development of the CSZs. It expands on (but does not repeat) Section 1.3. Therefore, this section is best read with the conceptual explanation presented in Section 1.3 (and illustrated on **Figure 1a**) firmly in mind.

3.1 Delineation of Crop Sensitivity Zones

Crop Sensitivity Zones were developed to facilitate the use of data discussed in Section 2 to inform AGR beneficial use objectives. Water quality targets that are protective of this beneficial use need to maintain adequate quality of the irrigation water supply. Infrastructure determines the groupings of turnouts that draw water from similar sources, and this infrastructure exists in surface and subsurface hydrographic networks. Surface hydrographic networks are mapped more thoroughly than groundwater recharge zones and subsurface flow patterns, and are thus a more reliable initial basis for delineating CSZs. An initial delineation is essential to the identification of SMCs. This is because the SMC definition is a crop's acreage divided by the total irrigated land acreage, both as measured *inside the CSZ*. Therefore, these acreage figures can only be assessed after an initial delineation of CSZs.

Locations of SMCs, when viewed across the entire Central Valley (presented later in Figure 8a) showed many geographic concentrations of particular crops into groupings of fields. Recharge areas for these groupings of fields were observed to be relatively restricted in many cases, suggesting that protection of their water supply might naturally focus on fairly defined areas, some smaller than those envisioned in the Workplan (which estimated 25 CSZs in the whole Central Valley). It became evident that the relatively large CSZs would be most useful if primarily defined by hydrographic boundaries. This way, the main recharge areas for SMC irrigation waters would be more likely to fall within the CSZ within which the crops occur. The preliminary CSZ boundaries used to identify SMCs, which followed hydrographic boundaries, were thus retained as final boundaries of 24 final CSZs.

These same hydrographic groupings gather features that are also related to AGR beneficial uses:

- Turnouts that could be controlled from a common distribution point, should this be necessary;
- To the extent that they are contiguous with surface hydrographic areas, groundwater basins; and
- To the extent that available irrigation water quality drives cropping choices, groupings of SMC plantings that may warrant protective standards.

From an implementation standpoint, the importance of the first point can be illustrated by the following examples. The figures reference hydrography but they are not extended to constitute to a direct application of the tributary rule. Rather the focus is on identifying recharge areas that most greatly influence applied water quality. Furthermore, the examples given are schematic and conceptual in nature.

- Surface Water Recharge Areas with Co-Mingled Surface Drainage (**Figure 5a**): In this illustration, irrigation of SMCs is primarily with surface water, and surface return flows are primarily routed to channels that are tributary to downstream irrigation supply. In this case, criteria developed based on SMCs might reasonably apply to the channel network upstream of each patch of SMCs, and (by extension) to up-watershed sources, which might include salt sources discharging to this network.
- Surface Water Recharge Areas with Isolated Surface Drainage (**Figure 5b**): In this illustration, surface return flows are collected in drains that are not tributary to downstream SMCs, but rather conveyed in an isolated drainage collection network. Due to this lack of connection, applied water quality targets for SMC patches shown would be unrelated to surface water discharges in the area, and thus would not seem relevant when interpreting narrative AGR water quality objectives for the drainage collection network.
- Groundwater Recharge Areas (**Figure 5c**): In the SMC area shown on the left side of **Figure 5c**, only surface water is applied. Unless irrigation with groundwater is predicted for the area, applied water quality targets based on SMCs in this patch would be unrelated to narrative AGR objectives for groundwater. On the other hand, SMCs in the right-hand patch are at least partly irrigated with groundwater. Therefore, concentration targets based on this crop patch could inform narrative AGR water quality objectives for that groundwater and areas that recharge it. Dilution of discharges and other mitigating factors should be appropriately considered.

Again, to facilitate these types of considerations during implementation, hydrographic data were primarily employed to determine not only the preliminary, but also the final CSZ boundaries, as hydrography tends to group similar and interconnected surface water supplies. Other factors, such as cropping patterns, water quality of irrigation water, soils, climatic conditions, and management factors were then mapped within the CSZs. All of these data themes can then be used to analyze SMCs and their irrigation water quality requirements within a CSZ. Regulatory application of results will be facilitated by the hydrographically contiguous nature of the CSZ. Again, further explanation of the conceptual basis for this process is contained in Section 1.3, and illustrated on **Figure 1b**.

The initial assessment resulted in a selection of 19 focused zones based on the Hydrologic Unit boundaries presented in **Figure 3**, drawing the names for each unit from their numeric designations in the original hydrographic database. The selected zones cover the majority of irrigated areas of the Central Valley. Due to their large size, three zones (Hydrologic Units 20, 51, and 58) were further refined into smaller areas within the Hydrologic Area boundaries. The new units were numbered by adding a “1” or a “2” to the name drawn from the hydrographic database. This methodology resulted in a total of 22 CSZs.

Other data themes listed in the Workplan as potentially affecting CSZ boundaries would then be primarily employed for their other intended purposes:

- Crop data in conjunction with soil, climate, and management: Compiled in Task 5.1 (this Report) for use per Hoffman (or an alternative) in Task 5.3 to develop refined crop sensitivity target concentrations. The stage is thus set for Task 5.3, which cannot be performed without these inputs. The implied multivariate determination of CSZ boundaries (including several of these variables as inputs) was found to be inconsistent with the broader goal of a usable method to interpret narrative AGR objectives, and was thus not pursued. The reasons for this are those described in the preceding paragraphs.
- Irrigation and drainage districts, drainage basins: The intended purpose of these data was to understand the routing of water to sensitive crops. Hydrographic data are more precise and appropriate in this regard. Nevertheless, district and basin delineations were collected and mapped as part of Task 5.1, per the Workplan, and are available as part of this Report for future use. Drainage basin boundaries have been compared to the CSZs in this Report.
- Groundwater basin boundaries were not required by the Workplan, but have been added as a GIS layer during the review process of this Report to view the basin boundaries in comparison to the CSZ boundaries.

3.1.1 Crop Sensitivity Zones and Drainage Basins

During the development of the CSZs, boundaries of the drainage basin areas from CVRWQCB (1992) were overlaid on the CSZ boundaries. Drainage basins are not strictly hydrographic, but rather were delineated based on input from water managers throughout the region, and are intended to reflect how drainage is actually managed. Drainage is one part of the hydrographic network on which the CSZs were based, with irrigation supply, natural, and other channels making up the rest of that network. **Figure 6** shows the 22 CSZs in comparison to the drainage basin areas. The two sets of boundaries subdivide a similar region into units of comparable scale, with internal boundaries that in some cases nearly match. The fact that drainage hydrography was considered in each analysis is probably the reason for this similarity.

3.2 Sensitive Crop Locations

The focus of this section is the location and quantification of SMC acreage in the CSZs. CV-SALTS has identified SMCs as sensitive crops that occupy more than 5% of the irrigated land in a CSZ. There are alternative SMC approaches; one example is documented in this Report (see **Attachment B**).

Figure 7a shows the distribution of crops grown in the Central Valley based on the DWR data. **Figure 7b** defines the crop sensitivity classes based on the four narrative classes of crop sensitivity: Sensitive (S), Moderately Sensitive (MS), Moderately Tolerant (MT), and Tolerant

(T). The location of major sensitive crops is shown on **Figure 8a.** Major sensitive crops are defined here as those occupying more than 5% of the irrigated land within a CSZ. **Figure 8b** shows the location of minor sensitive crops, which are defined as those that occupy less than 5% of the irrigated land within each CSZ. The acreage of each crop in each CSZ is listed in **Table 4**. As described earlier, the crop pattern data were screened to identify the major and minor crops within each CSZ.

Figure 8a shows the distribution of the SMCs (i.e., major crops in the S class). The focus of the mapping shown in **Figure 8a** is crops in the "Sensitive" class. However, additional classes exist, and can be used to develop suitable target applied water salinity concentrations for areas where no sensitive crops exist. These concentrations would of course be higher.

Figure 9 displays the estimated average maximum root zone salinity requirement of crops to achieve 95% of crop yield potential. Crop yield potential is defined here as the production level that could be achieved under favorable conditions with no production limitation from irrigation water salinity. **Figure 10** is similar, but the estimated threshold is for applied water TDS. As described previously, these estimates do not account for a number of factors that can influence crop yield response to salinity, and so should be viewed as a helpful way to differentiate quantitatively among degrees of crop sensitivity and potential yield impact of saline irrigation water. This screening method, commonly used in irrigation assessment and planning, takes account of published, quantitative functions relating soil salinity to crop yield reduction, and quantitative relationships between applied water salinity and salinity of the root zone (soil). The latter requires an assumed leaching fraction, which CV-SALTS stipulated should be 15%. The yield functions are shown in **Table 5** and illustrated on **Figure 4a**, and the soil-water functions are illustrated in **Figure 4b** and **4c**. A fuller analysis, taking climatic, management, and soil conditions into account, is needed to identify applied water salinity targets. This is the work that is scoped under Task 5.3, employing the data displayed throughout Section 4 of this Report.

It is anticipated that locations and specific requirements of sensitive crops will be helpful in defining irrigation water quality requirements within the CSZs. Hydrographic data can be used to determine recharge areas that could feasibly influence irrigation water supply to areas where SMCs are expected to be planted. This use of hydrographic data is conceptually illustrated for three CSZs (201, 202, and 582). **Figures 11a** through **11e** illustrate the conceptual use of hydrographic data in relation to the locations of sensitive crops. **Figures 11a**, **11b**, and **11c** show the distribution of SMCs, moderately sensitive major crops, and sensitive minor crops, respectively, within the CSZs 201 and 202. SMCs are seen to be concentrated in the southeast, along northern and eastern margins, and along the Sacramento River, and to be comprised of walnuts and almonds (Figure 11a). Relative to the entire irrigated acreage in the area, these clusters are relatively limited in spatial scope. Moderately sensitive major crops, on the other hand, are shown to be more generally and widely distributed. Thus, irrigation supplies to SMC areas might influence narrative AGR interpretations where those waters are recharged. Recharge to other irrigation supply sources in these CSZs might (from the AGR perspective) be primarily driven by tolerance levels of moderately sensitive major crops. Sensitive minor crops (see Figure 11c) are, taken together, far more diverse, but less widespread than SMCs, and similarly concentrated along the Sacramento River and eastern margin of the areas. **Figure 11d** shows the surface tributary area upstream of SMC concentrations in CSZs 201 and 202. As we might expect, the primary recharge areas for surface irrigation supply to SMCs I sin the uplands, outside of most of the regions irrigated agricultural area. Areas such as the eastern and northern margins are primarily irrigated with groundwater (see Figure 30). **Figure 11e** further illustrates the use of hydrographic data for CSZ 582 where the surface recharge network is identified in relation to the locations of the SMCs. Irrigation sources were not mapped by DWR for this area. It appears that surface supplies to the southern area containing sensitive crops is again primarily in the uplands, not other irrigated areas in this CSZ. Even sensitive crops in CSZ 581 (see green dot) flow primarily from these upland sources, or from a few distinct lowland sources (main irrigation canals importing water). These areas can be evaluated relative to hydrographic connectivity illustrated in **Figures 5a** through **5c** (discussed previously) when seeking to identify AGR water quality objectives that will be protective of SMCs in these areas. Basic data to perform this type of detailed analysis is provided in this Report, but the detailed analysis itself is beyond the scope of the current work. Please note again that these figures are not intended to imply the strict application of the tributary rule, but rather that the hydrographic network could be helpful in differentiating between areas that could or could not influence applied water quality in an area where SMCs are being grown.

Table 4 Summary of Total Acreage of Crops by CSZs

		Crop Sensitivity Zones (CSZs)																							
Crops and Sensitivity Thresholds		**4**	**7**	**8**	**10**	**11**	**15**	**19**	**31**	**44**	**60**	**61**	**201**	**202**	**31**	**35**	**41**	**44**	**45**	**57**	**75**	**511**	**512**	**581**	**582**
Sensitive (S)	Almonds	26,569	0	1	0	7,205	1,677	154	74	347	0	745	34,732	30,339	12,579,355	850,644,038	130,079,204	8,920,872	255,269,365	111,668,597	5,236,161	254,979,364	85,544,121	311,469,557	359,903,478
	Apples	72	23	0	953	61	628	2	84	2,049	0	0	0	260	15,710,369	8,595,771	975,678	982,975	10,842,864	1,033,607	2,779	10,048,472	7,722,829	528,168	10,702,434
	Apricots	15	0	0	0	147	2	0	2	1,143	22	0	0	2	42,963	1,119,043	32,882,147	4,070,315	189,797	1,804,459	4,354,845	3,609,950	5,066,178	3,153,350	450,394
	Avocados	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	367,803	0	1,394,855
	Beans (dry)	650	0	0	427	1,527	93	1,047	267	511	0	0	1,786	6,526	21,638,686	10,959,560	91,257,674	33,377,881	1,444,570	6,839,031	6,707,059	26,246,100	1,993,713	17,315,290	52,618,717
	Beans (green)	0	0	0	0	35	0	0	49	354	0	0	0	0	116,617	10,183	1,168,278	0	0	501,595	0	0	114,103	0	1,130,575
	Carrots	0	0	0	0	0	0	0	0	0	0	0	0	11	0	914,286	1,297,948	932,610	644,315	63,310,513	0	0	43,796	61,731,127	14,196,602
	Cherries	16	0	0	262	12	371	0	112	546	0	0	4	0	41,121,034	3,317,228	4,657,257	139,558	686,028	13,718,157	921,809	4,426,688	4,032,081	3,006,566	6,792,413
	DECIDUOUS FRUITS AND NUTS	0	0	0	0	0	2,155	23	0	266	0	0	0	0	6,739,158	7,385,123	107,820	623,297	0	0	191,639	0	0	0	0
	Flowers, nursery & Christmas tree farms	126	4	41	4	476	105	521	100	74	164	0	56	603	4,253,221	11,278,052	1,331,399	59,793	2,540,865	1,423,686	0	2,392,425	2,676,476	1,320,614	22,386,152
	Grapefruit	0	0	0	0	0	0	0	0	4	0	0	0	0	0	11,760	181,956	0	0	562,887	0	0	1,259,781	78,823	6,193,756
	Lemons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170,137	0	0	12,198,369	0	0	5,944,591	1,282,775	23,864,907
	Miscellaneous subtropical fruits	34	0	0	0	33	0	9	0	0	2	0	0	24	0	0	53,513	0	0	2,631,145	0	31,866	312,470	0	309,529
	Onions and garlic	35	0	0	5	677	0	57	16	101	0	0	483	77	1,981,664	2,204,506	10,323,710	1,883,829	3,173,251	35,149,918	478,034	118,471,319	659,752	9,920,746	4,549,926
	Oranges	106	0	9	0	185	17	0	0	0	0	0	354	48	0	352,536	2,741,453	0	19,931,980	119,355,657	0	2,130,136	205,452,574	8,538,002	463,394,950
	Peaches and nectarines	71	0	19	54	148	6,614	170	1	197	68	0	8	13,951	3,841,091	66,853,127	6,225,009	398,326	12,141,835	16,047,428	0	60,125,677	241,282,390	3,845,826	16,526,619
	Pears	6	0	1	7,095	35	1,639	195	141	191	0	0	16	143	2,171,635	144,607	0	667,633	587,079	0	0	16,252	4,180,226	0	1,859,274
	Strawberries	7	71	49	6	28	59	119	36	19	0	0	197	35	172,393	4,547,540	24,134	174,557	64,779	27,129	0	20,264	270,538	0	173,856
	TRUCK, NURSERY AND BERRY CROPS	0	0	0	0	0	31	0	0	68	0	0	0	0	1,980,334	476,709	97,365	1,081,341	0	0	0	0	0	0	0
	Walnuts	30,756	0	3,463	88	19,583	20,207	3,274	1,157	1,288	269	0	8,898	30,896	121,303,692	110,591,390	41,750,162	17,009,922	6,898,010	5,457,250	1,787,073	59,170,249	11,372,777	0	143,091,575
	Sub-total	***58,465***	***98***	***3,581***	***8,894***	***30,151***	***33,598***	***5,572***	***2,040***	***7,156***	***526***	***745***	***46,535***	***82,915***	***233,652,213***	***1,079,405,461***	***325,324,845***	***70,322,909***	***314,414,738***	***391,729,427***	***19,679,399***	***541,668,761***	***578,296,200***	***422,190,846***	***1,129,540,011***
Moderately Sensitive (MS)	Alfalfa & alfalfa mixtures	5,185	0	771	27,713	52,955	945	6,039	1,439	4,013	0	124	22,547	4,991	51,658,985	271,130,675	319,976,375	175,797,141	154,252,004	184,483,528	4,221,285	426,695,333	51,478,363	256,952,756	468,258,416
	Broccoli	0	1	2	3	4	5	6	7	8	9	10	11	12	9,877	340,031	1,640,111	0	0	327,043	0	3,228,419	82,547	253,132	4,206,003
	Cabbage	0	0	0	0	0	0	0	0	6	0	0	0	0	409,909	127,776	0	0	0	0	0	0	0	0	208,017
	Cauliflower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,151,942	0	0	0	0	484,972	0	47,393	2,335,532
	Celery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77,175	0	0	0	0	0	0	0	0	0
	Clover native pasture	15	0	0	165	112	130	535	1,213	0	0	0	1,575	0	527,873	822,234	0	0	50,309	0	0	456,795	6,805	0	0
	Cole crops (when breakdown is not needed)	0	0	0	0	8	0	0	0	0	0	0	0	6	0	0	127,329	82,188	0	0	0	0	0	0	476,997
	Corn (field & sweet)	3,179	0	9	31,216	8,722	803	7,632	8,052	9,540	0	0	14,667	10,246	56,940,176	481,605,933	108,259,749	221,115,345	78,595,870	65,217,947	1,002,685	212,724,110	43,501,892	39,296,270	465,148,667
	Eucalyptus	9,133	0	0	0	2	71	33	11	0	23	0	0	18	140,761	667,504	190,585	202,272	1,083,701	243,548	0	901,982	1,409,940	1,093,569	614,039
	FIELD CROPS	0	0	1	0	0	220	62	0	1,305	0	0	0	0	4,623,549	1,468,282	0	4,226,840	0	0	0	0	0	0	0
	Flax	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81,259	0	0
	Lettuce (all types)	0	0	2	0	0	0	0	0	0	0	0	7	0	0	2,518,682	526,609	0	0	2,210,225	0	3,505,536	574,586	637,049	124,678
	Melons, squash, and cucumbers (all types)	773	0	66	389	2,077	339	355	439	229	0	0	3,234	7,682	6,222,741	6,850,967	86,480,599	21,017,748	1,569,045	15,887,960	732,699	92,814,530	2,993,212	2,840,886	3,298,103
	Misc. grasses (normally grown for seed)	0	0	0	857	1,696	0	0	0	0	0	0	185	144	9,218	0	0	0	0	0	0	1,432,587	385,184	0	0
	Peas	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peppers (chili, bell, etc.)	0	0	0	0	839	0	3	156	315	0	0	489	0	9,082,145	1,368,187	1,369,871	1,572,762	227,029	16,522,132	0	5,346,753	758,134	479,357	943,561
	Plums	0	0	0	0	79	437	0	0	20	0	0	0	0	596,513	2,550,555	2,228,007	192,288	9,648,520	3,067,342	0	26,033,710	93,311,198	503,426	64,543,488
	Potatoes	0	0	0	673	24	0	0	0	0	0	0	43	0	0	0	0	14,545,545	0	14,642,769	0	83,182	64,888	0	243,504
	Prunes	20,212	0	451	0	2,784	16,495	1,330	0	0	686	0	3,173	27,253	83,724	5,671,567	1,091,448	0	5,059,466	0	0	5,094,387	3,028,465	0	15,999,175
	Raisin grapes	0	0	0	0	0	0	0	0	0	0	0	0	0	114,304	0	0	0	0	0	0	0	0	0	0
	RICE	962	0	0	0	0	40,330	20,021	0	0	0	0	0	0	11,762,775	12,422,342	0	54,403	0	0	0	0	0	0	0
	Spinach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	503,794	0	0	0	0	0	0	0	0
	Sweet potatoes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36,664,696	46,703	0	0	2,161,659	0	1,040,633	86,083	190,101	485,883
	Table grapes	0	0	0	0	0	0	0	0	0	0	0	192	9	0	0	0	0	0	0	0	123,345	0	0	0
	Tomatoes	10	0	0	6,979	30,687	17	1,726	917	4,548	0	0	14,551	6,900	59,738,736	72,176,677	193,574,193	91,456,153	7,852,665	35,453,307	1,226,541	412,924,311	2,722,150	58,585,903	9,048,516
	Turf farms	0	0	11	141	602	0	85	187	0	0	0	0	0	0	3,241,544	2,518,528	4,485,988	0	2,148,067	0	15,644	1,659,017	0	0
	Wine grapes	21	80	73	0	102	0	0	0	0	0	0	0	0											
	Sub-total	***39,521***	***80***	***1,384***	***68,133***	***100,692***	***59,789***	***37,821***	***12,415***	***19,975***	***709***	***124***	***60,664***	***57,250***	***201,921,286***	***899,704,828***	***719,685,842***	***534,748,673***	***258,338,607***	***342,365,527***	***7,183,211***	***1,192,906,228***	***202,143,722***	***360,879,843***	***1,035,934,579***

Table 4 (Continued) Summary of Total Acreage of Crops by CSZs

		Crop Sensitivity Zones (CSZs)																						
Crops and Sensitivity Thresholds		**4**	**7**	**8**	**10**	**11**	**15**	**19**	**31**	**44**	**60**	**61**	**201**	**202**	**31**	**35**	**41**	**44**	**45**	**57**	**75**	**511**	**512**	**581**	**582**
Moderately Tolerant (MT)	Artichokes	0	0	0	21	3	0	0	0	0	0	0	0	2	0	18,781	572,150	0	0	0	0	0	25,673	0	24,631
	Figs	103	0	0	38	10	15	0	0	27	0	0	0	0	0	14,885,217	0	0	38,759,492	0	0	73,570	13,513,702	1,857,030	0
	Grain sorghum	0	0	0	1,312	178	0	84	0	0	0	17	455	839	602,385	1,855,866	0	1,808,404	19,132	3,028,534	0	2,038,707	59,232	10,602,257	13,711,619
	Kiwis	136	0	396	27	0	586	13	0	0	0	0	39	843	86,290	813,817	0	0	120,254	0	0	1,096,341	2,397,347	0	6,334,720
	Miscellaneous and mixed grain and hay	349	0	118	468	450	183	1,290	181	500	449	0	714	489	1,549,823	1,051,606	370,127	845,538	0	0	4,082,547	1,048,335	0	0	0
	Olives	8,997	0	588	0	534	1,849	205	286	0	0	0	3,382	610	9,422	345,709	0	0	7,453,092	0	0	1,322,413	10,700,402	1,707,302	72,827,524
	Pistachios	639	0	41	0	226	57	49	30	58	0	0	839	326	279,238	21,676,571	1,098,188	125,859	93,272,471	14,582,538	0	52,605,393	2,659,908	219,311,579	99,898,280
	Safflower	444	0	28	14,204	6,813	91	1,627	838	3,039	0	0	3,770	4,769	913,138	0	3,447,617	73,395,778	284,205	3,921,686	975,571	17,933,093	34,884	1,367,194	4,592,052
	Sudan	39	0	15	2,217	3,185	305	588	4,039	385	0	0	486	1,066	879,471	12,831,845	19,010,852	2,968,955	8,592,797	22,598,793	0	23,548,460	5,088,478	11,709,900	21,575,104
	Sunflowers	670	0	0	336	7,912	0	636	0	0	0	8	8,983	3,840	0	0	0	6,354,404	0	0	0	74,566	0	0	134,388
	Wheat	68	0	14	1,736	10,859	0	0	0	0	208	0	2,180	418	0	9,281,507	2,770,220	0	176,542	0	0	0	93,673	0	0
	Sub-total	***11,446***	***0***	***1,201***	***20,360***	***30,169***	***3,086***	***4,491***	***5,374***	***4,008***	***657***	***25***	***20,848***	***13,203***	***4,319,767***	***62,760,919***	***27,269,153***	***85,498,938***	***148,677,985***	***44,131,552***	***5,058,118***	***99,740,879***	***34,573,299***	***246,555,262***	***219,098,318***
Tolerant (T)	Asparagus	6	0	0	987	138	0	0	9	1,481	0	0	0	464	3,440,973	553,296	9,720,293	87,376,208	0	1,500,370	0	3,088,473	0	0	0
	Barley	71	0	0	76	0	0	0	0	0	0	0	315	0	0	6,147,868	0	0	0	0	0	0	0	0	201,804
	Cotton	0	0	0	0	0	0	0	0	0	0	0	1,987	1,517	0	67,362,589	411,565,877	0	105,528,087	219,962,102	0	1,218,425,668	23,064,775	576,849,416	345,454,462
	Dates	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jojoba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	594,705	0	46,245	19,137	0	0
	Mixed pasture	28,533	1,845	12,064	31,783	9,162	12,981	17,865	13,002	4,201	168	64	10,238	6,391	88,570,519	385,360,472	47,400,843	16,455,444	41,556,535	12,046,122	822,927	18,807,337	37,812,919	9,725,198	21,275,391
	Native pasture	71	8,220	106	1,977	586	168	286	675	2,875	2	0	26	218	667,214	136,968	62,420	334,758	1,231,112	146,762	54,616	3,540,719	8,044,036	0	2,001,835
	Oats	19	0	20	0	0	0	99	0	0	0	0	161	0	0	3,875,009	829,257	0	595,544	0	0	0	217,829	0	0
	Sugar beets	0	0	0	1,577	0	0	812	383	250	0	0	10	29	9,308,668	9,883,741	35,046,079	16,798,791	2,512,715	630,352	503,413	52,989,850	59,342	4,963,438	17,339,803
	Sub-total	***28,700***	***10,065***	***12,189***	***36,401***	***9,893***	***13,150***	***19,062***	***14,068***	***8,806***	***170***	***64***	***12,737***	***8,619***	***101,987,374***	***473,319,943***	***504,624,768***	***120,965,201***	***151,423,993***	***234,880,412***	***1,380,956***	***1,296,898,292***	***69,218,037***	***591,538,052***	***386,273,294***
Not Defined	Castor beans	0	0	0	0	0	0	0	0	0	0	**0**	**7**	**0**	0	0	0	0	0	0	0	0	0	0	0
	Hops	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	235,503	0	0
	Miscellaneous field	38	0	8	0	351	27	0	6	0	0	0	242	211	0	0	0	0	33,843	0	0	1,416,446	0	0	367,013
	Miscellaneous truck	59	4	0	14	256	12	24	0	74	11	0	55	206	2,055,164	3,039,182	6,201,379	140,620	40,121	2,744,080	0	2,785,418	9,473,604	561,177	2,040,040
	Sub-total	***97***	***4***	***8***	***14***	***607***	***38***	***24***	***6***	***74***	***11***	***0***	***305***	***416***	***2,055,164***	***3,039,182***	***6,201,379***	***140,620***	***73,964***	***2,744,080***	***0***	***4,201,864***	***9,709,107***	***561,177***	***2,407,053***
	Grand Total	**138,230**	**10,247**	**18,364**	**133,801**	**171,512**	**109,661**	**66,971**	**33,903**	**40,020**	**2,073**	**957**	**141,088**	**162,403**	**543,935,804**	**2,518,230,333**	**1,583,105,987**	**811,676,341**	**872,929,287**	**1,015,850,998**	**33,301,683**	**3,135,416,023**	**893,940,366**	**1,621,725,181**	**2,773,253,255**

Table 5 Crop Salinity Thresholds

Crop	Threshold Salinity (A)	Slope (B)	Rating	Crop	Threshold Salinity (A)	Slope (B)	Rating	Crop	Threshold Salinity (A)	Slope (B)	Rating	Crop	Threshold Salinity (A)	Slope (B)	Rating	Crop	Threshold Salinity (A)	Slope (B)	Rating
Artichoke	6.1	11.5	MT	Turnip	0.9	9	MS	Pummelo	--	--	S	Bermuda	6.9	6.4	T	Rescue grass	--	--	MT
Asparagus	4.1	2	T	Turnip, greens	3.3	4.3	MT	Raspberry	--	--	S	Bluestem,	--	--	MS	Rhodes grass	--	--	MT
Bean, Common	1	19	S	Watermelon			MS	Rose apple	--	--	S	Brome,	--	--	MT	Rye (forage)	7.6	4.9	T
Bean, Mung	1.8	21	S	Almond	1.5	19	S	Sapote, white	--	--	S	Brome, smooth	--	--	MS	Ryegrass, Italian	--	--	MT
Beet, red	4	9	MT	Apple	--	--	S	Tangerine	--	--	S	Buffelgrass	--	--	MS	Ryegrass, perennial	5.6	7.6	MT
Broccoli	2.8	9.2	MS	Apricot	1.6	24	S	Barley	8	5	T	Burnet	--	--	MS	Salt grass, desert	--	--	T
Brussels sprouts			MS	Avocado	--	--	S	Bean, Common	1	19	S	Canary grass,	--	--	MT	Sesbania	2.3	7	MS
Cabbage	1.8	9.7	MS	Blackberry	1.5	22	S	Broad bean	1.6	9.6	MS	Clover alsike	1.5	12	MS	Sirato	--	--	MS
Carrot	1	14	S	Boysenberry	1.5	22	S	Canola	10.4	13.5	T	Clover, Berseem	1.5	5.7	MS	Sphaerophysa	2.2	7	MS
Cauliflower			MS	Castorbean	--	--	MS	Corn	1.7	12	MS	Clover, Hubam			MT	Sudan grass	2.8	4.3	MT
Celery	1.8	6.2	MS	Cherimoya	--	--	S	Cotton	7.7	5.2	T	Clover, ladino	1.5	12	MS	Timothy	--	--	--
Corn, sweet	1.7	12	MS	Cherry, sweet	--	--	S	Cowpea	4.9	12	MT	Clover, red	1.5	12	MS	Trefoil, big	2.3	19	MS
Cowpea	4.9	12	MT	Cherry, sand	--	--	S	Crambe	2	6.5	MS	Clover, strawberry	1.5	12	MS	Trefoil, narrowleaf bird's	5	10	MT
Cucumber	2.5	13	MS	Currant	--	--	S	Flax	1.7	12	MS	Clover, sweet	--	--	MT	Trefoil, broadleaf bird's foot	--	--	MT
Eggplant	1.1	6.9	MS	Date palm	4	3.6	T	Guar	8.8	17	T	Clover, white	--	--	MS	Vetch,	3	11	MS
Garlic	3.9	14.3	MS	Fig	--	--	MT	Kenaf	--	--	T	Corn, forage	1.8	7.4	MS	Wheat (forage)	4.5	2.6	MT
Kale	--	--	MS	Gooseberry	--	--	S	Millet, channel	--	--	T	Cowpea (forage)	2.5	11	MS	Wheat, durum	2.1	2.5	MT
Kohlrabi	--	--	MS	Grape	1.5	9.6	MS	Oat	--	--	T	Dallis grass	--	--	MS	Wheat grass, standard crested	3.5	4	MT
Lettuce	1.3	13	MS	Grapefruit	1.2	13.5	S	Peanut	3.2	29	MS	Dhaincha	--	--	MT	Wheat grass, fairway crested	7.5	6.9	T
Muskmelon	1	8.4	MS	Guayule	15	13	T	Rice, paddy (field water)	1.9	9.1	MS	Fescue, tall	3.9	5.3	MT	Wheat grass, intermediate	--	--	MT
Okra	--	--	S	Jojoba	--	--	T	Rye	11.4	10.8	T	Fescue, meadow	--	--	MT	Wheat grass, slender	--	--	MT
Onion	1.2	16	S	Jujube	--	--	MT	Safflower	--	--	MT	Foxtail, meadow	1.5	9.6	MS	Wheat grass, tall	7.5	4.2	T
Onion, Seed	1	8	MS	Lemon	1.5	12.8	S	Sesame	--	--	S	Glycine	--	--	MS	Wheat grass, western	--	--	MT
Parsnip	--	--	S	Lime	--	--	S	Sorghum	6.8	16	MT	Grama, blue	--	--	MS	Wild rye, Altai	--	--	T
Pea	3.4	10.6	MS	Loquat	--	--	S	Soybean	5	20	MT	Guinea grass	--	--	MT	Wild rye, beardless	2.7	6	MT
Pepper	1.5	14	MS	Mango	--	--	S	Sugar beet	7	5.9	T	Harding grass	4.6	7.6	MT	Wild rye, Canadian	--	--	MT
Potato	1.7	12	MS	Olive	4	12	MT	Sugarcane	1.7	5.9	MS	Kallar grass	--	--	T	Wild rye, Russian	--	--	T
Purslane	6.3	9.6	MT	Orange	1.3	13.1	S	Sunflower	4.8	5	MT	Kikuyagrass	--	--	T	Other	--	--	ND
Pumpkin	--	--	MS	Papaya	--	--	MT	Tricale	6.1	2.5	T	Love grass	2	8.4	MS	Walnut	--	--	S
Radish	1.2	13	MS	Passion fruit	--	--	S	Wheat	6	7.1	MT	Milkvetch, cicer	--	--	MS	Kiwi	--	--	MT
Spinach	2	7.6	MS	Peach	1.7	21	S	Wheat (semi-	8.6	3	T	Millet, Foxtail	--	--	MS	Eucalyptus	--	--	MS
Squash, scallop	3.2	16	MS	Pear	--	--	S	Wheat, durum	5.9	3.8	T	Oatgrass, tall	--	--	MS	Nursery	--	--	S
Squash, zucchini	4.9	10.5	MT	Persimmon	--	--	S	Alfalfa	2	7.3	MS	Oat (forage)	--	--	T	Mixed	--	--	S
Strawberry	1	33	S	Pineapple	--	--	MT	Alkali grass,	--	--	T	Orchard grass	1.5	6.2	MS				
Sweet potato	1.5	11	MS	Pistacio	--	--	MT	Alkali sacaton	--	--	T	Panicgrass, blue	--	--	MT				
Tomato	2.5	9.9	MS	Plum	2.6	31	MS	Barley (forage)	6	7.1	MT	Paspalum, Polo	--	--	T				
Tomato, cherry	1.7	9.1	MS	Pomegranate	--	--	MT	Bentgrass	--	--	MS	Rape	--	--	MT				

4. Other CSZ Properties Related to Crop Sensitivity

The boundaries of the CSZs were overlaid on the GIS data for soil and agroclimatic conditions, applied water quality, and management to illustrate the overall spatial variations and any apparent trends, either between or within the CSZs. These data can later be employed to inform Hoffman or similar analyses, establishing quantitative relationships between land cover and irrigation water quality needed.

4.1 CSZ Properties Shown on Maps and in Summary Tables

GIS maps for soils, applied water quality, and climate were developed within the CSZ boundaries to illustrate the spatial distribution of properties related to salt sensitivity within each CSZ and across the CSZs. Summary data tables for soils properties are also prepared.

4.1.1 Soil Data

Soil properties were mapped and summarized within each CSZ. Specific soil properties were selected due to their significance in Hoffman or similar analyses; similar maps of other properties can readily be drawn from the same dataset, but are beyond the scope of the current work.

Figures 12 through **16b** show the distribution of soil EC, SAR, drainage classes, depth to water table, and available water supply at two soil depth intervals. The shallower depth interval might better related to shallow rooted or establishing crops, whereas the deeper interval would better express the degree of water storage that can be accessed by established, especially deep-rooted crops. **Tables 5** and **6** present these data in summary tables.

ECe

The spatial distribution of soil EC (ECe) data (expressed as dS/m at 25 degrees C) is shown in **Figure 12**. ECe and drainage class are indicative of the extent to which it might be challenging to maintain a soil at levels of salinity suitable for sensitive crop cultivation. Soils with greater challenge might generally be associated with less sensitive crops, but not exclusively so. When other factors favor a choice to plant a sensitive crop, a farmer may be willing to invest more resources in achieving and maintaining favorable root zone salinity levels.

SAR

The spatial distribution of SAR is shown in **Figure 13**. SAR is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in soil water extracted from saturated soil paste. SAR is used as an index of determining the potential sodium hazard. Water infiltration is affected by both the salinity and the SAR of the soil and applied water. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity and aeration, and a general degradation of soil structure. Based on a visual comparison of the EC map in **Figure 12** and SAR map in **Figure 13**, the spatial trends of the two soil properties appear to be generally consistent, both maps showing large EC and SAR values in the same general areas.

Drainage Classes

The drainage classes are mapped in **Figure 14** and tabulated in **Table 5**. The NRCS (1993) employs seven classes of natural soil drainage: excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. The description of these classes can be found in NRCS (1993), Chapter 3. Poorly drained areas (shown as very poorly drained, poorly drained, or somewhat poorly drained) tend to correspond to areas with higher EC and SAR. Under poorly drained conditions, crop productivity may be limited unless soil is artificially drained.

Depth to Water Table

The depth to water table is shown in **Figure 15**. The depth to water table affects nutrient and crop management, and can be related to drainage.

AWS

Figures 16a and **16b** show the distribution of AWS in the upper 8 and 40 inches of soil, respectively. AWS is reported as water depth (in cm) for the specified depth of the soil. Available water supply in the upper 8 inches indicates the soil’s capacity to provide adequate water to a young perennial, or shallow-rooted annual crop. Available water supply in the upper 40 inches indicates the soil’s capacity to provide adequate water to an established, especially perennial, growing crop. The greater these values, the better buffered the crop is against drought stress due to intermittent drying. Drought stress is indirectly related to salinity, since one of the effects of salinity is to make it more difficult for plants to take up water.

4.1.2 Source and Quality of Applied Water

Applied surface water quality (TDS) data were mapped within the CSZs (see **Figures 17** through **19**). **Figure 17** shows the TDS of the most recent measurements from agricultural and non-agricultural wells mapped throughout the region. The majority of the agricultural wells identified in the dataset are located in the northern portion of Region 5 based on the DWR dataset. As described earlier, the RWQCB WDR Dairy Data includes TDS from monitoring wells while the NWQMC dataset contains groundwater TDS without the well types identified. It may be possible to infer groundwater quality in the absence of well types; thus, TDS data without well types were also included. Groundwater TDS is typically below 400 mg/L at most locations, with elevated salinity observed mainly within Fresno and Merced counties. Note that these data capture only the groundwater component of applied water. In **Figure 18**, applied water quality for the Kings

River Area is shown. Again, these estimates are for the flow-weighted averages of applied water quality, in this case at a very fine scale of one square mile. **Figure 19** shows the TDS of applied water quality within the WARMF domains. These concentrations are flow-weighted averages of applied surface water and groundwater. Note that for some areas, WARMF predicts no applied water, so that no applied water salinity is shown. **Figure 19a** shows the difference between the applied water salinity (**Figure 19**) and preliminary estimate of crop requirement (**Figure 10**) to illustrate where water quality appears to be providing appropriate quality for the crop needs. Positive values indicate salinity of applied water exceeds preliminary estimate of crop sensitivity threshold. **Figure 20** shows the distribution of applied water quality acreage, based on the same WARMF dataset. Please note these are average applied water quality estimates for the entire WARMF catchments as such extreme values that may exist in field were not captured.

4.1.4 Climate Data

Climatic indices (estimated ETo, maximum EP, and AW [to alfalfa]) for average conditions for the CSZs are shown in **Figures 21 through 23**, based on the DWR land use data. Climate indices for the CSZs were also prepared for the drought- and median-year scenarios as shown in **Figures 24** through **29**. The most significant for the CST are probably data for ETo (as an index of the strength of evaporative demand) and EP (as an index of the amount of natural reclamation that might occur). These are based on historical data. The extent to which future conditions are reflected will depend on the pace and distribution of climate change, as it affects these parameters in these locales.

4.1.5 Management Factors

Irrigation management factors for the source of irrigation water and the method of irrigation are shown in **Figures 30** and **31**, respectively, based on the DWR land use survey data. The method of irrigation can affect the influence of a given level of applied water salinity on the crop, and should therefore be taken into account. For example, drip and microspray irrigation can maintain relatively low levels of salinity in soil volumes that are repeatedly wetted, where roots can reliably find moisture. Where such irrigation methods are the norm for SMCs, applied water salinity targets should not ignore their influence. That is, target salinity concentrations should be higher.

The source of irrigation water is a helpful clue in identifying the water bodies that may require protection so that the crop itself is protected from water quality degradation. As previously discussed, where groundwater is a major or the predominant source, subsurface hydrography will be key to knowing where sensitive recharge zones are. Where this is the case, subsurface hydrography is anticipated to be evaluated on a more site-specific basis, due to the lack of broad-scale characterization.

Table 6 Summary of Soils Data for Electrical Conductivity, Sodium Adsorption Ratio, and Available Water Supply by CSZs

Crop Sensitivity Zones (CSZs)	Average EC (dS/cm)	Average SAR	Average AWS 0-25 cm Soil Depth (cm)	Average AWS 0-100 cm Soil Depth (cm)
4	0.1	0.007	3.1	9.2
7	0.002	-	2.9	9.4
8	0.011	-	2.9	9.5
10	1.3	1.2	3.7	14
11	1.4	2.0	3.6	13
15	0.2	0.1	2.9	9.7
19	0.2	0.005	2.9	8.6
31	0.4	0.004	2.9	8.2
35	1.3	0.9	2.9	9.4
41	2.8	5.5	3.3	12
44	0.9	0.3	4.3	16
45	4.6	2.8	2.8	9.1
57	2.4	7.6	3.2	11
60	0.1	-	2.8	7.7
61	0.4	0.2	3.7	11
75	1.1	0.5	3.8	15
201	1.1	1.1	3.4	11
202	0.6	0.4	3.4	11
511	4.8	4.4	2.4	8.8
512	0.5	0.2	2.9	10
581	3.1	8.6	3.0	11
582	1.2	3.7	3.0	11

Table 7 Summary of Drainage Class by CSZs – Acreage Percentage

Crop Sensitivity Zones (CSZs)	Excessively Drained	Somewhat Excessively Drained	Well Drained	Moderately Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
4	3%	6%	75%	7%	5%	3%	0%
7	7%	8%	76%	7%	2%	0%	0%
8	8%	6%	73%	13%	1%	0%	0%
10	0%	1%	6%	8%	32%	37%	15%
11	6%	0%	63%	5%	14%	12%	0%
15	2%	13%	34%	27%	21%	2%	0%
19	0%	4%	39%	43%	11%	3%	0%
31	0%	2%	42%	46%	8%	0%	0%
35	3%	8%	51%	22%	11%	4%	0%
41	0%	1%	43%	3%	7%	35%	11%
44	0%	0%	6%	4%	15%	28%	47%
45	1%	5%	44%	31%	12%	7%	0%
57	0%	12%	78%	5%	5%	0%	0%
60	2%	3%	95%	0%	0%	0%	0%
61	0%	1%	85%	5%	6%	3%	0%
75	0%	0%	86%	14%	0%	0%	0%
201	2%	4%	63%	9%	10%	12%	0%
202	2%	1%	18%	28%	29%	21%	0%
511	1%	17%	40%	4%	32%	4%	2%
512	1%	21%	52%	12%	9%	5%	0%
581	0%	5%	77%	6%	8%	3%	0%
582	0%	6%	66%	21%	5%	1%	0%

5. Conclusions and Recommendations

A process for employing crop sensitivity, hydrographic, hydrologic, other environmental (soil and climate), and management data to inform AGR water quality objectives was developed. Crop sensitivity zones were developed in detail, as were numerous themes of spatial crop, soil, climatic, water quality, hydrographic, and water management data within these zones. It is anticipated that these data will serve as inputs to analyses scoped as Task 5.3 of this project, work that has yet to be authorized or completed.

Water quality targets that would be protective of SMCs might be defined within these CSZs, with the potential to focus on recharge areas and waters that supply irrigation to SMCs. Integrated consideration of cropping patterns, crop sensitivity, water quality, and irrigation source water recharge areas is the most promising approach from the perspective of regulatory application of the process.

These initial CSZ delineations are a reasonable starting point to begin investigating the connections between crop sensitivity calculations and potential AGR standards. The hydrographic basis should facilitate evaluations of connections between drainage and "downstream" irrigation supplies (meaning waters significantly influenced by the discharge in question).

A number of issues and questions related to these types of calculations and their appropriate use in a regulatory setting remain to be addressed (Dickey, 2012; Letey et al., 2011). Once available, the responses to those issues and questions should yield helpful guidance to subsequent phases of this work.

It is clear from the crop distribution maps that SMCs tend to be rather localized within the initial CSZs. This would imply that protection of these crops might best be focused onto waters tapped to irrigate these areas, and might not apply in the same manner to waters that are not so used. Careful hydrographic and hydrologic analysis will be needed at this point. AGR objectives may vary within a CSZ, depending on hydrographic connections between recharge and end-use areas for waters applied to sensitive crops. This level of refinement is justified on the one hand by the importance of protecting AGR beneficial uses, and on the other by the constraints that AGR objectives may impose on dischargers.

The snapshot of crop distribution provided is extremely useful and is probably a good indication of where sensitive crops tend to be grown over the long term. However, these patterns can and do shift over time, and it will become necessary to grapple with how to locate areas where such shifts have occur, so that interpretations of AGR standards may be suitably updated to reflect these changes..

CV-SALTS has provided initial policy direction relative to the definition of drought years, major crops, and acceptable yield reductions due to water quality. With the completion of Task 5.3, it will be possible to evaluate how these thresholds affect applied water quality targets that may serve to inform AGR objectives. It would be useful to include a process step in which this evaluation can be performed, so that implications of policy direction on these key parameters can be considered. For example, an alternative method of applying the major crop threshold is provided in **Attachment B**. The need for such an alternative will be more evident once it can be considered in the light of the results of Task 5.3.

Work such as that completed with the KRCD is extremely useful in ensuring that real water supply operations and the best local knowledge are incorporated into CV-SALTS analyses and decisions. Relatively brief, efficient communication allowed substantial refinement of applied water quality inputs. This will improve all subsequent analysis for this area. The same sort of consultation would be indispensable in refining information about applied water routing, to ensure that more stringent AGR thresholds are applied in areas that need this protection, and to avoid such thresholds where they would provide no such benefit. The data request process and activities log (**Attachment A**) show that DWR Northern District staff are in the process of compiling useful data for their region, and will be coordinating with staff from other Central Valley districts to do the same.

6. References

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Attachment A – Irrigation Data Request and Tabulation of Process and Responses through July 9, 2013

Attachment B – Major Crop Designations for Each CSZ

Addendum - Agricultural Workshop Materials and Comment and Response Table

The context of this addendum is described in the Prologue to this Report. Materials contained herein are as follows:

- A comment and response table, listing reviewers' comments, along with the project teams' responses to those comments, through several rounds of review and revision.
- Material from a workshop featuring input from agricultural stakeholders active in the CV-SALTS process.

Workshop materials include two Powerpoint presentations, one containing the main presentation, and the second containing a set of maps related to the example method application that is the subject of slide 16 of the main presentation. All data shown on the map are drawn from themes of information developed under Tasks 5.1 and 5.2, and are included in the geodatabase delivered with this Report. The numbered process steps are noted in order on slide 16, and again on each corresponding map. Maps were developed for the Sacramento Valley region (CSZs 201and 202) as the working example. Following are descriptions of the maps and two associated figures, by slide number:

1. Irrigated crop land cover, as shown by DWR data
2. Crop salinity tolerance class distributions on the land
3. A map of major crops falling into the Sensitive class
4. A map of the approximate TDS of applied water required for 95% of maximum crop yield (all crops)
5. Similar to previous map, but for sensitive major crops (SMCs) only
6. A map of applied water quality, as estimated by WARMF, overlain by areas with SMCs
7. A bar graph showing the approximate TDS of applied water required for 95% of maximum crop yield for sensitive crops, including almonds present in the example.
8. A table showing that walnuts present in the example are also sensitive, even though the quantitative yield loss function has not been developed.
9. A map showing sources of irrigation water as mapped by DWR, relative to SMCs.
10. A map showing groundwater basins, relative to SMCs.
11. A map showing the hydrographic network, relative to SMCs.
12. Same map, zoomed in.
13. A map of major crops falling into the Moderately Sensitive class.