APPENDIX D. Methodology for Delineating Management Zones

The Recycled Water Policy (RWP) promotes the management of salt and nitrate at the appropriate scale through the adoption of local salt and nitrate implementation plans that are tailored to the local water quality concerns. Within the Central Valley Regional Water Board's jurisdiction, dischargers have the option to manage salt and nitrate individually through existing compliance programs, or collectively in a holistic manner, within areas referred to as management zones. The purpose of this appendix is to identify the key factors that may be considered when delineating a management zone boundary, which may also serve as the area of interest for management of salt and/or nitrate at the local level.

D.1 OPTIONS FOR DELINEATING AREAS OF ANALYSIS

There are many options that local or regional entities may choose from while delineating areas of analysis for the purpose of developing a management zone (or several management zones). Examples of the types of boundaries (including physical, geographical, political, institutional, regulatory, management, and/or model boundaries) that may be considered by local and regional entities for future delineation of management zones are described below[1]. Some of the options include:

- DWR-defined groundwater basins and subbasins as defined in Bulletin 118;
- Integrated Regional Water Management Plan Regions;
- Groundwater Management Plan areas;
- Sustainable Groundwater Management Act of 2014 Groundwater Sustainability Agencies (GSAs);
- Local District and Water-Related Agency boundaries;
- City and County Ordinances and Urban Water Management Plans;
- Agricultural Water Quality Coalitions;
- Watershed Areas; and/or
- Smaller scaled zones and other user-defined management zones.

D.1.1 DWR-Defined Groundwater Basins and Subbasins

California's groundwater resources are widespread and diverse. In an average year, groundwater supplies about 30% of the state's overall water demands; in drought years, it may be 40% or greater (DWR 2003). There are currently 431 delineated groundwater

[1] The types of boundaries that may be considered were presented in the *Tasks 7 and 8 – Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions* (LWA et al. 2013).

basins in ten hydrologic regions that underlie 40% of California. Of these 431 basins, 24 are subdivided into a total of 108 subbasins, which results in a total number of 515 DWR-designated groundwater basins/subbasins. DWR's Bulletin 118 contains details on the types and boundary characteristics of groundwater basins. Generally, a groundwater basin is defined as "an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom" (DWR 2003).

DWR's identification of basins was initially based on the presence and areal extent of unconsolidated alluvial sediments identified on 1:250,000 scale, geologic maps published by the California Department of Conservation, Division of Mines and Geology. The basins have since been further evaluated through review of other relevant reports.[2] Notably, subbasins have been created based on geologic and/or hydrologic boundaries, but more typically they have been created based on institutional boundaries for purposes such as collecting and analyzing data and managing water resources.

In the Central Valley Regional Water Board's jurisdiction (Region 5), there are 106 groundwater basins and/or subbasins; 33 of these basins/subbasins are located in the Central Valley Floor. The area covered by the groundwater basins/subbasins in Region 5 is about 20,760 mi^2, while the area covered by basins/subbasins overlying just the Central Valley Floor is 19,483 mi^2 (i.e., approximately 94% of the groundwater basins/subbasins in Region 5 overlie the Central Valley Floor).

D.1.2 Integrated Regional Water Management Plans

In 2002, the California Legislature enacted Senate Bill (SB) 1672, the Integrated Regional Water Management Planning Act of 2002, to encourage local agencies to work cooperatively to manage available local and imported water supplies. The Act facilitates the development of integrated regional water management plans (IRWMPs) that coordinate local programs and projects to improve source water quality; provide water supply reliability; augment agricultural, domestic, or environmental water supply; and improve the quality or quantity of groundwater (Kretsinger and Narasimhan 2006). Eligibility for funding from this program hinges on applicants having completed (or in the process of preparing based on a set schedule) a Groundwater Management Plan (GMP) or an IRWMP, depending on the type of project proposed.

There are 48 Integrated Regional Water Management Regions in California (**Figure D-1**), with 31 active IRWMPs and 17 IRWMPs in development[3]. Of the 31 active IRWMPs,

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[2] DWR's initial definition of groundwater basins has been subject to review and revisions to basin and subbasin boundaries. The USGS and others have redefined the extent of some basins as part of groundwater investigations conducted in more modern studies (R. Hanson, personal communication November 7, 2012).

[3] http://www.water.ca.gov/irwm/grants/rap.cfm

approximately 80 percent are reliant on local GMPs to manage groundwater and about 20 percent take an active role in managing groundwater (DWR 2012). IRWMP areas cover much of the state and are variable in size and shape. Of the 48 Integrated Regional Water Management Regions, 23 are located in Region 5.

Some of the active IRWMP areas have developed groundwater flow models in association with the plan implementation. An example of such an IRWMP, along with a groundwater flow model, is the Upper Kings Basin IRWMP (WRIME, 2007) and the Kings Basin Integrated Groundwater and Surface water Model (Kings IGSM) (WRIME, 2007). However, there is no compilation of all the IRWMP areas that have used models as a tool in conjunction with their planning process and/or as a tool to facilitate actions outlined in their plans.

Figure D-1. Integrated Regional Water Management Regions
[http://www.water.ca.gov/irwm/grants/rap.cfm]

D.1.3 Groundwater Management Plans

In 1992, the legislature passed Assembly Bill (AB) 3030, the Groundwater Management Act, which at that time was considered a breakthrough for groundwater management at the local level. Subsequently, SB 1938, the Groundwater Management Act adopted in 2002, amended and expanded the requirements for AB 3030 GMPs. That law required public agencies seeking state funds, administered through DWR for the construction of groundwater projects or groundwater quality projects, to prepare and implement a GMP with certain required components (Water Code Section 10753.7). Previously, all plans were voluntary, and there were no required plan components.

The requirements for preparing a GMP[4] included establishing basin management objectives, developing a plan to involve other local agencies in the basin in a cooperative planning effort, and comprehensive monitoring programs (including groundwater levels[5] and quality; surface water flows and quality; and inelastic land surface subsidence for basins where it is identified as a potential concern) to assess changes in basin conditions and "generate information that promotes efficient and effective groundwater management" (Water Code Section 10753.7).

As of April 2015, about 119 GMPs had been adopted (DWR 2015). **Figure D-2** shows the location of Pre-SB 1938 and SB 1938 GMPs. Areas covered by GMPs are variable in size and shape, covering about 31,200 square miles of California, and much of the Central Valley Floor. Of the 119 adopted GMPs, 85 are located within Region 5. Beginning January 1, 2015, new GMPs can no longer be adopted and existing plans cannot be renewed pursuant to the new Sustainable Groundwater Management Act (California Water Code Section 10750.1). This Act is discussed below.

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[4] GMPs are required to be prepared in order for entities to be eligible for grant funds.

[5] DWR has implemented the new California Statewide Groundwater Elevation Monitoring Program (CASGEM), which is being incorporated as part of many GMP monitoring programs http://www.water.ca.gov/groundwater/casgem/entities.cfm . Additionally, there are other areas where local entities have applied to DWR to become designated CASGEM Monitoring Entities where a GMP has not been prepared and adopted.

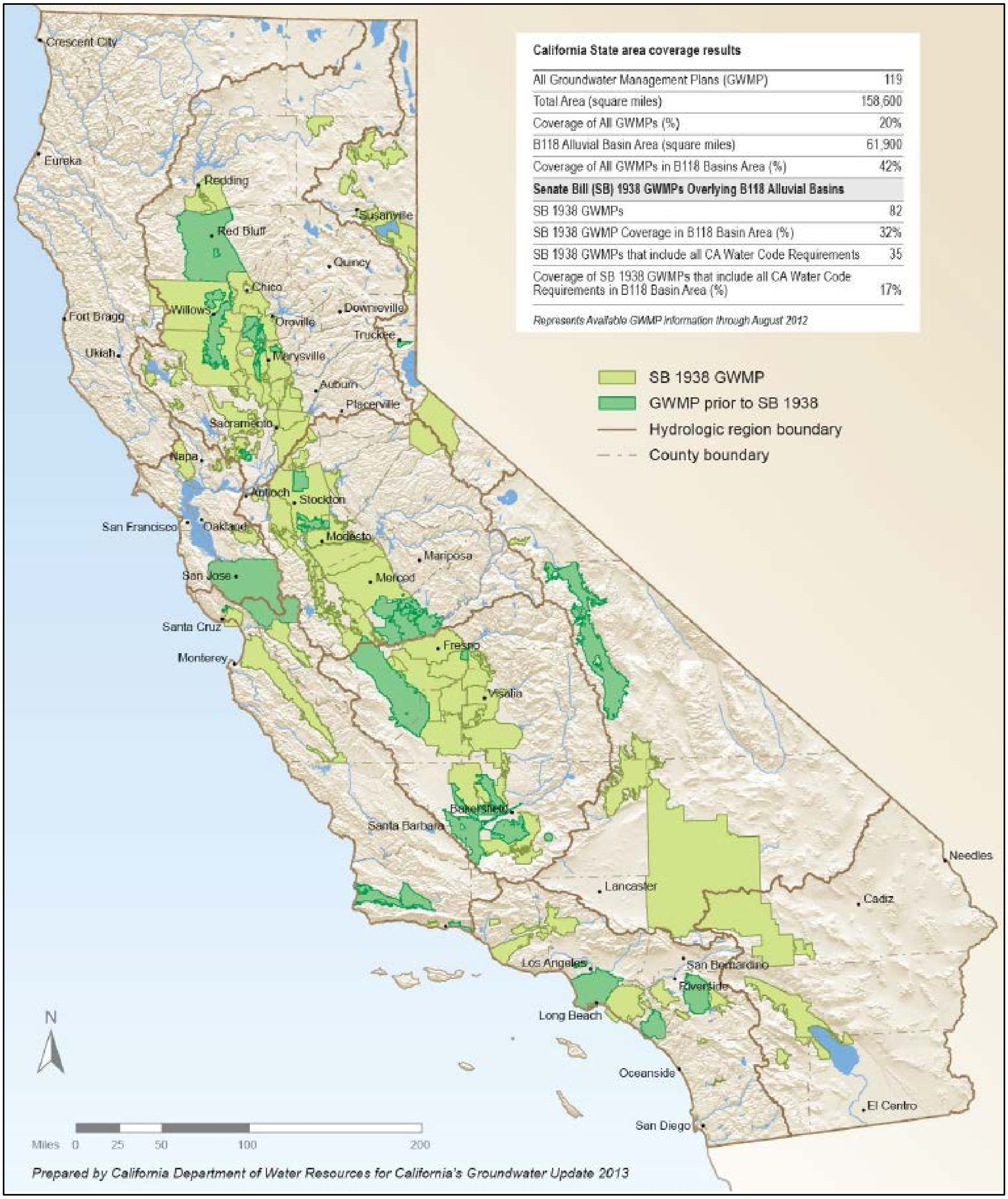

Figure D-2. Location of Groundwater Management Plans in California (DWR Groundwater Update 2013; April 2015)

D.1.4 Sustainable Groundwater Management Act of 2014 GSAs

In an attempt to manage California's groundwater resources at a local level, the Sustainable Groundwater Management Act (SGMA) of 2014 requires (by June 30, 2017) the formation of Groundwater Sustainability Agencies (GSAs). These GSAs are to be locally-controlled groups consisting of one or more local agencies that implement the provisions of the SGMA, including enforcing a Groundwater Sustainability Plan (GSP). The GSAs are to be formed in the State's medium and high priority groundwater basins and subbasins (as determined by DWR under the California Statewide Groundwater Elevation Monitoring (CASGEM) Program)[6]. The GSA is responsible for developing and implementing a GSP to meet the sustainability goal of the basin/subbasin and ensure that it is operated within its sustainable yield, without causing undesirable results (such as chronic lowering of groundwater levels, degraded water quality, etc.). The GSPs will include coordinated monitoring and reporting for the areas covered by the GSAs.

D.1.5 Local District or Water-Related Agencies

More than 20 types of local districts or agencies are identified by DWR. These districts/agencies are listed below in **Table D-1.**

Table D-1. Examples of Types of Local Districts or Water Agencies

Community Services District	Municipal Water District
County Sanitation District	Public Utility District
County Service Area	Reclamation District
County Water Authority	Recreation and Park District
County Water District	Resort Improvement District
County Water Works District	Resource Conservation District
Flood Control and Water Conservation District	Water Conservation District
Irrigation District	Water District
Metropolitan Water District	Water Replenishment District
Municipal Utility District	Water Storage District

The total number of such agencies that have general powers to manage some aspect of groundwater within their boundaries is uncertain (DWR 2003). However, 13 Special Act districts (formed between 1933-1993 by the State Legislature to meet the unique water needs of a specific area) regulate or limit extraction and 7 agencies adopted plans under Water Code Section 10750 [which details provisions for groundwater management (California Water Code 2005)]. Water district areas cover much of the state, with many areas overlapping each other (**Figure D-3**). There are 457 water-related districts in Region 5.

[6] http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm

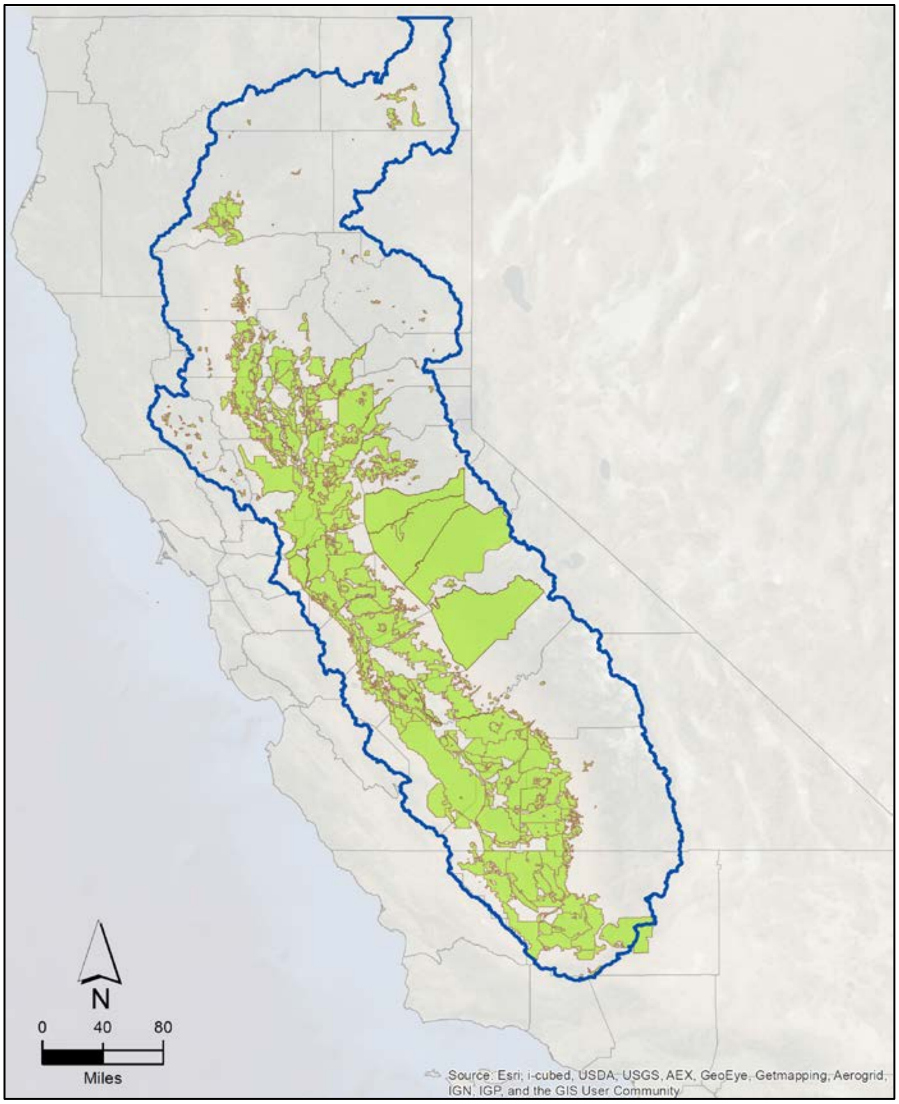

Figure D-1. Water Districts Located within Central Valley Regional Water Quality Control Board Region 5[7]

D.1.6 City and County Ordinances and Urban Water Management Plans

Ordinances adopted by city and county local governments are also a relatively recent means of managing groundwater, with 24 out of 27 existing ordinances adopted since 1990 (DWR 2003). The main purpose of many of these ordinances is to limit groundwater export from the county or from certain groundwater basins or areas within the county. DWR (2003) prepared a "model ordinance" to further encourage local entities to actively engage in groundwater management.

In 1983, the California Legislature enacted the Urban Water Management Planning Act (UWMP Act; Water Code Sections 10610-10657) to facilitate long-term resource

[7] Water district GIS coverage can be obtained at: http://portal.gis.ca.gov/geoportal/

planning and ensure adequate water supplies to meet existing and future water demands. The UWMP Act states that every urban water supplier that provides water to 3,000 or more customers should make efforts to ensure that water supplies are sufficient to meet the needs of its various categories of customers during normal, dry, and multiple-dry years. The UWMP Act specifies the contents of the UWMPs and describes how urban water suppliers should adopt and implement the plans. When the UWMP Act was first adopted in 1983, groundwater was not explicitly addressed. The UWMP Act has, however, subsequently been amended by at least 18 bills. With legislation passed in 2001, groundwater reliability finally became incorporated in the Act as a required component of UWMPs. The areas covered by cities and counties with UWMPs are political and may not have a hydrologic basis.

D.1.7 Agriculture Water Quality Coalitions

California is known for the wide range of agricultural commodities the state produces and distributes worldwide. It is also recognized that the production of food crops and other commodities comes with chemical constituents associated with many of these land uses, including irrigated lands. In 2003, the Irrigated Lands Regulatory Program (ILRP) was initiated to prevent agricultural runoff from impairing surface waters[8]. The Long-Term Irrigated Lands Program has been expanded to protect both surface water and groundwater.

The Central Valley Regional Water Board has coordinated with growers to encourage them to combine resources by forming water quality coalitions. There are 14 coalition groups that work directly with their member growers to assist in complying with ILRP requirements.[9] Of the estimated 35,000 growers in the Central Valley, there are about 25,000 landowners/operators who are part of one of these 14 coalition groups:

(1) Sacramento Valley Water Quality Coalition
(2) California Rice Commission[10]
(3) San Joaquin County and Delta Water Quality Coalition
(4) East San Joaquin Water Quality Coalition
(5) Westside San Joaquin River Watershed Coalition
(6) Grassland Bypass (Drainage) Area
(7) Kings River Watershed Coalition Authority
(8) Westlands Water Quality Coalition
(9) Kaweah Basin Water Quality Association
(10) Tule Basin Water Quality Coalition
(11) Cawelo Water District Coalition

[8] http://www.swrcb.ca.gov/rwqcb5/water_issues/irrigated_lands/index.shtml

[9] http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/coalition_groups/index.shtml

[10] Estimated extent based on the 2012 USDA Cropland Data Layer

(12) Westside Water Quality Coalition
(13) Kern River Watershed Coalition Authority
(14) Buena Vista Coalition

The boundaries of these coalitions are broad and cover much of Region 5 (**Figure D-4**). In some of the larger coalitions, a more focused area within the coalition boundary, such as areas determined to have a relatively higher vulnerability, may be more appropriate for an management zone than the coalition in its entirety.

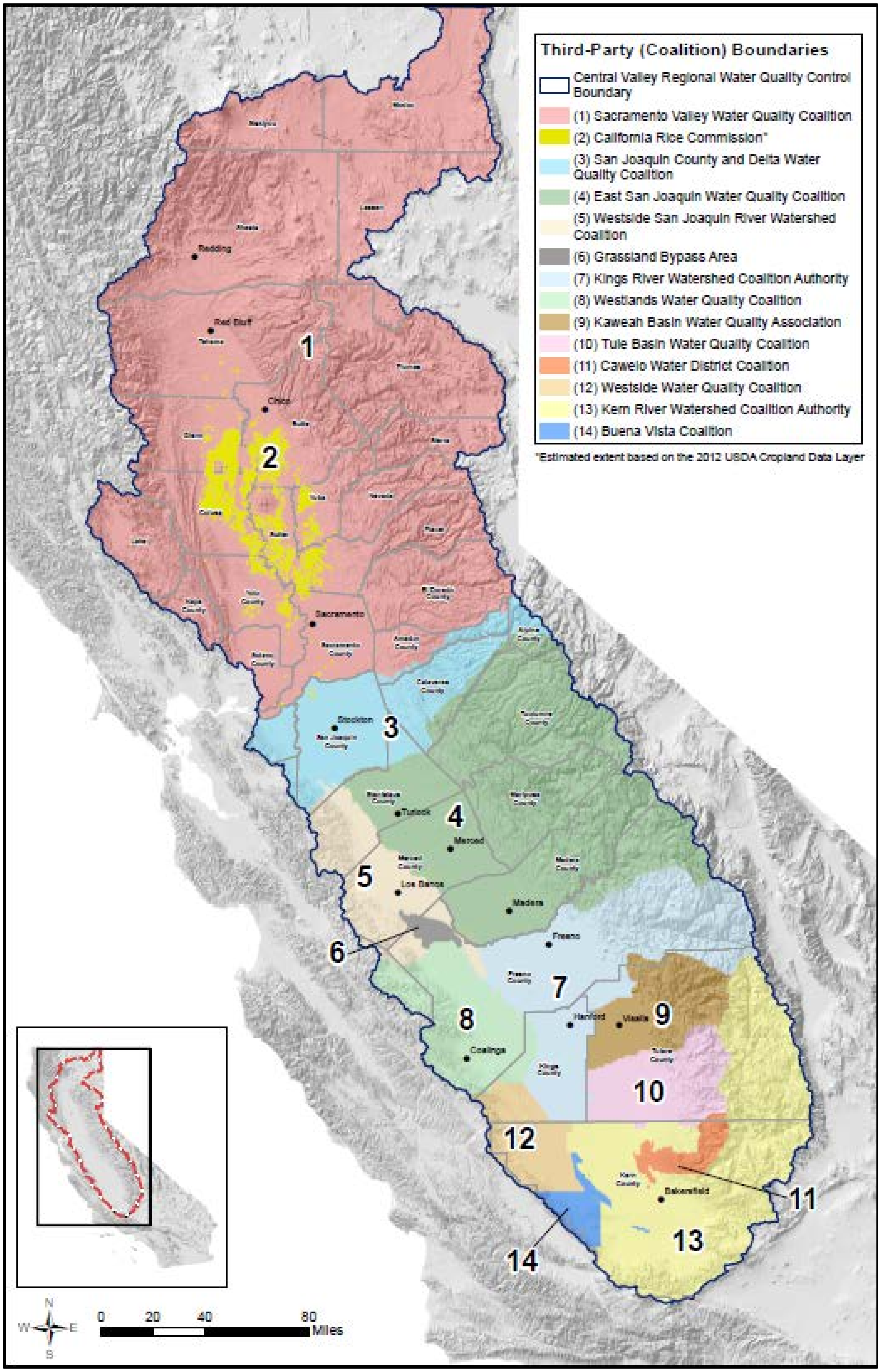

Figure D-2. Agricultural Coalition Groups

D.1.8 Watershed Areas

Watersheds are commonly used by national, state, and local agencies for assessing the regions drained by or contributing water to streams, lakes, rivers, marshes, and groundwater. However, when the term "watershed" is used alone it is broad and can be ambiguous. There are Federal standards and procedures for using the Watershed Boundary Dataset (WBD), a comprehensive collection of hydrologic unit data which are consistent with the national criteria for delineation and resolution of watersheds[11]. The guidelines are designed to enable local, regional, and national partners to delineate hydrologic units consistently and accurately. Procedures to enable such consistency improve watershed management through efficient sharing of information and resources and also ensure that digital geographic data are usable with other related Geographic Information System data.

The United States is divided and subdivided into successively smaller watershed-based hydrologic units which are classified into four levels, including regions, subregions, accounting units, and cataloging units. The hydrologic units are arranged or nested within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system[12]. The WBD contains the most current 8-digit, 10-digit and 12-digit HUCs**.**

D.1.9 Smaller Scaled Zones and Other User-Defined Management Zones

Future management zones can be delineated such that significant constraints are not placed on how the boundaries are determined. For example, a modeling tool, the USGS "Zonebudget" post-processing modeling tool, allows for a user-defined zone[13]. With this tool, currently defined U.S. Geological CVHM[14] subregions can be otherwise defined in different configurations to become management zones that suit the salt and nitrate management objectives at local and regional scales.

There will likely be hydrogeologic factors associated with the structure of existing modeling platforms, like CVHM, that will also need to be considered when newly defined Management Zones are created. These may include the addition of layers to CVHM to

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[11] http://pubs.usgs.gov/tm/tm11a3/ The WBD document establishes Federal standards and procedures for creating the WBD as seamless and hierarchical hydrologic unit data. The data within the WBD have been reviewed for certification through the 12-digit hydrologic unit for compliance with the criteria outlined in the document. Although not required as part of the framework WBD, the guidelines contain details for compiling and delineating the boundaries of two additional levels, the 14- and 16-digit hydrologic units, as well as the use of higher resolution base information to improve delineations.

[12] http://water.usgs.gov/GIS/huc.html

[13] http://water.usgs.gov/nrp/gwsoftware/zonebud3/zonebudget3.html

[14] http://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html

add to the understanding of the subsurface heterogeneity, as well as the addition or movement of groundwater production wells and alteration of pumping amounts for both agricultural and domestic uses to better reflect local conditions. Refining the CVHM grid using a smaller scale may also be helpful. Changes to the Farm Process[15] may also be necessary to adjust land cover and water application rate differences.

The ICM was developed as the first of several phases of work that needed to be completed in order to develop the preliminary draft of the Central Valley SNMP. The ICM work effort also provides foundational information for the more detailed, subregional analyses that may be undertaken in the future by local stakeholder groups if they develop local plans to management salt and/or nitrate. Local and regional entities may want to include more details on point sources of salt and nitrate loading that are not captured in the ICM '*Concept Level*' analyses (LWA et al. 2013). Incorporation of point sources at the "field-scale", or very site-specific scale, will necessarily occur as needed and as time and resources permit for local and regional entities to consider management scenarios that evaluate the potential effects or lack of significant effect of such sources. Local entities are best equipped to handle this data collection which would include improved hydrography (water being applied and drained, recirculated, etc.), application rates of both water and fertilizer, etc. The water quality and land cover data (such as collected for the ICM) will be essential to the more detailed approaches in later phases of the salt and nitrate management planning and implementation.

A hypothetical example of the use of the CVHM as a tool for purpose of developing local plans to manage salt and/or nitrate follows:

- The local entity elects to use its jurisdictional or other appropriate area of analysis to meet its objectives;
- Zonebudget can be run using the selected boundary to define which cells of the CVHM fall within its area of analysis or management zone. The Zonebudget results provide boundary conditions (horizontal and vertical flows in and out of the management zone, or new "local" model area;
- The new local model grid is refined from 1 mi^2 cells to a user-defined smaller cell size to increase spatial resolution on the local model;
- The hydrogeologic parameters (e.g., horizontal hydraulic conductivity, vertical hydraulic conductivity, storage, and layering) in the local model can retain those assigned in CVHM, or they can be updated based on additional local knowledge;
- Land cover would be refined to recognize local differences between what is in CVHM and the current land cover in the local model area;
- Pumpage can be refined based on local knowledge;

[15] For the CVHM, the processes of evaporation, transpiration, runoff, and deep percolation to groundwater were estimated using the MODFLOW-FMP (Farm Process). http://ca.water.usgs.gov/projects/central-valley/cvhm-farm-process.html

- Surface water deliveries and/or sources of recharge can be refined based on local knowledge;
- The MODFLOW FMP has the capability to facilitate scaling and/or linkages for local model (i.e., “child” or embedded model) purposes;
- A solute transport model (such as MODPATH-OBS) can be applied to evaluate salt and nitrate transport in the local model area. This includes locally defined salt and nitrate mass loading estimated for the local model area based on historical and current land cover;
- Management scenarios can be developed to assess the potential long-term implications of current sources of mass loading and/or changes (improvements) in sources of mass loading.

D.2 CONSIDERATIONS FOR DELINEATING FUTURE MANAGEMENT ZONES AND LOCAL PLANS TO MANAGE SALT AND NITRATE

As local and regional entities consider the boundaries that are appropriate to their needs as related to local salt and nitrate management plan development, it remains important to consider hydrogeologic factors that may not carry forward with the new boundary in the same way as the area that may have encompassed the new management zone (e.g., CVHM grid cells reconfigured in groups not aligned with either the 2009 version of CVHM or CVHM2 [in progress] subregions). In other words, additional water budget considerations will likely be necessary for new, user-defined management zones. A brief discussion of three different scales useful for developing water budgets and datasets necessary for a management zone is provided below:

- **Existing and New Model Boundaries:** Large scale groundwater flow models, such as the CVHM and C2VSim[16], undoubtedly benefit from ongoing updates of input parameters as datasets evolve at the local scale through other investigations. Large scale models (or “parent” models) serve a very useful role in providing boundary conditions for local or “child” models nested within the larger model area (LWA et al. 2016). Accordingly, model refinements and higher resolution at the local scale will best inform the salt and nitrate management scenarios considered and actions taken by local entities and regional collaborations. It is recommended that local and regional entities consider the CVHM as a potential tool for the development of a local model. However, local and regional entities may have knowledge of previously developed groundwater flow models for their areas that may also serve as appropriate foundations for management zone development purposes.
- **Local Management Plans for Salt or Nitrate:** Development of local plans will benefit from the preliminary ‘*Concept Level*’ results of the ICM, and the subsequent efforts for the archetype work in Alta Irrigation District (LWA et al. 2016). It is also possible for local and regional entities that develop an

[16] http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm

understanding through the ICM results that on the scale of the ICM analyses do not appear to be priority areas for the more detailed examination of salt and nitrate loading and effects compared to other areas. For example, the ICM results show IAZs where ambient groundwater quality is already elevated with respect to salt and nitrate concentrations and these likely warrant more detailed examination than those with lower salt and nitrate concentrations.

- **Point Source or Field Scale Analyses:** The ability to perform the point source (field-scale) analyses in management zones will require further efforts to collect the necessary data. Local entities are best equipped to handle this data collection which would include improved hydrography (water being applied and drained, recirculated, etc.), application rates of both water and fertilizer, etc. The groundwater quality data organized for the ICM and the groundwater quality data developed by CV-SALTS (Luhdorff & Scalmanini and LWA 2014) will provide a useful foundation to the more detailed approaches and additional data collection necessary for future management zones and also local management plans.

The boundary for the AID management zone archetype was pre-selected by CV-SALTS to be the AID boundary. The archetype study area was expanded as a result of the ultimate interest in using a groundwater flow and transport model as a tool for assessing short and long-term salt and nitrate management strategies or scenarios. The AID management zone model area (which covers areas to the west and south of AID, including Consolidated Irrigation District) was greater in area based on hydrologic considerations and groundwater modeling requirements. The development of such modeling tools for future local entities interested in testing short and long-term salt and nitrate management scenarios will benefit from a more regional approach. This may include use of a modeling tool that allows consideration of a range of parameters and strategies. Modeling tools may have their own constraints; however, they can be used to inform other planning and implementation needs. Using the larger study area was necessary for the analysis of the AID management zone to achieve more accurate water budgets and determination of water quality entering and leaving the management zone.

Table D-2 summarizes general factors for entities to consider when determining the area for a future management zone that best fits local planning and management objectives and future strategies for the long-term protection of and/or strategies for improving groundwater quality.

Table D-2. Factors to Consider When Delineating a Management Zone Area

Category	Factors for Consideration
Institutional	One entity -- boundary aligned with management zone objectives?
	More than one entity -- boundary aligned with multiple objectives?
Physical Setting	Geologic boundaries and/or features (e.g., faults, confining units, etc.) that need to be factored into the management zone delineation?
	Hydrologic boundaries (e.g., streams, lakes, groundwater divide, ocean, groundwater basins/subbasins, etc.) that need to be factored into the area?
	Existing hydrogeologic studies/evaluations -- physical conceptualization of subsurface system; is it well understood with respect to groundwater quality impacts?
	Groundwater monitoring network -- provide an understanding of groundwater flow directions in the aquifer system? Will this influence the management zone area delineation?
Groundwater Quality Characterization	Availability of groundwater quality data and distribution of those data -- does this affect the selection of the management zone area, or is this something that is not important to the selection of the area and can be addressed as needed?
	Existing groundwater quality characterization, i.e., does the existing data provide an understanding of the distribution of key constituents of concern (salt, nitrate, other) within various units of the aquifer system -- will this influence the management zone area delineation?
	Groundwater quality monitoring network -- does it provide good understanding of movement of constituents, including vertical movement from the land surface to groundwater, from the upper part of the aquifer system to the lower part of the aquifer system, and surface water/groundwater interaction as applicable?
Sources of Supply	Location of groundwater use generally known, including completion depths of municipal, irrigation, private and other types of water supply wells?
	Intensive water resources use (especially groundwater); is the use localized within the management zone area of interest or is it more broadly distributed? Does this affect management zone area considerations?
	Recycled water -- what is the source of supply (or supplies) and locations(s) of use? Does this affect the management zone area delineation?
	Stormwater -- what is the source of supply (or supplies) and locations(s) of discharge and recharge? Does this affect the management zone area delineation?
Land Cover	Land cover data readily available -- does the land cover relate to entity management zone area objectives?
	Variety of land use types -- adequately encompassed in the management zone area?
Tools	Existing groundwater flow and/or transport model (s) exist that overlie management zone area of interest? Would one or more of such models be useful for accomplishing management zone objectives? [it may be useful to consider the model area and aspects of existing models when determining the management zone area of interest.]
Regional Collaboration	Is the management zone area within an existing IRWM, GMP/future GSA, Agriculture Coalition, etc., and are there factors related to other programs that need to be considered when delineating the management zone area?
Water Resources Management Strategies	Are there existing or planned management strategies that would affect the selection of the management zone area, i.e., conjunctive use program, recharge facilities, etc.?

D.3 SUMMARY

As described above, local and regional entities may choose to define management zones in a number of ways based on the salt and nitrate management planning and/or other objectives. Local and regional entities will benefit by selecting management zones that align with other water resources related planning efforts. For example, previous GMPs and/or IRWMPs have typically involved monitoring programs and other data collection efforts that can inform the local salt or nitrate management plan data needs. Similarly, other planning efforts that have resulted in knowledge about surface water and/or groundwater quality in a local/regional entity's area can provide important foundational information for the development of a management zone and associated management plan. The formation of GSAs will also provide the framework and necessary coordination for monitoring and managing groundwater resources in the context of both quantity and quality.