Appendix G

Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results

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Acronyms and Abbreviations

AW_{dem}	Demand for applied water
AWMP	Agricultural Water Management Plan
CAD	Cowell Agreement Diversion
CALAG	California Agriculture
CALVIN	California Value Integrated Network
C_{dem}	Demand for CUAW
CSJWCD	Central San Joaquin Water Conservation District
C_{SWdem}	Surface water demand for CUAW
CUAW	consumptive use of applied water
CVP	Central Valley Project
CVPM	Central Valley Production Model
DAUs	Detailed Analysis Units
DWR	California Department of Water Resources
ETAW	evapotranspiration of applied water
FERC	Federal Energy Regulatory Commission
F_{SWdem}	Demand for farm surface water
GIS	geographic information systems
GWMPs	groundwater management plans
IMPLAN	Impact Analysis for Planning
kWh	kilowatt hour
LSJR	Lower San Joaquin River
M&I	municipal and industrial
Merced ID	Merced Irrigation District
MID	Modesto Irrigation District
NCRMs	Net Crop Revenue Models
NWR	National Wildlife Refuge
OID	Oakdale Irrigation District
PF	percolation factors

PMP	Positive Mathematical Programming
ResLoss	reservoir losses
SED	substitute environmental document
SEWD	Stockton East Water District
SOI	sphere of influence
SSJID	South San Joaquin Irrigation District
State Water Board	State Water Resource Control Board
SWAP	Statewide Agricultural Production
SWRCB	State Water Resources Control Board
TAF/y	thousand acre-feet per year
TID	Turlock Irrigation District
USBR	U.S. Bureau of Reclamation
WEAP	Water Evaluation and Planning
WMP	Water Management Plan
WSE	Water Supply Effects
WTP	Water Treatment Plant

G.1 Introduction

Agricultural production in the Lower San Joaquin River (LSJR) Watershed is dependent on irrigation water supply from various sources, including surface water diversions, groundwater pumping, and deliveries from the federal Central Valley Project (CVP). Implementation of the LSJR alternatives would have the potential to affect the amount of allowable surface water diversions from within the LSJR Watershed and would also potentially affect groundwater levels. Thus, agricultural production would, in turn, depend upon the LSJR alternatives' effects on these irrigation water supplies.

This appendix describes the methods and modeling results that estimate the potential effects of the LSJR alternatives on groundwater and agricultural production, as well as the associated economic effects in the LSJR Watershed. Estimated changes in allowable surface water diversions and groundwater pumping that result from implementation of the LSJR alternatives were used to analyze effects on the economy. The study area evaluated in this appendix includes the irrigation districts that regularly receive surface water from the Stanislaus, Tuolumne, or Merced Rivers and the four primary groundwater subbasins under this area. They are collectively referred to as "irrigation districts" and include: South San Joaquin Irrigation District (SSJID), Oakdale Irrigation District (OID), Stockton East Water District (SEWD), Central San Joaquin Water Conservation District (CSJWCD),Turlock Irrigation District (TID), Modesto Irrigation District (MID), and Merced Irrigation District (Merced ID). District boundaries, counties in which they are located, and key municipalities in the region are identified in Figure G.1-1.

The agricultural economic analysis described in this appendix follows three major steps, described in Sections G.2, G.4, and G.5. First, total annual applied water for agriculture in each of the irrigation districts, along with annual agricultural groundwater use, is determined based on surface water diversions and agricultural demands calculated in the State Water Resource Control Board's (State Water Board) Water Supply Effects (WSE) model as described in Appendix F.1, *Hydrologic and Water Quality Modeling*. Second, the Statewide Agricultural Production (SWAP) model, a regional economic model for agricultural production, is used to estimate how changes in surface water diversions and groundwater pumping will affect agricultural production and related revenues in the irrigation districts. Third, multipliers derived from the Impact Analysis for Planning (IMPLAN) input-output model, a regional economic impact model widely used for assessing the economic impacts of changes in natural resources, are used to estimate the total (direct, indirect, and induced) economic impacts on employment and sector output resulting from predicted changes in agricultural production. The discussion describes the effects on all inter-connected sectors of the regional economy.

Section G.3, *Estimation of Groundwater Balance*, estimates the net change in the annual contribution from the irrigation districts to the groundwater subbasins that may result from the LSJR alternatives. The net change in the annual groundwater balance is derived from changes in surface water diversions and groundwater pumping described in Section G.2, *Total Applied Water for Agricultural Production*. This groundwater evaluation is used to determine the groundwater impacts described in Chapter 9, *Groundwater Resources*. This groundwater analysis is not part of the SWAP and IMPLAN analyses, but it uses the same assumptions regarding the fate of surface water diversions and groundwater pumping.

There are three LSJR alternatives, each consisting of a specified percentage of unimpaired flow[1] requirement for the Stanislaus, Tuolumne, and Merced Rivers (the three eastside tributaries of the LSJR). For a particular alternative, each of the three eastside tributaries of the LSJR must maintain or exceed the specified percentage of its own unimpaired flow at the LSJR confluence from February–June. The percentage unimpaired flow requirements are 20 percent, 40 percent, and 60 percent, respectively, for LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4.[2] Flows must not drop below the specified percent of unimpaired flow or below existing flow requirements, whichever is larger, on each of the three eastside tributaries. In addition, each of the alternatives includes adaptive implementation. Adaptive implementation consists of four methods that generally allow the percent of unimpaired flow to increase or decrease, depending on the alternative and certain criteria, or be shifted within February–June, or outside of that time period (i.e., to the fall). In addition, adaptive implementation allows for a minimum flow on the SJR at Vernalis. Specific details of the LSJR alternatives are presented in Chapter 3, *Alternatives Description*, of this recirculated substitute environmental document (SED), and are the basis for how the alternatives are modeled in this appendix. The results presented in this appendix are organized by 20 percent, 40 percent, and 60 percent of unimpaired flow.

The allowable surface water diversions and supplemental groundwater pumping for each of the LSJR alternatives are used to estimate groundwater impacts discussed in the following chapters: Chapter 9, *Groundwater Resources*; Chapter 11, *Agricultural Resources* (the agricultural production generated by SWAP and agricultural impacts); Chapter 20, *Economic Analyses* (economic value estimated by IMPLAN and economic effects); and Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options*. This appendix, and the respective chapters that use information from this appendix, compare the results of the LSJR alternatives to baseline results. The difference between baseline and an alternative for groundwater, agricultural production, or crop revenue is the effect attributed to implementing that alternative. In general, the modeling results indicate that as flow requirements on each of the rivers increase, the surface water diversions decrease; in response, groundwater pumping increases, agricultural production may decrease, and the regional economy may be affected.

G.2 Total Applied Water for Agricultural Production

This section describes the methods for estimating changes in applied water associated with the LSJR alternatives and presents a summary of these changes. *Applied water* refers to water that is applied directly to a crop and can come from either groundwater pumping, surface water diversions, or both. Some of the applied water will be used consumptively by the crops (consumptive use of applied water [CUAW]) and the rest will seep into the soil and contribute to groundwater (deep

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[1] *Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds.It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

[2] Any reference in this appendix to 20 percent Unimpaired, 40 percent Unimpaired, and 60 percent Unimpaired is the same as LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4, respectively. Any reference to 1.0 EC objective and 1.4 EC objective is the same as SDWQ Alternative 2 and SDWQ Alternative 3, respectively.

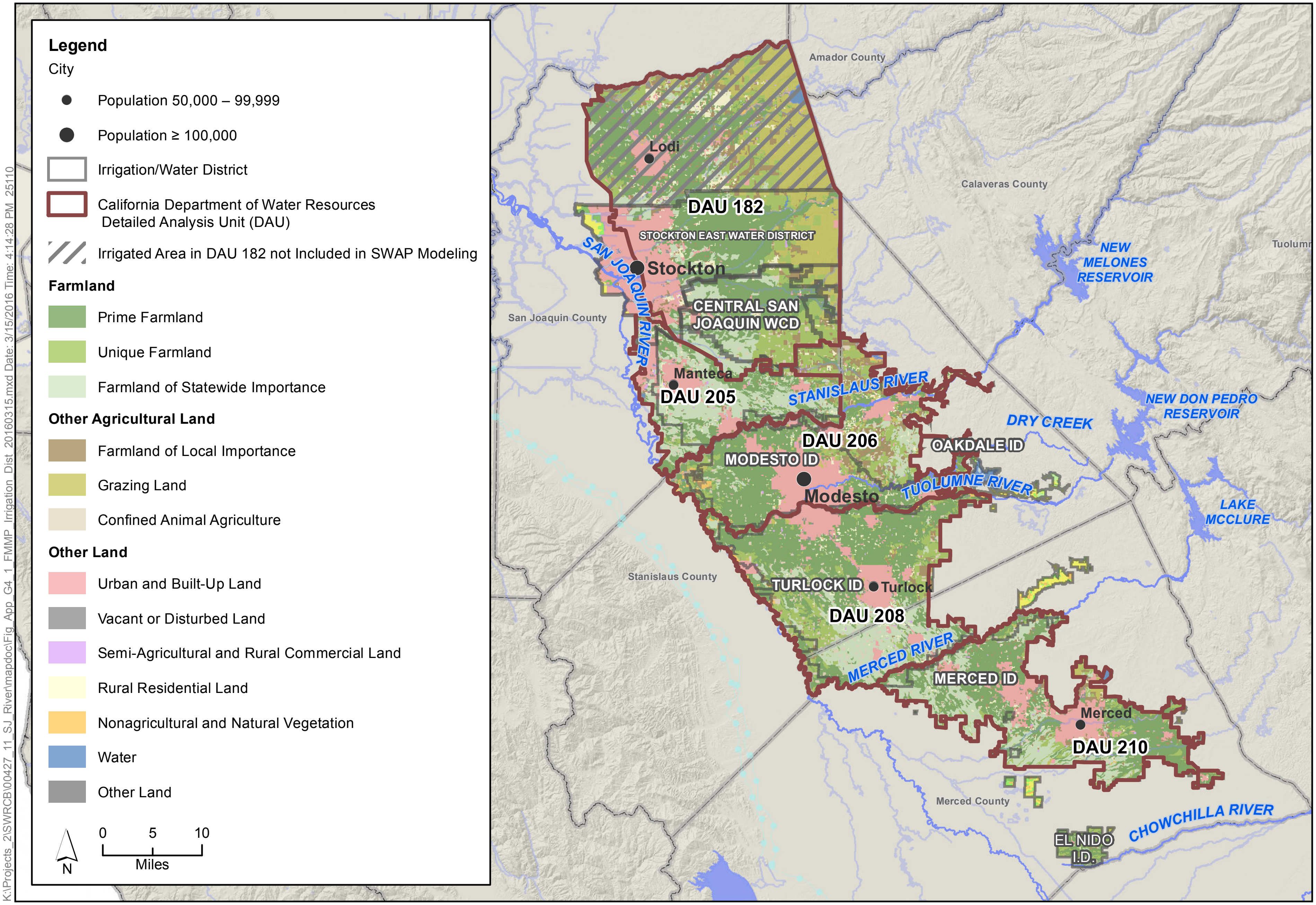

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Figure G.1-1
Vicinity Map

percolation[3]). The term CUAW is considered to be synonymous with evapotranspiration of applied water (ETAW).

The amount of applied water available will depend on whether there is sufficient water to meet demand. There are several levels of demand, starting with the most basic—demand for CUAW. The following terms are used in subsequent text regarding methodology for calculating applied water.

- Demand for CUAW ($\mathbf{C_{dem}}$), also referred to as crop demand, is the amount of water that crops would use consumptively, assuming there is no water shortage.
- Surface water demand for CUAW ($\mathbf{C_{SWdem}}$), also referred to as crop surface water demand, is the portion of $\mathbf{C_{dem}}$ that the crop growers intend to meet using surface water diversions after applying minimum groundwater pumping. (See below for further description of minimum groundwater pumping.)
- Demand for applied water ($\mathbf{AW_{dem}}$) is $\mathbf{C_{dem}}$ plus the amount of water that would be lost to deep percolation under conditions of full water supply.
- Surface water demand for applied water ($\mathbf{AW_{SWdem}}$) is the portion of $\mathbf{AW_{dem}}$ that is not met by minimum groundwater pumping.
- Demand for farm surface water ($\mathbf{F_{SWdem}}$) is the demand for applied surface water plus the amount of water that would be lost from the distribution system if the full applied water demand were to be satisfied.
- Full surface water demand, also referred to as demand for diversion, is the total amount of surface water that would need to be diverted from a river in order to meet all municipal surface water demands that have surface water rights and irrigate all crops that are typically grown when surface water rights can be fully diverted. It includes water that would be lost from the distribution system due to seepage and evaporation and assumes a typical minimum amount of groundwater pumping each year.

Applied surface water was estimated by partitioning diversions from each river between different types of uses and losses. Applied surface water is the amount of water diverted from the river that reaches a farm, after riparian water rights and municipal and industrial (M&I) needs are satisfied and all losses (including offstream reservoir seepage, distribution system losses, and spills) are subtracted. If groundwater pumping is not sufficient to make up any deficit in applied surface water, then agriculture would be affected.

As described in Appendix F.1, *Hydrologic and Water Quality Modeling*, the State Water Board's WSE model was used to estimate the various levels of demand and surface water diversions for each LSJR alternative. If crop needs are not fully satisfied by minimum groundwater pumping and surface water diversions, there may be additional groundwater pumping up to a maximum that is based on the capacity of the groundwater pumping and distribution infrastructure.

The WSE model results were post-processed in the GW and SW Use Analysis V16 spreadsheet to estimate additional groundwater pumping for surface water replacement and to calculate overall effects on groundwater subbasins. The results were further post-processed to estimate the percent

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[3] Surface runoff from irrigated land, which is tracked separately as part of the spills and return for each district, may also contribute to deep percolation, but for the SED, this contribution is assumed to be small and was not modeled.

of applied water demand met from all sources, which was used as an input to the SWAP model. The methods and results for estimating groundwater pumping, the fate of water diverted from rivers, and the volume of applied surface water are described below. These estimates are then used as inputs to the groundwater analysis described in Section G.3, *Estimation of Groundwater Balance*, and as inputs to the SWAP model described in Section G.4, *Estimating Agricultural Production, Associated Revenue, and Groundwater Pumping Costs*. Ultimately, the results of this analysis are used to inform the environmental impact analysis in the following chapters: Chapter 9, *Groundwater Resources*; Chapter 11, *Agricultural Resources*, and Chapter 14, *Energy and Greenhouse Gases*. It is also used to inform the economic analyses in Chapter 20, *Economic Analyses*, and provide context for groundwater use in Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options*.

G.2.1 Inputs from the WSE Model

The WSE model is a monthly water balance spreadsheet model that estimates allowable surface water diversions and reservoir operations needed to achieve the target flow requirements of the LSJR alternatives on the three eastside tributaries. A more detailed description of the model is presented in Appendix F.1, *Hydrology and Water Quality Modeling*. Within the constraints of reservoir storage rules, instream flow requirements, and diversion demands, the model uses a water balance to calculate the resulting river flows, allowable surface water diversions, and reservoir storage levels. Model calculations are performed on a monthly time step for each tributary using the 82 years of CALSIM II[4] hydrology (water years 1922–2003) as input to New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure, respectively. The CALSIM II model run that was used as a source of information for the WSE model is the CALSIM II “Current Conditions” case used in the California Department of Water Resources (DWR) *2009 Delivery Reliability Report* (DWR 2010a). This version of CALSIM II closely represents the baseline conditions over 82 years of climate history.

For the calculation of applied water and groundwater recharge over each irrigation year, March–February, the necessary time series to extract from the WSE model includes the information listed below.

- Municipal and Industrial (M&I) surface water demands for the city of Modesto and Degroot Water Treatment Plant (WTP).
- Riparian demands for diversion from each river.
- Spills/return flows for each irrigation district.
- The Woodward, Turlock, and Modesto Reservoir seepages.
- Minimum groundwater pumping for each irrigation district.
- Constant deep percolation and distribution loss factors (for the groundwater assessment).
- Crop surface water demands (surface water demand for CUAW) for each irrigation district.

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[4] CALSIM is a generalized water resources simulation model for evaluating operational alternatives of the SWP/CVP system. CALSIM II is the latest application of the generic CALSIM model to simulate SWP/CVP operations. CALSIM and CALSIM II are products of joint development between DWR and the U.S. Bureau of Reclamation. This SED uses the terms CALSIM and CALSIM II interchangeably.

- Merced ID sphere of influence (SOI) demands for Stevinson, Merced National Wildlife Refuge (NWR), and other areas.
- Merced ID SOI delivery for each alternative.
- SEWD municipal delivery for each alternative.
- The percent of crop surface water demands met for each alternative for each river.

All these parameters are summed annually over each irrigation year. Only the last three parameters vary between alternatives as discussed in the following sections.

G.2.1.1 Diversions

The calculation of applied water starts with the WSE model's estimated diversions for the Stanislaus, Tuolumne, and Merced Rivers. Some of the diversions go towards meeting riparian water rights, but the majority go to large irrigation districts. The analysis of water supply for the irrigation districts is separated as follows.

- Stanislaus River—SSJID
- Stanislaus River—North OID (north of the Stanislaus River)
- Stanislaus River—South OID (south of the Stanislaus River)
- Stanislaus River—SEWD and CSJWCD
- Tuolumne River—MID
- Tuolumne River—TID
- Merced River—Merced ID (Diversions for Merced ID include water that goes to irrigation districts that are within the Merced ID SOI, including Stevinson Water District, Le Grand-Athlone Water District, and Lone Tree Mutual Water Company.)

The WSE model calculates the amount of surface water diverted as the lesser between the amount of surface water available from the associated watershed, the maximum diversion allowed by water rights, or the amount needed to satisfy full surface water demand. On the Stanislaus River, if water is still available for diversion after the SSJID and OID diversions are determined, water is allocated to SEWD and CSJWCD. Deliveries to SEWD and CSJWCD are defined by their contract terms with the U.S. Bureau of Reclamation (USBR) and not by their demand; therefore, the maximum combined diversion for SEWD and CSJWCD is 155 thousand acre-feet per year (TAF/y) as specified in their contracts with USBR. The irrigation district diversions are calculated as a total for each tributary; irrigation district diversions from the Stanislaus River combine SSJID and OID, and diversions from the Tuolumne River combine MID and TID. The SEWD and CSJWCD diversions are calculated as a total.

G.2.1.2 Apportionment of Surface Water Diversions between Districts

Since the WSE model calculates irrigation district diversions as totals for each tributary, the surface water diversions need to be apportioned between the individual districts. On the Stanislaus River, diversions for SSJID and OID are apportioned by assuming that each district would receive the same percent of its crop surface water demand (i.e., CUAW minus minimum groundwater pumping that would not be lost to deep percolation). For the Tuolumne River, diversions for MID and TID are apportioned using the same method as for SSJID and OID. On the Merced River, Merced ID is the only irrigation district modeled; however, Merced ID passes some of its water to areas outside the district boundary to areas within its SOI. The SOI demands for the Merced National Wildlife Refuge and Stevinson are met before Merced ID's own demands, while the other SOI demands are met after the districts.

If water is available for SEWD and CSJWCD, but it totals less than their contract amount, the diversion is apportioned between these districts using the following steps, which are based on information in CALSIM II.

1. When the Total Contractor Diversion is between 155 and 98 TAF, CSJWCD receives (80/155)* Div and SEWD receives (75/155)* Div.
2. When the Total Contractor Diversion is between 98 and 59 TAF, CSJWCD receives 49 TAF and SEWD receives the remainder.
3. When the Total Contractor Diversion is between 59 and 10 TAF, SEWD receives 10 TAF (for municipal demands) and CSJWCD receives the remainder.
4. When the Total Contractor Diversion is below 10 TAF, SEWD receives it all.

G.2.1.3 Parameter Estimates

In order to estimate applied surface water and groundwater recharge, multiple parameters need to be extracted from the WSE model. A description of these parameters, as well as numeric values and data sources used to estimate these terms are described below.

Municipal and Industrial Surface Water Supply

Municipal and industrial water suppliers use a relatively small portion of the total surface water diversion from the Stanislaus and Tuolumne Rivers. On the Stanislaus River, water is delivered to the DeGroot WTP through SSJID. The water use of the plant is assumed to be 16 TAF/y, based on information in the SSJID Agricultural Water Management Plan (AWMP) (SSJID 2012). On the Tuolumne River, the City of Modesto has an agreement with MID to purchase surface water from the district. In the WSE model, the City of Modesto is assumed to divert 30 TAF/y (MID 2012). For a more conservative estimate of the groundwater and agricultural impacts, it is assumed that municipal deliveries would not be cut in times of surface water shortage. This is a simplifying assumption based on the program of implementation in Chapter 3, *Alternatives Description*, which describes actions to assure that implementation of the LSJR alternatives (i.e., percent of unimpaired flow requirement) does not impact supplies of water for minimum health and safety needs. Potential impacts on municipal and industrial water users are evaluated in Chapter 13, *Service Providers*.

There is one exception to the analytical assumption that all municipal demands for surface water would be met. In the WSE model, SEWD and CSJWCD diversions from the Stanislaus River are calculated separately from the SSJID and OID diversions because they only receive water after SSJID and OID water rights have been met. As a result, in some years SEWD is not able to meet its municipal demand for Stanislaus River water, which is assumed to be 10 TAF/y (SEWD 2014). These municipal needs, however, could be met by either Calaveras River water or groundwater.

Riparian Diversions

WSE model riparian diversions are the same as those used in the CALSIM model. Demands for riparian diversions are met before diversions are allocated to the irrigation districts. Cowell

Agreement Diversion (CAD) demands on the Merced River are treated as riparian demands in the WSE model. However, the CALSIM II time series of CAD diversions does not fully divert the Cowell Agreement Flow described in Appendix F.1, *Hydrologic and Water Quality Modeling*. Therefore, in the WSE model, the monthly CAD diversions are increased so that they equal the full Cowell Agreement Flows.

Spills/Returns

Estimates of spills/returns come from CALSIM II. Operational spills and returns represent water diverted by the districts that returns to the river, including surface runoff from irrigated land. In addition, irrigation districts often use excess flow to maintain constant pressure head in the distribution system and maintain delivery. This water is eventually spilled or released from the distribution system and returned to the river. These estimates vary monthly, but are assumed to be the same for all LSJR alternatives. However, spills, returns, and riparian demands may actually vary based on crop water use, but the variability is relatively small and it is difficult to model how these parameters may change in response to changes in water availability.

Offstream Reservoir Losses

A large amount of water seeps into the ground from Woodward Reservoir, Turlock Lake, and Modesto Reservoir. The estimated annual loss for these reservoirs is 30 TAF/y, 47 TAF/y, and 31 TAF/y, respectively. The estimates for Woodward and Modesto Reservoirs are based on information in the SSJID Agricultural Water Management Plan (AWMP) and MID AWMP, respectively. The value for Turlock Lake is from TID's response to an August 2015 information request (pers. comm. Hashimoto, P.E.). These offstream reservoirs lose a relatively small amount of water to evaporation, with evaporation being within the margin of error for the seepage estimate. The estimates for offstream reservoir losses also account for distribution system seepage upstream of the regulating reservoirs.

Merced ID SOI Demands and Deliveries

Merced ID SOI demands include the Stevinson Entitlement, required deliveries to Bear Creek in the Merced NWR as part of the Merced ID Federal Energy Regulatory Commission (FERC) license, deliveries to El Nido, and water sales by Merced ID to other nearby entities (Merced ID 2013). Merced ID SOI demands occur outside of the district but share the district's distribution system. El Nido was incorporated into the district in 2005 (Merced ID 2013); however, CALSIM II represents El Nido separately from the district, so the WSE model represents them separately. In the WSE model, Merced NWR has an annual demand of 15 TAF/y, which is the same as in CALSIM. The values for El Nido, Stevinson, and other SOI demands are 13 TAF/y, 24 TAF/y, and 16 TAF/y, respectively, and they were extracted from the Merced Operations Model released as part of Merced ID's FERC relicensing process (Merced ID 2015).

The Stevinson Entitlement is an adjudicated delivery from Merced ID and the delivery to Merced NWR is part of the districts FERC license, so it is assumed in the WSE model that in times of shortage both demands are satisfied before water is delivered to the district itself. Since El Nido was incorporated with Merced ID in 2005, they receive the same cut as the rest of the district in the WSE model if there is a shortage. Finally, other SOI demands are assumed to represent voluntary water sales by Merced ID, and these SOI water users will only receive delivery if the Merced ID demands are fully satisfied. For the groundwater analysis, it is assumed that any cuts to SOI demands besides

El Nido can be replaced with groundwater (groundwater pumping capabilities for El Nido are assumed to be included in the total district groundwater pumping estimate described in Section G.2.2, *Methodology for Calculating Applied Water*).

Minimum Groundwater Pumping

For the estimation of irrigation district demand for applied surface water, it is assumed that some of the total irrigation district demand for applied water would be met by minimum groundwater pumping. A minimum groundwater pumping amount was applied to account for irrigated areas that are not supplied by surface water. These minimum amounts are likely to occur each year regardless of water year type. However, in the WSE model there are a few months in certain years when the estimated applied water demand is less than the minimum groundwater pumping for that month, so the minimum groundwater pumping is reduced to prevent demands from being oversatisfied.

Minimum groundwater pumping estimates are based on evaluation of irrigation district pumping estimates in CALSIM, AWMPs, groundwater management plans (GWMPs), and information provided by the irrigation districts. The final values selected come primarily from the AWMPs and the irrigation districts (Table G.2-1).

Table G.2-1. Annual Minimum Groundwater Pumping Estimates for each Irrigation District

Irrigation District	Annual Minimum Groundwater Pumping (TAF/y)	Source
SSJID	25.6	SSJID Information Request (Rietkerk pers. comm.)
OID North[a]	7.9	OID Information Request (Knell pers. comm.)
OID South[a]	10.4	OID Information Request (Knell pers. comm.)
MID	12.0	MID Information Request (Salyer pers. comm.)
TID	80.6	TID AWMP (2012)
Merced ID	37.0	Merced ID AWMP (2013)

TAF/y = thousand acre-feet per year

[a] OID provided information that total minimum pumping for OID was 18.3 TAF/y. This value is divided between North and South OID based on the relative irrigated area of each.

To simplify calculating the water supply, agricultural, and groundwater impacts on SEWD and CSJWCD, it is assumed that they have no minimum groundwater pumping. This is justified because the LSJR alternatives will only affect the districts' access to surface water diversions from the Stanislaus River, which are contract amounts not based on either districts crop demand. However, to provide context for groundwater use in the Eastern San Joaquin Basin, it is necessary to characterize the total water use of these districts, which does include some level of minimum groundwater pumping.

From Table G.4-3 shown in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*, the applied water demand for SEWD and CSJWCD are 157 and 119 TAF/y, respectively. SEWD also supplies urban demands at about 50 TAF/y (SEWD 2014). Both districts can divert Stanislaus river water as described above (up to 75 TAF/y for SEWD and up to 80 TAF/y for CSJWCD), but SEWD also has an agreement to divert water from the Calaveras River up to 67 TAF/y (San Joaquin County Department of Public Works 2004). The total water demand for both districts is 326 TAF/y, and the maximum total surface water supply after accounting for distribution losses is 192 TAF/y (distribution loss factors are described below). The remaining demand is 133 TAF/y, which is the minimum groundwater pumping for SEWD and CSJWCD combined. In this case the minimum groundwater pumping refers to applied water demand of SEWD and CSJWCD that can't be met with surface water even if they receive their full surface water allotments from all sources.

Distribution Loss Factors

Distribution losses are primarily caused by seepage from canals and ditches, although a small amount of water is also lost to evaporation. Total distribution losses are estimated as a fraction of the applied surface water and spills based on information from the district AWMPs. These factors are referred to as demand side distribution loss factors, or **DF**, as they represent the losses as a percent of the demands. The calculation is performed in this manner as opposed to using a fraction of total diversions because there are some portions of the total diversion that are assumed not to contribute to distribution losses (e.g., offstream reservoir seepage and M&I water use). The values for the demand side distribution loss factors range between 5 and 32 percent (Table G.2-2). These factors can be adjusted to provide supply side distribution loss factors, which represent the distribution losses as a percent of diversions made to account for applied water, operational spills, and return flows. These fractions are equal to **DF**/(1+**DF**) and vary between 5 and 24 percent.

Calculations of **DF** for all districts, except SEWD and CSJWCD, are described in Appendix F.1, *Hydrologic and Water Quality Modeling*. For SEWD and CSJWCD, supply side distribution loss factors are first calculated and then converted to demand side factors. From the SEWD Water Management Plan (WMP), the 2010 surface water supply was 118,216 AF (SEWD 2014: Section 5, Table 6), conveyance seepage was 7,136 AF (only includes losses for Calaveras and New Melones diversion systems [SEWD 2014: Section 5, Table 4]), and conveyance evaporation was 2,068 AF (includes evaporation losses and precipitation gains for Calaveras and New Melones diversion systems [SEWD 2014: Section 5, Table 4]). The supply side distribution loss factor is calculated as (7136+2,068)/118,216 = 0.078 and it is converted to a demand side factor by dividing it by 1 minus itself, 0.078/(1- 0.078) = 0.084. From the CSJWCD WMP the 2009 surface water supply was 31,957 AF (page 4, CSJWCD 2013), and the conveyance seepage was 7,500 AF (page 18, CSJWCD 2013). There was no estimate of conveyance evaporation. The supply side distribution loss factor is calculated as 7,500/31,957 = 0.23 and the demand side factor is, 0.23/(1- 0.23) = 0.31.

Table G.2-2. Distribution Losses as a Percent of Demand and Diversion

District	Demand Side Distribution Loss Factors (%)	Supply Side Distribution Loss Factors (%)	Source or Notes
SSJID	17	15	SSJID AWMP 2012
North OID	17	15	Assumed to be the same as SSJID
South OID	29	22	OID AWMP 2012
SEWD	8	8	SEWD WMP 2014
CSJWCD	31	23	CSJWCD WMP 2013
MID	5	5	MID AWMP 2012
TID	8	7	TID AWMP 2012
Merced ID	32	24	Merced ID AWMP 2013

Deep Percolation Factors for Applied Water

Deep percolation represents the portion of applied water that is not consumptively used and instead seeps into groundwater. Much like the demand side distribution loss factors, deep percolation factors (**PF**) represent deep percolation of applied water as a percent of consumptive use. The factors vary by district between 10 and 46 percent (Table G.2-3). These factors can be adjusted to provide supply side deep percolation factors, which represent the deep percolation as a percent of total applied water. These fractions are equal to **PF**/(1+**PF**) and vary between 9 and 32 percent. The factors for all districts except SEWD and CSJWCD are estimated based on information in the AWMPs, as shown in Appendix F.1, *Hydrologic and Water Quality Modeling*.

From the SEWD WMP, the 2010 crop water need was estimated at 127,575 AF (SEWD 2014: Section 5, Table 6), and the deep percolation from agricultural land was estimated at 12,965 AF (SEWD 2014: Section 5, Table 6). The demand side deep percolation factor is calculated as 12,965/127,575 = 0.10. The deep percolation factor for CSJWCD was assumed to be the same as SEWD, as there was not enough information in the CSJWCD WMP to calculate a district specific factor.

Table G.2-3. Field Losses to Deep Percolation as a Percent of Consumptive Use and Applied Water

District	Deep Percolation as Percent of Consumptive Use	Deep Percolation as Percent of Total Applied Water	Source
SSJID	28	22	SSJID AWMP 2012
North OID	19	16	OID AWMP 2012
South OID	19	16	OID AWMP 2012
SEWD/CSJWCD[a]	10	9	SEWD WMP 2014
MID	38	28	MID AWMP 2012
TID	46	32	TID AWMP 2012
Merced ID	25	20	Merced ID AWMP 2013

[a] The deep percolation factor for CSJWCD is assumed to be the same as for SEWD because CSJWCD WMP 2013 did not present the necessary information to calculate the district's own factor.

G.2.1.4 Crop Surface Water Demand

One of the primary values used in the WSE model, the groundwater assessment, and the agricultural assessment is the total consumptive use demand for each irrigation district, $\mathbf{C_{dem}}$, which is based on CALSIM II data. The estimates for $\mathbf{C_{dem}}$ are first used in the WSE model as part of the calculations for determining the diversion demand. The portion of the CUAW demand that is to be met by surface water, $\mathbf{C_{SWdem}}$, is a key value transferred from the WSE model to the post-processing analysis files for groundwater and agriculture. $\mathbf{C_{SWdem}}$, also referred to as the *crop surface water demand*, is defined for each irrigation district as:

$$\overbrace{C_{SWdem} = C_{dem} - MinGW * \left(1 - \left(\frac{PF}{1+PF}\right)\right)}^{for\ each\ district\ except\ SEWD\ and\ CSJWCD}$$

Where,

PF is the deep percolation factor for the district.

MinGW is the annual minimum groundwater pumping for the irrigation district. Multiplying **MinGW** by 1-(**PF**/(1+**PF**)) gives the portion of the **MinGW** that is used consumptively by the crops and does not percolate to groundwater.

The CUAW demand of SEWD and CSJWCD is calculated based on the contract with USBR. In total, up to 80 TAF/y can be diverted by CSJWCD, and up to 75 TAF/y can be diverted by SEWD. All of the contract diversions are assumed to be used for applied water demands and distribution losses, except for the first 10 TAF/y diverted by SEWD, which goes to municipal demands. Using the deep percolation and distribution loss factors given above, the annual CUAW demand for SEWD and CSJWCD to be met with Stanislaus River water are estimated at 54 TAF/y and 56 TAF/y, respectively.

G.2.1.5 Percent of Crop Surface Water Demand Met

The final parameter needed from the WSE model for input to the groundwater and agricultural post-processing spreadsheets is the percent of crop surface water demand met for each district. This is determined by distributing the total tributary diversions described above to each of the individual irrigation district demands. For all districts except SEWD and CSJWCD, the first step is to subtract district demands assumed to not be cut in times of shortage from the total non-CVP and non-riparian river diversion, $\mathbf{Div_T}$, where **T** is the tributary name. These *off-the-top demands* include the offstream reservoir losses (**ResLoss**), municipal and industrial demands (**M&I**), and return flows (**R**). In addition, on the Merced River, SOI deliveries met prior to the district demands (Merced NWR and Stevinson) must be subtracted as well. The equation is:

$$DivF_T = Div_T - \overbrace{\left(ResLoss + M\&I + R*(1+DF)\right)}^{for\ each\ district\ on\ tributary\ T} - \overbrace{(SOI_{NWR} + SOI_{Stev})*(1+DF)}^{Merced\ River\ only}$$

Note that return flows and SOI demands have distribution losses associated with them. This equation gives the total surface water diversion on tributary **T** for farm diversions, $\mathbf{DivF_{,T}}$. Farm diversions represent water diverted for applied water demand and associated distribution losses.

Farm diversions are then compared to the farm surface water demand for each irrigation district, $\mathbf{F_{SWdem}}$. For each irrigation district except SEWD and CSJWCD, farm surface water demand is calculated as:

$$\overbrace{F_{SWdem} = (C_{dem} * (1+PF) - MinGW)*(1+DF)}^{for\ each\ district\ except\ SEWD\ and\ CSJWCD}$$

Note that there are no distribution losses associated with groundwater pumping. When the total applied water demand ($\mathbf{C_{dem}}$*(1+**PF**)) is reduced by the minimum groundwater pumping, this also reduces the distribution losses that would have occurred if the demand was met entirely with surface water.

Finally, the percent of farm surface water demand met for tributary **T**, or $\mathbf{F_{\%SWmet,T}}$, is calculated as:

$$F_{\%\,SWmet\,,T} = \frac{DivF_T}{(Sum\ of\ all\ F_{SWdem}\ on\ tributary\ T)} * 100 = C_{\%\,SWmet\,,T}$$

Since farm diversion is just the CUAW multiplied by constant factors to account for deep percolation and distribution losses, the $\mathbf{F_{\%\,SWmet,T}}$ is equal to the percent of crop surface water demand met, $\mathbf{C_{\%SWmet,T}}$. Though $\mathbf{C_{\%SWmet,T}}$ is calculated for the tributary as a whole, it is assumed that any districts that share tributary **T** (SSJID and OID on the Stanislaus and MID and TID on the Tuolumne) will both have the same $\mathbf{C_{\%SWmet,T}}$ in any given year.

For SEWD and CSJWCD, the percent of crop surface water demand met is calculated after apportioning the total CVP diversion between them, as described above. $\mathbf{Div_{SEWD}}$ and $\mathbf{Div_{CSJWCD}}$ represent the total diversion to each of the contractors. The volume of these diversions that goes to consumptive use, $\mathbf{C_{met}}$, is calculated as:

$$\overbrace{C_{met\,,Z} = \left(\left(Div_Z - (M\&I_{SEWD}\ for\ SEWD\ only)\right)/\left((1 + PF_Z) * (1 + DF_Z)\right)\right)}^{Z = SEWD\ or\ CSJWCD}$$

The percent crop surface water demand met for contractor **Z,** $\mathbf{C_{\%SWmet,Z}}$**,** is $\mathbf{C_{met,Z}}$ divided by contractor **Z**'s crop surface water demand, $\mathbf{C_{dem}}$. Note that because the minimum groundwater pumping for the contractors is zero in this analysis, the crop surface water demand, $\mathbf{C_{SWdem}}$, equals the total crop demand, $\mathbf{C_{dem}}$.

G.2.2 Methodology for Calculating Applied Water

Once the above parameters are extracted from the WSE model, a spreadsheet is used to calculate impacts on groundwater and surface water use in the study area. The following steps are used in the calculation of total applied water, which is the total amount of surface water and groundwater applied to the crops by each of the irrigation districts.

G.2.2.1 Applied Water Demand

Applied water demand, $\mathbf{AW_{dem}}$, is the amount of water needed at the farm gate to meet crop consumptive use demands and account for deep percolation. Here $\mathbf{AW_{dem}}$ is calculated for district **D** using the following equation:

$$AW_{dem\,,D} = C_{SW\,dem\,,D} * (1 + PF_D) + MinGW_D$$

Where,

$\mathbf{C_{SWdem,D}}$ is district **D**'s crop surface water demand from the WSE model.

$\mathbf{PF_D}$ is district **D**'s deep percolation factor.

$\mathbf{MinGW_D}$ is district **D**'s minimum groundwater pumping.

G.2.2.2 Applied Surface Water

Applied surface water, **ASW**, is the portion of surface water diversions used to satisfy the applied water demand. **ASW** is calculated for district **D** using the following equation:

$$ASW_D = C_{SW\,dem\,,D} * C_{\%SW\,met\,,D} * (1 + PF_D)$$

Where,

$\mathbf{C_{\%SWmet,D}}$ is the percent of crop surface water demand met for district **D**.

G.2.2.3 Additional Groundwater Pumping

Additional groundwater pumping, or groundwater replacement pumping, refers to pumping performed, above the minimum required groundwater pumping, to replace surface water in times of shortage. If minimum groundwater pumping and applied surface water are sufficient to meet crop demand, then no additional groundwater pumping is needed, otherwise additional groundwater pumping is applied up to the maximum pumping amount, **MaxGW**. A high value for maximum groundwater pumping can reduce potential for agricultural impacts, but it increases the potential for groundwater impacts.

The demand for additional groundwater pumping was calculated for each irrigation district and each LSJR alternative. The additional groundwater pumping performed annually for district D, $\mathbf{AddGW_D}$, was calculated as either the remaining applied water demand after applying surface water and minimum groundwater pumping, or the difference between minimum and maximum groundwater pumping, whichever is smaller:

$$AddGW_D = MIN\left(\left(AW_{dem,D} - ASW_D - MinGW_D\right), \left(MaxGW_D - MinGW_D\right)\right)$$

Because baseline is representative of 2009 infrastructure, the primary groundwater analysis utilizes estimates of maximum groundwater pumping that were typical in 2009 (Table G.2-4). However, as a result of recent drought conditions, more wells have been drilled, and therefore an assessment using estimates of maximum groundwater pumping for 2014 is also discussed (Table G.2-4). Unless specified otherwise, results presented in this appendix were generated using the maximum groundwater pumping estimates for 2009 infrastructure.

Table G.2-4. Annual Maximum Groundwater Pumping Estimates for each Irrigation District

	Annual Maximum Groundwater Pumping (TAF/y)	
Irrigation District	2009 Estimate	2014 Estimate
SSJID	59	74
OID North[a]	17	28
OID South[a]	22	37
MID	28	139
TID	125	251
Merced ID	253	253
SEWD[b]	60	60
CSJWD[b]	61	61
In-District Total	626	903

TAF/y = thousand acre-feet per year

[a] Total OID maximum GW pumping estimates of 39.5 TAF/y for 2009 infrastructure and 64.3 TAF/y for 2014 infrastructure are divided between North and South OID based on the relative irrigated area of each.

[b] SEWD and CSJWD estimates are based on total replacement of CVP contract surface water supplies only (total 155 TAF), minus estimated conveyance losses (see text).

The 2009 values are the maximum annual district and private groundwater pumping estimates presented in each district's respective AWMP (SSJID 2012; OID 2012; MID 2012; TID 2012; Merced ID 2013), while the 2014 estimates primarily are sourced from the district's responses to the September information request letters (Rietkerk pers. comm.; Knell pers. comm.; Hashimoto pers. comm.; Salyer pers. comm.). All of the 2014 maximum groundwater pumping estimates are greater than the 2009 maximum groundwater estimates, except for Merced ID. The Merced ID information request response (Eltal pers. comm.) did not report an estimate of the district's groundwater pumping capacity; therefore, Merced ID is assumed to have the same GW pumping capacity in 2014 as in 2009. This is reasonable because Merced ID had well-developed groundwater pumping capabilities in 2009, and it is unlikely that they significantly increased their capacity within 5 years. The MID response letter reported district pumping capacity at 78 TAF/y but did not report an estimate of private pumping capacity within the district; therefore, the increase in private pumping capacity from 2009 to 2014 was estimated based on the private pumping increase in neighboring TID. As of 2014, TID had a private pumping capacity of 1.03 AF/acre (Hashimoto pers. comm.). Using the TID value of 1.03 AF/acre private capacity with the Modesto irrigated area of 58,611 acres (MID AWMP 2012) would be equivalent to 60.6 TAF/y of private pumping capacity for MID in 2014, resulting in a total maximum district plus private 2014 pumping capacity for MID of 138.6 TAF/y.

The SEWD and CSJWCD analysis focused only on the portion of the CVP contract delivery that could come from the Stanislaus River. The other water used by these districts would not be affected by the LSJR alternatives. If no Stanislaus River water is available to these districts, then it is assumed there would be enough groundwater pumping capacity to fully replace any lost surface water supply, which would be 60 and 61 TAF/y for SEWD and CSJWCD, respectively (full contract amount minus estimated distribution losses, and not including 10 TAF/y assumed to be minimum M&I delivery for SEWD, that would not be considered a part of crop demand).

G.2.2.4 Total Applied Water and Percent Crop Demand Satisfied

Applied water represents water applied to crops to satisfy CUAW demands and to account for deep percolation. Because groundwater pumping is generally applied directly to the crops, it is used entirely for applied water demands. The total applied water, $\mathbf{AW_{total}}$, is the sum of the minimum ground water pumping, applied surface water, and additional ground water pumping, as shown below:

$$AW_{total,D} = ASW_D + MinGW_D + AddGW_D$$

The total applied water is also compared to the total demand for applied water. The percent of applied water demand met annually, $\mathbf{AW_{\%met}}$, is calculated for each irrigation district and each alternative as:

$$AW_{\%met,D} = 100 * AW_{total,D} / AW_{dem,D}$$

These percentages are then passed to the SWAP model and used with the crop distribution information for the calibration year in SWAP (2010) to calculate how crop acreages would be affected in years with some level of scarcity. Crop distributions are discussed further in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*.

G.2.3 Estimates of Groundwater Use and Unmet Demand

The net impact of the LSJR alternatives in the form of reduced surface water availability to irrigation districts would be moderated by increased groundwater pumping. Knowledge of the current and future rates of groundwater pumping, therefore, are needed to determine the net water supply impact. In other words, groundwater pumping must be estimated to determine the overall unmet demand for agricultural water. Unmet demand is defined as a shortage of water supply to satisfy field crop applied water needs, after accounting for both surface water and groundwater supplies.

Table G.2-5 shows the likely increase in groundwater pumping within irrigation district boundaries, assuming 2009 annual groundwater pumping capacity estimates and no change in the assumed irrigation efficiencies of the irrigation districts. Based on this assumption, mean annual groundwater pumping is expected to increase by 21 TAF under LSJR Alternative 2, 105 TAF under LSJR Alternative 3, and 216 TAF under LSJR Alternative 4. Groundwater pumping increases are highest in below normal, dry and critically dry years, and lowest in wet and above normal years.

Table G.2-5. Annual Average In-District Groundwater Use Based on Estimated 2009 Groundwater Pumping Capacities

	Average Annual Groundwater Use					
	All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Total GW pumping capacity (TAF/y)	626	626	626	626	626	626
Baseline GW use (TAF)	260	185	203	228	221	485
LSJR Alt 2 (20% UF) GW use (TAF)	281	178	193	242	284	554
Increase over Baseline (TAF)[a]	21	-8	-10	15	63	69
LSJR Alt 3 (40% UF) GW use (TAF)	364	192	235	376	524	614
Increase over Baseline (TAF)[a]	105	6	32	149	302	129
LSJR Alt 4 (60% UF) GW use (TAF)	476	260	457	578	616	624
Increase over Baseline (TAF)[a]	216	75	254	350	395	139

GW = groundwater

TAF/y = thousand acre-feet per year

UF = unimpaired flow

[a] LSJR Alt 2/3/4 minus baseline may be different from increase due to rounding.

Table G.2-6 shows the change in mean annual in-district unmet applied water demand after accounting for the surface water diversions and groundwater pumping based on estimated 2009 pumping capacities. The mean annual baseline unmet demand for all year types is 45 TAF/y. Most of the unmet demand occurs in critically dry years, with some also in dry years—the mean annual baseline unmet demand in critically dry years is 224 TAF/y. Under LSJR Alternatives 2, 3, and 4 the mean annual unmet demand for all year types increases by 29, 137, and 360 TAF/y, respectively, compared to baseline. For the LSJR alternatives, most of the unmet demand occurs in dry and critically dry years, but for LSJR Alternatives 3 and 4, all year types see greater unmet demand.

Table G.2-6. Annual Average In-District Applied Water Demand, Groundwater Pumping, and Unmet Demand Based on Estimated 2009 Groundwater Pumping Capacities

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Baseline and LSJR Alternatives		Total Applied Water Demand (TAF)	1,604	1,483	1,565	1,643	1,696	1,720
Baseline	Surface Water Supply	Baseline Applied Surface Water (TAF)	1,300	1,298	1,362	1,415	1,465	1,011
	Baseline GW pumping (2009 Max)	Baseline GW Pumping (TAF)	260	185	203	228	221	485
		Baseline Unmet Demand (TAF)	45	0	0	0	9	224
		Baseline Unmet Demand (%)	3%	0%	0%	0%	1%	13%
LSJR Alternative 2	Surface Water Supply	Alt. 2 Applied Surface Water (TAF)	1,249	1,305	1,372	1,396	1393	803
	With additional GW pumping (2009 Max)	Alt. 2 GW Pumping (TAF)	281	178	193	242	284	554
		Alt. 2 Unmet Demand (TAF)	75	0	0	5	19	363
		Alt. 2 Unmet Demand (%)	5%	0%	0%	0%	1%	21%
		Alt. 2 Increase in Unmet Demand from Baseline (TAF)	29	0	0	5	10	139
LSJR Alternative 3	Surface Water Supply	Alt. 3 Applied Surface Water (TAF)	1,058	1,287	1,293	1,163	943	489
	With additional GW pumping (2009 Max)	Alt. 3 GW Pumping (TAF)	364	192	235	376	524	614
		Alt. 3 Unmet Demand (TAF)	182	4	37	104	230	618
		Alt. 3 Unmet Demand (%)	11%	0%	2%	6%	14%	36%
		Alt. 3 Increase in Unmet Demand from Baseline (TAF)	137	4	37	104	221	394
LSJR Alternative 4	Surface Water Supply	Alt. 4 Applied Surface Water (TAF)	723	1,180	890	632	409	201
	With additional GW pumping (2009 Max)	Alt. 4 GW Pumping (TAF)	476	260	457	578	616	624
		Alt. 4 Unmet Demand (TAF)	405	43	218	433	671	896
		Alt. 4 Unmet Demand (%)	25%	3%	14%	26%	40%	52%
		Alt. 4 Increase in Unmet Demand from Baseline (TAF)	360	43	218	433	661	672

The recent drought has provided insight into how groundwater pumping may increase in response to surface water supply shortages. In the last few years, groundwater pumping capacity and utilization has increased to historically high levels. Table G.2-7 shows that groundwater pumping would be greater under baseline and the LSJR alternatives when applying the 2014 annual groundwater pumping capacity estimates instead of the 2009 estimates. Mean annual in-district groundwater pumping under baseline conditions for all year types is 30 TAF higher with the 2014 pumping capacity estimates compared to 2009 levels (290 TAF versus 260 TAF). Under LSJR Alternatives 2,3, and 4 the mean annual groundwater pumping in all year types increases by 32, 172, and 357 TAF/y, respectively, over baseline conditions. Most of the groundwater pumping occurs in below normal, dry, and critically dry years, but under LSJR Alternative 4, above normal years also have high groundwater use.

Table G.2-7. Annual Average In-District Groundwater Use Based on Estimated 2014 Groundwater Pumping Capacities

	Average Annual Groundwater Use					
	All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Total GW pumping capacity (TAF/y)	903	903	903	903	903	903
Baseline GW use (TAF)	290	185	203	228	231	633
LSJR Alt 2 (20% UF) GW use (TAF)	322	178	193	247	302	742
Increase over Baseline (TAF)[a]	32	-8	-10	20	71	110
LSJR Alt 3 (40% UF) GW use (TAF)	462	194	259	460	690	883
Increase over Baseline (TAF)[a]	172	9	56	233	460	250
LSJR Alt 4 (60% UF) GW use (TAF)	647	283	600	826	890	901
Increase over Baseline (TAF)[a]	357	97	397	598	659	268

GW = groundwater

TAF/y = thousand acre-feet per year

UF = unimpaired flow

[a] LSJR Alt 2/3/4 minus baseline may be different from increase due to rounding.

Table G.2-8 shows the change in mean annual unmet in-district water demand after taking into account the substitution of reduced surface water with additional groundwater pumping based on estimated 2014 pumping capacities. The mean annual baseline unmet demand is 15 TAF, which is 30 TAF/y lower than mean annual baseline unmet demand using estimated 2009 pumping capacities. Under baseline conditions, demands can be fully satisfied in all year types except critically dry years, when unmet demand averages about 76 TAF/y. When compared to baseline, the mean annual unmet demand increases by 19 TAF/y in LSJR Alternative 2, by 69 TAF/y in LSJR Alternative 3, and by 219 TAF/y in LSJR Alternative 4. For the LSJR alternatives, most of the unmet demand occurs in dry and critically dry years, but for LSJR Alternatives 3 and 4, all year types see greater unmet demand.

Table G.2-8. Annual Average In-District Applied Water Demand, Groundwater Pumping, and Unmet Demand Based on Estimated 2014 Groundwater Pumping Capacities

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Baseline and LSJR Alternatives		Total Applied Water Demand (TAF)	1,604	1,483	1,565	1,643	1,696	1,720
Baseline	Surface Water Supply	Baseline Applied Surface Water (TAF)	1,300	1,298	1,362	1,415	1,465	1,011
	Baseline GW pumping (2009 Max)	Baseline GW Pumping (TAF)	290	185	203	228	231	633
		Baseline Unmet Demand (TAF)	15	0	0	0	0	76
		Baseline Unmet Demand (%)	1%	0%	0%	0%	0%	4%
LSJR Alternative 2	Surface Water Supply	Alt. 2 Applied Surface Water (TAF)	1,249	1,305	1,372	1,396	1393	803
	With additional GW	Alt. 2 GW Pumping (TAF)	322	178	193	247	302	742
		Alt. 2 Unmet Demand (TAF)	34	0	0	0	1	175

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
	pumping (2009 Max)	Alt. 2 Unmet Demand (%)	2%	0%	0%	0%	0%	10%
		Alt. 2 Increase in Unmet Demand from Baseline (TAF)	19	0	0	0	1	98
LSJR Alternative 3	Surface Water Supply	Alt. 3 Applied Surface Water (TAF)	1,058	1,287	1,293	1,163	943	489
	With additional GW pumping (2009 Max)	Alt. 3 GW Pumping (TAF)	462	194	259	460	690	883
		Alt. 3 Unmet Demand (TAF)	84	2	13	20	63	349
		Alt. 3 Unmet Demand (%)	5%	0%	1%	1%	4%	20%
		Alt. 3 Increase in Unmet Demand from Baseline (TAF)	69	2	13	20	63	273
LSJR Alternative 4	Surface Water Supply	Alt. 4 Applied Surface Water (TAF)	723	1,180	890	632	409	201
	With additional GW pumping (2009 Max)	Alt. 4 GW Pumping (TAF)	647	283	600	826	890	901
		Alt. 4 Unmet Demand (TAF)	234	21	75	185	397	619
		Alt. 4 Unmet Demand (%)	15%	1%	5%	11%	23%	36%
		Alt. 4 Increase in Unmet Demand from Baseline (TAF)	219	21	75	185	397	543

These results show the sensitivity of the calculation of unmet demand to assumed levels of groundwater pumping. With higher groundwater pumping, the severity of water shortages can be reduced, but this also puts greater strain on groundwater supplies. Whether such increased levels can be maintained over the long term has not been determined. The estimated 2009 pumping capacities, therefore, are used to determine the economic impacts of reduced overall water supply, with the understanding that higher pumping capacities may be possible for a limited time in some areas.

G.2.4 Estimates of Total Applied Water

Figures G.2-1A through G.2-1D show the annual allocation of surface water diversions to meet the various demands on each tributary for baseline and each LSJR alternative, with the combination of "CUAW-SW" and "Applied SW Percolation" representing applied surface water. Municipal supplies, riparian diversions, and regulating reservoir losses remain relatively unchanged from year to year and between alternatives. Applied surface water, applied surface water percolation, distribution system percolation, and distribution system evaporation vary as a function of annual surface water allocation. Operational spills and return flows are held fixed between alternatives, with some annual variation inherent in the CALSIM estimates also used in the WSE model.

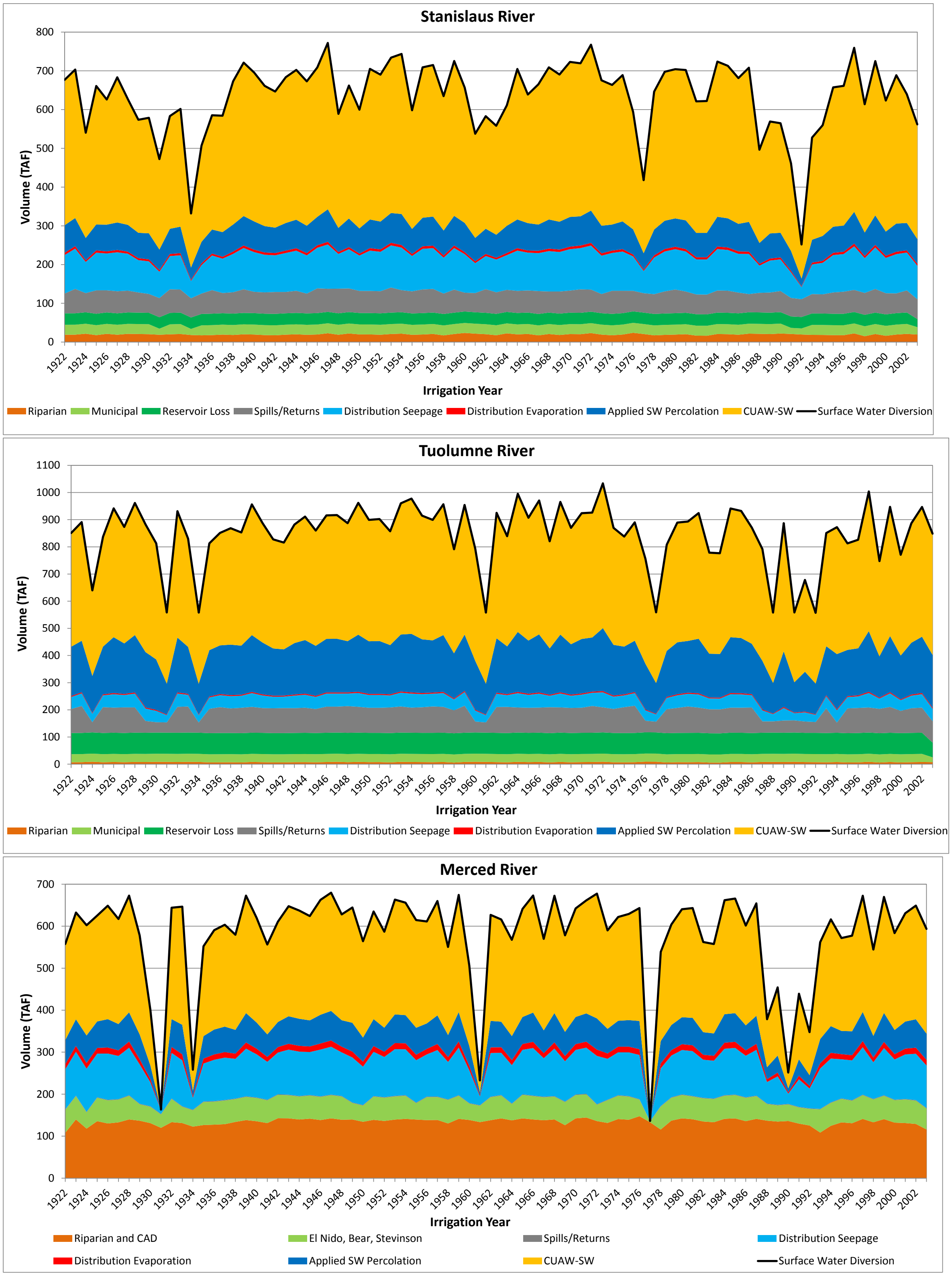


Figure G.2-1A. Partitioning of Baseline Diversions into End Uses

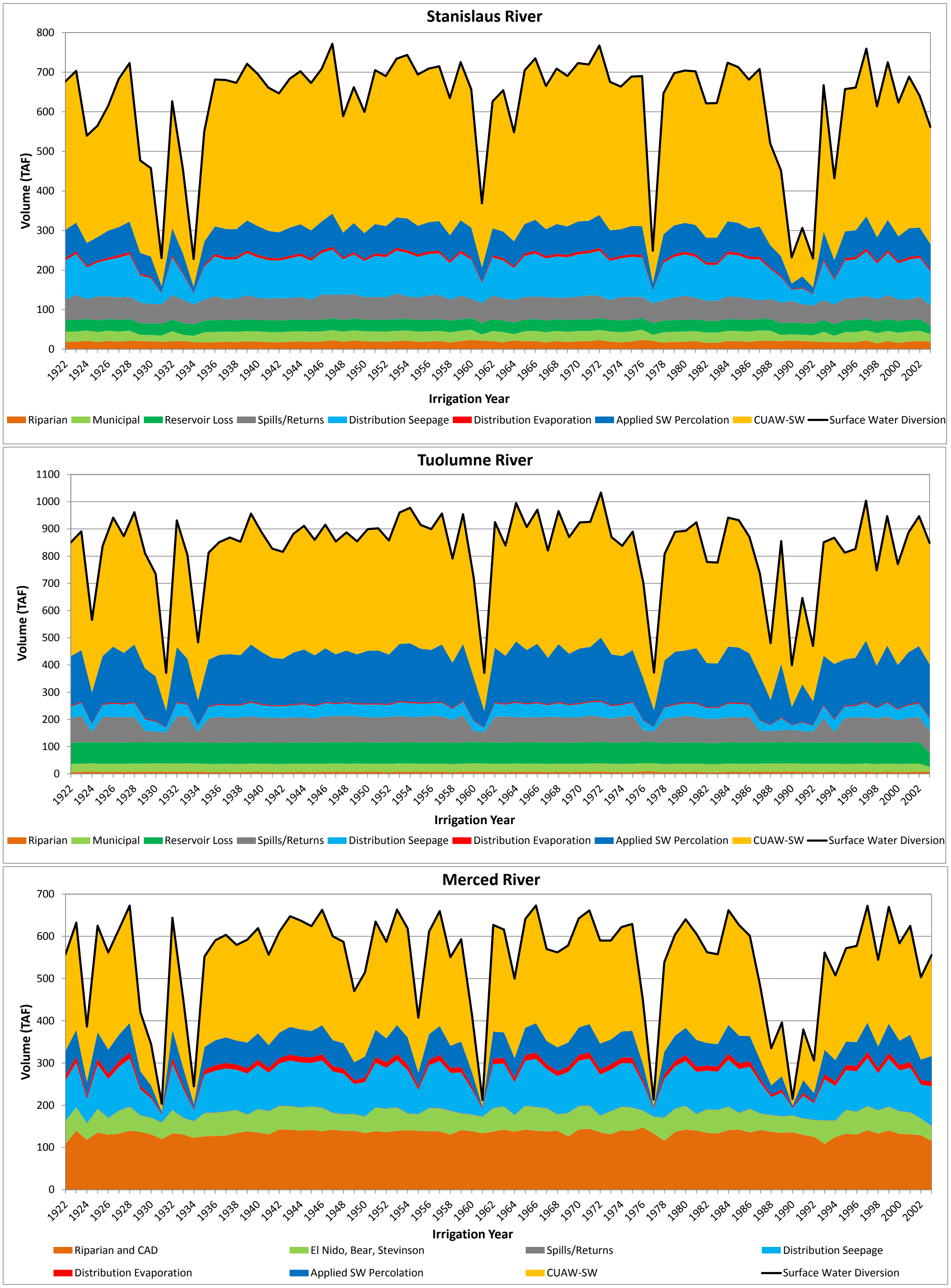


Figure G.2-1B. Partitioning of LSJR Alternative 2 Diversions into End Uses

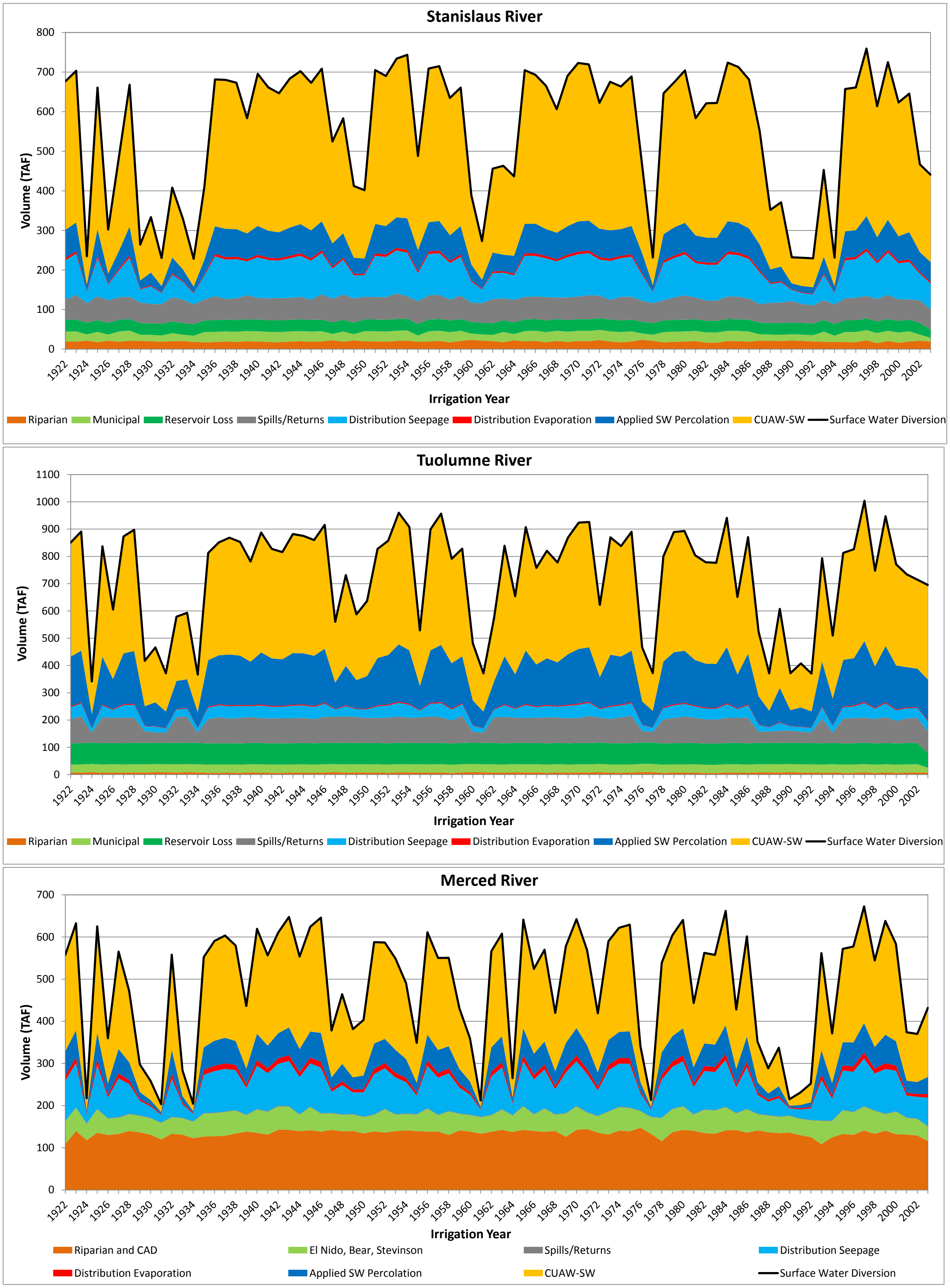
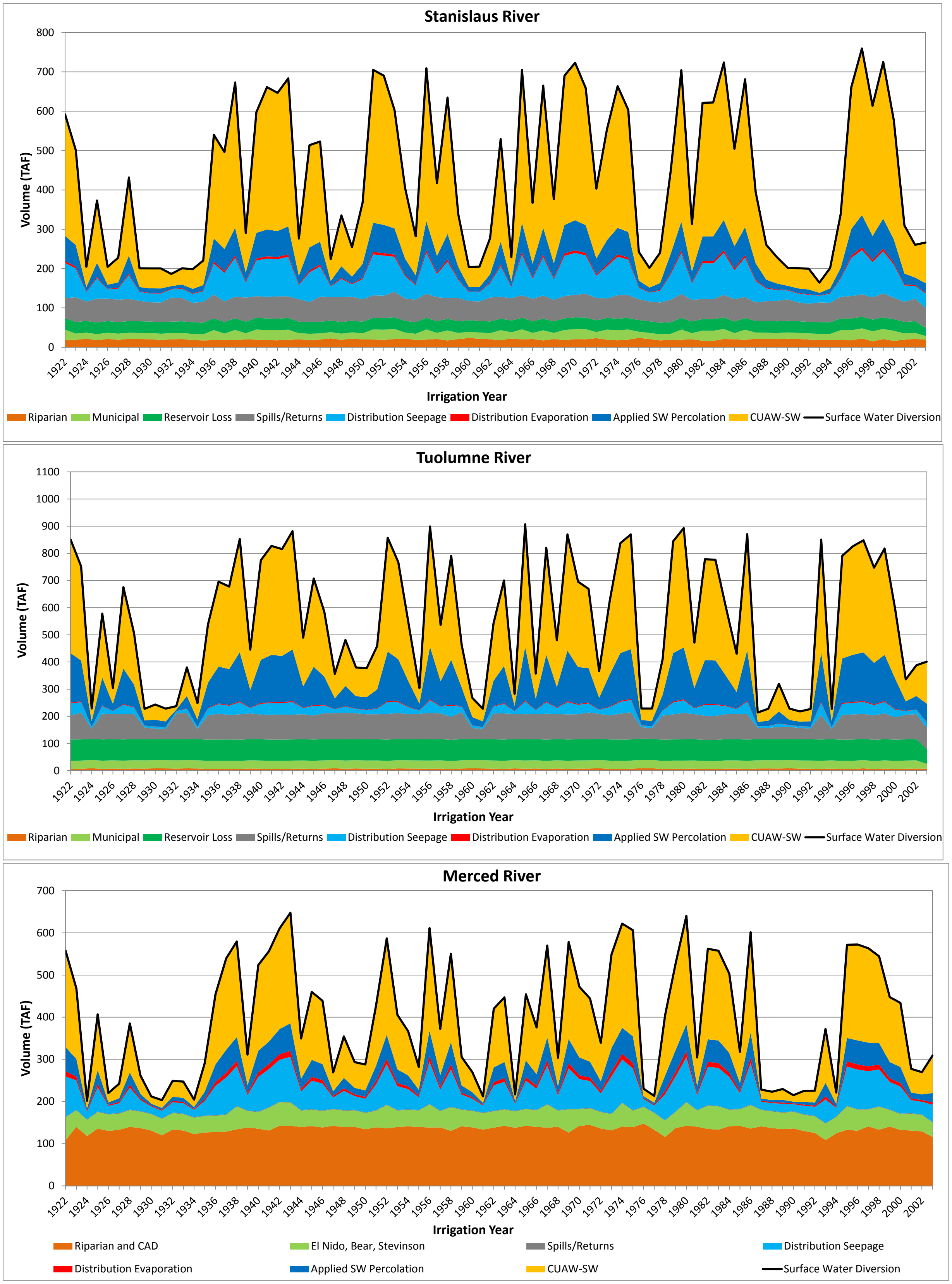


Figure G.2-1C. Partitioning of LSJR Alternative 3 Diversions into End Uses


Stanislaus River

Tuolumne River

Merced River

Figure G.2-1D. Partitioning of LSJR Alternative 4 Diversions into End Uses

On the Stanislaus and Tuolumne Rivers, average annual applied water deliveries to the districts account for over 50 percent of the average annual surface water diversions for each of the LSJR alternatives and baseline. On the Merced River, the average annual applied water deliveries to Merced ID account for between 40 and 50 percent of the average annual surface water diversions for each of the LSJR alternatives and baseline. However, this does not include the portion of riparian diversions used for applied water, which is especially significant on the Merced because more than 100 TAF/y goes to Cowell Agreement diversions and other riparian users. On the Stanislaus and Tuolumne Rivers, water use by holders of riparian water rights is relatively small.

As the percent of unimpaired flow used for instream flow requirements increases from LSJR Alternative 2 to LSJR Alternative 4, the amount of water available for diversions becomes progressively smaller, as does the distribution system seepage, CUAW supplied by surface water, and percolation from applied water. Furthermore, because some end uses do not vary between the alternatives (i.e., riparian diversions, municipal and industrial water use, spills, and offstream reservoir losses), the percent decrease in CUAW, and deep percolation is greater than the percent decrease in total diversions. However, even under LSJR Alternative 4, on average approximately 30–50 percent of diversions goes to CUAW (depending on the river). However, with this alternative, the year-to-year variations in applied water are very large, with some large shortages occurring in years that had almost full water supply under baseline conditions.

In years with low water supply, surface water diversions are not sufficient to meet full agricultural demand for applied surface water (i.e., total demand for CUAW and deep percolation that is not met by minimum groundwater pumping). As a result, groundwater pumping increases. However, even under baseline conditions, there are some years when increased groundwater pumping will not be enough to fully mitigate surface water shortages for the agricultural demands of the irrigation districts (Figure G.2-2A). The capacity of each irrigation district to pump groundwater varies and depends on existing infrastructure. Capacity for increased groundwater pumping (2009 values) by Merced ID is almost sufficient to meet full demand in drought years. There is moderate capacity to compensate for a reduction in surface water supply on the Stanislaus River, but this comes largely from SEWD and CSJWCD, which can fully compensate for a reduction in their Stanislaus River supply. In contrast, SSJID and OID have only a limited ability to increase groundwater pumping because their surface water supply has historically been reliable and they have not needed to increase their groundwater pumping capacity. The irrigation districts that get their water from the Tuolumne River, TID and MID, similarly have limited ability to increase groundwater pumping (Table G.2-4).

Most of the applied water for the irrigation districts comes from surface water. Under baseline conditions, almost all of the demand for applied water is met with surface water and minimum groundwater pumping, but there is a small to moderate amount of supplemental groundwater pumping during dry years (Figure G.2-2A). As the required percent of unimpaired flow increases for the LSJR alternatives, the amount of surface water available for crop application decreases, (Figures G.2-2B, G.2-2C, and G.2-2D). Much of the deficit in surface water diversions from the Stanislaus and Merced Rivers can be compensated by increased groundwater pumping by SEWD, CSJWCD, and Merced ID, but there is little compensation for deficits in surface water diversions from the Tuolumne River.

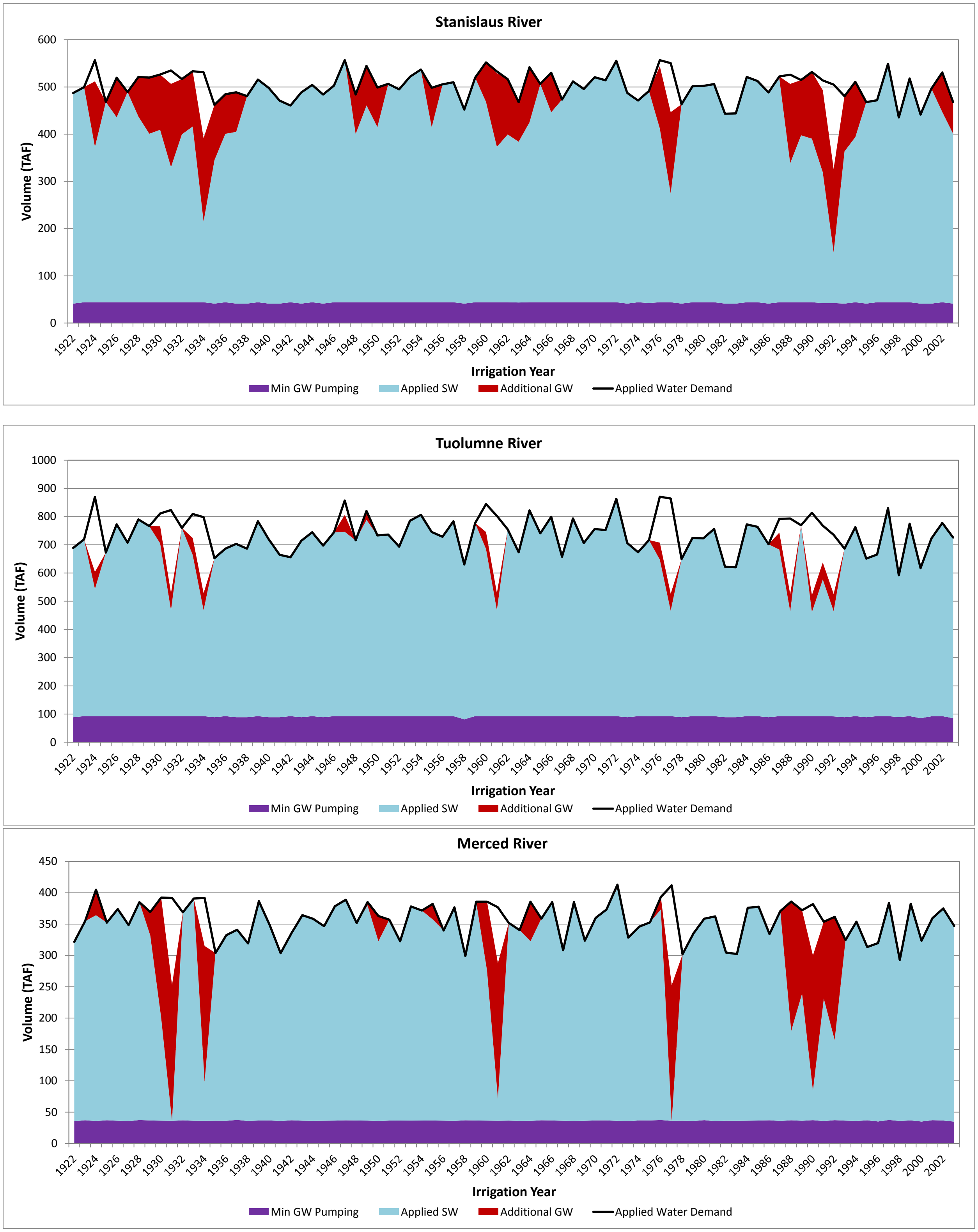


Figure G.2-2A. Baseline Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers

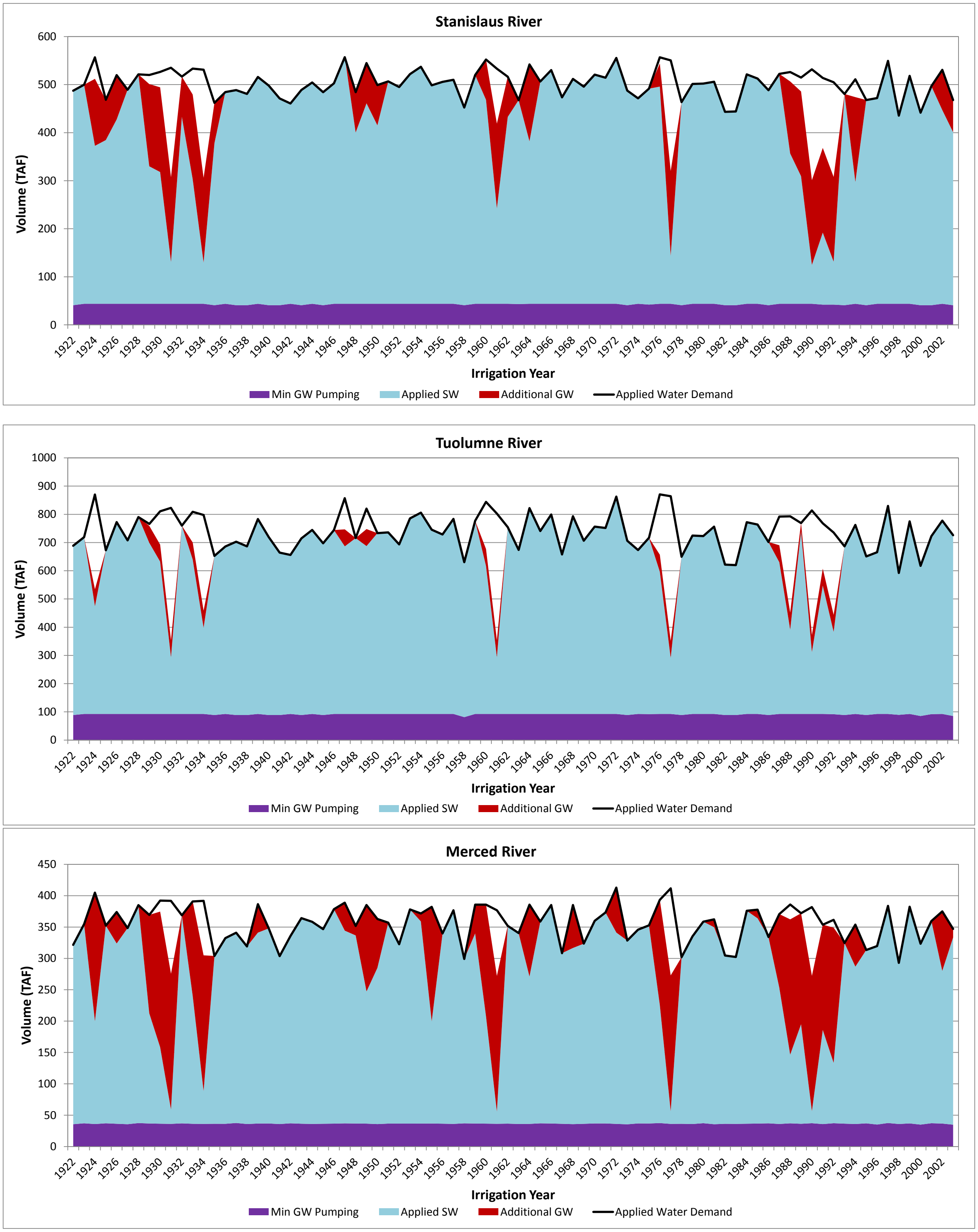


Figure G.2-2B. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 2

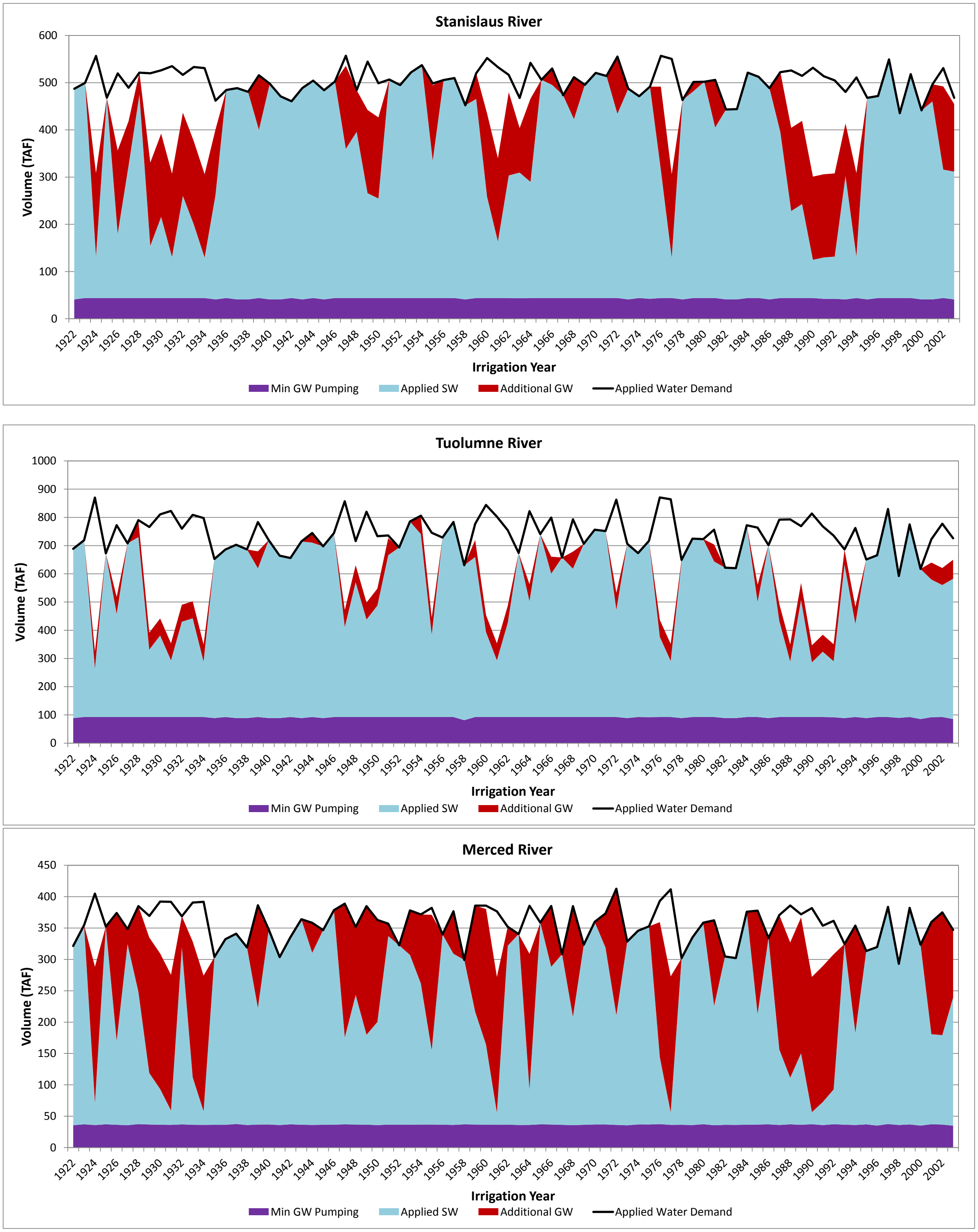


Figure G.2-2C. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 3

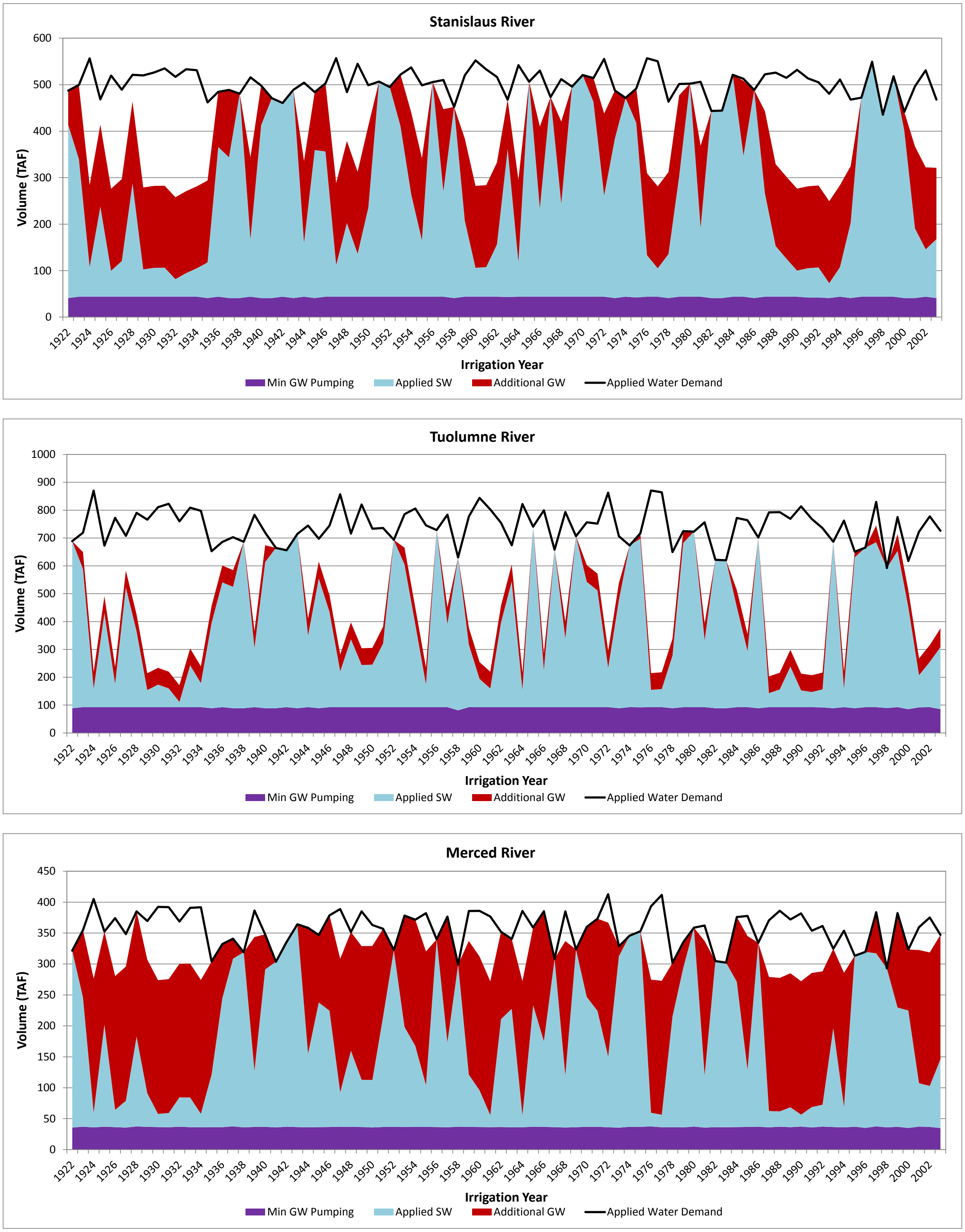


Figure G.2-2D. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 4

The results for applied surface water deficit are separated by irrigation district in Table G.2-9, pre-groundwater replacement, and Table G.2-10, post-groundwater replacement (2009 maximum groundwater pumping). The deficit in applied surface water ranges from an average total for all irrigations districts of 134 TAF/y for baseline conditions to a total of 709 TAF/y under LSJR Alternative 4. This represents 9 percent and 50 percent of the total annual demand for applied surface water for baseline and LSJR Alternative 4, respectively. When additional groundwater pumping is considered, the deficit in average total applied water drops from 134 TAF/y to 48 TAF/y under baseline, and drops from 709 TAF/y to 413 TAF/y under LSJR Alternative 4, which reduces the total average percent deficit in surface water demand to 3 percent for baseline and 29 percent for LSJR Alternative 4.If the additional groundwater pumping is based on 2014 infrastructure capacity, the average annual percent deficit in applied surface water demand of all district decreases from 3 percent to 1 percent for baseline and from 29 percent to 17 percent for LSJR Alternative 4 (Table G.2-11).

Table G.2-9. Average Annual Applied Surface Water Deficit Pre-Groundwater Replacement

Irrigation District	Applied Surface Water Deficit				Change from Baseline		
	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	5	13	28	57	7	22	52
OID	7	17	37	78	10	30	70
SEWD	24	19	26	42	-5	2	18
CSJWCD	17	14	25	41	-3	8	24
MID	14	20	49	101	6	34	87
TID	32	45	108	224	13	76	192
Merced ID	34	58	102	167	23	67	132
All Districts	134	185	375	709	51	241	575
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	4	9	20	40	5	16	36
OID	4	9	19	39	5	15	36
SEWD	40	32	44	71	-9	4	31
CSJWCD	28	22	40	68	-5	13	40
MID	7	10	24	50	3	17	43
TID	7	10	24	50	3	17	43
Merced ID	11	18	32	52	7	21	41
All Districts	9	13	26	50	4	17	40

Table G.2-10. Average Annual Applied Surface Water Deficit Post-Groundwater Replacement (2009 Maximum Groundwater Pumping)

	Applied Surface Water Deficit				Change from Baseline		
Irrigation District	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	2	7	16	37	5	14	36
OID	5	13	30	65	8	25	60
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	11	17	41	89	5	30	78
TID	23	35	86	190	12	63	167
Merced ID	7	7	15	31	1	8	25
All Districts	48	79	187	413	31	139	365
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	1	5	11	26	3	10	25
OID	2	7	15	33	4	13	30
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	5	8	20	44	3	15	38
TID	5	8	19	43	3	14	37
Merced ID	2	2	5	10	0	2	8
All Districts	3	6	13	29	2	10	25

Table G.2-11. Average Annual Applied Surface Water Deficit Post-Groundwater Replacement (2014 Maximum Groundwater Pumping)

	Applied Surface Water Deficit				Change from Baseline		
Irrigation District	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	1	5	11	29	4	10	28
OID	3	9	21	51	6	18	48
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	0	2	4	23	2	4	23
TID	6	14	38	108	8	32	102
Merced ID	7	7	15	31	1	8	25
All Districts	17	38	89	242	21	72	226
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	1	4	8	21	3	7	20
OID	1	4	11	26	3	9	24
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	0	1	2	11	1	2	11
TID	1	3	8	24	2	7	23
Merced ID	2	2	5	10	0	2	8
All Districts	1	3	6	17	1	5	16

G.3 Estimation of Groundwater Balance

G.3.1 Methodology for Estimating Change in Groundwater Recharge

The LSJR alternatives would likely cause changes in groundwater recharge and groundwater pumping in the four groundwater subbasins (the Eastern San Joaquin, Modesto, Turlock, and Merced) that underlie the surface water delivery areas from the three eastside tributaries (the Stanislaus, Tuolumne, and Merced Rivers) (Figure G.3-1). In addition, a portion of the Merced ID delivery area (El Nido) overlies the northern portion of the Chowchilla Subbasin. Consequently, the small part of the Chowchilla Subbasin that is north of the Chowchilla River has been combined with the Merced Subbasin to form an “Extended” Merced Subbasin to avoid diluting some Merced ID groundwater effects into the entirety of the Chowchilla Subbasin, which will be largely unaffected.

A groundwater subbasin can be used sustainably as a water source if the average annual water balance is not negative. The inflows to the basin (recharge) may be from adjacent subbasins; from overlying rivers and streams; or from infiltration from rainfall, irrigation canals, reservoirs, and water applied to crops (i.e., applied water). The outflows from the subbasin are predominantly pumping from wells by irrigation districts, municipalities, or individual users for irrigating crops or as potable water sources, but outflows can also include seepage to springs and rivers when the groundwater elevation is higher than the surface water. Figure G.3-2 depicts a conceptual water budget with various inflows and outflows.

In order to assess the effect of the LSJR alternatives on groundwater, groundwater in the four subbasins was considered to be four separate pools of water with no separation between shallow and deep aquifers. However, groundwater can move slowly between subbasins and there may be differences in effects between shallow (semi-confined) and deep (confined) sections of the aquifer. To the extent that water moves between subbasins, some of the groundwater impacts could have slight effects on adjoining subbasins, which would reduce the effects within the subbasins of concern. In some areas, deeper sections of the aquifer may be separated from shallower sections by substrate with low permeability. The evaluation of groundwater effects was not separated by depth because (1) there is some connectivity between the different depths, and (2) increased groundwater pumping would occur in both shallow and deep wells. Substrate with low permeability (e.g., the Corcoran Clay at the western side of the four subbasins) might slow the interaction between deeper confined and shallower unconfined sections of the aquifer, but water pumped from a deeper confined section of the aquifer would eventually be replaced by water from above or from the edges. Furthermore, within the four subbasins, the number of deep and shallow wells is too large to feasibly assign pumping increases to separate sections of the aquifer. The simplifying assumptions of separating the aquifers by subbasin and not depth are acceptable because the purpose of the analysis is to estimate the average effect of the LSJR alternatives on the subbasins as a whole, not effects at specific well locations.

To evaluate potential groundwater effects, all components of the groundwater balance that potentially could be altered by the LSJR alternatives were evaluated. All of these components are related to irrigation district operations. The annual net contribution of irrigation district water to the groundwater subbasins was calculated by summing the offstream reservoir seepage, conveyance losses, and deep percolation from irrigated lands and subtracting total groundwater pumping for each irrigation district overlying the subbasin. For shorthand, this groundwater balance is referred to as the *irrigation district groundwater balance*.

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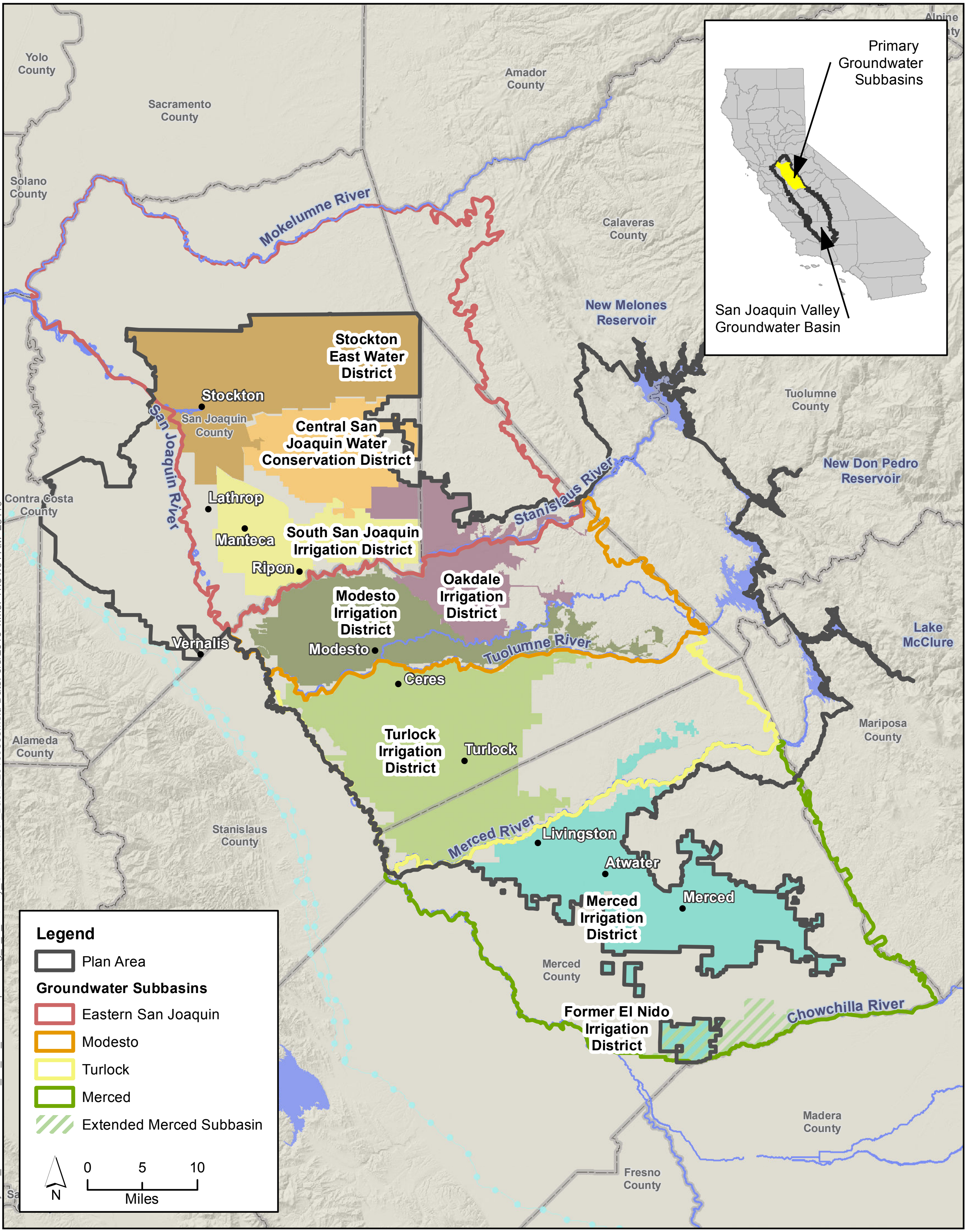

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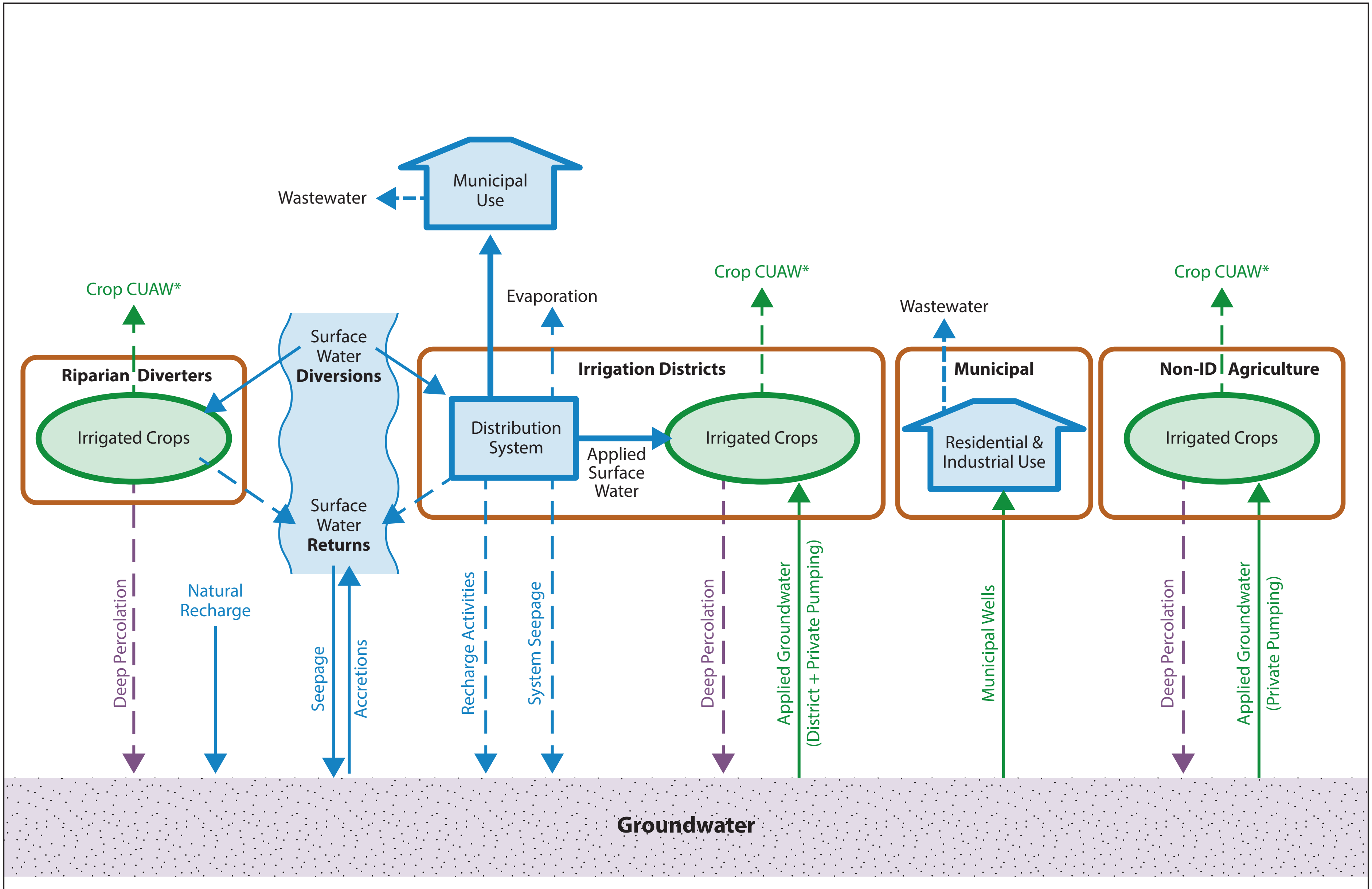
Figure G.3-1
Vicinity Map of Groundwater Subbasins



* CUAW = Consumptive Use of Applied Water

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Figure G.3-2
Conceptual Water Budget

For SEWD and CSJWCD, only the portion of their water use that could be affected by water supply from the Stanislaus River was included in the analysis. Two of the irrigation districts, OID and Merced ID, affect the results for two subbasins because their service area boundaries are not confined to a single subbasin; the OID service area is above Eastern San Joaquin and Modesto Subbasins, and the Merced ID service area is above the Turlock and Extended Merced Subbasins. Based on GIS mapping, the OID irrigated land was divided with 43 percent of the total assumed to be north of the Stanislaus River (in the Eastern San Joaquin Subbasin) and 57 percent of the total assumed to be south of the Stanislaus River (in the Modesto Subbasin)(OID 2012). Based on information in the Turlock GWMP (Turlock Groundwater Basin Association 2008) and the Merced AWMP (2013), Merced ID was divided with 5 percent of the irrigated acres assumed to be north of the Merced River (in the Turlock Subbasin) and 95 percent south of the Merced River (in the extended Merced Subbasin).

If the irrigation districts were able to use groundwater to fully replace any surface water shortage, then the effect of the LSJR alternatives on groundwater would approximately be equal to the decrease in river diversions (with a minor difference due to evaporation from the distribution system). If the irrigation districts had no ability to use groundwater to compensate for a reduction in surface water supply, then the effect of the LSJR alternatives on groundwater would be equal to the reduction in percolation from the distribution system plus the reduction in percolation from applied water. Because the irrigation districts have some ability to replace reductions in surface water supply with groundwater, the effect of the LSJR alternatives on groundwater is intermediate between the reduction in diversion and the reduction in percolation.

Net change in the groundwater balance associated with the different LSJR alternatives was calculated by comparing the irrigation district groundwater balance for the LSJR alternatives with the irrigation district groundwater balance for baseline conditions. The average annual LSJR alternative-related change in the groundwater balance was then compared to the total surface area of the groundwater subbasin. This metric was used in the impact analysis described in Chapter 9, *Groundwater Resources*.

G.3.2 Subbasin Groundwater Pumping and Recharge from Areas Outside of Irrigation Districts

Agricultural groundwater pumping outside of the irrigation districts, but within the subbasins, was estimated in order to provide perspective on the full groundwater effect of irrigation district pumping. Agricultural land outside of the irrigation districts is irrigated almost entirely with groundwater. Agricultural water demand for irrigated lands outside of the irrigation districts was estimated by multiplying estimates of applied water rates for different crop types by the number of acres of each crop type. The groundwater pumping in these areas remains relatively constant during droughts because crop demands are generally met with groundwater regardless of how much surface water is available (although crop demands may be somewhat greater during drought years, especially if spring conditions were dry).

Total irrigated acres outside of the irrigation districts was estimated by using geographic information systems (GIS) software to analyze DWR's agricultural land survey that is available as GIS coverages for each of DWR's Detailed Analysis Units (DAUs). DWR organizes its DAU data by county. DAU data from the following three counties were used: San Joaquin County (data were from 1996), Stanislaus County (data were from 2004), and Merced County (data were from 2002).

Irrigated acres within the irrigation districts were excluded. The irrigated acres for each subbasin were then subdivided into acres for each of the top 20 most common crops based on DWR data for the distribution of crops in DAU 182 (Eastern San Joaquin Subbasin), DAU 207 (Modesto Subbasin), DAU 209 (Turlock Subbasin), and DAUs 211 and 212 (Merced Subbasin) (Table G.3-1). The total irrigated acres outside of the irrigation districts is 204,634 acres in the Eastern San Joaquin Subbasin, 26,675 acres in the Modesto Subbasin, 117,759 acres in the Turlock Subbasin, and 182,363 acres in the Merced Subbasin. The acreage for each type of crop outside of the irrigation districts was then multiplied by the average estimate for applied water needed for that particular type of crop in terms of feet per irrigation season (i.e., AF/acre per irrigation season) (Table G.3-1).

Table G.3-1. Percent of Crop Acres Relative to Total Crop Area and Applied Water Rates for Areas Outside Irrigation Districts

Groundwater Subbasin	Eastern San Joaquin		Modesto		Turlock		Merced	
DAU	182		207		209		211 and 212	
	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate
Crop Category:	%	AF/ac	%	AF/ac	%	AF/ac	%	AF/ac
Alfalfa	5	4.6	0	NA	2	4.3	20	4.3
Almond/Pist	1	3.4	58	3.3	64	3.2	17	3.2
Corn	11	2.5	2	2.5	8	2.4	21	2.6
Cotton	0	NA	0	NA	0	NA	5	3.2
Cucurbits	1	1.8	0	NA	0	NA	0	1.5
Dry Beans	2	2.3	0	NA	0	2.2	0	2.2
Grain	5	0.3	0	1.0	1	1.0	4	0.9
Onion And Garlic	0	1.5	0	NA	0	NA	0	NA
Other Deciduous	27	3.4	7	3.5	3	3.5	1	3.4
Other Field	1	3.2	11	2.4	5	2.3	7	2.5
Other Truck	1	3.0	4	1.0	5	1.1	6	1.1
Pasture	4	4.9	11	4.0	4	4.3	8	4.4
Potato	0	NA	0	NA	0	NA	0	NA
Rice	1	5.3	0	NA	0	NA	0	5.7
Safflower	0	1.1	0	NA	0	NA	0	NA
Subtropical	0	3.0	0	NA	0	NA	0	2.8
Sugar Beets	0	NA	0	NA	0	NA	0	NA
Tomato, Fresh	1	2.1	0	NA	0	NA	2	1.6
Tomato, Processing	6	2.8	0	NA	0	NA	6	2.5
Vine	35	0.9	7	2.3	7	2.3	2	2.4

Source: DWR 2010b.
NA = Not Applicable, which means that the crop is not grown in this particular DAU
AF/ac = Acre-foot per acre (for an irrigation season)

Total applied water demand for irrigated areas outside of the irrigation districts in the four groundwater basins is estimated to be 476 TAF/y in the Eastern San Joaquin Subbasin, 83 TAF/y in the Modesto Subbasin, 351 TAF/y in the Turlock Subbasin, and 556 TAF/y in the Merced Subbasin. It is assumed that most of the irrigated land outside of the irrigation districts is irrigated with pumped groundwater and all demands are met. However, these estimates of groundwater pumping outside of the irrigation districts may be slightly high because some surface water may be available to these areas (e.g., Mokelumne River water for North SJWCD, Merced ID deliveries to land outside the ID, and surface water diversions by riparian users along the three eastside tributaries). Within the Eastern San Joaquin Subbasin, 13,000 acres of Woodbridge ID[5] is supplied with surface water from the Mokelumne River (San Joaquin County Department of Public Works 2004). Using an average applied water rate of 476,000 AF/204,634 acres = 2.32 AF/acre for non-district areas in the Eastern San Joaquin Subbasin the applied water demand for Woodbridge is about 30 TAF/y. This demand is subtracted from the computation of groundwater pumping for areas outside of the irrigation districts.

In addition, some municipal groundwater demands based on DWR Bulletin 118 (DWR 2003a, 2003b, 2003c, 2003d, 2003e) are included for each of the subbasins. The municipal demands account for 47 TAF/y in the Eastern San Joaquin Subbasin, 81 TAF/y in the Modesto Subbasin, 65 TAF/y in the Turlock Subbasin, and 54 TAF/y in the Merced Subbasin.

Unfortunately, calculating groundwater recharge from agricultural land outside the irrigation districts is difficult, as water use data for these areas is limited. Therefore, to estimate percolation to groundwater, average supply side deep percolation factors are calculated for each subbasin based on the in-district areas of each subbasin. These factors represent deep percolation as a percent of applied water in each groundwater subbasin and they are estimated from data in the district AWMPs and WMPs. However, based on information in the AWMPs and WMPs it is easier to calculate the demand side deep percolation factor (deep percolation as a percent of CUAW) first and then convert it to a supply side factor. The demand side factor is equal to the total deep percolation over all irrigation districts in the subbasin divided by the sum of total CUAW demand for all irrigation districts in the subbasin. The subbasin deep percolation factors are summarized in Table G.3-2.

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[5] In this document, the term *irrigation districts* is generally meant to refer only to those districts that have significant surface water supplies, even though there are some districts outside of the irrigation-district area.

Table G.3-2. Calculation of Average Deep Percolation Factors for each Groundwater Subbasin

Irrigation Districts in Subbasin[a]	Groundwater Subbasin						
	Eastern San Joaquin[b]			Modesto		Turlock[e]	Merced
	SSJID	North OID[c]	SEWD	South OID[c]	MID[d]	TID	Merced ID
Sources	Table 5-1, SSJID AWMP	Table 5-14, OID AWMP	Table 6 Section 5, SEWD WMP	Table 5-14, OID AWMP	Tables 44 and 47, MID AWMP	Table 4.9, TID AWMP	Table 5.20, Merced ID AWMP
Deep Percolation (AF)	42,321	10,571	12,965	13,925	58,132	159,111	60,116
Consumptive use of Applied Water (AF)	152,454	55,621	127,575	73,263	153,067	349,690	237,838
Demand Side Deep Percolation Factor	20%			32%		46%	25%
Supply Side Deep Percolation Factor	16%			24%		31%	20%

[a] Irrigation Districts refers to the districts described above in Section G.2.1, *Inputs to the SWAP Model.*

[b] The CSJWCD WMP did not present information on deep percolation or consumptive use so it was not included in these calculations even though it is part of the Eastern San Joaquin Subbasin.

[c] OID deep percolation and consumptive use of applied water was divided between North and South OID based on the relative irrigated area of each.

[d] Modesto ID consumptive use of applied water was determined using the Crop ET (173,179 AF, Table 44) and subtracting Annual Effective Precipitation (20,112 AF, Table 47).

[e] 5% of Merced ID is located in the Turlock Subbasin, but it was ignored for calculating the deep percolation factors.

Since the LSJR alternatives would only affect the availability of surface water in the LSJR Watershed, groundwater pumping and recharge for areas outside of the districts would not change in any of the LSJR alternatives. These values are primarily used for context and to characterize the magnitude of groundwater use in the LSJR Watershed. The estimates of irrigated acres and applied water associated with the irrigated acres outside of the irrigation districts are provided in Chapter 9, *Groundwater Resources* (Tables 9-5 and 9-6). The estimates of total groundwater pumping for each subbasin and estimates of net input to each subbasin including the areas outside of the irrigation district are presented in Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options* (Tables 22-4 and 22-5).

G.3.3 Change in Net Subbasin Inputs

The annual net irrigation district groundwater balance (Section G.3.1, *Methodology for Estimating Change in Groundwater Recharge*) is the sum of the inputs discussed above and extractions from the groundwater basin that occur as a result of the operations of the irrigation districts that receive surface water supplies. If this balance is negative, it represents a situation in which more water is extracted than recharged. Although this may lead to subbasin overdraft, it is not the same as subbasin overdraft. There are more factors that influence whether subbasins are in overdraft that are not included here, such as stream-groundwater interaction, natural percolation from precipitation, groundwater effects from holders of riparian water rights, groundwater pumping for irrigated land outside of irrigation districts, municipal groundwater pumping, and lateral groundwater movement. These factors are not included in this discussion because they can be assumed to be constant for each LSJR alternative; for some terms, reliable information is limited.

G.3.2.1 Baseline

During most years, under baseline conditions irrigation districts contribute more surface water to groundwater stores than the districts remove by groundwater pumping (Figure G.3-3). However, during times of drought, seepage from the conveyance system and deep percolation from applied surface water is reduced at the same time groundwater pumping increases. This can cause the irrigation districts to temporarily become net users of groundwater. In general, however, the irrigation district contributions to groundwater help to offset the groundwater pumping for irrigated land outside of the irrigation districts, which is primarily irrigated with groundwater. For context, groundwater pumping for irrigation outside of the irrigation districts is estimated to be approximately 450 TAF/y for the Eastern San Joaquin Subbasin, 80 TAF/y for the Modesto Subbasin, 350 TAF/y for the Turlock Subbasin, and 560 TAF/y for the Merced Subbasin (Table 9-6).

The baseline contribution of the irrigation districts to the subbasins is typically 100 to 200 TAF/y if surface water supply meets the irrigation district needs (Figure G.3-3). However, during droughts, contributions to groundwater are reduced, and in some years, the irrigation districts above the Eastern San Joaquin and Extended Merced Subbasins become net users of groundwater under baseline conditions. Drought affects the net irrigation district contribution to groundwater more often in the Eastern San Joaquin Subbasin than it affects the other subbasins. However, during the worst droughts, drought affects the Extended Merced Subbasin more severely. The severity and frequency of water shortage and the ability of the irrigation districts to increase groundwater pumping directly affects the irrigation district contributions to the subbasins.

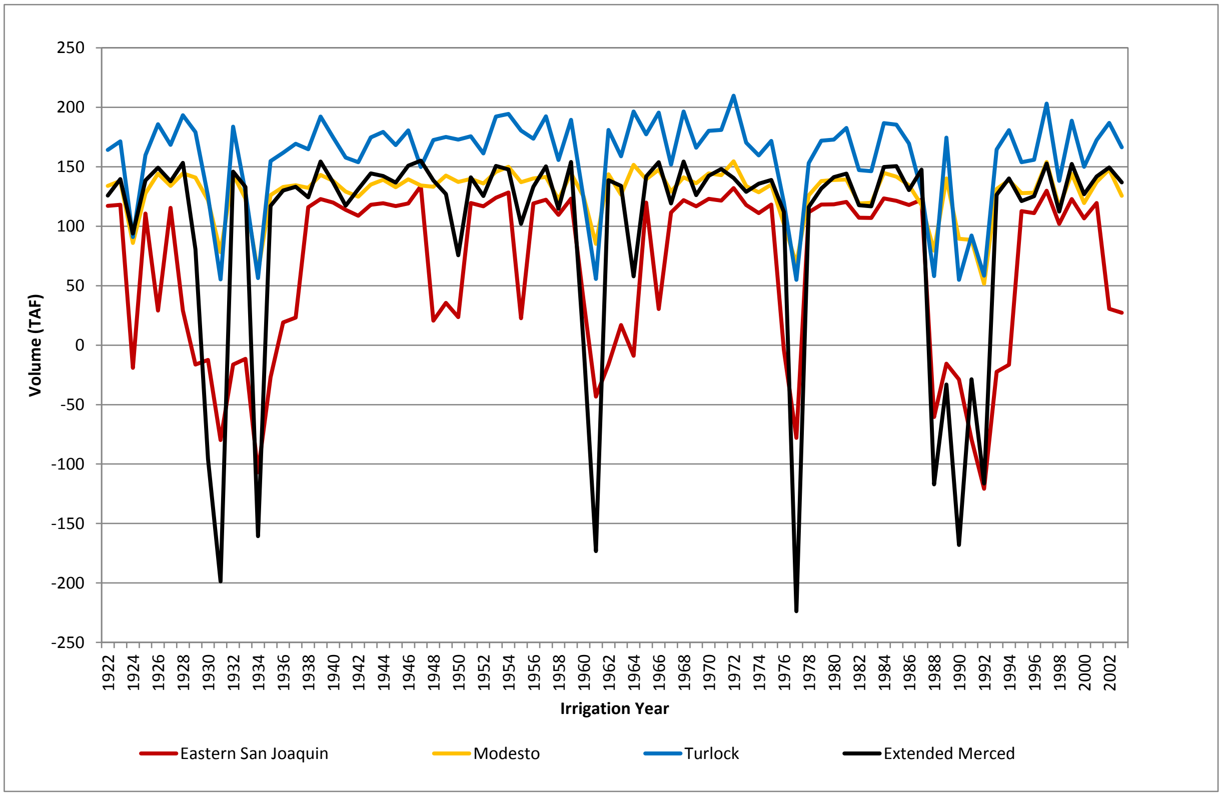

Figure G.3-3. Net Annual Contribution to Groundwater Subbasins by the Irrigation Districts under Baseline Conditions (Assuming 2009 Maximum Groundwater Pumping)

G.3.2.2 Change in Groundwater Balance Associated with the LSJR Alternatives

Under the LSJR alternatives, the contributions to groundwater from the irrigation districts are expected to diminish and be more frequently negative (net groundwater pumping) as the instream flow requirement increases. Figures G.3-4A through G.3-4D show the estimated net groundwater balance for each subbasin for all LSJR alternatives as time-series plots assuming 2009 maximum groundwater pumping rates for the 82 years simulated by the WSE model. In both the Eastern San Joaquin and Extended Merced Subbasins, the irrigation district groundwater balance shows negative net input to groundwater much more frequently in all alternatives, especially in LSJR Alternative 4. In the Turlock Subbasin, the district groundwater balance shows a negative contribution to groundwater only under LSJR Alternative 4, primarily in severe drought years. The district groundwater balance for the Modesto Subbasin always remains positive even under LSJR Alternative 4. However, even when the irrigation district groundwater balance remains positive, a reduction in net groundwater recharge from the districts would increase the impact of non-district groundwater pumping for drinking water and irrigation. The estimates of annual district groundwater contribution shown in these figure are used to produce the exceedance curves for the discussion of groundwater impacts in Chapter 9, *Groundwater Resources*. These annual estimates are also used to generate average annual results for the impact analysis in Chapter 9 and to create the summary of groundwater effects described in the following section.

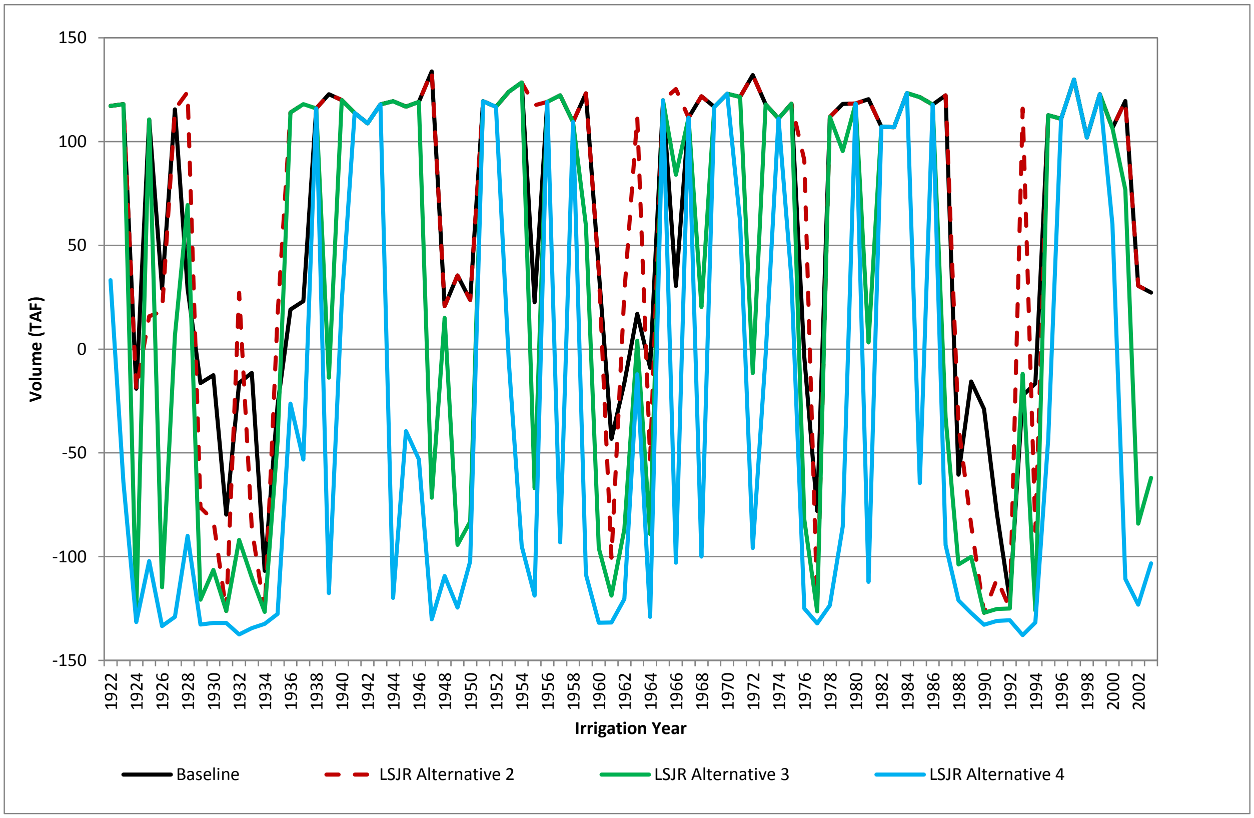

Figure G.3-4A. Annual Net Contribution to the Eastern San Joaquin Groundwater Subbasin by SSJID, OID, SEWD, and CSJWCD

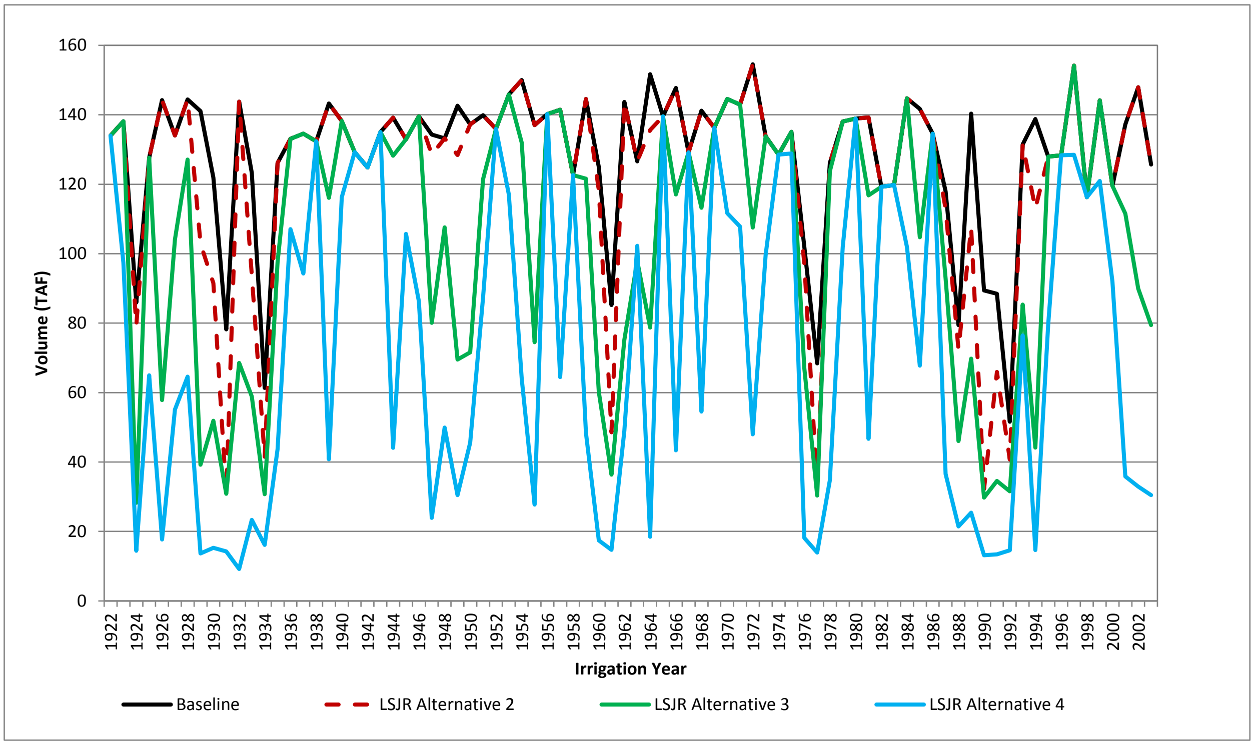

Figure G.3-4B. Annual Net Contribution to the Modesto Groundwater Subbasin by MID and OID

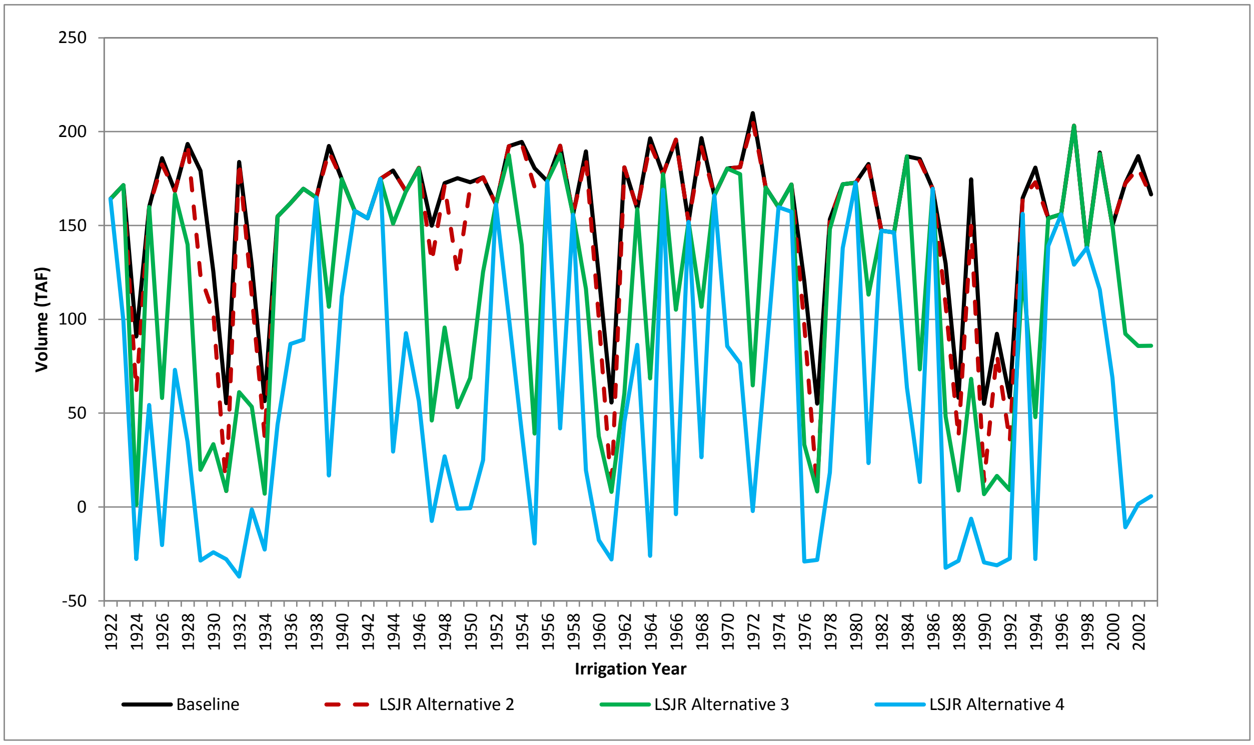

Figure G.3-4C. Annual Net Contribution to the Turlock Groundwater Subbasin by TID and Merced ID

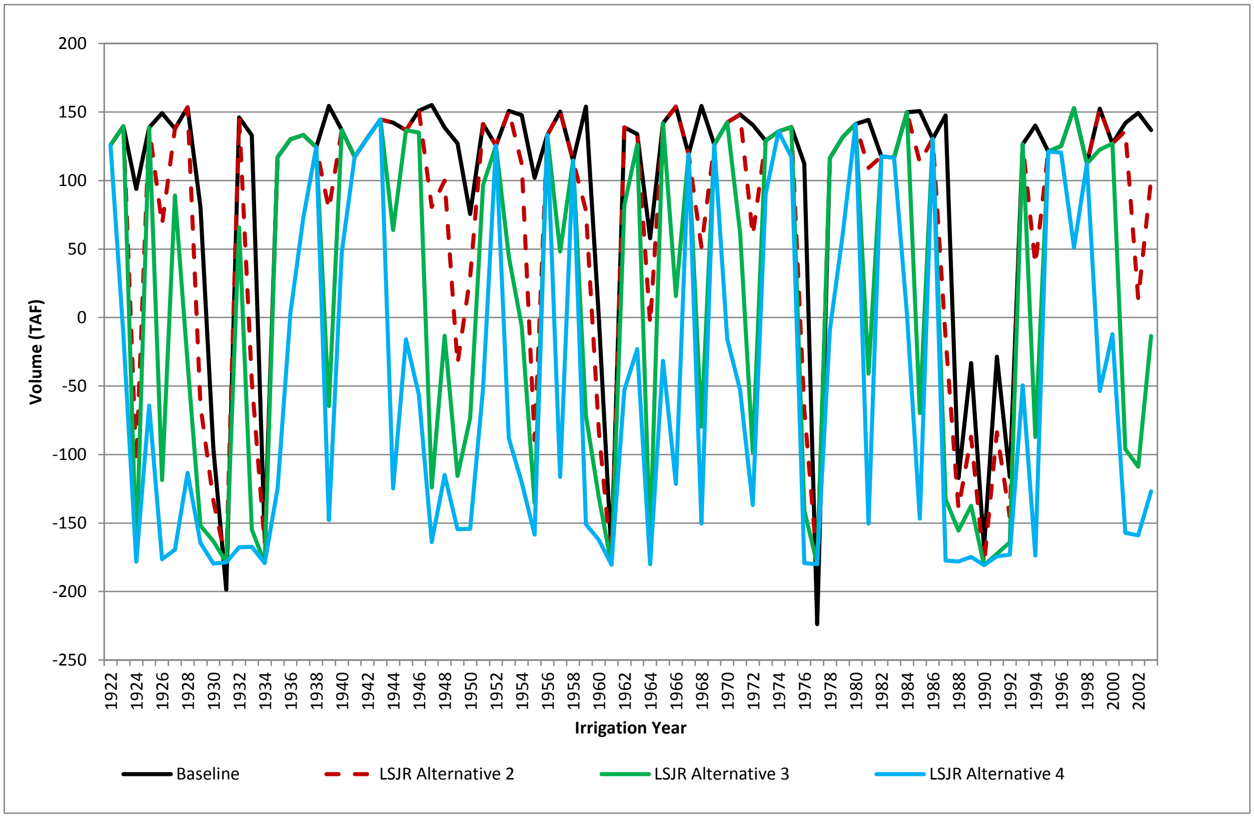

Figure G.3-4D. Annual Net Contribution to the Extended Merced Groundwater Subbasin by Merced ID

G.3.2.3 Summary of Groundwater Effects Associated with LSJR Alternatives

Under the LSJR Alternatives, groundwater pumping is expected to increase (Table G.3-3) at the same time groundwater recharge is expected to decrease (Table G.3-4), both as a result of decreased surface water supply for the irrigation districts. The average annual net effect of reduced surface water supplies on the irrigation district groundwater balance is shown in Table G.3-5. Assuming 2009 levels of maximum groundwater pumping, under LSJR Alternative 2, changes in the irrigation district groundwater balance would be relatively small compared to baseline values, with the average annual change varying from an increase of 2 TAF/y (increased net recharge) for the Eastern San Joaquin Subbasin to a decrease of 30 TAF/y (decreased net recharge) for the Extended Merced Subbasin,. Under LSJR Alternative 3, all subbasins have a negative change in the district groundwater balance, ranging from 25 TAF/y for the Modesto Subbasin to 82 TAF/y for the Extended Merced Subbasin. For LSJR Alternative 4, the average annual reduction in the district groundwater balance is even greater, ranging from 57 TAF/y for the Modesto Subbasin to 152 TAF/y for the Extended Merced Subbasin.

If the higher 2014 maximum pumping rates are used in the analysis, there would be correspondingly higher impact to groundwater in the Eastern San Joaquin, Modesto, and Turlock Subbasins. Using LSJR Alternative 4 as an example, the average annual district groundwater balance decreases by an additional 11 TAF/y, 46 TAF/y, and 44 TAF/y compared to the 2009 max groundwater pumping scenario in the Eastern San Joaquin, Modesto, and Turlock Subbasins, respectively. There is no change in the impact on the Extended Merced Subbasin (because for this subbasin, there was no difference between the 2009 and 2014 maximum groundwater pumping estimates as described in section G.2.2, *Methodology for Calculating Applied Water*). For the analysis of groundwater impacts in Chapter 9, *Groundwater Resources*, the average net change in groundwater balance for each subbasin is divided by the subbasin area to determine the decrease in net irrigation district contributions to groundwater relative to total subbasin area for each LSJR alternative.

Table G.3-3. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Pumping by the Irrigation Districts

		Increase in Groundwater Pumping Relative to Baseline (TAF/y)		
Groundwater Subbasin	Baseline Groundwater Pumping (TAF/y)	LSJR Alternative 2[a]	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	79	-4	23	69
Modesto	27	1	8	15
Turlock	91	2	16	30
Extended Merced	65	23	61	110
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	80	-2	30	81
Modesto	39	6	37	76
Turlock	109	6	48	95
Extended Merced	65	23	61	110

TAF/y = thousand-acre feet per year

[a] Under LSJR Alternative 2, there is a slight decrease in groundwater pumping for the Eastern San Joaquin Subbasin because changes in the New Melones Index for the Alternative compared to Baseline lead to slightly higher annual diversions on average for SEWD and CSJWCD.

Table G.3-4. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Recharge by the Irrigation Districts

		Change in Recharge Relative to Baseline (TAF/y)		
Groundwater Subbasin	Baseline Groundwater Recharge (TAF/y)	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	144	-2	-12	-33
Modesto	155	-4	-17	-43
Turlock	250	-5	-27	-70
Extended Merced	164	-7	-21	-42
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	144	-2	-11	-30
Modesto	159	-3	-10	-26
Turlock	255	-4	-17	-49
Extended Merced	164	-7	-21	-42

Table G.3-5. Estimated Effect of LSJR Alternatives on Average Annual Irrigation District Groundwater Balance

Groundwater Subbasin	Baseline Irrigation District Groundwater Balance (TAF/y) (positive indicates recharge)	Change in Groundwater Balance Relative to Baseline (TAF/y)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	65	2	-36	-101
Modesto	129	-6	-25	-57
Turlock	158	-7	-43	-100
Extended Merced	99	-30	-82	-152
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	64	0	-41	-112
Modesto	120	-9	-46	-103
Turlock	146	-10	-65	-144
Extended Merced	99	-30	-82	-152

G.4 Estimating Agricultural Production, Associated Revenue, and Groundwater Pumping Costs

The SWAP model is used to estimate agricultural production and associated revenues under baseline conditions and for each of the LSJR alternatives. SWAP uses estimates of applied water identified in Section G.2.4, *Estimates of Total Applied Water*, along with crop distribution inputs for each district to estimate agricultural production and associated revenues under baseline conditions and for each of the LSJR alternatives. This section describes the SWAP model, including the reasons for using it in this analysis, and then describes the model inputs and presents modeling results.

G.4.1 Description of the Statewide Agricultural Production Model

The SWAP model employs Positive Mathematical Programming (PMP), which is a self-calibrating method for modeling agricultural production that ensures that crop production matches base dataset of inputs in a given year (Howitt 1995). PMP introduces a non-linear cost function derived from the first order conditions of a Leontief production constrained model. Additional details on the PMP methodology are presented in several reports and peer reviewed publications, including: Howitt et al. (2012), Medellín-Azuara et al. (2010), and Medellín-Azuara et al. (2012).

PMP has become a widely accepted method for analyzing water demand and undertaking policy analysis. PMP is considered a deductive method, which is superior to inductive (statistical) based methods for analyzing the effects of changes in the availability of water for agricultural production (Young 2005; Scheierling et al. 2006). This type of model works well with the multitude of resource, policy, and environmental constraints often observed in practice (Griffin 2006). Furthermore, PMP does not require large datasets, is directly based on profit-maximizing behavior of farmers, and is better suited to estimate policy response of farming activities than strictly statistical methods (Howitt et al. 2010). In contrast to statistical methods, SWAP more explicitly accounts for changes in water availability due to reduced diversions as part of the constraint set in the model. By comparing a base case with current diversions and a policy scenario with reduced diversions, the analyst is able to economically quantify changes in revenue, cropping patterns, and applied water per unit area by crop and region.

The SWAP model estimates the agricultural production (crop acreages) and revenues (total production value) associated with the different levels of surface water diversions predicted to be needed under baseline conditions and the LSJR alternatives. The SWAP model predicts the production decisions of farmers at a regional level based on principles of economic optimization. The model assumes that farmers maximize net returns to land and management subject to resource, technical, and market constraints. The model selects those crops, water supplies, and irrigation technology that maximize profit subject to these equations and constraints. The model accounts for land and water availability constraints given a set of factors for production and their cost, and calibrates to *observed* (baseline) yearly values of land, labor, water, and supplies used in each region.

The SWAP model also has some comparative advantages over other agricultural production models, including DWR's California Agriculture (CALAG) and DWR's Net Crop Revenue Models (NCRMs). The following is a brief description of those models and the comparative advantages of SWAP.

CALAG is an extended and improved version of Central Valley Production Model (CVPM). As is the case for SWAP, PMP is the numerical basis of CALAG (DWR 2008). CALAG, however, does not explicitly include the cost of production factors in its formulation and instead uses constant variable production costs by crop and region. The SWAP model, in contrast, can capture farmer adjustments in use of inputs, such as water per acre changes during drought conditions. Thus, CVPM and CALAG are well suited to represent water supply operations but are less useful for modeling detailed changes in production, such as water per unit area, labor per unit area, or supplies per unit area. SWAP estimates cropping patterns and input use for all policies evaluated, capturing adaptation of crop farming production to changing water availability conditions. When faced with increasing water scarcity, farmers have been shown to adjust in three ways: make changes in water per acre, make changes in crop mix, and make changes in the total number of irrigated acres. Although CVPM and CALAG are considered robust models in that they can account for two of these changes, SWAP can incorporate all three of these potential adjustments. The SWAP model incorporates sources of region-specific, water supply information consistent with both models and has additional modules to account for technological improvement, climate change, changes in crop prices, and changes in water quality.

The NCRMs are spreadsheet programs that estimate average net crop revenues for 26 crop groups in 27 California counties and regions. These models combine data on acres and average yields and prices from various county and state sources. The price-level feature of the NCRMs spreadsheets adjusts cost and gross revenue data to a common year, adjusts for changes in various types of costs, and then calculates weighted-average estimates of a typical grower's annual net crop revenue, whether profit or loss (DWR 2008). Because NCRMs use fixed budgets, they cannot model farmer reactions to changes in water availability based on profit-maximizing behavior, as can be done in SWAP. Instead, the NCRM spreadsheets provide a snapshot of agriculture production, but do not capture changes in cropping patterns or use of production inputs in response to changes in water availability.

The SWAP model has been used in a wide range of policy analysis projects. The first formal application of SWAP was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California, known as the California Value Integrated Network (CALVIN) model. The SWAP model provided the economic value of water shortages in agriculture, by month and region, for CALVIN. Then, CALVIN determines monthly water allocation in storage and deliveries for urban, agricultural, and environmental uses based on water availability, operating costs, economic costs of shortages, and minimum environmental flow constraints (Draper et al. 2003). DWR used SWAP to develop planning scenarios and analyses supporting preparation of the 2009 Water Plan Update (DWR 2009). In conjunction with USBR and the CH2M HILL consulting firm, SWAP was used by the Stockholm Environment Institute as a subsidiary model in the application of a Water Evaluation and Planning (WEAP) model in the California Central Valley. WEAP is a climate-driven, water resource model that systematically simulates natural water flows and management of infrastructure to balance supply and demand (Yates et al. 2005). SWAP takes advantage of the WEAP priority-based allocation and provides cropping patterns for a wide range of water availability conditions. In doing this, SWAP converts a water allocation simulation model into a hydro-economic model that allocates water based on the economic value of final uses.

Recently, SWAP applications have been expanded to include drought impact analysis (Howitt et al. 2015; Medellin-Azuara et al. 2015). In addition, SWAP has been used to evaluate salinity in soil and shallow groundwater for both the Sacramento–San Joaquin Delta of California (Lund et al. 2007) and areas south of the Delta (Howitt et al. 2009; Tanaka et al. 2008), and for studying the effects of climate change (Medellin-Azuara 2012).

G.4.2 Crop Distribution and Applied Water Inputs for SWAP

For this analysis, SWAP was initially configured to model agricultural production in the main agricultural areas of the LSJR Watershed and calibrated to land use and applied water data for 2010. SWAP outputs were generated for two groundwater pumping scenarios, one for 2009 level of groundwater pumping, which represents a typical year of pumping, and a second assuming estimates of 2014 groundwater pumping. Using the estimates of applied water described in Section G.3, *Estimation of Groundwater Balance*, SWAP estimates of agricultural production (crop acreages) and revenues (total production value) were generated for baseline and each of the LSJR alternatives. Annual results for each of the LSJR alternatives are then compared to results for baseline conditions to estimate the net effects of the alternatives.

Each of the seven irrigation districts have published AWMPs or WMPs that include information on the number of irrigated acres within their service areas. These numbers were similar to estimates of irrigated acres obtained from GIS clips from DWR DAU crop surveys. Attachment 1 to this appendix, *Comparison of AWMP and DAU Crop Distributions for Irrigation Districts*, provides additional information regarding the acreage numbers in the AWMPs and those provided by DWR, as well as irrigated acre totals used for each district. For the purposes of this analysis, the irrigated acreage estimates provided by the irrigation districts in the AWMPs are used. These values are summarized in Table G.4-1.

Table G.4-1. Irrigation District Irrigated Acres

Irrigation District	Irrigated Acres	Description	Source
SEWD	50,981	Value for 2010	Table 2, SEWD WMP 2014
CSJWCD	48,000	Value for 2009	Table 2, CSJWCD WMP 2013
SSJID	58,551	Average Value for 1994 to 2008	Table 5-3, SSJID AWMP 2012
OID	54,317	Average Value for 2005 to 2011	Table 5-3, OID AWMP 2012
MID	58,611	Value for 2009 minus 542 acres of open land	Table 21, MID AWMP 2012
TID	146,030	Average Assessed Acres for 2007 to 2011	Text page 13, TID AWMP 2012
Merced ID	100,237	Average Value for 2000 to 2008	Table 5.3, Merced ID AWMP 2013

Using the total irrigated acres described above, a crop distribution (relative percentages of each crop type) was then applied to distribute the acreages among different crop types. Two potential crop type distributions were obtained, one from DWR based on 2010 DAU data (refer to map in Figure G.1-1) and one from the district AWMPs. In addition, district applied water rates for each crop were also obtained from both sources (except for CSJWCD, which did not have applied water estimates in its WMP). These land use distributions and associated applied water rates are compared for each district in Attachment 1 of this appendix. For all irrigation districts except SEWD and CSJWCD, the crop distribution and applied water rates based on DWR DAU data were used. For SEWD and CSJWCD, the crop distribution was taken from their respective AWMPs, but the DWR DAU applied water rates were still used.

To develop crop distribution estimates for each DAU, DWR surveys land and water uses within each county periodically, depending on changes that have occurred within that county. Surveys began in 1947, with the first digitized survey completed in 1988, and are available from the DWR website. Table G.4-2 below lists the counties within the study area. DWR uses the Agriculture Commissioner annual reports to then update crop yields appropriate for subsequent water years until a new crop survey is done. Table G.4-2 also shows the years in which the last survey was performed in each county in the study area and indicates which data year was used. Even if later years were available, 2010 data was used because it is a good representation of baseline conditions. For CEQA purposes, the baseline is considered to be anytime between 2009 and 2011; 2010 is considered a good year for modeling purposes because it was a year when there was enough water available to generally meet the full crop demand.

Table G.4-2. Counties within Study Area and Date Last Surveyed by the California Department of Water Resources (DWR)

County	Year Last Land Surveyed	Date Last Estimated by DWR from Commissioner Reports
Calaveras	2000	2010
Madera	2001	2010
Mariposa	1998	2010
San Joaquin	1996	2010
Stanislaus	2004	2010
Tuolumne	1997	2010
Merced	2002	2010

Each DAU has a specific cropping pattern and crop applied water rates. The water demand for each DAU is calculated by distributing the AWMP irrigated acreage among the different crop categories based on the DAU cropping pattern and then multiplying the acreage of each crop by its applied water rate. Table G.4-3 shows the 2010 cropping pattern for each irrigation district, and Table G.4-4 shows the 2010 crop applied water demands for each irrigation district. At the top of the tables, the irrigation districts are matched to their corresponding DAU. Some irrigation districts (OID and TID) include parts of two counties and each DAU–County combination has a different cropping pattern. The relative area for these irrigation districts was measured using GIS, and then the total irrigated acres were distributed over each DAU in the same proportion. SEWD and CSJWCD share the same DAU and were combined into a single regional unit for the SWAP analysis.

The crop groups in SWAP follow the DWR classifications and include: Almonds and Pistachios, Alfalfa, Corn, Cotton, Cucurbits, Dry Beans, Fresh Tomato, Processing Tomato, Grains, Onion and Garlic, Pasture, Rice, Safflower, Subtropical (includes citrus), and Vineyards, as well as Other Orchards, Other Field Crops, and Other Truck Crops.

Table G.4-3. Estimated 2010 Crop Distribution for Each Irrigation District and DAU (acres)

Irrigation District:	SSJID	OID			SEWD	CSJWCD	SEWD + CSJWCD	MID	TID			Merced ID
DAU-County:	205-SJ	206-SJ	206-Stan	206-Total	182-SJ	182-SJ	182-SJ	206-Stan	208-Stan	208-Merc	208-Total	210-Merc
Crop Categories:	Crop Irrigated Area (acres)											
Alfalfa	3,175	0	2,131	2,131	823	6,070	6,893	2,674	11,993	2,378	14,371	5,810
Almond/Pist	27,032	28	10,486	10,513	17	0	17	13,157	25,185	8,591	33,776	30,615
Corn	8,332	1,370	8,389	9,758	925	15,174	16,098	10,525	31,308	12,042	43,350	19,088
Cotton	0	0	0	0	0	0	0	0	0	0	0	2,490
Cucurbits	490	0	101	101	819	0	819	127	316	153	469	646
Dry Beans	175	11	203	214	770	0	770	255	1,073	0	1,073	0
Grain	1,670	207	169	376	1,228	7,081	8,310	212	379	77	455	3,135
Onion And Garlic	602	0	0	0	179	0	179	0	0	0	0	0
Other Deciduous	6,854	10	6,494	6,504	37,092	6,070	43,161	8,149	6,628	1,611	8,238	4,887
Other Field	210	297	7,509	7,806	0	0	0	9,422	19,567	9,511	29,078	7,193
Other Truck	437	0	2,807	2,807	1,124	0	1,124	3,523	6,060	1,918	7,977	11,803
Pasture	1,664	1,871	6,968	8,839	1,528	2,529	4,057	8,743	3,787	997	4,784	5,994
Potato	0	0	0	0	0	0	0	0	0	0	0	0
Rice	84	3,709	541	4,250	0	0	0	679	0	0	0	1,199
Safflower	162	0	0	0	0	0	0	0	0	0	0	0
Subtropical	1,747	103	34	137	0	0	0	42	63	0	63	0
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	277
Tomato, Fresh	70	0	0	0	2,199	5,867	8,066	0	379	0	379	1,844
Tomato, Processing	454	0	0	0	0	0	0	0	0	0	0	1,383
Vine	5,393	0	879	879	4,276	5,210	9,485	1,103	1,326	690	2,016	3,873
Total Acres:	58,551	7,605	46,712	54,317	50,981	48,000	98,981	58,611	108,063	37,967	146,030	100,237

Sources: Merced ID 2013; MID 2012; OID 2012; TID 2012; SEWD 2014; SSJID 2012; DWR 2010b.

Table G.4-4. Estimated 2010 Applied Water Demand by Crop and Irrigation District (acre-feet)

Irrigation District:	SSJID	OID			SEWD	CSJWCD	SEWD + CSJWCD	MID	TID			Merced ID
DAU-County:	205-SJ	206-SJ	206-Stan	206-Total	182-SJ	182-SJ	182-SJ	206-Stan	208-Stan	208-Merc	208-Total	210-Merc
Crop Categories:	Crop Applied Water Demand (Acre-Feet)											
Alfalfa	15,745	0	9,751	9,751	3,816	28,132	31,948	12,235	54,530	10,647	65,177	26,010
Almond/Pist	93,721	88	38,586	38,673	58	0	58	48,415	78,929	26,922	105,851	100,953
Corn	24,271	3,916	20,968	24,885	2,337	38,350	40,687	26,310	79,088	29,986	109,074	48,220
Cotton	0	0	0	0	0	0	0	0	0	0	0	7,659
Cucurbits	988	0	159	159	1,446	0	1,446	200	505	238	743	951
Dry Beans	434	25	445	470	1,786	0	1,786	558	2,379	0	2,379	0
Grain	1,285	109	164	273	400	2,303	2,703	205	355	76	431	2,957
Onion And Garlic	1,123	0	0	0	265	0	265	0	0	0	0	0
Other Deciduous	26,494	38	22,787	22,825	127,239	20,821	148,059	28,591	23,080	5,761	28,841	16,583
Other Field	705	960	18,357	19,317	0	0	0	23,033	48,530	23,892	72,422	17,838
Other Truck	1,393	0	3,144	3,144	3,407	0	3,407	3,945	6,957	2,134	9,091	13,551
Pasture	8,917	9,630	32,215	41,845	7,551	12,496	20,048	40,421	17,508	4,474	21,982	26,896
Potato	0	0	0	0	0	0	0	0	0	0	0	0
Rice	454	19,459	3,079	22,537	0	0	0	3,863	0	0	0	6,532
Safflower	231	0	0	0	0	0	0	0	0	0	0	0
Subtropical	5,942	335	94	429	0	0	0	118	175	0	175	0
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	434
Tomato, Fresh	165	0	0	0	4,606	12,290	16,896	0	596	0	596	2,951
Tomato, Processing	1,355	0	0	0	0	0	0	0	0	0	0	3,280
Vine	6,471	0	2,063	2,063	3,719	4,531	8,250	2,588	2,946	1,515	4,461	9,187
Total Applied Water Demand:	189,695	34,560	151,810	186,370	156,628	118,924	275,552	190,480	315,578	105,645	421,223	284,003

Sources: Merced ID 2013; MID 2012; OID 2012; TID 2012; SEWD 2014; SSJID 2012; DWR 2010b.

The SWAP output for a particular LSJR alternative or for baseline conditions is a time-series of 82 annual estimates of the associated crop acreages, applied water, and revenue across the period of simulation. For the purpose of evaluating each LSJR alternative, this range of annual estimates is compared against those for baseline. The SWAP model output was aggregated into six regions, V01 through V06, which correspond to the irrigation districts, as described in Table G.4-5.

Table G.4-5. SWAP Analysis Regions

SWAP Analysis Region	Irrigation Districts
V01	SSJID
V02	OID
V03	SEWD/CSJWCD
V04	MID
V05	TID
V06	Merced ID

G.4.3 SWAP Modeling Results

This section presents SWAP model output characterizing the total agricultural production (crop acreages) and associated revenues (total production value) associated with baseline conditions and the three LSJR alternatives. Also presented are the changes in production and revenue values between the baseline and LSJR alternatives. As indicated in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*, SWAP results (crop acreage and associated revenues) are presented by irrigation district.

G.4.1.1 Effects on Crop Acreage

As described in Section G.4.1, *Description of the Statewide Agricultural Production Model*, the SWAP model optimizes available land and water such that net returns to farmers are maximized. As water becomes more scarce, the crops most affected, in general, are Pasture, Alfalfa, Rice, and Other Field Crops. These crops are affected more because they require relatively high water-use, as compared to annual crops and/or crops that generate lower net revenue per acre. The lower net-revenue crops cover large portions of the study area; consequently, these crop groups are substantially reduced for the LSJR alternatives with higher unimpaired flow requirements, particularly for LSJR Alternative 4. The SWAP model output (Tables G.4-6a–f) identifies crop acreage in each district in the study area under baseline conditions and LSJR Alternatives 2–4; predicted changes in crop acreage in each district also are shown for each LSJR alternative relative to baseline conditions.

Table G.4-6a. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for SSJID (V01)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
SSJID(V01)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	3,080	5.3	-166	-5.4	-523	-17.0	-1,350	-43.8
Almonds and Pistachios	27,022	46.4	-59	-0.2	-162	-0.6	-505	-1.9
Corn	8,248	14.2	-376	-4.6	-788	-9.6	-2,318	-28.1
Cotton	0							
Cucurbits	486	0.8	-24	-4.9	-43	-8.8	-139	-28.6
Dry Bean	172	0.3	-9	-5.1	-23	-13.7	-65	-37.7
Grain	1,666	2.9	-15	-0.9	-38	-2.3	-242	-14.5
Onion and Garlic	602	1.0	-1	-0.1	-2	-0.3	-5	-0.9
Orchards	6,847	11.8	-21	-0.3	-55	-0.8	-150	-2.2
Other Field Crops	203	0.3	-11	-5.3	-35	-17.4	-90	-44.1
Other Truck Crops	431	0.7	-21	-4.9	-52	-12.1	-143	-33.2
Pasture	1,582	2.7	-107	-6.8	-419	-26.5	-802	-50.7
Rice	82	0.1	-4	-5.1	-13	-16.3	-35	-42.8
Safflower	158	0.3	-9	-5.5	-23	-14.8	-64	-40.5
Subtropical	1,743	3.0	-6	-0.3	-22	-1.3	-49	-2.8
Sugarbeet	0							
Tomato (Fresh)	70	0.1	-1	-0.8	-2	-2.2	-5	-7.7
Tomato (Processing)	446	0.8	-23	-5.1	-61	-13.6	-168	-37.8
Vine	5,391	9.3	-6	-0.1	-16	-0.3	-50	-0.9
TOTAL	58,229		-857	-1.5	-2,277	-3.9	-6,181	-10.6

Table G.4-6b. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for OID (V02)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
OID(V02)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	2,098	3.9	-121	-5.8	-302	-14.4	-851	-40.5
Almonds and Pistachios	10,519	19.4	-19	-0.2	-52	-0.5	-158	-1.5
Corn	9,810	18.1	-79	-0.8	-204	-2.1	-1,291	-13.2
Cotton	0							
Cucurbits	103	0.2	-1	-0.8	-2	-2.0	-7	-7.0
Dry Bean	216	0.4	-3	-1.5	-8	-3.8	-52	-24.3
Grain	387	0.7	-2	-0.5	-5	-1.3	-16	-4.1
Onion and Garlic	0							
Orchards	6,508	12.0	-11	-0.2	-29	-0.5	-89	-1.4
Other Field Crops	7,865	14.5	-419	-5.3	-795	-10.1	-2,388	-30.4
Other Truck Crops	2,854	5.3	-14	-0.5	-37	-1.3	-129	-4.5
Pasture	8,597	15.9	-511	-5.9	-2,001	-23.3	-4,191	-48.8
Rice	4,188	7.7	-214	-5.1	-535	-12.8	-1,557	-37.2
Safflower	0							
Subtropical	137	0.3	-1	-0.4	-2	-1.4	-4	-2.9
Sugarbeet	0							
Tomato (Fresh)	0							
Tomato (Processing)	0							
Vine	881	1.6	-2	-0.2	-5	-0.5	-14	-1.6
TOTAL	54,162	100	-1,395	-66.5	-3,978	-7.3	-10,748	-19.8

Table G.4-6c. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for SEWD/CSJWCD (V03)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
SEWD/CSJWCD(V03)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	6,870	6.9	0	0.0	0	0.0	0	0.0
Almonds and Pistachios	17	0.0	0	0.0	0	0.0	0	0.0
Corn	16,096	16.3	0	0.0	0	0.0	0	0.0
Cotton	0							
Cucurbits	818	0.8	0	0.0	0	0.0	0	0.0
Dry Bean	768	0.8	0	0.0	0	0.0	0	0.0
Grain	8,320	8.4	0	0.0	0	0.0	0	0.0
Onion and Garlic	179	0.2	0	0.0		0.0		0.0
Orchards	43,174	43.6	0	0.0	0	0.0	0	0.0
Other Field Crops	0							
Other Truck Crops	1,119	1.1	0	0.0	0	0.0	0	0.0
Pasture	4,019	4.1	0	0.0	0	0.0	0	0.0
Rice	0							
Safflower	0							
Subtropical	0							
Sugarbeet	0							
Tomato (Fresh)	8,064	8.2	0	0.0	0	0.0	0	0.0
Tomato (Processing)	0							
Vine	9,487	9.6	0	0.0	0	0.0	0	0.0
TOTAL	98,931	100	0	0.0	0	0.0	0	0.0

Table G.4-6d. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for MID (V04)

MID(V04)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	2,513	4.4	-111	-4.4	-581	-23.1	-1,258	-50.0
Almonds and Pistachios	13,139	22.9	-27	-0.2	-105	-0.8	-329	-2.5
Corn	10,506	18.3	-266	-2.5	-725	-6.9	-3,537	-33.7
Cotton	0							
Cucurbits	128	0.2	-1	-1.1	-5	-3.7	-39	-30.5
Dry Bean	254	0.4	-12	-4.8	-30	-11.9	-101	-39.7
Grain	215	0.4	-3	-1.3	-13	-6.0	-71	-32.8
Onion and Garlic	0							
Orchards	8,138	14.2	-15	-0.2	-59	-0.7	-197	-2.4
Other Field Crops	9,376	16.3	-500	-5.3	-1,816	-19.4	-4,428	-47.2
Other Truck Crops	3,548	6.2	-24	-0.7	-86	-2.4	-1,028	-29.0
Pasture	7,754	13.5	-217	-2.8	-2,094	-27.0	-4,434	-57.2
Rice	639	1.1	-33	-5.1	-146	-22.9	-324	-50.8
Safflower	0							
Subtropical	42	0.1	0	-0.1	-1	-1.5	-1	-3.2
Sugarbeet	0							
Tomato (Fresh)	0							
Tomato (Processing)	0							
Vine	1,103	1.9	-2	-0.2	-9	-0.8	-28	-2.5
TOTAL	57,354	100	-1,211	-2.1	-5,670	-9.9	-15,774	-27.5

Table G.4-6e. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for TID (V05)

TID(V05)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	13,115	9.1	-284	-2.2	-3,023	-23.1	-6,599	-50.3
Almonds and Pistachios	33,741	23.5	-43	-0.1	-183	-0.5	-509	-1.5
Corn	43,283	30.1	-470	-1.1	-1,554	-3.6	-11,442	-26.4
Cotton	0							
Cucurbits	469	0.3	-3	-0.7	-12	-2.6	-39	-8.4
Dry Bean	1,065	0.7	-31	-2.9	-87	-8.2	-392	-36.8
Grain	460	0.3	-4	-0.8	-14	-3.1	-50	-10.8
Onion and Garlic	0							
Orchards	8,221	5.7	-13	-0.2	-54	-0.7	-150	-1.8
Other Field Crops	28,848	20.1	-1,537	-5.3	-4,687	-16.2	-13,102	-45.4
Other Truck Crops	8,020	5.6	-41	-0.5	-156	-1.9	-505	-6.3
Pasture	4,106	2.9	-171	-4.2	-1,166	-28.4	-2,458	-59.9
Rice	0							
Safflower	0							
Subtropical	63	0.0	0	-0.2	-1	-1.5	-2	-3.2
Sugarbeet	0							
Tomato (Fresh)	379	0.3	-1	-0.2	-3	-0.9	-9	-2.4
Tomato (Processing)	0							
Vine	2,014	1.4	-3	-0.2	-13	-0.7	-37	-1.8
TOTAL	143,783	100	-2,600	-1.8	-10,954	-7.6	-35,294	-24.5

Table G.4-6f. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for Merced ID (V06)

Merced ID(V06)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	5,634	5.6	-35	-0.6	-154	-2.7	-470	-8.3
Almonds and Pistachios	30,616	30.7	-3	0.0	-27	-0.1	-87	-0.3
Corn	19,109	19.2	-3	0.0	-62	-0.3	-211	-1.1
Cotton	2,482	2.5	0	0.0	-11	-0.4	-38	-1.5
Cucurbits	649	0.7	0	0.0	-2	-0.3	-6	-0.9
Dry Bean	0							
Grain	3,177	3.2	-1	0.0	-9	-0.3	-30	-0.9
Onion and Garlic	0	0.0						
Orchards	4,884	4.9	-1	0.0	-5	-0.1	-16	-0.3
Other Field Crops	7,145	7.2	36	0.5	-10	-0.1	-129	-1.8
Other Truck Crops	11,912	11.9	-2	0.0	-27	-0.2	-91	-0.8
Pasture	5,622	5.6	-17	-0.3	-468	-8.3	-1,468	-26.1
Rice	1,158	1.2	4	0.4	-13	-1.1	-57	-4.9
Safflower	0							
Subtropical	0							
Sugarbeet	277	0.3	0	0.0	-1	-0.2	-2	-0.6
Tomato (Fresh)	1,847	1.9	0	0.0	-2	-0.1	-5	-0.3
Tomato (Processing)	1,383	1.4	0	0.0	-6	-0.5	-22	-1.6
Vine	3,874	3.9	0	0.0	-4	-0.1	-13	-0.3
TOTAL	99,769	100	-22	0.0	-800	-0.8	-2,644	-2.6

It should be noted that the SWAP results presented in Tables G.4-6a through G.4.6f assume a maximum groundwater pumping capacity similar to what was available in 2009. If groundwater pumping capacity for 2014 is used instead, the results show an overall decrease in the reduction (or fallowing) of average annual crop acreage within all irrigation districts, but particularly MID. For SSJID, OID, MID, and TID higher groundwater pumping capacities based on 2014 estimates allow them to pump more groundwater in times of need and prevent crops from being fallowed, as shown in Table G.4-7 for LSJR Alternatives 3 and 4. For example, the predicted reduction in crop acreage in OID under LSJR Alternative 3 (3,978 acres or 7.3 percent compared to 2009 levels, as shown in Table G.4-6b) would decrease to an estimated 2,491 acres (4.6 percent reduction compared to 2009 conditions) under the higher 2014 groundwater pumping scenario.

Table G.4-7. Percent Decrease in Average Annual Crop Area Associated with 2009 and 2014 Groundwater Pumping under LSJR Alternatives 2, 3, and 4, by Irrigation District

	Percent Reduction in Crop Area (% of district crop area)	
LSJR Alternative	Max Groundwater Pumping for 2009	Max Groundwater Pumping for 2014
LSJR Alternative 2		
SSJID	1.5	1.3
OID	2.6	1.7
MID	2.1	0.3
TID	1.8	0.8
LSJR Alternative 3		
SSJID	3.9	2.6
OID	7.3	4.6
MID	9.4	0.7
TID	7.6	2.5
LSJR Alternative 4		
SSJID	10.6	8.4
OID	19.8	13.8
MID	27.5	5.3
TID	24.5	11.3

Over the wide range of value-based farm sizes potentially affected in the study area, the predicted effects under the LSJR alternatives would not be expected to have a disproportionate effect based on farm size. Factors contributing to this conclusion include that an estimated 60 percent of farming operations in San Joaquin, Stanislaus, and Merced Counties report net revenue gains in 2012, with the remaining operations reporting net revenue losses (USDA 2012). An additional consideration is that the median annual value of agricultural sales within the three counties analyzed was at least $50,000 in 2012. Although the lack of readily available information linking farm size and access to water, either from diversions or groundwater, limits our ability to explore potential effects based on farm size, the combination of these factors contribute to reaching this conclusion.

Livestock (beef cattle) and dairies, the two main animal operations in California, require both irrigated and non-irrigated crops as production inputs. Evaluating the effects of the LSJR alternatives on these two sectors requires a forward-linkage assessment that typically is beyond the capabilities of traditional input-output analysis, including IMPLAN. Nevertheless, it is possible to draw some inferences using economic information about the affected dairy and livestock sectors and the built-in information about the relationships in IMPLAN for the study area.

Beef cattle require pasture (including non-irrigated winter pasture) and other fodder crops, whereas dairy cattle rely heavily on alfalfa, locally grown silage corn, and a concentrate that is usually imported from out of state. Implementation of some of the LSJR alternatives may limit the economic feasibility of growing feed crops near affected water districts. Thus, these districts would experience some cost increase for inputs during water-short years. Dry forms of feed crops, such as alfalfa hay, can be imported to replace the limited supply of locally grown feed crops when regional markets for these crops are operating. However, silage corn, which has higher water content, is more costly to transport and is often not sold in the market. Because of the higher transport cost, this product is more often produced by farm operators. The ability to substitute various crops in the milk cow and the beef cattle diet with imported feed crop or concentrate is considered the determining factor for potential economic impacts of the LSJR alternatives on livestock and dairy net returns. In addition, the ability to substitute corn for fodder crops is limited by dairy dietary restrictions.

G.4.1.2 Effects on Agricultural Revenue

Based on the redistribution of crop production during times of water scarcity, the SWAP model also (in addition to crop redistribution, described above) estimates the gross revenues generated by the redistribution of crop acreage.

For the agricultural revenue effects analysis, SWAP estimates total direct gross crop revenues generated in the seven irrigation districts identified in Table G.4-5, which were aggregated into six SWAP analysis regions (also shown in Table G.4-5.) These direct revenues generated by farming operations are measured in terms of gross total production value and do not include any of the associated indirect or induced effect on the regional economy; these effects are addressed in the following section, G.5 *Estimating Effects of Agricultural Production on the Regional Economy and Local Fiscal Conditions*. Although SWAP output is calibrated and reported in 2005 dollars, the output is subsequently adjusted with a deflation factor of 1.08 derived from U.S. Bureau of Economic Analysis (BEA) data (BEA 2016) to report results in 2008 dollars, consistent with the results of the regional economic analysis.

As described in Section G.2, *Total Applied Water for Agricultural Production*, water supply conditions in the LSJR Watershed are highly variable over time; consequently, associated data or modeling results are sometimes better characterized by exceedance plots than by simple average or median statistics. To characterize the magnitude and variability of revenues, Figure G.4-1 presents an exceedance plot of SWAP estimates of annual revenues for crop production across the total LSJR Watershed over the 82-year historical record under baseline conditions and for each of the LSJR alternatives. The difference in the cumulative distribution of annual revenue above or below baseline is calculated for each LSJR alternative and presented in Table G.4-8.

SWAP estimates of average annual agricultural revenues by district are presented in Table G.4-9. As shown, farm operators in the TID would account for $16 million (45percent) of the estimated $36 million reduction in average annual revenues under LSJR Alternative 3. Under LSJR Alternative 4, farm operators in the TID would account for $50 million (43 percent) and in the Modesto ID would account for $29 million (25 percent) of the estimated $117 million reduction in average annual revenues.

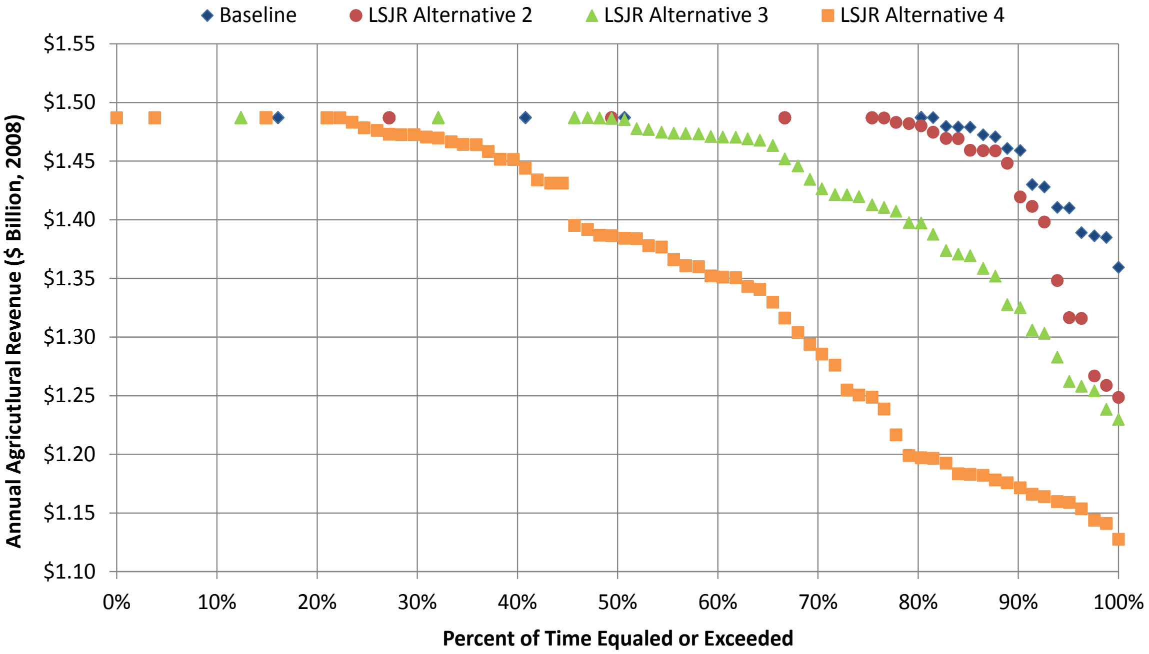

Figure G.4-1. Exceedance Plot of SWAP Estimates for Annual Agricultural Revenue in the Irrigation Districts for the LSJR Alternatives and Baseline Across the 82 Years of Simulation

Table G.4-8. Baseline Statistics for Annual Agricultural Revenue in the Irrigation Districts based on SWAP Results and the Change in those Statistics for each of the LSJR Alternatives

	Baseline	LSJR Alternative 2 (20% Unimpaired) Difference from Baseline		LSJR Alternative 3 (40% Unimpaired) Difference from Baseline		LSJR Alternative 4 (60% Unimpaired) Difference from Baseline	
Statistics	($Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
Avg	1,477	-9	-0.6	-36	-2.5	-117	-7.9
Min	1,359	-111	-8.1	-129	-9.5	-232	-17.1
90th Percentile	1,459	-37	-2.5	-134	-9.2	-287	-19.7
80th Percentile	1,487	-6	-0.4	-90	-6.0	-289	-19.5
70th Percentile	1,487	0	0.0	-58	-3.9	-199	-13.4
60th Percentile	1,487	0	0.0	-16	-1.1	-136	-9.1
50th Percentile	1,487	0	0.0	-1	-0.1	-102	-6.8
40th Percentile	1,487	0	0.0	0	0.0	-39	-2.6
30th Percentile	1,487	0	0.0	0	0.0	-15	-1.0
20th Percentile	1,487	0	0.0	0	0.0	0	0.0
10th Percentile	1,487	0	0.0	0	0.0	0	0.0
Max	1,487	0	0.0	0	0.0	0	0.0

Table G.4-9. SWAP Estimates of Annual Average Agricultural Revenues (and Changes in Revenues) from Baseline Conditions for the LSJR Alternatives, by Irrigation District

	Baseline	LSJR Alternative 2 (20% Unimpaired) Difference from Baseline		LSJR Alternative 3 (40% Unimpaired) Difference from Baseline		LSJR Alternative 4 (60% Unimpaired) Difference from Baseline	
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
SSJID	229	-2	-1.0	-6	-2.6	-19	-8.1
OID	129	-2	-1.4	-5	-3.9	-14	-11.1
SEWD and CSJWCD	334	0	0.0	0	0.0	0	0.0
MID	148	-2	-1.2	-7	-5.0	-29	-19.5
TID	341	-3	-1.0	-16	-4.8	-50	-14.7
Merced ID	296	0	-0.1	-2	-0.5	-5	-1.7
Total	1,477	-9	-0.6	-36	-2.5	-117	-7.9

G.4.4 Groundwater Pumping Costs

In addition to the impacts on crop acreage and revenues described above, increased groundwater pumping under the LSJR alternatives would incur additional costs to farm operators. The levels of increased groundwater pumping are described in section G.2.1, *Inputs from the WSE Model*, and G.2.2, *Methodology for Calculating Applied Water*, and are summarized in Table G.4-11 below.

The additional costs for groundwater pumping are estimated assuming average groundwater levels, energy costs, and pump efficiency for the irrigation districts. An average energy price of $0.189/kilowatt hour (kWh), as used in the SWAP model (DWR 2012), was applied for the entire irrigation season. Many irrigation districts have hydropower projects and receive discounted power that would be less expensive than the average price assumed; thus, this represents a conservative assumption. Note that kilowatt is a metric unit, so the calculations below relied on several conversion factors.

To calculate pumping energy the following equation was used:

$$Pumping\ Energy = \frac{Volume\ Pumped * Depth\ to\ GW * Water\ Density * Acc.Due\ to\ Gravity}{Pump\ Efficiency}$$

Acceleration due to gravity is a constant of 9.81 m/s^2 and the density of water was considered to be constant at 1000 kg/m^3. The pumping energy efficiency was assumed to be 0.7.

The average groundwater depth across each irrigation district was extracted from the latest version of the SWAP model as described in Medellin-Azuara et al. (2015). Table G.4-10 summarizes the assumed average groundwater depths for each irrigation district.

Table G.4-10. Average Groundwater Depth by Irrigation District

Groundwater Subbasin	Average Depth (feet)
SSJID	128
OID	88
SEWD/CSJWCD	83.3
MID	90.7
TID	90.7
Merced ID	90.7

In addition to the energy cost, SWAP also represents a fixed cost of $27 for every AF of groundwater pumped to the surface, based on well design in the Northern San Joaquin Valley, and an operation and maintenance cost for the equipment of $0.025 for every AF of groundwater pumped up 1 foot (DWR 2012).

Pumping costs are part of the farm crop production budget. In some cases, farms rely entirely on groundwater for irrigation. In other cases, groundwater supplements or augments surface water sources, especially during droughts or water cutbacks. This supplementation with groundwater pumping has an effect on farm profits. Potential effects on farm profits were modeled assuming that the increase in pumping costs represents a reduction in sole proprietor income (profits). This follows the approach in Medellin-Azuara et al. (2015). This loss in profits is associated with the remaining cultivated area and is in addition to the gross revenue losses associated with water curtailments-related fallowing. The reduction in farm profit also has an induced effect on both employment and economic activity in the local area. These effects are estimated using multipliers derived from the IMPLAN model (described in the next section) that relate farm profit loss to sector output of the local economy in dollars and employment in the local economy. For every million dollars of farm profit that is lost, an additional $774,000 is lost in the local economy, and 5.8 jobs are eliminated. The regional effects are usually smaller than the proprietor income losses because a proportion of the induced expenses is leaked from the area of study.

As shown in Table G.4-11, with greater groundwater pumping in each of the alternatives there is an increased cost, which cuts into farm profits. Under baseline conditions average groundwater pumping costs are about $15.3 million per year, and this cost increases by $1.3 million, $6.2 million, and $12.7 million per year in LSJR Alternatives 2, 3, and 4, respectively. The IMPLAN-based results indicate that there is an additional induced cost to the local economy ranging from $1 million per year in LSJR Alternative 2 to $9.8 million per year in LSJR Alternative 4. The total estimated impact on economic output from increased groundwater pumping and the associated cost would range from $2.3 million per year under the LSJR Alternative 2 to $22.6 million per year under LSJR Alternative 4. Loss in proprietor income may also have some impact on employment in the area of study. The induced employment impact ranges from about 7 jobs per year in LSJR Alternative 2 to about 74 jobs per year in LSJR Alternative 4. However, there would likely be more jobs lost in the agricultural industry itself as a direct effect (e.g., with less profit, farmers cannot hire as many workers) and as indirect effects (e.g., jobs would be lost in industries that support agriculture, such as fertilizer companies).

One of the effects of increased pumping costs would be to transfer income from farming to mostly power utilities. Most of the benefits in employment and economic output from this transfer would be expected to occur outside the area of the LSJR Watershed.

Table G.4-11. The Average Annual Cost of Groundwater Pumping in the Irrigation Districts, and its Associated Induced Effects on Total Economic Output and Employment under Baseline Conditions and for the LSJR Alternatives

			Change from Baseline		
		Baseline[a]	LSJR Alternative 2 (20% Unimpaired)	LSJR Alternative 3 (40% Unimpaired)	LSJR Alternative 4 (60% Unimpaired)
Avg. Annual GW Pumping	TAF/y	258	21	104	216
Avg. Annual Cost of GW Pumping	$Millions, 2008/y	15.3	1.3	6.2	12.7
Induced Economic Effect	$Millions, 2008/y	11.9	1.0	4.8	9.8
Induced Employment Effect	Jobs/y	89	7	36	74

GW = groundwater
TAF/y = thousand acre-feet per year

$Millions, 2008/y = millions of $ per year (in 2008 $)

[a] The baseline induced effects are approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

G.5 Estimating Effects of Agricultural Production on the Regional Economy and Fiscal Conditions

This section describes the methods used to estimate how changes in agricultural production will impact the regional economy in the LSJR alternatives. Baseline conditions are first characterized, followed by an assessment of each of the LSJR alternatives. This analysis uses marginal multipliers from the Impact Analysis for Planning (IMPLAN) economic input-output model to estimate regional economic impacts associated with the direct agricultural-related production and revenue effects from the SWAP analysis (refer to Section G.4.3, *SWAP Modeling Results*).

G.5.1 Description of the IMPLAN Input-Output Model

To estimate the regional economic effects of agricultural production under baseline conditions and for the LSJR alternatives, the 2010 IMPLAN model was used (IMPLAN Group LLC 2015). IMPLAN is an input-output multiplier model that provides a snapshot of the interrelationships among sectors and institutions in a regional economy. Production in the various economic sectors of the economy is simulated in IMPLAN by using fixed factors, which account for dynamics such as production per unit of input, value added, and employment. It then applies these factors in a social accounting matrix, which accounts for changes in transactions between producers, and intermediate and final consumers in other sectors of the economy. In addition, IMPLAN uses region/sector-specific multipliers to estimate the indirect and induced economic effects (positive or negative) of changes in one sector on all other connected sectors in the regional economy. The IMPLAN model and data also can be used to develop order-of magnitude estimates of tax revenue effects on the local, state and the federal government.

The IMPLAN model has been used for many years by state, federal, and municipal entities to calculate economic effects of public policies and programs. These entities include the DWR, the State Water Resources Control Board (SWRCB), the U.S. Army Corps of Engineers, USBR, the Bureau of Economic Analysis, and the Bureau of Land Management. The IMPLAN model was used previously by the State Water Board to estimate the potential regional effects of reduced farm production in the San Joaquin Valley in the *Environmental Impact Report for the Implementation of the 1995 Bay/Delta Water Quality Control Plan* (State Water Board 1999), and in the Economic Analysis for the *Environmental Impact Report on the Irrigated Lands Regulatory Program* (State Water Board 2011). These previous uses were similar to the current use of IMPLAN to estimate the regional economic effects of the LSJR alternatives. The multipliers employed in this analysis, however, generally follow a finer resolution because they are crop-group specific, and have been developed based on IMPLAN results from county-level models. For the IMPLAN analysis Eastern San Joaquin, Stanislaus, and Merced Counties are treated as an aggregate three-county area.

The input-output analysis approach employed by IMPLAN typically results in overestimates of the indirect effects on jobs and personal income. One of the fundamental assumptions in input-output analysis is that trading patterns between industries are fixed. This assumption implies that suppliers always cut production and lay off workers in proportion to the amount of product supplied (to farms or other industries reducing production). In reality, businesses are always adapting to changing conditions. For example, when a farm cuts production, some suppliers would be able to replace part of their sales losses by finding new markets in other areas. Growth in other parts of a local economy can be expected to provide opportunities for firms. For these and other reasons, effects on job and income estimated using input-output analysis should generally be considered as upper limits on the actual effects experienced (State Water Board 1999).

In general, changes in agricultural production also would affect businesses serving farming operations and farm workers. Job and output multipliers derived from IMPLAN can be used to estimate the effects to other connected sectors of a regional economy. For this application, direct agricultural-related revenues generated by the SWAP model, and indirect and induced economic effects estimated using the IMPLAN multipliers together provide an estimate of the total economic effects on economic output and jobs within the study area.

Potential reductions in surface water deliveries to agricultural operators would be expected to affect several sectors of the economy, not just agriculture. When farm production falls as a result of reduced water availability, farmers would be expected to hire fewer seasonal workers and may lay off some year-round workers. Without jobs, household spending by these workers is likely to fall, affecting retailers and other businesses in the region. In addition, farmers would reduce purchases of equipment, materials, and services from local businesses, thereby reducing jobs and income of these suppliers. The total regional economic effect is the sum of the direct effects on agriculture and the indirect and induced effects associated with these direct effects on farmers.

G.5.2 Modeling Inputs for Regional Economic Impact Analysis

For this analysis, the 19 SWAP crop categories are aggregated into the eight default IMPLAN crop groups, as shown in Table G.5-1 below. The IMPLAN model contains two other default crop groups, “Greenhouse, Nursery, and Floriculture Production” and “Tobacco Farming”, but these groups are not used in this analysis.

For this analysis, direct agricultural revenue effects, which are outputs of the SWAP model and are summarized in section G.4.3, *SWAP Modeling Results*, are summed for the SWAP categories in each IMPLAN crop group. The total revenue associated with agricultural production, including the direct, indirect, and induced effects, is then calculated by multiplying the direct revenue for each IMPLAN crop group by the corresponding IMPLAN multiplier, shown in Table G.5-2. The total annual economic impact is then estimated as the change in total annual revenue (including direct, indirect, and induced effects) for each alternative relative to the total annual revenue under baseline conditions. The majority of the study area modeled in IMPLAN is contained within San Joaquin, Merced, and Stanislaus Counties, which are considered a good representation of the agricultural area in the LSJR Watershed.

Table G.5-1. Comparison of SWAP Crop Categories to IMPLAN Crop Groups

IMPLAN Crop Group	SWAP Crop Category
Code 1 - Oilseed	Safflower
Code 2 - Grain	Grain Corn Dry beans Rice
Code 3 - Vegetable and Melon	Cucurbits Tomatoes, Fresh Tomatoes, Processing Onion and Garlic Other Truck Crops
Code 4 - Fruit	Subtropical Vine Other Deciduous/Orchard Crops
Code 5 - Tree Nut	Almonds and Pistachios
Code 8 - Cotton	Cotton
Code 9 - Sugar Beets	Sugar Beets
Code 10 - All Other Crops	Alfalfa Pasture Other Field Crops

Changes in agricultural revenues from SWAP, with respect to baseline conditions, are considered a direct impact on the agricultural sector. The IMPLAN model incorporates ratios of jobs per unit of sector output that can be used to estimate changes in jobs associated with direct agricultural revenue losses. In other words, for a certain level of production, there will be a corresponding number of jobs supported. The total employment associated with a particular level of agricultural production can be estimated by multiplying agricultural revenues from SWAP by the employment-to-revenues ratio (or the total employment multiplier) for the agricultural sector. The total employment multipliers, which include direct, indirect, and induced effects on employment measure the number of jobs per million dollars of sector revenue in 2008 dollars. IMPLAN data used starts in 2010 dollars, but is converted to 2008 dollars with an deflation factor of 0.98 derived from BEA data (BEA 2016) before calculating the employment multipliers. The employment multipliers are shown in Table G.5-2 for each crop group. The total annual employment impact is then estimated as the change in total annual employment for each alternative relative to total annual employment under baseline conditions. The IMPLAN-derived total economic output and total employment multipliers for the three-county region are presented in Tables G.5-2 and G.5-3.

Table G.5-2. IMPLAN Total Economic Output Multipliers, by Crop Group

	Three-County Region IMPLAN Economic Multipliers			
IMPLAN Industry Code	Direct	Indirect	Induced	Total
Code 1 - Oilseed	1.00	0.39	0.18	1.57
Code 2 - Grain	1.00	0.59	0.20	1.79
Code 3 - Vegetable and Melon	1.00	0.36	0.40	1.76
Code 4 - Fruit	1.00	0.34	0.44	1.78
Code 5 - Tree Nut	1.00	0.32	0.38	1.70
Code 8 - Cotton	1.00	0.60	0.27	1.88
Code 9 - Sugar Beets	1.00	0.44	0.23	1.68
Code 10 - All Other Crops	1.00	0.47	0.29	1.76
Code 11 - Livestock	1.00	0.88	0.16	2.03
Code 12 - Dairy	1.00	0.57	0.12	1.69

Table G.5-3. IMPLAN Total Employment Multipliers, by Crop Group (jobs/$ Million of revenue, 2008)

	Three-County Region IMPLAN Employment Multipliers			
IMPLAN Industry Code	Direct	Indirect	Induced	Total
Code 1 - Oilseed	7.49	3.07	1.51	12.08
Code 2 - Grain	11.83	4.47	1.68	17.97
Code 3 - Vegetable and Melon	2.15	3.60	3.34	9.09
Code 4 - Fruit	3.11	4.06	3.69	10.86
Code 5 - Tree Nut	7.44	3.91	3.16	14.51
Code 8 - Cotton	2.81	4.77	2.27	9.85
Code 9 - Sugar Beets	21.07	4.08	1.95	27.09
Code 10 - All Other Crops	2.84	4.15	2.39	9.38
Code 11 - Livestock	4.73	4.71	1.30	10.74
Code 12 - Dairy	4.39	2.63	0.99	8.01

Note: The data in IMPLAN represents the employment in some crop categories higher than what would be expected in reality. In particular, the employment multipliers for Grain and Sugar Beets are expected to be lower than shown here.

G.5.3 Results of Regional Impact Analysis

This section presents estimates of the total economic output and total employment within the three-county region using the IMPLAN-based multipliers shown in Tables G.5-2 and G.5-3 applied to estimated changes in crop production revenues associated with the LSJR alternatives. Total effects include both the direct effects based on agricultural-related revenues (as estimated by the SWAP model), and the associated indirect and induced effects on the regional economy. This section also provides estimates of the total effects on both economic output and employment.

G.5.3.1 Effects on Total Economic Output

As an overview, Table G.5-4, presents effects on average annual total economic output (including direct, indirect, and induced Effects) related to agricultural production in the irrigation districts under baseline conditions. The table also presents differences from baseline conditions, both in dollars and as a percent, for each LSJR alternative. Information in the table includes average direct effects and average induced and indirect effects. In general, as the flow requirements in the alternatives get larger, the negative effect on total economic output increases.

Table G.5-4. Average Annual Total Economic Output Related to Agricultural Production in the Irrigation Districts under Baseline Conditions and the Change for Each of the LSJR Alternatives

		Change from Baseline ($ Millions, 2008)		
Economic Effects	Baseline Total Economic Output ($ Millions, 2008)[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Direct Economic Output	1,477	-9	-36	-117
Indirect and Induced Economic Output	1,109	-7	-27	-89
Total Economic Output	2,586	-17	-64	-206
% of Baseline Total Economic Output	100	-0.6	-2.5	-8.0

[a] The baseline economic output is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

To characterize the magnitude and variability of the results, Figure G.5-1 presents an exceedance plot of total economic output related to agricultural production in the irrigation districts across the 82 years of simulation under baseline conditions and for each of the LSJR alternatives.

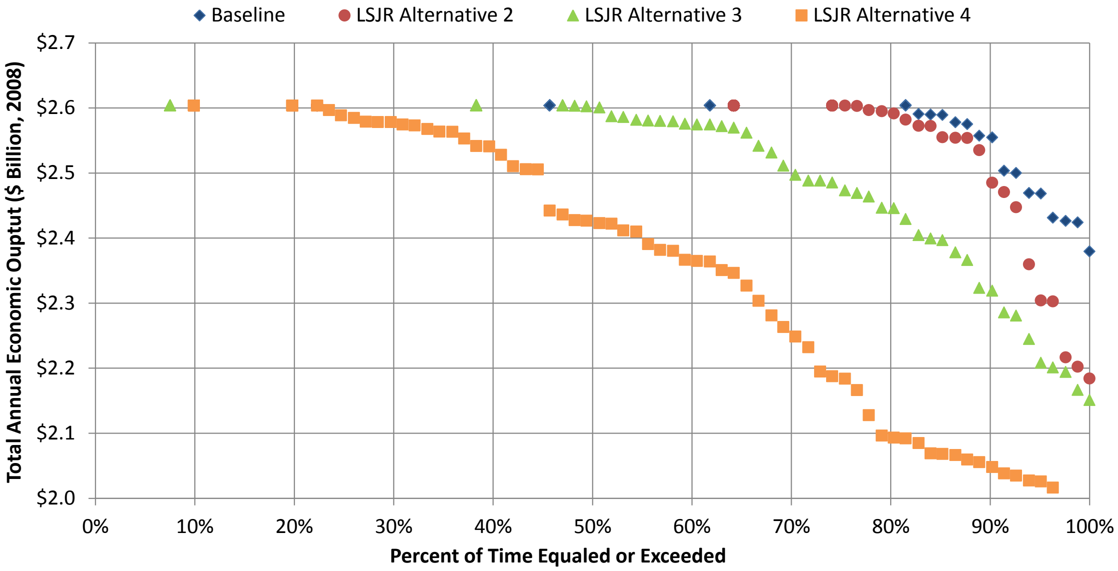

Figure G.5-1. Exceedance Plot of Total Economic Output Related to Agricultural Production in the Irrigation Districts for the LSJR Alternatives and Baseline across 82 Years of Simulation

Table G.5-5 presents several summary statistics for the exceedance timeseries above, including the cumulative distribution of the total economic output. These statistics are shown for baseline conditions while the change in each statistic relative to the baseline value is shown for each LSJR alternative.

It should be noted that the results of the IMPLAN modeling are not disaggregated by tributary watershed. As explained in Section G.3, *Estimation of Groundwater Balance*, the LSJR alternatives would be expected to reduce overall surface water diversions on the Tuolumne and Merced Rivers more than those on the Stanislaus River. Similarly, corresponding effects on economic activity would not be expected to be distributed equally across the three eastside tributary watersheds. Effects on total economic output would be concentrated in the larger urban areas (Stockton, Modesto, and Merced) where most of the trade takes place.

G.5.3.2 Effects on Total Employment

In addition to estimating total economic output, the IMPLAN model is used to estimate how changes in agricultural production in the irrigation districts might affect employment in the agricultural and other sectors. Any change in employment would not be isolated in the irrigation districts, but would likely occur over a wider area around the affected districts, particularly in larger urban areas where most of the trade takes place. The percent change in the total employment is similar to the percent change in total economic output for each LSJR alternative. Table G.5-6 presents a summary of the total number of jobs associated with crop production and related economic activity under baseline conditions, as well as the change, both in total jobs and as a percent, for each LSJR alternatives. Information in the table includes average direct effects and average induced and indirect effects. In general, as the flow requirements in the alternatives get larger, the negative effect on total employment increases.

Table G.5-5. Baseline Statistics for Total Economic Output Related to Agricultural Production in the Irrigation Districts and the Change in those Statistics for each of the LSJR Alternatives

	Baseline Total Economic Output[a]	LSJR Alternative 2 Difference from Baseline		LSJR Alternative 3 Difference from Baseline		LSJR Alternative 4 Difference from Baseline	
Statistics	($ Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
Avg	2,586	-17	-0.6	-64	-2.5	-206	-8.0
Min	2,379	-195	-8.2	-228	-9.6	-408	-17.1
90th Percentile	2,555	-64	-2.5	-235	-9.2	-506	-19.8
80th Percentile	2,604	-11	-0.4	-158	-6.1	-510	-19.6
70th Percentile	2,604	0	0.0	-103	-3.9	-351	-13.5
60th Percentile	2,604	0	0.0	-29	-1.1	-238	-9.1
50th Percentile	2,604	0	0.0	-2	-0.1	-179	-6.9
40th Percentile	2,604	0	0.0	0	0.0	-68	-2.6
30th Percentile	2,604	0	0.0	0	0.0	-26	-1.0
20th Percentile	2,604	0	0.0	0	0.0	0	0.0
10th Percentile	2,604	0	0.0	0	0.0	0	0.0
Max	2,604	0	0.0	0	0.0	0	0.0

[a] The baseline economic output is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Table G.5-6. Average Annual Total Employment Related to Agricultural Production in the Irrigation Districts under Baseline Conditions and the Change for Each of the LSJR Alternatives

Employment Effects	Baseline Total Employment (# of Jobs)[a]	Change from Baseline (# of Jobs)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Direct Employment	8,087	-53	-190	-692
Indirect and Induced Employment	10,514	-64	-242	-782
Total Employment	18,601	-117	-433	-1474
% of Baseline Total Employment	100	-0.6	-2.3	-7.9

[a] The baseline employment is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

To characterize the magnitude and variability of the employment results over time, Figure G.5-2 presents an exceedance plot of total employment from crop production and related economic activity in the irrigation districts across the 82 years of simulation under baseline conditions and for each of the LSJR alternatives.

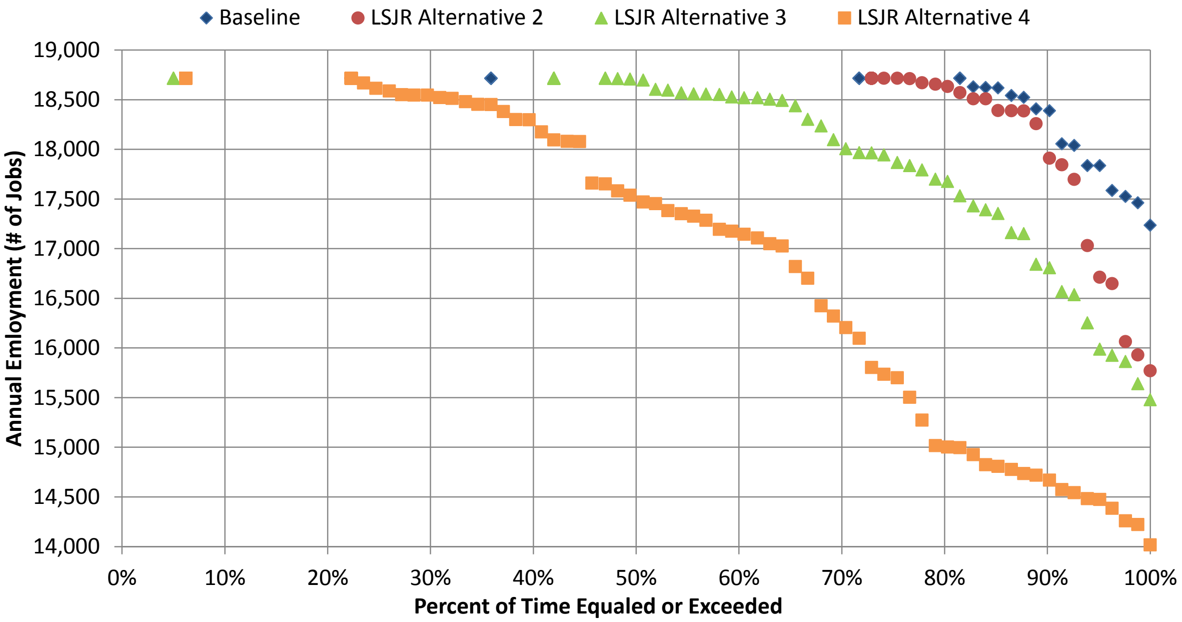

Figure G.5-2. Exceedance Plot of Total Employment Related to Agricultural Production in the Irrigation Districts for the LSJR Alternatives and Baseline across 82 Years of Simulation

Table G.5-7 presents several summary statistics for the exceedance timeseries above, including the cumulative distribution of the total employment. These statistics are shown for baseline conditions while the change in each statistic relative to the baseline value is shown for each LSJR alternative.

Table G.5-7. Baseline Statistics for Total Employment Related to Agricultural Production in the Irrigation Districts and the Change in those Statistics for Each of the LSJR Alternatives

	Baseline Total Employment[a]	LSJR Alternative 2 Difference from Baseline		LSJR Alternative 3 Difference from Baseline		LSJR Alternative 4 Difference from Baseline	
Statistics	(Jobs/y)	(Jobs/y)	% Change	(Jobs/y)	% Change	(Jobs/y)	% Change
Avg	18,601	-117	-0.6	-433	-2.3	-1,474	-7.9
Min	17,236	-1,467	-8.5	-1,758	-10.2	-3,219	-18.7
90th Percentile	18,391	-445	-2.4	-1,580	-8.6	-3,717	-20.2
80th Percentile	18,716	-78	-0.4	-1,034	-5.5	-3,711	-19.8
70th Percentile	18,716	0	0.0	-683	-3.6	-2,477	-13.2
60th Percentile	18,716	0	0.0	-193	-1.0	-1,558	-8.3
50th Percentile	18,716	0	0.0	-14	-0.1	-1,211	-6.5
40th Percentile	18,716	0	0.0	0	0.0	-467	-2.5
30th Percentile	18,716	0	0.0	0	0.0	-177	-0.9
20th Percentile	18,716	0	0.0	0	0.0	0	0.0
10th Percentile	18,716	0	0.0	0	0.0	0	0.0
Max	18,716	0	0.0	0	0.0	0	0.0

[a] The baseline employment is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

G.5.4 Fiscal Effects

G.5.4.1 Overview

Agricultural production encourages economic activity throughout local economies, generating millions of dollars in revenue for farmers and related industries. Federal, state, and local governments also collect a portion of this income by imposing various taxes. Tax revenue is used to support government operation and maintain necessary programs, such as health and safety, public protection, and transportation systems. In the agricultural sector, taxes are usually levied on farmer income, the sale of farm products and farming related goods, and the assessed value of agricultural property itself. Furthermore, farm production has a ripple effect creating economic activity in other sectors that in turn generates more tax revenue.

Each level of government uses a general fund in which most of the annual tax revenue is deposited. From the general fund, the county allocates money to all of its activities and services that are not paid for through a special fund. The San Joaquin, Stanislaus, and Merced County general funds receive 32 percent, 45 percent, and 20 percent of their revenue from taxes, respectively. Overall, about 85 percent to 90 percent of the tax revenue for each county goes to the general fund. Most of the remaining tax revenue is assigned to special revenue funds such as library funds, road funds, or fire prevention funds if given voter approval. In San Joaquin and Stanislaus Counties, a small amount of tax revenue goes to governmental business type activities.

Reductions in agricultural production may have fiscal impacts on tax revenue for cities, counties, the state, and the federal government. First, there is a direct impact on sales tax revenue associated with the reduction in agricultural production because there is less crop product to sell. Property taxes may also take a small hit as property values fall from fallowing of farmland and reduced economic activity in the area. Second, indirect impacts will result in industries that provide inputs to the agricultural industry. With fewer crops to grow, farmers will not buy as much fertilizer, pesticides, or farm equipment. Lastly, induced impacts result because of the changes in spending throughout the economy as labor income has changed. Farmers won’t need as much help during the growing and harvesting seasons, which may force some people to relocate and limit spendable income for others.

Were there to be a significant drop in tax revenue from reduced agricultural production, it could result in impacts on public services. Although vital services, such as health and safety, would likely maintain funding by tapping into other available sources of revenue, less critical services, such as public transportation and road systems, could be forced to operate with smaller budgets. Furthermore, when crop production falls, so does the number of farm-related jobs, and with more people unemployed, there could be a greater need for social welfare services. Some workers may leave the area to find work elsewhere, thereby reducing the local tax base, while those who can’t leave the area due to lack of funds would most likely be unable to contribute much to the government in the form of taxes.

Any impacts from the LSJR alternatives on fiscal revenue that could result from decreases in agricultural production are expected to be limited. Tax revenue directly or indirectly related to agricultural production comprises a small fraction of the total tax revenue for the federal and state governments. The total tax revenue collected by the federal and state governments are both several magnitudes larger than the tax revenue collected in any one county, so these entities are insulated from regional impacts. A summary of 2010 total tax revenue for San Joaquin, Stanislaus, and Merced Counties, the state of California, and the federal government is shown in Table G.5-8.

Table G.5-8. 2010 Total Revenue and Total Tax Revenue for Different Levels of Government

Level of Government	Name	Total Revenue ($ Millions, 2010)[a,b]	Total Tax Revenue ($ Millions, 2010)[a,b]	Major Sources of Tax Revenue (% of total tax revenue)	
Federal	United States	2,162,724	2,162,724	Individual Income Tax (42)	Payroll Taxes (40)
State	California	192,857	94,520	Individual Income Tax (46)	Sales Taxes (36)
County	San Joaquin	911	234	Property Taxes (83)	Sales Taxes (9)
	Stanislaus	678	106	Property Taxes (76)	Sales Taxes (22)
	Merced	435	70	Property Taxes (93)	Sales Taxes (6)

Sources: State of California 2010; County of San Joaquin 2010; County of Stanislaus 2010; County of Merced 2010.

[a] Total for 2010 fiscal year. California state and county fiscal year is from July 1 2009 to June 30 2010, while the federal government fiscal year is from September 1 2009 to October 30 2010.

[b] Includes revenue to all funds besides business type activity funds.

Although reductions in federal and state tax revenue would be larger under the LSJR alternatives than at the local level in absolute terms, county and municipal governments could likely experience a greater impact as their tax revenue reductions would represent a larger portion of their total funds. In addition, there are numerous city governments within each of the affected counties of the three-county study area that also depend on tax dollars related to agriculture, as farm products are often distributed and sold within the cities. Potential effects on local governments, however, may not be severe. One recent report found that lost agricultural production during California's drought between 2012 and 2014 did not substantially impact the finances of most local governments (MIS 2014).

Table G.5-9 presents total tax revenue received by local governments for each county within the three-county study area, and the contribution of crop farming related production and import tax revenues to each county's total. Taxes on production and imports represent sales tax, property tax, and other miscellaneous taxes (severance, motor vehicle license); it does not include income or corporate taxes, but these taxes primarily go to the state and federal governments. Of the three counties, the agricultural sector makes the greatest percent contribution in Merced County, where it generates about 4.5 percent of the tax revenue. The San Joaquin and Stanislaus Counties receive greater total tax revenue than Merced, but a smaller percent contribution from agriculture because they have significantly larger urban populations.

Table G.5-9. Estimates of Local Government Tax Revenue and Crop Farming Contribution from IMPLAN

County	Total Annual Tax Revenue to Local Governments[a] ($ Millions, 2010)	Total Annual Tax Revenue from Crop Farming to Local Governments[b] ($ Millions, 2010)	Crop Farming Contribution as % of Total Tax Revenue (%)
San Joaquin	983	18	1.9
Stanislaus	736	11	1.4
Merced	283	13	4.5

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

$ Million, 2010 = millions of 2010 dollars.

[a] Local government includes the governments of both the county and cities within the county.

[b] Includes only Taxes on Production and Imports, not Personal Taxes.

G.5.4.2 Fiscal Analysis Methods

This section presents the methods used to assess the potential effects on federal, state, and local tax revenues that could result from implementing the LSJR alternatives. To estimate the effect of agricultural revenue losses on tax revenue, information from the IMPLAN input-output model was employed to estimate fiscal economic multipliers. These multipliers were developed from IMPLAN tax revenue results based on consideration of an agricultural revenue loss of 1 million dollars in crop farming (represented in IMPLAN as an aggregate economic sector, North American Industry Classification System, or NAICS, 111) within the three-county region of San Joaquin, Stanislaus, and Merced Counties, and for each of the three counties individually. At the federal level, total (direct, indirect, and induced) tax revenue losses were estimated from the IMPLAN results template. State and local taxes, however, are lumped in the default IMPLAN report templates so state and county financial reports and other tax information were used to develop a breakdown between state and local tax revenues; this breakdown is shown in table G.5-10.

Table G.5-10. IMPLAN Tax Revenue Breakdown between State and Local Governments

Description of IMPLAN Tax Source	State Portion (%)	Local Portion (%)
Dividends	100	
Social Ins Tax- Employee Contribution	100	
Social Ins Tax- Employer Contribution	100	
Tax on Production and Imports: Property Tax		100
Tax on Production and Imports: Sales Tax[a]	Depends on County	
- San Joaquin County	82.5	17.5
- Stanislaus County	86.6	13.4
- Merced County	87.9	12.1
Tax on Production and Imports: Motor Vehicle Lic		100
Tax on Production and Imports: Severance Tax	100	
Tax on Production and Imports: Other Taxes[b]	50	50
Tax on Production and Imports: S/L NonTaxes[b]	50	50
Corporate Profits Tax	100	
Personal Tax: Income Tax	100	
Personal Tax: NonTaxes (Fines- Fees)[b]	50	50
Personal Tax: Motor Vehicle License		100
Personal Tax: Property Taxes		100
Personal Tax: Other Tax (Fish/Hunt)	100	

Sources: ILG 2013; BOE 2009; BOE 2015.

[a] Sales tax rates can differ from city to city in a county, but a single average county tax rate is assumed for this assessment. The proportions are based on county tax rates for 2010 (8.25% in Merced, 8.375% in Stanislaus, and 8.5% in San Joaquin). The 2010 base sales tax rate was 8.25%, with 7.25% of the tax revenues going to the state and 1.00% going to local governments. Values for 2010 are used because IMPLAN data for 2010 was used in the regional economy assessment described above.

[b] For a few categories, the proportion of revenues shared between state and local governments is not available, so it was assumed to be shared equally.

Table G.5-11 presents estimates of the fiscal impact on the entire three-county region associated with a reduction of 1 million dollars in agricultural revenue; the fiscal impact multipliers derived from these estimates also are presented in Table G.5-11. The results show that a 1 million dollar reduction in agricultural revenue over this region would have a direct impact of $119,245 in tax revenue over all levels of government. Accounting for the indirect and induced effects of the 1 million dollar reduction would increase the tax revenue losses to $257,932. To develop fiscal impact multipliers for the different levels of government, the total loss at each level was divided by 1 million dollars. In other words, the total federal tax impact is 15.2 percent ($152,471/$1,000,000) of the agricultural revenue loss, the total state tax impact is 6.1 percent ($60.848/$1,000,000) of the loss, and the total local tax impact is 4.5 percent ($44,613/$1,000,000) of the loss.

Table G.5-11. Resulting Fiscal Impact in Response to a $1 Million Loss in Agricultural Revenue for the Three-County Region

	Tax Revenue Impact ($, 2010)		Fiscal Impact Multipliers	
Level of Government	Direct	Total[a]	Direct	Total
Federal	-76,222	-152,471	0.076	0.152
State	-27,094	-60,848	0.027	0.061
Local	-15,928	-44,613	0.016	0.045

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

[a] Includes direct, Indirect, and induced effects of a $1 million (in 2010 dollars) loss in agricultural revenue.

Fiscal impacts for individual counties also were analyzed using the same approach described above, applying a 1 million dollar revenue loss to all crop agriculture in each county by itself. Subsequently, Table G.5-12 presents the tax impacts on the individual county analysis and the fiscal impact multipliers used to calculate these impacts. Depending on the county, the total federal tax impact would be between 10.9 percent and 15.4 percent of the agricultural revenue loss, the total state tax impact would be between 4.7 percent and 6.1 percent of the loss, and the total local tax impact would be between 3.3 percent and 4.5 percent of the revenue loss.

Table G.5-12. Fiscal Impacts by County of a Hypothetical $1 Million Crop Revenue Loss

	Tax Revenue Impact ($ Million, 2010)		Fiscal Impact Multipliers	
Level of Government	Direct	Total[a]	Direct	Total
San Joaquin				
Federal	-75,482	-154,003	0.075	0.154
State	-27,156	-61,415	0.027	0.061
Local	-15,691	-44,731	0.016	0.045
Stanislaus				
Federal	-83,268	-153,658	0.083	0.154
State	-28,707	-60,647	0.029	0.061
Local	-15,998	-40,519	0.016	0.041
Merced				
Federal	-70,966	-108,684	0.071	0.109
State	-26,757	-47,082	0.027	0.047
Local	-15,404	-32,610	0.015	0.033

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

$ Million, 2010 = millions of 2010 dollars.

[a] Includes direct, indirect, and induced effects of a $1 million (in 2010 dollars) loss in agricultural revenue.

These county fiscal impact multipliers were then used with the SWAP results for crop revenue as described in Section G.4.3, *SWAP Modeling Results*, to estimate the tax revenue losses. Though the tax revenue impacts reported in both Table G.5-11 and G.5-12 are in 2010 dollars the fiscal multipliers are unitless and can be applied directly to the SWAP results. Since the SWAP results were calculated by irrigation district and not county, the crop revenue for districts that shared a county were added together. For OID and TID, which fall across two counties, the revenue was divided between the counties based on the relative area of the irrigation districts in each county. According to the OID AWMP (2012), 20 percent of OID falls in San Joaquin County and 80 percent falls in Stanislaus County. TID was estimated to have 74 percent of its area in Stanislaus County and 26 percent of its area in Merced County, based on GIS analysis.

G.5.4.3 Results

This section presents potential effects on federal, state and local tax revenues that could result from implementing the LSJR alternatives. Table G.5-13 shows the annual average tax revenue for each level of government related to agricultural production in the three counties individually and over the three-county region as a whole. Under baseline, the federal government receives about $210 million and the state receives about $85 million from agricultural production over all three counties, which is only 0.01 percent and 0.09 percent of their total tax revenue for 2010 (after accounting for inflation), respectively. Both federal and state tax revenue from agricultural production over the three counties decrease by about 0.7 percent in LSJR Alternative 2 up to about 8.1 percent in LSJR Alternative 4, relative to Baseline; however, these changes are relatively small compared to the total revenue for 2010 (after accounting for inflation).

Table G.5-13. Estimated Change in Tax Revenue Associated with Predicted Changes in Annual Agricultural Production for LSJR Alternatives 2, 3, and 4 Relative to Baseline Conditions

		Tax Revenue Effects of Agricultural Production			
		Baseline	Change Relative to Baseline ($ Millions, 2008)		
County	Level of Government	($ Millions, 2008)[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
San Joaquin	Federal	91	-0.41	-1.08	-3.29
	State	36	-0.16	-0.43	-1.31
	Local	26	-0.12	-0.31	-0.96
Stanislaus	Federal	77	-0.89	-3.60	-11.88
	State	31	-0.35	-1.42	-4.69
	Local	20	-0.23	-0.95	-3.13
Merced	Federal	42	-0.12	-0.63	-1.98
	State	18	-0.05	-0.27	-0.86
	Local	13	-0.03	-0.19	-0.59
All Counties	Federal	210	-1.41	-5.31	-17.15
	State	85	-0.56	-2.12	-6.86
	Local	59	-0.39	-1.45	-4.68

Sources: 2010 IMPLAN county data files, and IMPLAN model runs for LSJR alternatives.

$ Millions, 2008 = millions of 2008 dollars.

[a] The baseline tax revenue is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Table G.5-14 focuses effects of the LSJR alternatives on local governments and how these effects compare to the total annual tax revenue from Table G.5-8. Under baseline, local governments in San Joaquin, Stanislaus, and Merced Counties receive $26, $20, and $13 million in tax revenue annually from agricultural production, respectively. These revenues represent about 2.7 percent to 4.5 percent of the total annual tax revenue for local governments in each of the three counties. For the LSJR alternatives, the impact of changes in agricultural production and revenues on tax revenue is relatively small compared to the total annual tax revenue. Stanislaus County has the largest reduction in tax revenue of the three counties, but its losses do not exceed 0.4 percent of the total annual tax revenue under any alternative.

Table G.5-14. Estimates of Local Tax Revenue Associated with Predicted Changes in Annual Agricultural Production, as a Percent of Total Tax Revenue

County	Estimates of Total Annual Tax Revenue to Local Governments[a,b] ($ Millions, 2008)	Tax Revenue Related to Predicted Annual Agricultural Production, by County: Baseline Value as % of Estimated Total Annual Tax Revenue[c]	Change Relative to Baseline as % of Estimated Total Annual Tax Revenue: LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
San Joaquin	963	2.7	0.0	0.0	-0.1
Stanislaus	722	2.8	0.0	-0.1	-0.4
Merced	278	4.5	0.0	-0.1	-0.2

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

$ Million, 2008 = millions of 2008 dollars.

[a] Local government includes the governments of both the county and cities within the county.

[b] Dollar values from IMPLAN are in $2010 and had to be converted to $2008 with a conversion factor of 0.980 derived from BEA data (BEA 2016).

[c] The baseline tax revenue is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Based on these results, only relatively minor impacts would be expected on tax revenues at all levels of government as a result of implementing the LSJR alternatives. Tax revenue from agricultural production is a larger percentage of income for local governments than for the federal or state government, but the impact would still be small compared to tax revenue from other sources. Although the three counties are some of the largest agricultural producers in the state, most local governments do not heavily depend on tax revenue from agriculture. Some localized impacts on small towns that rely on agriculture could result, but overall cities within these counties would not be expected to experience major budgetary changes that could impact the delivery of public services.

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Attachment 1

Comparison of AWMP and DAU Crop Distributions for Irrigation Districts

Appendix G
Attachment 1

For the analysis of agricultural impacts that could result from the LSJR alternatives, it was necessary to estimate the crop mixture produced in the various irrigation districts that rely on surface water from the Stanislaus, Tuolumne, and Merced Rivers. Information on the crop mixtures was acquired from two sources: irrigation district Agricultural Water Management Plans (AWMPs) (or Water Management Plans [WMPs] for the CVP contractors) and DWR crop survey data for each Detailed Analysis Unit (DAU). These distributions are compared below for each irrigation district. The distributions are compared using the same estimate of total irrigated acres for each district, which are from the AWMPs as described in Table G.4-1 of Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*.

Stockton East Water District (SEWD)

Most of SEWD's irrigated acres fall within DAU 182, with a small portion located in DAU 185; since the irrigated acres in DAU 185 is small the crop distribution for DAU 182 was applied over the whole district. The SEWD WMP suggests that the district devotes more acreage to other deciduous crops (non-almond or pistachio tree crops such as orchards), cucurbits, and other truck crops and less acreage to alfalfa, almonds, corn, grain and vineyards when compared with the crop distribution for DAU 182. In the WMP the acreage for other deciduous crops is about 73 percent of the total acreage compared to 27 percent in the DAU crop distribution. In the DAU distribution vine crops represent 35 percent of the crop acreage compared to only 8 percent in the WMP distribution. The WMP also groups several smaller crops into a single "other" category, which is less than 1 percent of the crop mix.

In the WMP, all crops, except grain and vine crops, have lower applied water rates than for the DAU distribution. The vine crops need 3 times more water per acre and grain crops need 5.5 times more water per acre in the WMP. On the other hand, onions and other truck crops need 2 times more water per acre and bean crops need 3.5 times more water per acre when using the DAU distribution. The total applied water demand resulting from the DAU distribution is about 22,000 acre-feet (AF) lower than the AWMP distribution estimate. Other deciduous crops account for about 80 percent of the applied water demand in the AWMP distribution, but only account for 40 percent of the applied water demand in the DAU distribution.

Table 1. Comparison of SEWD WMP and DAU 182 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	WMP	DAU	WMP	DAU	WMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	821	2,376	3.5	4.6	2,858	11,012
Almond/Pistachio	17	727	2.4	3.4	40	2,475
Corn	922	5,487	1.8	2.5	1,676	13,868
Cotton						
Cucurbits	817	298	1.2	1.8	984	525
Dry Beans	768	886	0.7	2.3	508	2,055
Grain	1,225	2,401	1.8	0.3	2,227	781
Onion and Garlic	179	140	0.7	1.5	118	206
Other Deciduous	36,990	13,643	3.0	3.4	110,270	46,800
Other Field		444		3.2		1,414
Other Truck	1,121	449	1.5	3.0	1,661	1,361
Pasture	1,524	1,843	3.4	4.9	5,247	9,106
Potato						
Rice		645		5.3		3,408
Safflower		28		1.1		31
Subtropical		187		3.0		559
Sugar Beets						
Tomato, Fresh	2,193	530	1.3	2.1	2,754	1,110
Tomato, Processing		2,999		2.8		8,252
Vine	4,264	17,899	2.8	0.9	11,743	15,567
Other	140		2.8		386	
Total	50,981	50,981	2.8	2.3	140,472	118,530

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Central San Joaquin Water Conservation District (CSJWCD)

All of CSJWCD’s irrigated acres fall within DAU 182. The CSJWCD WMP suggests that the district devotes more acreage alfalfa, corn, grain, and tomatoes and less acreage to other deciduous crops and vineyards when compared with the crop distribution for DAU 182. In the WMP the acreage for corn is about 31 percent of the total acreage compared to 11 percent in the DAU crop distribution. In the DAU distribution other deciduous crops and vine crops represent 62 percent of the crop acreage compared to only 24 percent in the WMP distribution. The WMP also groups several smaller crops into a single “other” category, which is only 1percent of the crop mix. The CSJWCD WMP gave no estimates for crop water use.

Table 2. Comparison of CSJWCD WMP and DAU 182 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	WMP	DAU	WMP	DAU	WMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	6,000	2,237		4.6		10,368
Almond/Pistachio		684		3.4		2,330
Corn	15,000	5,166		2.5		13,057
Cotton						
Cucurbits		280		1.8		494
Dry Beans		834		2.3		1,935
Grain	7,000	2,260		0.3		735
Onion and Garlic		132		1.5		194
Other Deciduous	6,000	12,845		3.4		44,063
Other Field		418		3.2		1,331
Other Truck		423		3.0		1,281
Pasture	2,500	1,735		4.9		8,574
Potato						
Rice		607		5.3		3,209
Safflower		27		1.1		29
Subtropical		177		3.0		527
Sugar Beets						
Tomato, Fresh	5,800	499		2.1		1,045
Tomato, Processing		2,824		2.8		7,769
Vine	5,150	16,852		0.9		14,657
Other	550					
Total	48,000	48,000		2.3		111,599

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Southern San Joaquin Irrigation District (SSJID)

All of SSJID's irrigated acres fall within DAU 205. The SSJID AWMP suggests that the district grows more acreage for pasture and almonds and less acreage for other deciduous crops compared to the DAU distribution. In both distributions, almonds account for a large percent of the irrigated acres, about 58 percent in the AWMP distribution and 46 percent in the DAU distribution. Using the DAU distribution, about 14,500 acres or 25 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily corn, grain, and subtropical crops. However, the AWMP groups several smaller crops into a single "other" category and includes about 5,000 acres of double cropped grain and corn.

In the AWMP all crops, except vine crops, have lower applied water rates than in the DAU distribution. Vine crops need 2 times more water per acre in the AWMP, while pasture receives about 1.5 times more water in the DAU distribution. The total applied water demand resulting from the DAU distribution is similar to the AWMP distribution estimate.

Table 3. Comparison of SSJID AWMP and DAU 205 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	2,516	3,175	3.8	5.0	9,618	15,745
Almond/Pistachio	34,170	27,032	3.3	3.5	113,868	93,721
Corn		8,332		2.9		24,271
Cotton						
Cucurbits		490		2.0		988
Dry Beans		175		2.5		434
Grain		1,670		0.8		1,285
Onion and Garlic		602		1.9		1,123
Other Deciduous	3,793	6,854	3.4	3.9	12,973	26,494
Other Field		210		3.4		705
Other Truck		437		3.2		1,393
Pasture	4,327	1,664	3.5	5.4	15,157	8,917
Potato						
Rice		84		5.4		454
Safflower		162		1.4		231
Subtropical		1,747		3.4		5,942
Sugar Beets						
Tomato, Fresh		70		2.3		165
Tomato, Processing		454		3.0		1,355
Vine	4,594	5,393	2.4	1.2	10,809	6,471
Double Cropping Grain/Corn	5,515		2.7		15,109	
Other	3,635		3.2		11,562	
Total	58,551	58,551	3.2	3.2	189,096	189,695

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Oakdale Irrigation District (OID)

All of OID's irrigated acres fall within DAU 206; however, DAU 206 falls in both the San Joaquin and Stanislaus Counties and both portions have different crop distributions. The total irrigated acres for the district was divided between the two counties based on a GIS determination of the relative acres of DAU 206 that fall within both counties and the corresponding DAU crop distributions were applied to both areas. The OID AWMP suggests that the district grows more acreage for pasture and less acreage for almonds, truck crops, and other deciduous crops compared to the DAU distribution. In the AWMP distribution pasture accounts for 60 percent of the total acreage, compared to only 16 percent in the DAU crop distribution. Using the DAU distribution about 20,500 acres or 38 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily single crop corn, alfalfa, and other field crops. However, the AWMP also includes about 8,500 acres of double cropped grain and corn.

In the AWMP all crops, except other truck and other deciduous crops, have lower applied water rates than in the DAU distribution. Truck crops need 2 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 18,000 AF higher than the AWMP distribution estimate. Pasture accounts for about 64 percent of the applied water demand in the AWMP distribution, but only accounts for 22 percent of the applied water demand in the DAU distribution.

Table 4. Comparison of OID AWMP and DAU 206 Crop Distributions

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa		2,131		4.6		9,751
Almond/Pistachio	5,607	10,513	2.8	3.7	15,794	38,673
Corn		9,758		2.6		24,885
Cotton						
Cucurbits		101		1.6		159
Dry Beans		214		2.2		470
Grain		376		0.7		273
Onion and Garlic						
Other Deciduous	2,582	6,504	3.9	3.5	10,182	22,825
Other Field		7,806		2.5		19,317
Other Truck	134	2,807	2.5	1.1	335	3,144
Pasture	32,596	8,839	3.3	4.7	107,605	41,845
Potato						
Rice	3,626	4,250	3.8	5.3	13,762	22,537
Safflower						
Subtropical		137		3.1		429
Sugar Beets						
Tomato, Fresh						
Tomato, Processing						
Vine	1,093	879	1.7	2.3	1,891	2,063
Double Cropping Grain/Corn	8,500		2.2		18,735	
Other	179					
Total	54,317	54,317	3.1	3.4	168,303	186,370

WMP = water management plan DAU = Detailed Analysis Unit AF/acre = acre-feet per acre

Modesto Irrigation District (MID)

All of MID's irrigated acres fall within the Stanislaus County portion of DAU 206. The MID AWMP suggests that the district grows more acreage for almonds, grain, and other deciduous crops and less acreage for corn, field crops, and truck crops compared to the DAU distribution. In the AWMP distribution almonds and pistachios account for 34 percent of the total acreage, compared to only 22 percent in the DAU crop distribution. In the DAU distribution field and truck crops account for another 22 percent of the total irrigated acres, but total less than 1 percent of the area in the AWMP distribution. In addition, the DAU distribution accounts for a small amount of acreage for beans and subtropical crops that are not accounted for in the AWMP distribution. However, the AWMP also groups several smaller crops into a single "other" category and includes about 431 acres of double cropped grain and corn.

In the AWMP all crops, except rice crops, have higher applied water rates than in the DAU distribution. Grain crops need 2 times more water per acre and truck crops need 3.5 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 50,000 AF lower than the AWMP distribution estimate.

Table 5. Comparison of MID AWMP and DAU 206 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	3,417	2,674	5.1	4.6	17,303	12,235
Almond/Pistachio	20,006	13,157	4.0	3.7	80,327	48,415
Corn	4,622	10,525	2.8	2.5	13,010	26,310
Cotton						
Cucurbits	3	127	2.3	1.6	7	200
Dry Beans		255		2.2		558
Grain	5,730	212	2.0	1.0	11,668	205
Onion and Garlic						
Other Deciduous	11,624	8,149	4.5	3.5	51,827	28,591
Other Field	293	9,422	2.6	2.4	752	23,033
Other Truck	200	3,523	3.8	1.1	765	3,945
Pasture	9,377	8,743	5.6	4.6	52,234	40,421
Potato						
Rice	366	679	4.6	5.7	1,666	3,863
Safflower						
Subtropical		42		2.8		118
Sugar Beets						
Tomato, Fresh						
Tomato, Processing						
Vine	1,340	1,103	3.4	2.3	4,622	2,588
Double Cropping Grain/Corn	431		3.0		1,308	
Other	1202		2.9		3,460	
Total	58,611	58,611	4.1	3.2	238,951	190,480

WMP = water management plan DAU = Detailed Analysis Unit AF/acre = acre-feet per acre

Turlock Irrigation District (TID)

All of TID's irrigated acres fall within DAU 208; however, DAU 208 falls in both the Stanislaus and Merced Counties and both portions have different crop distributions. The total irrigated acres for the district was divided between the two counties based on a GIS determination of the relative acres of DAU 208 that fall within both counties and the corresponding DAU crop distributions were applied to both areas. The TID AWMP suggests that the district grows more acreage for almonds, grain, pasture, vine, and other deciduous crops and less acreage for corn, field crops, and truck crops compared to the DAU distribution. In the DAU distribution Single cropped corn and other field crops represent 50 percent of the crop acreage compared to only 8 percent in the AWMP distribution. However, in the AWMP 27 percent of the total acreage or 39,000 acres is used for double cropping, mostly for grain and corn or unirrigated forage and corn. In addition, the AWMP accounts for 2,000 acres of potatoes not in the DAU distribution and groups several smaller crops into a single "other" category.

In the AWMP all crops, except for pasture and alfalfa, have higher applied water rates than in the DAU distributions. Truck crops, tomatoes, and grain crops need about 2.5 times more water per acre and cucurbits need 2 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 110,000 AF lower than the AWMP distribution estimate.

Table 6. Comparison of TID AWMP and DAU 208 Crop Distributions

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	15,162	14,371	4.1	4.5	62,189	65,177
Almond/Pistachio	45,685	33,776	3.7	3.1	169,587	105,851
Corn	9,650	43,350	3.0	2.5	29,352	109,074
Cotton						
Cucurbits	379	469	2.8	1.6	1,045	743
Dry Beans	680	1,073	2.5	2.2	1,696	2,379
Grain	3,113	455	2.5	0.9	7,782	431
Onion and Garlic	17		3.9		66	
Other Deciduous	12,153	8,238	3.9	3.5	47,768	28,841
Other Field	868	29,078	2.5	2.5	2,153	72,422
Other Truck	37	7,977	2.6	1.1	95	9,091
Pasture	11,684	4,784	3.9	4.6	45,357	21,982
Potato	1,974		2.7		5,366	
Rice						
Safflower						
Subtropical	64	63	3.0	2.8	195	175
Sugar Beets	0		3.6		0	
Tomato, Fresh	4	379	3.6	1.6	15	596
Tomato, Processing						
Vine	3,197	2,016	2.7	2.2	8,653	4,461

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Double Cropping Grain/Corn	18,949		4.2		79,271	
Double Cropping Unirrigated Forage/Corn	9,944		3.5		34,693	
Double Cropping Other	10,368		3.4		35,609	
Other	2,104		3.7		7,753	
Total	146,030	146,030	3.7	2.9	538,645	421,223

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Merced Irrigation District (Merced ID)

Most of Merced ID’s irrigated acres fall within DAU 210 with a few small areas falling in other DAUs. Since the other areas were small the crop distribution for DAU 210 was applied for the entire district. The Merced ID AWMP suggests that the district grows more acreage for alfalfa, cotton, pasture, and tomatoes and less acreage for corn compared to the DAU distribution. Using the DAU distribution about 33,000 acres or 33 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily other truck, other field, and other deciduous crops. However, the Merced ID AWMP only presents a distribution of the district’s major crops and leaves out many of the smaller ones. Overall, the total crop area from the AWMP distribution falls about 29,000 acres short of the total irrigated acres for the district, 100,237 acres, specified in Table G.4-1 of Appendix G.

Both distributions have similar applied water rates, except for fresh tomatoes which require 50 percent more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 37,000 AF higher than the AWMP distribution estimate. This difference should be significantly smaller because the AWMP does not have an estimate of the applied water rate or demand for the 29,000 acres of “other” crops.

Table 7. Comparison of Merced ID AWMP and DAU 210 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	8,615	5,810	4.3	4.5	37,324	26,010
Almond/Pistachio	29,771	30,615	3.7	3.3	109,712	100,953
Corn	12,543	19,088	2.5	2.5	31,820	48,220
Cotton	4,819	2,490	2.8	3.1	13,382	7,659
Cucurbits		646		1.5		951
Dry Beans						
Grain		3,135		0.9		2,957
Onion and Garlic						
Other Deciduous		4,887		3.4		16,583
Other Field		7,193		2.5		17,838
Other Truck		11,803		1.1		13,551
Pasture	10,055	5,994	4.1	4.5	41,568	26,896
Potato						
Rice		1,199		5.4		6,532
Safflower						
Subtropical						
Sugar Beets		277		1.6		434
Tomato, Fresh	5,745	1,844	2.4	1.6	13,914	2,951
Tomato, Processing		1,383		2.4		3,280
Vine		3,873		2.4		9,187
Other	28,689					
Total	100,237	100,237	2.5	2.8	247,721	284,003

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre