Master Response 8.1
Local Agricultural Economic Effects and the SWAP Model

Overview

Growers in California make business decisions based on available resource, market forces, operational constraints, and individual preferences. Each grower has a unique mix of these individual conditions that cannot be fully captured in a model. However, the Statewide Agricultural Production (SWAP) model is able to reflect overall trends in observed grower behavior in response to changing conditions. The SWAP model was selected for the analysis in the substitute environmental document (SED) to evaluate local agricultural effects because the model is peer reviewed and already widely used by state and federal agencies to model cropping decisions. Using the SWAP model, one can modify the amount of available water and land in a specific area, and the model will estimate grower responses, including changes in cropping patterns. For example, having less available water leads to the model estimating a shift from some lower net revenue crops, such as field crops, to some higher net revenue crops, such as orchards.

This master response addresses comments raised regarding the application of the SWAP model to analyze and disclose potential local agricultural economic effects resulting from the plan amendments in the SED. Specifically, the State Water Resources Control Board (State Water Board) considered economics and the economic effects of the plan amendments in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results,* and Chapter 20, *Economic Analyses.* The local agricultural economic analysis was performed using the SWAP model, based on results of the Water Supply Effects (WSE) model and the agricultural practices and characteristics of the plan area and of individual irrigation districts.

In order to reasonably protect fish and wildlife, the plan amendments would increase the volume of water instream in some years, thus reducing the water available for other beneficial uses, such as agriculture. The SWAP model was used to provide a reasonable and accurate representation of the local agricultural response to reductions in water supply. While it is an accurate and useful tool for comparing different Lower San Joaquin River (LSJR) alternatives, including for economic analysis, actual economic effects may differ as the infinite number of decisions of individual growers are impossible to predict and the regional and global economies are always changing. For example:

- Can growers modify their crop mix?
- Can growers implement additional water management adaptations?
- What is the current market for growers' commodities?

No model can anticipate the wide range of market and other uncertainties or account for factors unrelated to purely rational economic behavior. As part of the State Water Board's programmatic analysis and sections 13141 and 13241 Porter-Cologne Water Quality Control Act requirements, the State Water Board must consider economics when approving amendments to a water quality control plan. The State Water Board need not consider or evaluate infinite individual choices of growers in the SED, but rather it must provide a reasonable comparative analysis to show relative magnitude and range of expected economic effects. The analysis describes changes under the LSJR alternatives and disclose a range of agricultural economic effects that could occur under lower unimpaired flows and higher unimpaired flows as described by the LSJR alternatives.

This master response describes the assumptions of the revised SWAP model run performed in response to several comments that highlighted opportunities for refinement in the original model run. Based on comments, a revised SWAP model run was created with refined assumptions. For example, it was determined that for some crops the SWAP model was allowing deficit irrigation to exceed realistic levels during dry years. For other crops, SWAP was underestimating the level to which deficit irrigation could occur. The revised model run does not result in any new potentially significant adverse environmental impacts or a substantial change in the severity of potentially significant adverse environmental impacts or economic effects identified in the SED.

The State Water Board reviewed all comments related to local agricultural economic effects and the SWAP model and developed this master response to address recurring comments and common themes. This master response references related master responses, as appropriate, where recurring comments and common comment themes overlap with other subject matter areas. This master response includes, for ease of reference, a table of contents following this *Overview* to help guide readers to specific subject areas. In particular, this master response addresses, but is not limited to, the following topics regarding the SED economic analysis and the SWAP model itself. As such, this master response covers the following topics.

- The scope of the agricultural economic analysis.
- Agricultural economic effects and groundwater.
- The SWAP model and its assumptions.
- The revised SWAP model scenario and its results.
- Other costs associated with crop production.

For discussion of how data and results are presented, please see Master Response 2.3, *Presentation of Data and Results in SED and Responses to Comments*. For responses to comments regarding impacts on agricultural resources, please see Master Response 3.5, *Agricultural Resources*. For an overview of the economic analysis and for responses to comments regarding the framework of the analysis, please see Master Response 8.0, *Economic Analyses Framework and Assessment Tools*. For responses to comments regarding economic and employment impacts in the wider regional economy, please see Master Response 8.2, *Regional Agricultural Economic Effects*.

Table of Contents

Scope of the Local Agricultural Economic Analysis

General Approach

The agricultural economic analysis in the SED considers potential economic effects that could result from changes in agricultural production caused by reduced surface water diversions under the LSJR alternatives. The analysis gives a reasonable estimate of the economic effects, taking into account historical observations and data for how growers have responded to reduced water supplies in the past. The analysis applies historical data, local and regional trends, and standard agricultural management practices to represent how water is managed on agricultural lands. The analysis does not account for site-specific actions that can or cannot be performed by individuals and does not quantify economic effects on specific individuals.

The analysis covers several variables related to agricultural economics. The effects of reduced water supplies on crop production and, in turn, crop revenue, are estimated using the SWAP model. cost to pump groundwater under the LSJR alternatives is also accounted for, as described in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results,* Section G.4.4. IMPLAN model multipliers are then applied to the SWAP model crop revenue results to estimate indirect and induced economic effects and employment effects in the regional economy. Fiscal economic multipliers, also from the IMPLAN model, are applied to the final regional economic effects to estimate the tax revenue for the local, state, and federal governments. Please refer to Master Response 8.2, *Regional Economic Effects*, for more information about the IMPLAN model and regional economic effects of the LSJR alternatives.

Many commenters were concerned that the SED did not fully account for the long-term economic effects of reduced water supply reliability and asserted that the SED's economic analysis only analyzes individual year impacts as opposed to those that would occur over multiple years. Furthermore, commenters were also concerned that the SED economic analysis did not account for the inter-annual effects of water supply variability, suggesting that more variable water supplies make it difficult to plan for the future and may convince growers to avoid planting permanent crops for fear of losing their investment. The SED captures how water supply availability would change over the long term in modeling changes in surface water diversions with the WSE model over 82 years of historical hydrologic conditions from 1922 to 2003 (results are presented in Appendix F.1, *Hydrologic ad Water Quality Modeling*). Water supply reliability and variability are inherently part of these modeling results. In general, many of the comments speculated about how growers, and the larger economy, could respond to the expectation of reduced water supply in the future and focus on potential worst-case scenarios. Modeling and estimating many of the considerations commenters raised would require knowledge of future conditions that are unknown. The SED analysis estimates how the LSJR alternatives would affect the baseline level of agricultural production based on historical grower behavior in response to reduced water supplies. This evaluation appropriately addresses potential changes of agricultural production from baseline.

Commenters were also concerned that the economic analysis did not include potential effects on dairies and other downstream agricultural industries, such as livestock operations or food processors, with some commenters expressing concerns that such operations would cease as a result of the plan amendments or as a result of establishing a specific percent of unimpaired flow. The potential economic effects on dairies and livestock operations, or food processors are qualitatively discussed in Appendix G, Master Response 3.5, *Agricultural Resources*, and Master

Response 8.2, *Regional Agricultural Economic Effects*. These effects are not quantified because it would require verified modeling assumptions as to how a change in local crop production—which is one input—affects production of milk, beef, or food processor output.

Geographic Scope

The local agricultural economic analysis focuses on estimating effects on crop revenue for diverters that regularly receive surface water from the Stanislaus, Tuolumne, or Merced Rivers (the eastside tributaries). The primary surface water diverters are collectively referred to as the *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). SEWD and CSJWCD are also sometimes referred to as *CVP contractors*. Underlying the irrigation districts are four major groundwater subbasins: the Eastern San Joaquin, Modesto, Turlock, and Merced Subbasins. See Appendix G, Figure G.1-1, for a map of the area and the modeled irrigation districts. Agriculture outside the specified irrigation districts, but within the groundwater subbasins, has historically been dependent on groundwater. Because the plan amendments propose to increase instream flows, which would reduce water available for surface water diversions, the analysis assumes that crop production that is occurring in solely groundwater-dependent areas would continue to rely on pumped groundwater to meet demands.

Commenters pointed out that there are several irrigation and water districts within Merced ID’s sphere of influence (SOI) that can potentially buy Merced River surface water from Merced ID but may not be able to do so if the LSJR alternatives are implemented. Some of these districts include: Merquin County Water District, Plainsburg Irrigation District, Ballico-Cortez Water District, and Eastside Water District. However, voluntary surface water transfers from Merced ID to its SOI are represented in the WSE model, with a total annual demand of 16 thousand acre-feet per year (TAF/y); however, these deliveries are only made if all of Merced ID’s district water demands are satisfied. As stated in Appendix G, Section G.2.1.2, *Parameter Estimates*, “it is assumed that any cuts to SOI demands besides El Nido can be replaced with groundwater.” This assumption is valid because under current conditions, these districts would still need to be able to satisfy their demands when Merced ID is unable to make voluntary transfers. This is corroborated on page 7-14 of the Merced ID 2013 Agricultural Water Management Plan (AWMP), “This program provides for in lieu recharge, as most growers within the SOI rely solely on groundwater when [Merced ID] surface water is not available ” (Merced ID 2013). Therefore, these SOI districts are assumed to always fully meet their agricultural water demand, and there are no impacts on agriculture.

Some commenters also stated that some other districts, such as South Delta Water Agency (SDWA), Banta Carbona Irrigation District, and West Stanislaus Irrigation District, receive water from the LSJR, but are not included in the economic analysis. Economic effects on these districts are not analyzed because they are downstream of the eastside tributaries where the unimpaired flow requirements are measured. Water diversions on the San Joaquin River (SJR) and in the southern Delta would not be adversely affected by unimpaired flow requirements on the eastside tributaries. Therefore, there are no potentially significant adverse impacts on agriculture from the LSJR alternatives in these downstream areas.

Commenters were also concerned that the SED did not consider agricultural economic effects on eastside tributary diverters who take their diversions above the major rim dams (New Melones, New Don Pedro, and New Exchequer) but may use that water either in the extended plan area or outside of the extended plan area. One such diverter, Madera Irrigation District (Madera ID), which has a relatively small appropriative water right that averages about 7.7 TAF/y on Big Creek (USBR 2011), a tributary to the Merced River South Fork above New Exchequer Dam. As discussed in Chapter 5, *Surface Hydrology and Water Quality*, "Although water rights in the extended plan area above the rim dams could also be affected by implementation of the flow objectives, the effect would be small compared to the effect downstream of the rim dams. The impact analysis therefore addresses those potential effects in less detail than for downstream areas. As described above in this section, the effects on agriculture are analyzed for the irrigation districts that regularly obtain water from the Stanislaus, Tuolumne, or Merced Rivers and the four primary groundwater subbasins under this area. Although other water users could be affected by implementation of the LSJR alternatives besides the irrigation districts that divert surface water below the rim dams, the overall agricultural economic effects would not be different from what is described in the SED because any reduction in diversions above the rim dams would make more water available for diversion by the irrigation districts below the rims dams.

Relationship with Groundwater

Many commenters expressed concerns regarding increased groundwater pumping and its various effects on agricultural economics. Some commenters were concerned about the relationship between groundwater pumping costs and increased depth to groundwater that they felt would result from the plan amendments. Some commenters also suggested that implementation of the plan amendments would result in both severe groundwater impacts and an unreliable surface water supply.

California's hydrology is variable, with surface water supplies varying from year to year. Growers who have access to both surface water and groundwater generally maximize their use of surface water because it is less expensive than groundwater, which requires energy to pump. However, during dry years, when threatened with reduced surface water supplies and potential losses in agricultural production, growers often increase groundwater pumping to keep crops in production. With or without the plan amendments, during dry years groundwater will likely be used in the future to compensate for some reduction in surface water supply. The conjunctive use of surface water and groundwater, if managed properly, can help provide a reliable long-term source of water for agriculture. The State Water Board analyzes effects on groundwater resources and local agricultural economies by making reasonable assumptions based on common agricultural practices, including the use of groundwater substitution when surface water supplies are reduced.

Groundwater Pumping Costs and Increased Groundwater Depth

Commenters were concerned that if the irrigation districts choose to increase groundwater pumping to replace the potential reductions in surface water supplies, then groundwater elevations could decrease in the underlying groundwater basins. They commented that the greater depth to groundwater would increase groundwater pumping costs beyond what was estimated in the SED because the SED assumed that groundwater depths would remain constant when groundwater pumping cost is estimated. Furthermore, commenters asserted that agricultural areas outside of the irrigation districts would experience increased groundwater pumping costs that were not analyzed in the SED because of the greater depths to groundwater. Commenters also stated that continued lowering of the groundwater table could force growers to install expensive, new wells as their old ones dried up, and these costs were not estimated in the SED.

If local water users choose to pump more groundwater to compensate for potential reductions in surface water supplies under the plan amendments, instead of reducing current levels of consumptive uses or making other adaptations, groundwater elevation would be reduced. Groundwater elevation effects would likely be greater in some areas and less in others, rather than uniformly distributed across the plan area. However, analyzing localized changes in groundwater elevations due to cones of depression from particular well fields is outside of the scope of the SED analysis as described in Master Response 3.4, *Groundwater and the Sustainable Groundwater Management Act*. Accurately estimating changes in local groundwater elevations over the entire plan area would require site-specific information, such as the location of and volume pumped from individual wells, the specific uses of that water, and the likelihood that individual pumpers would utilize groundwater substitution depending on the crop type, market, and pumping cost. This kind of detailed information on future conditions is not known and not required to consider economic effects of the plan amendments.

Annual groundwater pumping costs for the irrigation districts are estimated in the SED using constant average groundwater depths (Appendix G, Table G.4-10) extracted from the SWAP model. This is a valid assumption for a programmatic analysis to get a general sense for groundwater pumping costs because potential changes in groundwater depth would have a relatively minor effect on total groundwater pumping costs. The portions of groundwater pumping cost dependent on groundwater depth are the operations and maintenance (O&M) costs, about $0.03 for every acre-foot (AF) of groundwater pumped up 1 foot in SWAP, and the pumping energy cost, about $0.19/kilowatt hour (kWh) (assuming a well efficiency of 70 percent and multiplying by the density of water and acceleration due to gravity converts the energy cost to $0.27 for every AF of groundwater pumped up 1 foot). Therefore, to pump one acre-foot of groundwater up one foot it would cost about $0.30. The SWAP model estimate for the cost of groundwater pumping in the irrigation districts ranges from $52.12 to $65.59 per AF (see discussion of the SWAP Model below). Each additional foot of groundwater depth would cause the price of groundwater to increase by about 0.5 percent.

In addition, the cost of well installation can vary substantially depending on several site and project specific factors. Well installation costs will depend on the type and size of the well and soil conditions where the well will be drilled. Analyzing when and where wells will need to be replaced would require a project-level review of local conditions, which is not required for a programmatic document such as the SED. However, the costs associated with well replacement are discussed in Chapters 16, *Evaluation of Other Indirect and Additional Actions*, and Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options*. Over the long term, it is expected that the Sustainable Groundwater Management Act (SGMA) would help bring groundwater elevations to equilibrium and prevent continued lowering of the groundwater table, thus helping keep wells in production. Please see Master Response 3.4, *Groundwater and the Sustainable Groundwater Management Act*, regarding SGMA and historical groundwater conditions of the plan area.

SGMA and Water Reliability

Some commenters mischaracterize and conflate potential effects related to groundwater resources and agricultural economics. The response to implementation of the plan amendments by local growers cannot result in both maximum impacts on agriculture and maximum impacts on the groundwater aquifers because the majority of groundwater pumping is being done to keep irrigated agriculture in production, particularly in dry years. In other words, if more groundwater is pumped during drier years (as is done now, and could continue to be done under SGMA), there will be little to no effect on local agricultural economies; they would receive most of the water needed to maintain current levels of agricultural production, but there would be some effect on the local groundwater basins. If groundwater could not be pumped, then there would be little effect on the local groundwater subbasins, but there could be more of an effect on the local agricultural economies. Some commenters asserted there would be a mutual devastation of both, but in reality, the interdependence of the groundwater basin and local agricultural economies means one offsets the other.

SGMA is not a moratorium on groundwater pumping. In the long term, the enactment of SGMA is expected to make groundwater accessible and available for use in a sustainable manner. The sustainable yield of the subbasins under SGMA will be determined by local groundwater sustainability agencies (GSAs) during development of their groundwater sustainability plans (GSPs). GSAs must use a 50-year planning horizon for their GSPs and reach sustainability within 20 years. This means that eventual overall groundwater use will likely need to decrease in order to meet the goals of SGMA, but it is speculative as to how this will be achieved. Achieving SGMA's goals could include some combination of plans and projects, such as wet-year groundwater recharge projects, and demand reduction programs, such as increased irrigation efficiencies, strategic crop retirements, or both. However, even with SGMA and the plan amendments, conjunctive use of surface water and groundwater in both the near term and long term would continue to provide a certain volume of reliable water supply.

Water supply and water reliability are not interchangeable concepts. The actual volume of reliable water depends on many factors that may change through time. If there is less water available, but the certainty of that volume increases (such as with SGMA management), then the water supply is more reliable. Factors that will influence the reliability of water supplies include the effect of climate change on hydrology and crop consumptive use, crop types, use of water efficiency measures, and implementation of GSPs. Although an exact volume of reliable water supply cannot easily be determined, such a volume exists, and irrigated farming will adapt through time to appropriately use that volume.

Statewide Agricultural Production Model

The SWAP model is a regional economic model for irrigated agriculture production that simulates the decisions of California growers with respect to a calibrated set of base conditions. The decisions modeled in the SWAP model reflect overall trends in observed grower behavior in response to changing economic and physical conditions. Some of these responses include crop fallowing and crop shifting, deficit irrigation, and operations to maintain permanent crops and feed crops. A modeler can specify scenarios of available water and land in a specific area, and the SWAP model will estimate grower responses, including changes in cropping patterns. The primary goal of the SWAP model is to determine optimal land and water allocation and net crop revenue generated by the agricultural industry for each crop and region. In simple form, this calculation subtracts the cost of the production inputs (e.g., land, water, labor, other supplies) from the revenues generated by selling crop yield. However, the SWAP model also makes an important assumption that growers will operate to maximize their net revenue by choosing optimal cropping patterns at the district scale, being efficient with water use, and generally not wasting production inputs. By incorporating this assumption, the SWAP model becomes an economic optimization model. For full a technical discussion of the governing equations and model logic, please see Howitt et al. (2012).

Some commenters were concerned that the limitations of the SWAP model made it inappropriate for analyzing the agricultural economic effects of the SED. In particular, commenters argued that the SWAP model was not built to analyze the long-term economic effects and is better suited for short-term analyses (e.g., to determine how growers could respond to droughts). While the SWAP model has some limitations, as all models do, it is still the best available tool for modeling agricultural economic reactions to water supply shortage. The State Water Board staff reviewed other agricultural models, as described in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*, and determined that the SWAP model was the most useful for representing how growers would likely respond to reduced water supplies. The SWAP model is also a peer-reviewed model that has been used for policy analysis in the past by the California Department of Water Resources (DWR), the U.S. Department of Reclamation (USBR), and other state and federal agencies (DWR 2009; USBR 2015; Howitt et. al. 2012). The agricultural analysis in the SED focuses on reasonably foreseeable effects based on how growers have operated in the past. The long-term effects that commenters have argued are not accounted for in the SWAP analysis, such as contractions in overall irrigated area and shifts away from permanent crops, are not outcomes that have been observed in the past, and it would be speculative to assume how or if these effects would occur.

SWAP Model Configuration

Some commenters requested more detail on how the SWAP model was configured for the SED analysis. In particular, they asked for the SWAP model code itself and the database used as input to the SWAP model, such as agricultural production costs, crop yields, and crop revenues. Other commenters requested details on the SWAP model production functions and the model calibration for water supply costs. They argued that this information was not provided and, therefore, assessment of the model's assumptions was not possible. Still other commenters conducted their own versions of SWAP modeling runs (please see Master Response 8.2, *Regional Agricultural Economic Effects*, regarding commenters' use of the SWAP model).

The SED analysis employs the same version of the SWAP model described in Howitt et. al. 2012 and the 2012 Draft SED, with a few refinements. The SWAP model code was originally developed by Richard Howitt, Josue Medellin-Azuara, and other collaborators at the University of California, Davis (UC Davis). The State Water Board does not have the SWAP model code, which is the intellectual property of UC Davis. Further, the State Water Board would not be able to make use of the SWAP model code regardless because the State Water Board does not own a version of the software required to solve the model. For these reasons, the State Water Board contracted with UC Davis to run the model. As is generally the case for other analyses employing the SWAP model, UC Davis has protected its proprietary information and not made the SWAP code and its database public. Instead, input data, model refinements, and model assumptions for the SED analysis are discussed in Appendix G and in this master response.

A commenter also asserted that the SED did not adequately describe the calibration process for the SWAP model. The SED references several journal papers on the SWAP model that discuss the model production functions and calibration in detail, such as Howitt et al. 2012, in Appendix G, Section G.4, *Estimating Agricultural Production, Associated Revenue, and Groundwater Pumping Costs*. These references are part of the administrative record and are used to support the summaries contained in the SED. As such, it is not necessary to reproduce the full discussion of each journal article in the SED.

The SWAP model described in Howitt et al. 2012 represents the Central Valley with 27 regions based on Central Valley Production Model (CVPM) regions. Regions 10 through 13, plus part of region 8, represent the northern San Joaquin Valley. For each region, agricultural production is divided into 20 crop groups following DWR crop classifications (Table 8.1-1). Each group may represent several individual crops that share common characteristics in production, water use, and value.

Table 8.1-1. Department of Water Resources (DWR) Crop Group Classifications and Definitions

Crop Group	Crop Group Definition
Alfalfa	Alfalfa and alfalfa mixtures
Almond and Pistachio	Almonds and pistachios
Corn	Corn (field and sweet)
Cotton	Cotton
Cucurbits	Melons, squash and cucumbers
Dry Bean	Beans (dry)
Fresh Tomato	Tomatoes for market
Grain	Wheat, barley, oats, miscellaneous grain and hay, and mixed grain and hay
Onion and Garlic	Onions and garlic
Other Deciduous	Apples, apricots, cherries, peaches, nectarines, pears, plums, prunes, figs, walnuts and miscellaneous deciduous
Other Field	Flax, hops, grain sorghum, sudan, castor beans, miscellaneous fields, sunflowers, hybrid sorghum / sudan, millet and sugar cane
Other Truck	Artichokes, asparagus, beans (green), carrots, celery, lettuce, peas, spinach, flowers nursery and tree farms, bush berries, strawberries, peppers, broccoli, cabbage, cauliflower, brussel sprouts, and sweet potatoes
Pasture	Clover, mixed pasture, native pastures, induced high water table native pasture, miscellaneous grasses, turf farms, bermuda grass, rye grass and klein grass
Potatoes	Potatoes
Processing Tomato	Tomatoes for processing
Rice	Rice and wild rice
Safflower	Safflower
Sugar Beets	Sugar beets
Subtropical	Grapefruit, lemons, oranges, dates, avocados, olives, kiwis, jojoba, eucalyptus and miscellaneous subtropical fruit
Vine	Table grapes, wine grapes and raisin grapes

Sources: DWR 2010, 2017.

For modeling purposes, the SWAP model uses a proxy crop to represent each crop group in terms of price, yield, and production costs. Proxy crops are selected based on available crop cost and return studies from the University of California Cooperative Extension (UCCE)[1] and how well that crop is representative of the total regional acreage, water use, and revenues of the crop group. The UCCE cost and return studies are meant to describe the standard procedures and best management practices generally employed to produce a specific crop in a particular region and the production costs that can be expected. Gross crop revenues are calculated for each crop group and region based on the proxy crop's yield, in tons per acre and crop price per ton. Crop yields are derived from the UCCE cost and return studies, while crop prices are based on data compiled by the U.S. Department of Agriculture from county agricultural commissioner's annual crop reports. In addition, for each crop group and region, the SWAP model represents four general inputs to crop production: land, water, labor, and a combined category for other supplies (e.g., fertilizer, pesticides). All production inputs are defined in monetary terms as a cost per acre, except water costs which are defined as a cost per AF. Estimates for the production costs are derived from UCCE regional cost and return studies. Water costs are also broken down by source, including Central Valley Project (CVP), State Water Project (SWP), local, and groundwater. The proxy crops, as well as the regional crop yields and production costs used in the SED analysis, were not changed from the base SWAP model described in Howitt et al. 2012.

For the SED analysis, the SWAP model was modified to model six regions corresponding to the irrigation districts that divert surface water from the eastside tributaries (SEWD and CSJWCD are combined into one region for the analysis). The data used for the SWAP analysis, including agricultural production costs, crop yields, and crop prices, were extracted from the base SWAP model database. These inputs were intended to follow the SWAP model's underlying CVPM areas, depending on the irrigation district analyzed. The CVPM data, which is based on the UCCE cost and return studies and county agricultural commissioner's annual crop reports, was used for modeling crop production parameters at the district level because this data provides a reasonable approximation of the agricultural production characteristics within the CVPM regions, and, in turn, the irrigation districts that are part of those regions. However, for the SWAP model run in the 2016 Recirculated SED some of the irrigation districts were incorrectly overlaid on the CVPM regions in the SWAP database; the data was corrected in the revised SWAP model run described herein for this Final SED.

Correctly overlaying the irrigation district boundaries on the SWAP CVPM regions indicates that SEWD and CSJWCD are within Region 8, SSJID, OID, and MID are within Region 11, TID is within Region 12, and Merced ID is within Region 13. Please see Tables 8.1-2 through 8.1-4 for crop prices, crop yields, and input production costs used in the revised SWAP model scenario. Crop prices, yields (with a small exception for corn), and production costs (apart from surface water costs) for CVPM Regions 11, 12, and 13 are all the same. Surface water costs in Table 8.1-4 are based on the cost of local water supplies in the SWAP model database for all the irrigation districts except SEWD/CSJWCD, which use the cost of CVP water.

---

[1] University of California Cooperative Extension (UCCE) crop cost and return studies are available here: http://coststudies.ucdavis.edu.

Table 8.1-2. SWAP Model Input Data for SSJID, OID, MID, TID, and Merced ID

	Crop Price	Crop Yield	Land Cost	Labor Cost	Other Supply Cost
Crop Group	\$/Ton[a]	Ton/Acre	\$/Acre[a]	\$/Acre[a]	\$/Acre[a]
Alfalfa	157	8.0	317	21	544
Almond and Pistachio	4,227	1.0	812	318	1,678
Corn[b]	156	6.3, 6.5, 6.6	168	50	531
Cotton	2,017	0.6	217	199	538
Cucurbits	464	16.8	204	4,339	2,919
Dry Bean	779	1.3	209	55	423
Fresh Tomato	464	13.0	308	143	4,480
Grain	163	3.3	194	14	278
Onion and Garlic	601	13.0	336	682	2,625
Other Deciduous	1,601	2.7	526	223	1,427
Other Field	142	6.5	180	14	465
Other Truck	582	6.5	220	207	3,215
Pasture	220	2.5	92	24	138
Potatoes	225	25.0	680	410	1,568
Processing Tomato	52	40.0	298	276	1,200
Rice	221	5.0	269	81	556
Safflower	316	1.3	102	35	121
Sugar Beets	42	42.0	149	65	779
Subtropical	452	12.2	612	239	4,333
Vine	610	6.5	1,352	756	1,479

[a] The monetary year for dollar (\$) values is 2005.

[b] Corn yield for SSJID, OID, and MID is 6.3 tons/acre, for TID it is 6.5 tons/acre, and for Merced ID it is 6.6 tons/acre.

Table 8.1-3. SWAP Model Input Data for SEWD/CSJWCD

	Crop Price	Crop Yield	Land Cost	Labor Cost	Other Supply Cost
Crop Group	\$/Ton[a]	Ton/Acre	\$/Acre[a]	\$/Acre[a]	\$/Acre[a]
Alfalfa	132	7.0	249	18	414
Almond and Pistachio	4,235	1.1	453	274	1,900
Corn	121	6.0	181	101	329
Cotton	2,017	0.6	196	130	697
Cucurbits	464	16.8	204	4,339	2,919
Dry Bean	797	1.3	154	106	397
Fresh Tomato	464	13.0	308	143	4,480
Grain	143	3.0	95	33	227
Onion and Garlic	601	13.0	336	682	2,625
Other Deciduous	1,502	2.7	526	223	1,427

	Crop Price	Crop Yield	Land Cost	Labor Cost	Other Supply Cost
Crop Group	\$/Ton[a]	Ton/Acre	\$/Acre[a]	\$/Acre[a]	\$/Acre[a]
Other Field	142	6.5	180	14	465
Other Truck	582	6.5	220	207	3,215
Pasture	220	2.5	92	24	138
Potatoes	225	25.0	680	410	1,568
Processing Tomato	51	35.0	344	373	840
Rice	246	5.0	269	81	556
Safflower	299	1.3	102	35	121
Sugar Beets	42	42.0	149	65	779
Subtropical	452	12.2	612	239	4,333
Vine	610	7.0	1,024	828	1,627

[a] The monetary year for dollar (\$) values is 2005.

Table 8.1-4. SWAP Assumptions for the Cost of Groundwater Pumping and the Cost of Surface Water Delivery

	Cost of Groundwater[b]	Cost of Surface Water
Irrigation Districts	\$/Acre-Foot[a]	\$/Acre-Foot[a]
SSJID	65.59	36
OID	53.53	6
SEWD/ CSJWCD	52.12	16.5
MID	54.33	6
TID	54.33	15
Merced ID	54.33	15.25

[a] For more information on the SWAP model's assumptions for groundwater pumping costs, see Appendix G, Section G.4.4, *Groundwater Pumping Costs*.

[b] The monetary year for dollar (\$) values is 2005.

The irrigation district AWMPs are used to specify the total irrigated acres in each modeled irrigation district. The total irrigated area for each of the districts is then distributed among different crop types based on 2010 cropping patterns derived from data published by DWR for its DAUs (DWR 2010).[2] DWR uses the DAUs as boundaries for reporting information on agricultural production and water use within the Central Valley, and several of the DAUs correspond to irrigation districts being modeled in this analysis. In addition, crop applied water demands are also derived from DWR DAU data. DWR's applied water estimates reflect irrigation efficiencies, as well as the water required for cultural practices, such as the ponding of water in rice fields or the leaching of accumulated salts from the soil.

Under baseline conditions and for the LSJR alternatives, gross surface water availability for the irrigation districts is determined using the WSE model and then post processed to estimate surface

---

[2] For SEWD and CSJWCD, total irrigated area is distributed among different crop types based on the cropping patterns derived from their respective WMPs (CSJWCD 2013; SEWD 2014).

water available for irrigation (applied water) and the amount of supplemental groundwater pumping needed. Initial applied water demands (as described in Appendix G, Section G.2.2, *Methodology for Calculating Applied Water*) are estimated based on the CALSIM II model consumptive use of applied water (CUAW) demands and deep percolation factors derived from the irrigation district AWMPs. These initial applied water demands only represent a gross demand for irrigation and do not have an associated crop distribution to determine demand for individual crop types. Therefore, estimates of the total annual applied water delivery within each district are normalized to the 2010 DAU applied water demands for each district. In other words, delivery is adjusted so that the same relative applied water delivery (applied water delivery as a percent of the initial applied water demand) is met for the 2010 DAU applied water demand. The normalized applied water deliveries are then input to the SWAP model to determine the effects of the LSJR alternatives on agricultural production. Land use and applied water demands used in the SWAP model are reported in Appendix G, Table G.4-3 and Table G.4-4.

The final input to the SWAP model is the proportion of the applied water delivery that is sourced from groundwater and the proportion that is sourced from surface water for each modeled irrigation district. The proportions of groundwater and surface water use initially assumed as input to the SWAP model are shown in Table 8.1-5. These proportions are based on the expected groundwater use of each district for 2010. Since 2010 was an above normal water year, it is assumed that the irrigation districts, except SEWD and CSJWCD, would have had adequate surface water supplies to meet their demands, and the only groundwater pumping needed was the minimum groundwater pumping described in Appendix G, Table G.2-1. The proportion of 2010 groundwater use for SEWD and CSJWCD is calculated based on reported 2010 district diversions from the California Data Exchange Center (CDEC), and information from the irrigation district WMPs (CSJWCD 2013; SEWD 2014). These values do not account for how groundwater use changes annually under the LSJR alternatives, so the annual changes in groundwater pumping costs are accounted for separately from the SWAP model output, as described in Appendix G, Section G.4.4, *Groundwater Pumping Costs*.

Table 8.1-5. Proportions of Groundwater and Surface Water Use in the SWAP Model for each Irrigation District

Irrigation Districts	Proportion of Groundwater Use[a] (%)	Proportion of Surface Water Use[b] (%)
SSJID	13	87
OID	10	90
SEWD/ CSJWCD	69	31
MID	5	95
TID	21	79
Merced ID	12	88

[a] Expected proportion of groundwater use for applied water in 2010, assuming that groundwater use equals minimum groundwater pumping (SEWD and CSJWCD groundwater use estimated based on irrigation district WMPs) and applied water demand from the 2010 DWR DAU data.

[b] The proportion of surface water use equals 1 minus the proportion of groundwater use.

SWAP Model Assumptions

Rationality Assumption

As is with many planning-level models, the SWAP model is not intended to precisely predict the potential future cropping decision of every single grower in an area but rather to estimate a typical response to water supply reductions. Actual decisions made by growers may differ from a modeled result because of unique beliefs or circumstances. As stated by the Office of Technology Assessment,

> Human behavior cannot be analyzed in the same sense as interactions that take place in the physical sciences. Human interactions may be extremely complex, and involve many factors not readily subject to quantification. At best, social scientists can estimate statistical variations in human behaviors under a set of assumed conditions. (OTA 1982)

Furthermore, the SWAP model is not meant to model precise conditions but rather aid in planning by presenting how irrigated agriculture could respond to estimated surface diversions under the LSJR alternatives, based on reasonable assumptions of grower behavior and historical hydrologic conditions. The primary utility of a planning-level model is in comparative analysis, in which the physical conditions are represented at a sufficient level of precision to accurately represent the most important effects of a change in water supply.

In general, growers maximize net revenue, given land and water constraints. Adaptations employed to maximize revenue include altering the total irrigated area, crop mix, and applied water per unit area, as well as searching for alternative water supplies and negotiating water transfers. These adaptations altogether dampen the effects of water supply reductions. The assumption that growers maximize their net revenue might not apply to every grower, as some will make cropping decisions based on familiarity with a particular crop or based on personal preference; however, the SWAP model does not try to predict the behavior of individual growers. Instead, the model provides insights for large-scale cropping decisions and their corresponding economic costs.

Intra-District Water Transfers

Some commenters pointed out that at least one of the irrigation districts has restrictions on intra-district water transfers (water transfers within the district between individual growers) and does not support water markets. Other commenters were also concerned that the infrastructure necessary to conduct intra-district transfers may not be in place. As such, assuming that intra-district water transfers are conducted may overstate the flexibility in the system to accommodate surface water supply reductions.

Of the irrigation districts modeled, CSJWCD is the only one that “actively encourages water transfers within the district” (CSJWCD 2013). Other districts, such as SSJID, OID, MID, and Merced ID, may have general policies against internal transfers when there is plenty of surface water supply, but also can relax these policies as part of drought management to help growers cope with surface water shortage and optimize water use (SSJID 2015; OID 2016; MID 2015; Merced ID 2016). At one point or another during the 2013–2016 drought, each of these districts allowed intra-district transfers (Holland 2014; Holland 2015; Recede 2015). The remaining two irrigation districts, SEWD and TID, prohibit intra-district transfers and do not have policies to relax the restriction during water shortages, although TID does allow transfers of water between parcels as long as the parcels are both owned or rented by the same owner (SEWD 2017; TID 2015). However, during the drought, TID’s transfer rules and the potential for growers to sell water sparked debate between the district and some growers (Aredas 2015). Furthermore, TID did relax its transfer rules somewhat, allowing growers to transfer water from a parcel they did not own or rent the previous year, provided they currently own or rent both parcels and the parcel transferring water had a water receipt from the previous irrigation season. As for SEWD, the district generally relies on groundwater pumping to keep higher net revenue crops in production, which is reflected in the SWAP modeling.

SWAP is a large-scale planning model and as such it may not capture all the specifics of how particular districts operate nor does it actually model in such detail as to represent individual transfers of water. Instead, the SWAP model assumes that individual regions have internal water markets, which allows water to be moved between crops within a district. In modeling this behavior, the model allocates water among crop groups to maximize net revenue as if the region was run by a single representative grower who decided how best to allocate water supplies. In practice, reallocating water through agreements, transfers, and other means may require significant planning, but analysis at that level of detail cannot be modeled. Despite the model's limitations, it is the best available tool to give a high-level overview of how water can be managed across a region needed for a programmatic analysis.

Furthermore, with intra-district transfers limited, it should be expected that all crops would receive reductions in water supply proportional to their demand; however, this is not generally the case. In response to surface water shortages, districts and growers generally work together to optimize water management and maintain the most valuable crops. The fundamental logic of the SWAP model is built on the historical observation that higher net revenue crops, such as trees, tend to remain in production during short and extended periods of water shortage, while lower net revenue crops, such as field crops, come out of production. During the recent drought, this was again observed, as growers concentrated on growing higher net revenue permanent crops and let lower net revenue field crops come out of production (Weiser 2016).

Deficit Irrigation in the SWAP Model

To balance the reduction in water supply, the SWAP model takes two approaches. The first approach is to fallow land, and the second is to reduce the amount of water applied to crops through deficit irrigation. Under land fallowing, there is no crop and, therefore, no yield or revenue. Deficit irrigation reduces the yield and revenue per acre. The SWAP model finds the optimal (i.e., highest net revenue) use of the water supplies available by balancing deficit irrigation and fallowing, within constraints. The reduction in the amount of water applied to a crop is commonly known as *regulated deficit irrigation* or *strategic deficit irrigation*. The basic concept of deficit irrigation is to reduce the amount of applied water during the period(s) of plant growth when doing so is least harmful to the plant and has the least impact on yield. For example, cutting back summer water on alfalfa typically does not reduce the yield as much as cutback during spring months (IID 1994). Details on alfalfa stress are described in Chapter 11, *Agricultural Resources*. The ability of a crop to survive stress varies; in addition, the flexibility in irrigation systems can affect an irrigator's ability to deficit irrigate. Irrigation systems may be designed to accommodate specific flow rates, and reducing the flow rate or frequency of delivery could be a water management challenge. However, when the irrigator has more control over the application of water—such as with a pressurized system (i.e., sprinkler or drip)—deficit irrigation is much more viable.

In the version of the SWAP model described in Howitt et al. 2012, all crops are constrained to prevent deficit irrigation from falling below 85 percent of the crop's applied water demand (maximum deficit irrigation for all crops was 15 percent). These estimates were refined for the revised SWAP model run (see *Revised SWAP Model Scenario Description and Results*) based on review of literature regarding crop water management. Table 8.1-6 presents a tolerance classification of the crops represented in the SWAP model, the sources used to develop these classifications, and the maximum level of deficit irrigation used in the SED. A reconnaissance-level review indicates that crops can be ranked into three categories (*High*, *Medium*, and *Low*) based on a crop's ability to tolerate deficit irrigation and the ability to manage irrigation. Crops in the *Low* category typically respond poorly, in an agronomic sense, to deficit irrigation; alternatively, typical irrigation systems, both at the district level and on-farm, make deficit irrigation difficult to implement for these crops. Crops in the *Medium* category have large yield reductions of up to 50 percent but can be managed primarily because of pressurized irrigation systems. Crops in the *High* category have some yield reductions in response to deficit irrigation, but it is usually less than crops specified in the *Medium* category, and they can be managed using pressurized irrigation systems. In addition, alfalfa was rated *High* because of the plant's tolerance of dormancy and because higher quality yield is obtained in spring, when water demand is lower than in summer.

For crops indicated with a *High* tolerance, the maximum annual reduction in applied water for the SWAP model was set to between 25 and 30 percent. For the crops with a *Medium* tolerance the maximum annual reduction in applied water was kept at 15 percent. For the crops with a *Low* tolerance the maximum annual reduction in applied water was set to 0 percent. A higher limit on deficit irrigation will allow for greater flexibility in how water supplies are used and help avoid fallowing acres, while preventing deficit irrigation for some crops will limit the model flexibility and could lead to fallowing more acres.

Table 8.1-6. Ranking the Ability of Crop Categories Used in the SWAP Model to Accommodate Deficit Irrigation

Crop Category	Tolerance for Deficit Irrigation	Notes and (Reference(s))	Maximum Deficit Irrigation in SWAP (%)
Alfalfa	High	Summer drydown has less impact on yield than spring. Plant tolerates stress very well (Orloff et al. 2015a; IID 1994).	25
Almond and pistachio	High	Critical life-cycle periods require water. 15% reduction with no yield loss has been demonstrated. 30% reduction with moderate yield loss has also been demonstrated. Must use caution in successive years. (Schackel 2008; Goldhamer et. al. 2005).	30
Other deciduous (plums)	High	Critical life-cycle periods require water. 10–20% reduction with minor yield loss has been demonstrated (Fulton et al. 2015).	25
Subtropical	High	Must be properly managed, critical life-cycle periods. One study showed 25% reduction in applied water with no yield loss (Faber 2015).	25
Vine	High	Current practice for high-quality grapes but additional stress may affect yield (Prichard n.d.).	25
Sugar beet	Medium	Yield reduction with reduced irrigation (Carter et al. 1980).	15

Crop Category	Tolerance for Deficit Irrigation	Notes and (Reference(s))	Maximum Deficit Irrigation in SWAP (%)
Cucurbits	Medium	Yield reduction with reduced irrigation (Kemble and Sanders n.d.).	15
Dry bean	Medium	Critical life-cycle periods require irrigation (Emam et al. 2010).	15
Fresh tomato	Medium	Yield reduction with reduced irrigation (Celebi 2014).	15
Grain (wheat)	Medium	Yield reduction with reduced irrigation (Akram 2011).	15
Onion and garlic	Medium	Yield reduction with reduced irrigation (Kemble and Sanders n.d.).	15
Other truck	Medium	Yield reduction with reduced irrigation (Kemble and Sanders n.d.).	15
Pasture	Medium	Yield (i.e., grazing ability) reduction with reduced irrigation (Orloff et al. 2015b).	15
Processing tomato	Medium	Yield reduction with reduced irrigation (Hansen et al. n.d.).	15
Safflower	Medium	Yield reduction with reduced irrigation (Esendal et al. 2008).	15
Other field	Medium	Yield reduction with reduced irrigation (Akram 2011).	15
Corn	Low	Difficult to manage with current irrigation systems. Critical life-cycle periods require irrigation (Lundy 2015).	0
Cotton	Low	Critical life-cycle periods require irrigation. (Hutmacher et al. n.d.).	0
Rice	Low	Difficult to manage with current irrigation systems. Critical life-cycle periods require irrigation (UCCE 2009).	0

Some commenters were concerned that the SWAP model does not account for yield effects of deficit irrigation over multiple years, especially during consecutive dry years. The commenters argued that though the SWAP model reduces yield in a given year when applying deficit irrigation, it does not account for further yield reduction to permanent crops in the following year as the crops recover from being deficit irrigated. It is true that the SWAP model does not account for the cumulative effect of deficit irrigation over consecutive dry years; however, this is a limitation shared by all similar crop modeling tools reviewed, and no other tools were suggested by commenters. The purpose of the agricultural economic analysis is to generally estimate how crop production will respond to reduced water supplies. The SWAP model is a planning-level instrument used to evaluate broad tradeoffs among crops. Although it may lack precision in some aspects (as broad models usually do), it nonetheless provides sufficient detail and is the best available tool for considering economic effects associated with the plan amendments and the programmatic analysis of those amendments.

Fallowing of Permanent Crops in the SWAP Model

Several commenters questioned why the SWAP model would fallow acres of permanent crops (trees and vines) in some years, but still represent the full acreage of permanent crops the next year. Permanent crops, such as almond trees, take a few years to mature and begin producing. It is not plausible to assume that trees can be removed one year and then replanted the next at full production. Given the large establishment cost, it is rare that growers pull trees out of production when facing water or other resource shortages.

As permanent crops near the end of their lifespan, yields generally decline and eventually growers need to replace them. However, because permanent crops take a few years to mature, growers do not usually plan to remove their entire production at the same time; instead, they stagger replacement to guarantee they are producing something in every year. Therefore, in any given season, a portion of the perennial crop acres will be due for replacement. During water shortages, it is a common practice for growers to replace older trees a year or so early, even if they are not quite at the end of their lifespan, because younger trees require less water to grow, and the water saving would outweigh the loss in production.

The SWAP model includes an algorithm that calculates the maximum perennial retirement based on the time horizon of the analysis. As the time horizon of the analysis approaches the maximum bearing life of the perennial, any proportion can be removed from production. The version of the SWAP model used for the SED assumes that about 6 percent of trees will be replaced in any given year. In other words, it is assumed in the SWAP model that in all years, about 6 percent of the permanent crop acres are taken out of production and replaced with an equal number of acres planted a few years prior that are coming into production. Therefore, in years with plentiful water supplies, there is no net change in total acreage, and the SWAP model shows no fallowing of permanent crops. During water shortages, however, the model accentuates replacement of permanent crops by up to the annual replacement rate (6 percent). This represents the agricultural practice of replacing additional acres a year sooner than expected because young trees require less water to maintain. If water supplies return to normal the following year, the trees that were fallowed a year early are replaced as they originally were scheduled to be replaced, and full production resumes.

Corn Silage Production

Silage is a fermented, high-moisture stored fodder which can be fed to cattle, sheep, and other such ruminants (cud-chewing animals). Although silage corn is a relatively low-value crop, the effects of reduced silage production could be large because the dairy industry, in particular, relies upon relatively local supplies of silage to support a large dairy industry in the plan area. To represent the value of local corn silage as a feed crop for dairies, the SWAP model also includes a constraint to maintain some production of silage.

Upon the State Water Board's review of comments, it was found that the proportion of corn in the plan area that the SWAP model assumed to be grown for silage was lower than actual proportions of corn grown for silage in the plan area. For the revised SWAP model run (see *Revised SWAP Model Scenario Description and Results*), the proportion of corn grown as silage in each irrigation district was refined based on 2010 county agricultural commissioner crop reports for Merced, Stanislaus, and San Joaquin Counties. In Merced County, of the 102,200 acres of corn grown 90,100, or 88 percent, was considered silage; in Stanislaus County, all 88,700 acres of corn were grown as silage; in San Joaquin County, of the 108,200 acres of corn grown 57,100, or 53 percent, was considered silage (USDA 2018). Table 8.1-7 shows the refined corn silage area for each irrigation district.

Table 8.1-7. Acreage of Corn Silage used for the SWAP Model

	Total Corn[a]	Refined Estimate of Silage[b]	
Irrigation District	(Acres)	(% of Corn)	(Acres)
SSJID	8,332	53	4,397
OID[c]	9,758	80	7,770
SEWD + CSJWCD	16,098	53	8,496
MID	12,116	100	12,116
TID	39,981	100	39,981
Merced ID	19,930	88	17,571

[a] Total Corn acreage based on DWR DAU crop distributions for 2010.

[b] Refined estimate of silage based on 2010 data from National Agricultural Statistics Service County Agricultural Commissioner's data (USDA 2018).

[c] As OID is split between San Joaquin and Stanislaus Counties, the revised proportion of silage in the district is the average of the county silage proportions weighted by the percent of OID irrigated area in each county (43% of OID is located in San Joaquin County, and 57% is located in Stanislaus County).

Because corn silage is an important crop for dairies, and it is difficult to transport, silage was constrained in the SWAP model to try and maintain some proportion of the total silage acres. For the revised SWAP model run (see *Revised SWAP Model Scenario Description and Results*), the proportion of corn silage to be maintained was increased from 25 to 70. Therefore, if all grain corn has been fallowed and only 70 percent of the silage corn remains, then higher value, non-permanent crops will be fallowed before the rest of the corn silage acres. Because the estimate of corn silage acreage in the model was increased, this constraint will force the model to keep more corn acres in production, taking water away from other crops that may have higher net revenue. Please see Master Response 3.5, Agricultural Resources, regarding sudan grass as a potential replacement crop for corn silage and Master Response 8.2, *Regional Agricultural Economic Effects*, for discussion of potential economic effects on dairies.

Revised SWAP Model Run Description and Results

This section describes the assumptions of the revised SWAP model run performed in response to several comments that highlighted opportunities for refinement in the original model run. The revised model run does not result in any new potentially significant adverse environmental impacts or a substantial change in the severity of potentially significant adverse environmental impacts or economic effects identified in the SED.

Application of Deficit Irrigation for Permanent Crops

As described previously under *Deficit Irrigation in the SWAP Model*, the SWAP model is capable of applying deficit irrigation to crops during times of water shortage at the cost of reduced yield. In review of these results, it was noticed that in some years the deficit irrigation (water use per acre as a percent of full water demand per acre) for the permanent crops was unrealistically low. SWAP was intended to constrain water use to not allow deficit irrigation below 85 percent of the full water demand; however, the model code did not properly constrain the deficit irrigation for permanent crops. The SWAP model code was corrected as part of the revised SWAP Model Run. It should be noted that for all non-permanent crops deficit irrigation was being properly applied.

Assumptions for Maximum Deficit Irrigation and the Acreage of Corn Silage

As mentioned previously under *Corn Silage Production*, the SWAP model assumptions regarding deficit irrigation and corn silage were updated for the revised SWAP model run. Deficit irrigation constraints were updated based on Table 8.1-6. In the original model run, deficit irrigation was limited to 15 percent for all crops. For the revised model, greater levels of deficit irrigation can be applied to permanent crops consistent with available literature (See Table 8.1-6). Also, a few crops were prevented from applying deficit irrigation because they did not respond well to it or were difficult to manage. Corn silage area for all irrigation districts was also updated (Table 8.1-7), as the original estimates were found to be low compared to reported corn silage acres for the region. In addition, the proportion of corn silage in each district that the SWAP model was constrained to keep in production as a dairy feed crop was increased from 25 to 70 percent.

Total Irrigated Area for Irrigation Districts

In addition, based on comments received on the SED, the estimates of total irrigated acreage for MID, TID, and Merced ID were updated. For MID and Merced ID, the total irrigated acreages were updated to include double cropped acres. Double cropping in MID was 8,855 acres (MID 2012:Table 23), and the total irrigated acreage used in the SWAP model was 67,466 acres. Double cropping in Merced ID was 4,421 acres (Merced ID 2013:Table 5.3), and the total irrigated acreage used in the SWAP model was 104,658 acres. For TID, the SED used the assessed acres (146,030 acres) from TID’s 2012 AWMP, which included area that was not irrigated (e.g., roads), rather than total irrigated acres. The acreage for TID was updated to be 134,682 acres, using the average total irrigated area for 2007 to 2011 (TID 2012:Table 4.3). These changes were made for baseline and the LSJR alternatives. The total irrigated acreage for SSJID, OID, SEWD, and CSJWCD was not changed.

Crop Prices, Yields, and Production Costs

In review of the SWAP model input data for crop prices, yields, and production costs described previously in this master response, it was determined that some of the data from the SWAP database was incorrectly assigned to the irrigation districts. For instance, in the original SWAP run, crop prices for SSJID, OID, MID, TID, and Merced ID were based on the crop prices for CVPM Region 8 rather than CVPM Regions 11 through 13. In addition, the data for SEWD/CSJWCD and SSJID were switched, so SSJID was modeled with CVPM Region 8 data for yield and crop production costs, while SEWD/CSJWCD used CVPM Region 11 data. Finally, water costs in MID and TID were for CVPM

Region 13 rather than CVPM Region 12 and 11, respectively. The correct region and irrigation district data is used in the revised model run.

Groundwater Use

Finally, potential groundwater use was updated for the revised SWAP model run to help maintain permanent crops (Almonds/Pistachio, Other Deciduous, Subtropical, and Vine SWAP model crop categories) and 70 percent of corn silage acres. In the revised scenario, if an irrigation district's annual surface water supplies and groundwater supplies at the 2009 pumping capacity are not enough to meet the demands of permanent crops (after accounting for deficit irrigation) and 70 percent of the corn silage, then the district is allowed to pump additional groundwater up to their 2014 groundwater pumping capacity. Though prolonged pumping at the 2014 pumping capacities is likely unsustainable, the existence of this capacity makes it unreasonable to assume it would not be strategically employed to prevent losses of permanent crops during severe dry years. Moreover, such periodic use is recognized in SGMA. SGMA defines chronic lowering of groundwater levels as an "undesirable result" that must be avoided through sustainable groundwater management but caveats this statement as follows.

> "Undesirable result" means one or more of the following effects caused by groundwater conditions occurring throughout the basin: (1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods…(Wat. Code § 10721(x).)

This revised groundwater pumping scenario represents a groundwater pumping level between the 2009 and 2014 pumping scenarios that were used to determine the significance of groundwater impacts in Chapter 9, *Groundwater Resources*. Therefore, the new scenario does not result in any new potentially significant adverse environmental impacts or a substantial change in the severity of potentially significant adverse environmental impacts.

The additional pumping is calculated based on whether the available surface water and groundwater, up to the 2009 pumping capacity for each irrigation district, are enough to meet a minimum applied water demand for permanent crops and corn silage. If the minimum demand cannot be met with surface water and the 2009 groundwater pumping capacity, then each district can also pump groundwater to meet the shortfall, provided total groundwater pumping does not exceed the 2014 pumping capacity. In the case that a district fully uses its 2014 capacity, but still cannot meet both its permanent crop demand and 70 percent of its silage demand, then the silage constraint is relaxed in the SWAP model. See Appendix G, Section G.2.2.3 for the calculation steps used to determine groundwater use for the agricultural economic analysis.

The minimum applied water demand for permanent crops and corn silage is estimated based on crop total applied water demands shown in Appendix G, Table G.4-4, the allowable deficit irrigation levels shown in Table 8.1-6, and the proportions of corn that is silage shown in Table 8.1-7. Table 8.1-8 shows the minimum applied water demand in each irrigation district as a percentage of the full district applied water demand.

Table 8.1-8. Minimum Applied Water to Maintain Permanent Crops and 70 Percent of Corn Silage Acres as a Percent of the Total Applied Water Demand

Irrigation District	Minimum AW needed for Permanent Crops[a]	Minimum AW needed for 70% of the Silage Corn[b]	Total AW Demand[c]	Minimum AW needed for Permanent Crops and Corn Silage
	Acre-foot	Acre-foot	Acre-foot	% of Total AW Demand
SSJID	94,786	8,966	189,695	55
OID	46,059	13,869	186,370	32
SEWD + CSJWCD	94,994	9,946	230,129	46
MID	66,029	21,199	219,258	40
TID	91,494	70,419	388,490	42
Merced ID	93,964	31,070	296,529	42

AW = applied water.

[a] Total of permanent crop AW demands for each district from Appendix G, Table G.4-4, after accounting for deficit irrigation as shown in Table 8.1-6.

[b] Corn AW demand from Appendix G, Table G.4-4, multiplied by the proportion considered silage from Table 8.1-7 and reduced by 30%.

[c] Total AW demand from Appendix G, Table G.4-4.

Results and Discussion

This section presents the results of the revised SWAP model scenario. The primary results shown include groundwater use, irrigated acres, and agricultural gross revenue. All monetary values are presented in 2008 dollars to be consistent with the original analysis; please see Master Response 8.0, *Economic Analyses Framework and Assessment Tools,* for discussion of why dollar value is presented in 2008 dollars. (For presentation of regional economic effects using the revised SWAP model results please see Master Response 8.2, *Regional Agricultural Economic Effects*.)

Many commenters were concerned that presenting SWAP model results as annual averages in Appendix G did not fully describe the impacts that would be expected during critical years, and many commenters requested that the SWAP model results be presented as water year type averages. Results for irrigated crop area and irrigation district agricultural gross revenue are summarized by water year type average as commenters requested; however, it should be noted that the SWAP analysis is performed over irrigation years (March to February) not water years (October to September). This is a minor inconsistency as the primary period for agricultural diversions and crop production in the irrigation year (spring and summer) still correspond with the water year. Results for groundwater use are summarized through cumulative distributions, which provide information on the magnitude and frequency of annual impacts. Please see Master Response 2.3, *Presentation of Data and Results in the SED and Responses to Comments*, for discussion of how results are presented in the SED.

Groundwater Use

Figures 8.1-1 through 8.1-6 present exceedance charts of groundwater use for each of the irrigation districts (with SEWD and CSJWCD combined) in the revised SWAP model run. Groundwater use in the revised run shows more groundwater use than the 2009 groundwater pumping scenario and less than the 2014 groundwater pumping scenario that are discussed in Chapter 9 and Appendix G. In the revised run, groundwater use is allowed to increase above the 2009 capacity to maintain permanent crops and corn silage acres; however, whatever the demand is, pumping is not allowed to exceed the 2014 capacity. For Merced ID, there is no difference between the 2009 and 2014 pumping capacities as shown in Appendix G, Table G.2-4; therefore, irrigation district groundwater use cannot increase over level in the 2009 pumping scenario, and the results do not change. SEWD and CSJWCD groundwater pumping capacities in the 2009 and 2014 groundwater pumping scenarios are assumed to be their demand; therefore, they do not pump any additional groundwater in the revised scenario. Note that all of the underlying annual data for groundwater use under the revised SWAP model scenario, the 2009 groundwater pumping scenario, and the 2014 groundwater pumping scenario are available in the *GW and SW Use Analysis* spreadsheet posted on the State Water Board website.

Under baseline conditions, none of the districts needs to pump over the 2009 pumping capacity to maintain permanent crops and 70 percent of their corn silage acres. Under LSJR Alternative 2, both SSJID and MID use some of their 2014 pumping capacity in less than 5 percent of years (about 4 and 3 percent of years, respectively). At most, SSJID pumps an additional 5 TAF over its 2009 pumping capacity, while MID pumps an additional 10 TAF over its 2009 capacity. Under LSJR Alternative 3, SSJID, MID, and TID use some of their 2014 pumping capacity in less than 10 percent of the years (about 6, 8, and 1 percent of years, respectively). At most, SSJID pumps an additional 10 TAF, MID pumps an additional 15 TAF, and TID pumps an additional 5 TAF over their 2009 capacities. Under LSJR Alternative 4, SSJID, OID, MID, and TID use some of their 2014 pumping capacity in about 25, 15, 35, and 31 percent of years, respectively. At most, OID pumps an additional 10 TAF, MID pumps an additional 50 TAF, and TID pumps an additional 85 TAF over their 2009 capacities. SSJID reaches its 2014 pumping capacity (an additional 15 TAF over the 2009 pumping capacity) in about 10 percent of years.

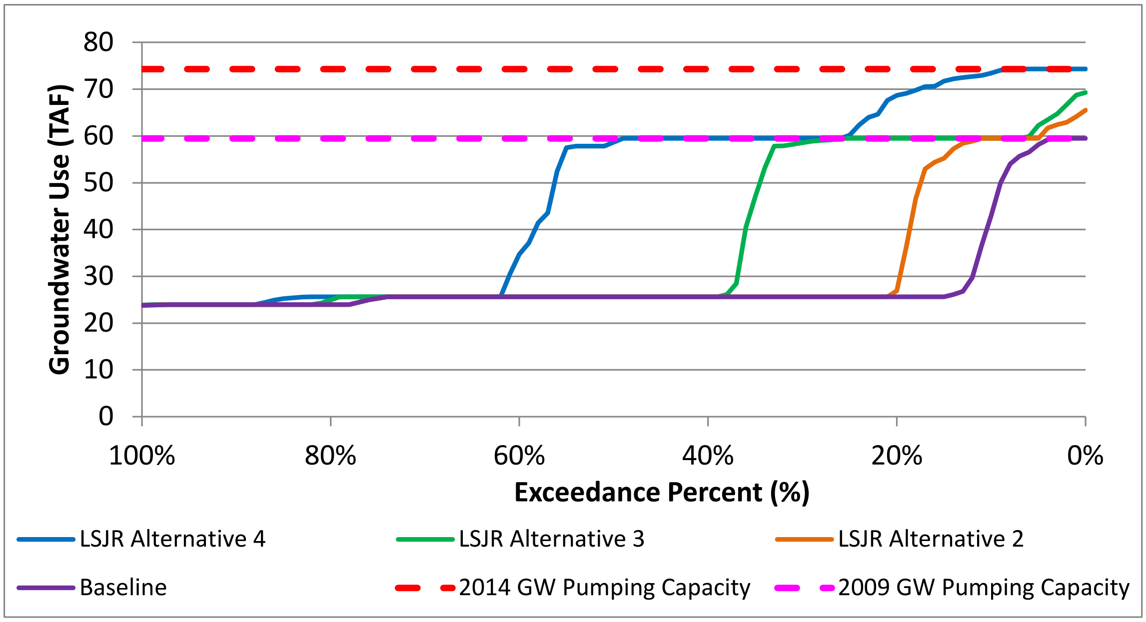

Figure 8.1-1. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in SSJID

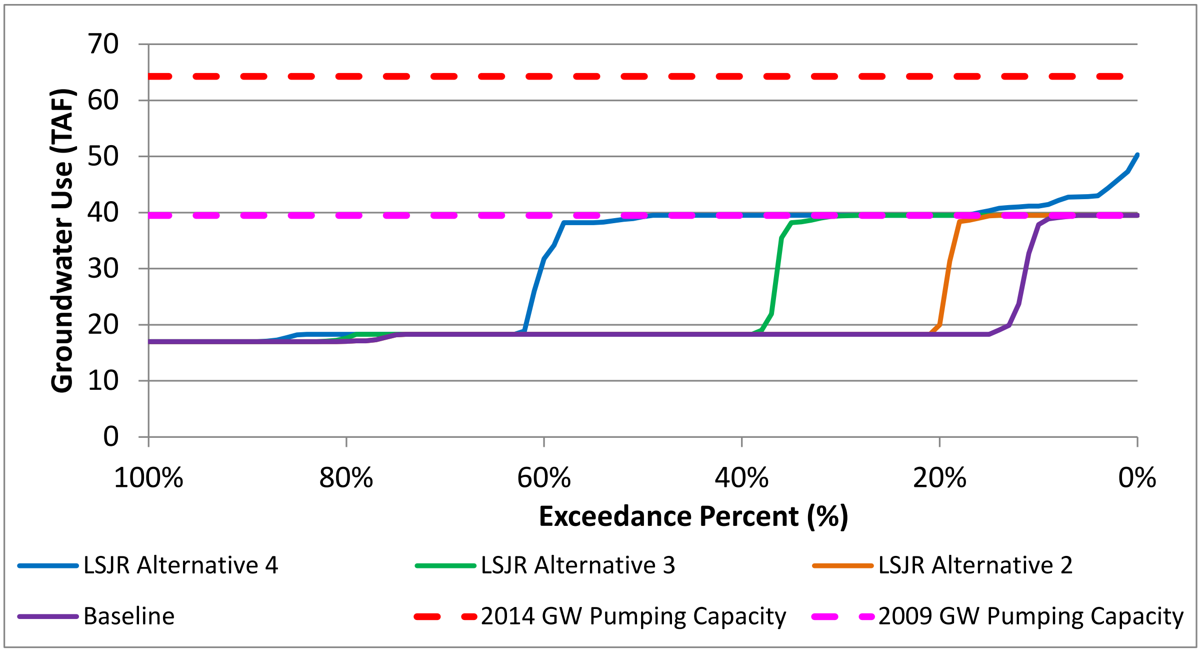

Figure 8.1-2. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in OID

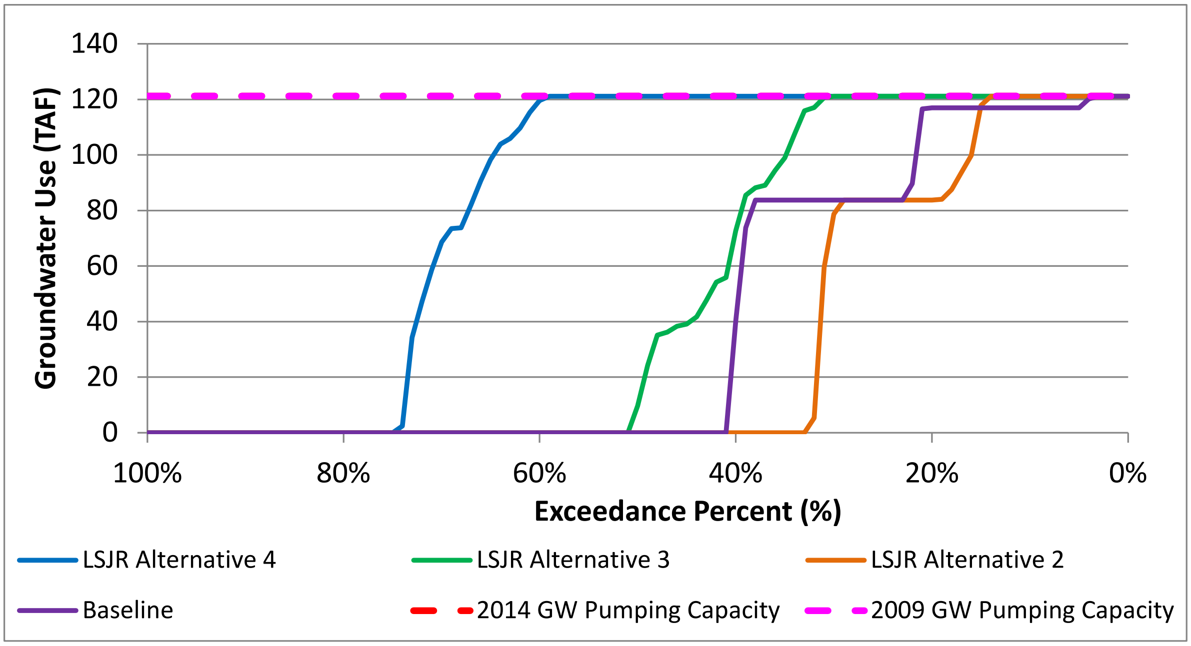

Figure 8.1-3. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in SEWD and CSJWCD combined

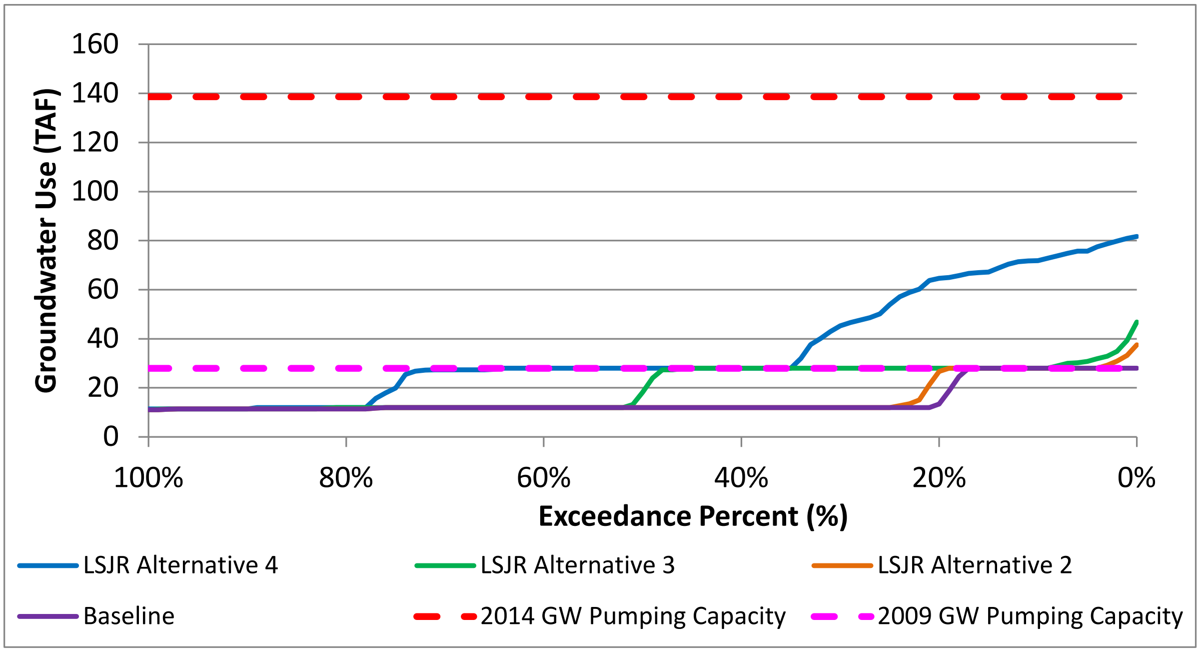

Figure 8.1-4. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in MID

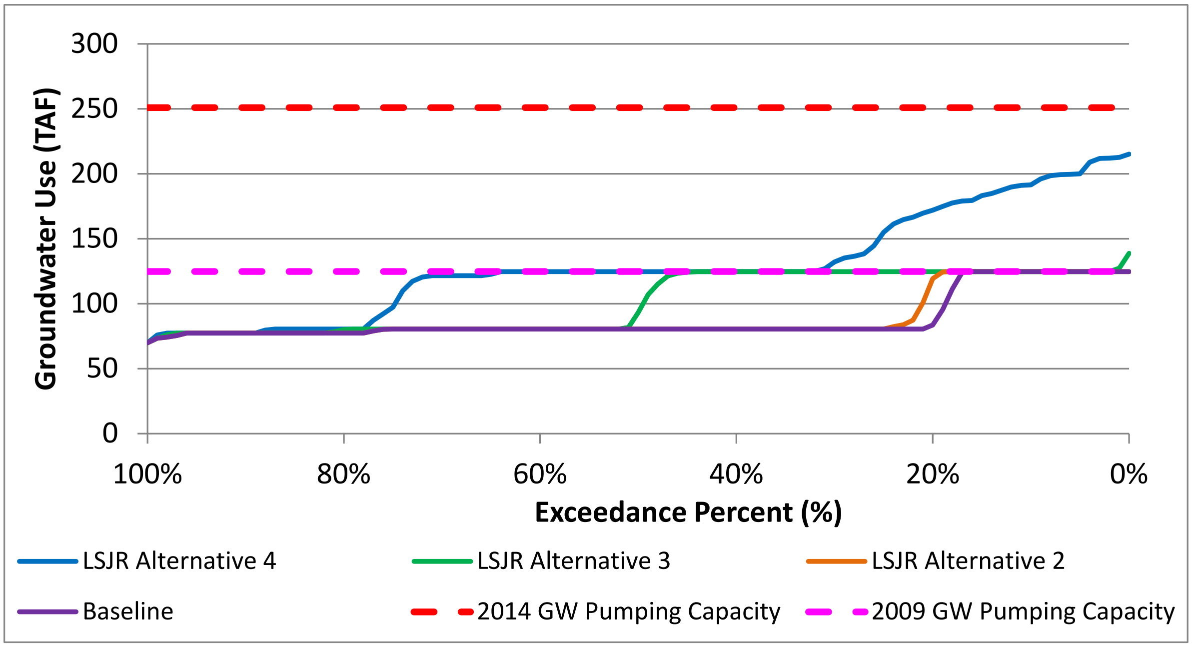

Figure 8.1-5. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in TID

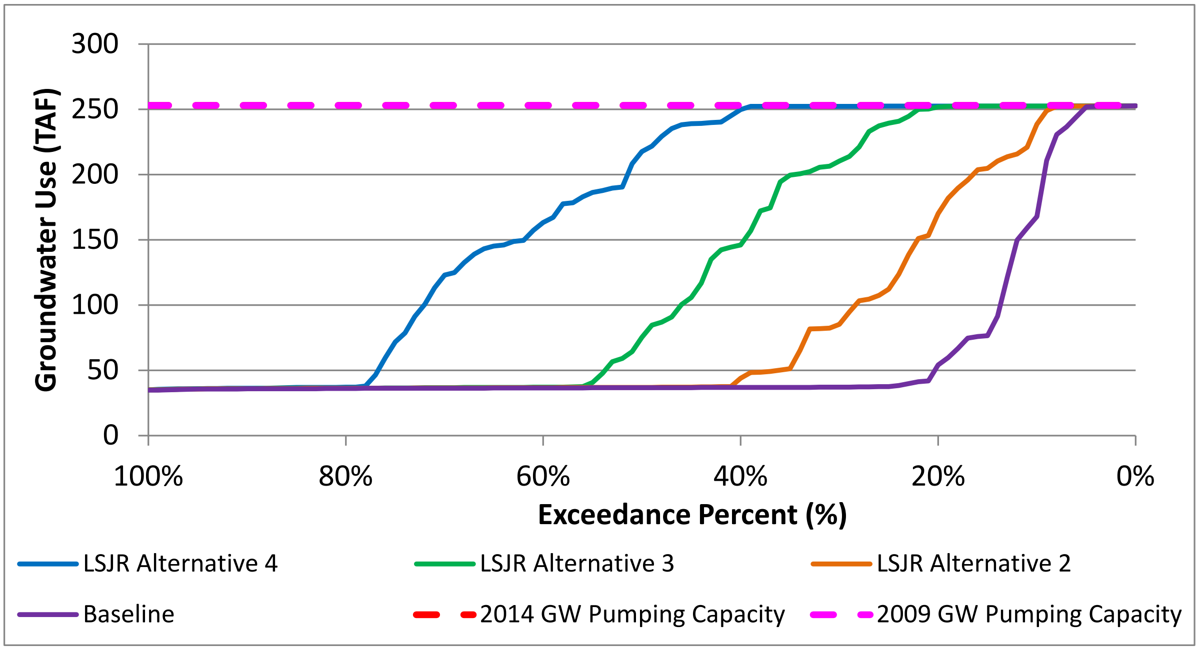

Figure 8.1-6. Exceedance Chart of Annual Groundwater (GW) Use for Applied Water in Merced ID

Tables 8.1-9, 8.1-10, and 8.1-11 present the average annual changes in groundwater use, groundwater recharge, and groundwater balance under the LSJR alternatives relative to baseline, based on the revised groundwater scenario used for the SWAP analysis. These tables are analogues to Tables G.3-3, G.3-4, and G.3-5 of Appendix G, which show the same results but assume either 2009 or 2014 maximum groundwater pumping capacities. Under LSJR Alternatives 2 and 3, results for the revised groundwater scenario are either the same or very slightly higher when compared to results for the 2009 maximum capacity scenario shown in Appendix G. Under LSJR Alternative 4, there is greater increase in groundwater use relative to the 2009 maximum capacity scenario, but it is still less than the increase in groundwater use for the 2014 maximum capacity scenario. Similarly, the change in groundwater recharge increases slightly (becomes less in the negative) under the revised groundwater scenario relative to the 2009 scenario, but is still less than under the 2014 scenario. Finally, the changes in the subbasin groundwater balances for the revised groundwater scenario also remain in between the changes under the 2009 and 2014 scenarios. As the groundwater effects determined from the revised groundwater scenario fall within the range of effects analyzed under the 2009 and 2014 scenarios in Chapter 9, the revised groundwater scenario does not introduce any impacts unanalyzed in the SED.

Table 8.1-9. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Pumping by the Irrigation Districts

Groundwater Subbasin	Baseline Groundwater Pumping (TAF/y)	Increase in Groundwater Pumping Relative to Baseline (TAF/y)		
		LSJR Alternative 2a	LSJR Alternative 3	LSJR Alternative 4
Eastern San Joaquin	79	-4	24	72
Modesto	27	2	8	28
Turlock	91	2	17	47
Extended Merced	65	23	61	110

TAF/y = thousand-acre feet per year.

Note: Results assuming general use of 2009 infrastructure, with opportunistic use of 2014 infrastructure.

[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 8.1-10. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Recharge by the Irrigation Districts

Groundwater Subbasin	Baseline Groundwater Recharge (TAF/y)	Change in Recharge Relative to Baseline (TAF/y)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Eastern San Joaquin	144	-2	-12	-32
Modesto	155	-4	-17	-39
Turlock	250	-5	-27	-64
Extended Merced	164	-7	-21	-42

TAF/y = thousand-acre feet per year.

Note: Results assuming general use of 2009 infrastructure, with opportunistic use of 2014 infrastructure.

Table 8.1-11. 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
Eastern San Joaquin	65	2	-36	-104
Modesto	129	-6	-25	-67
Turlock	158	-7	-43	-111
Extended Merced	99	-30	-82	-152

TAF/y = thousand-acre feet per year.

Note: Results assuming general use of 2009 infrastructure, with opportunistic use of 2014 infrastructure.

Applied Water Delivery

Figures 8.1-7 through 8.1-11 present exceedance charts of applied water delivery as a percent of applied water demand for the irrigation districts in the revised SWAP model run. These figures account for both applied surface water and groundwater. SEWD and CSJWCD are assumed to have enough groundwater pumping capacity to always meet their demand; therefore, no plot is shown for these two districts. Note that all of the underlying annual data for applied water delivery and applied water demand are available in the *GW and SW Use Analysis* spreadsheet posted on the State Water Board website.

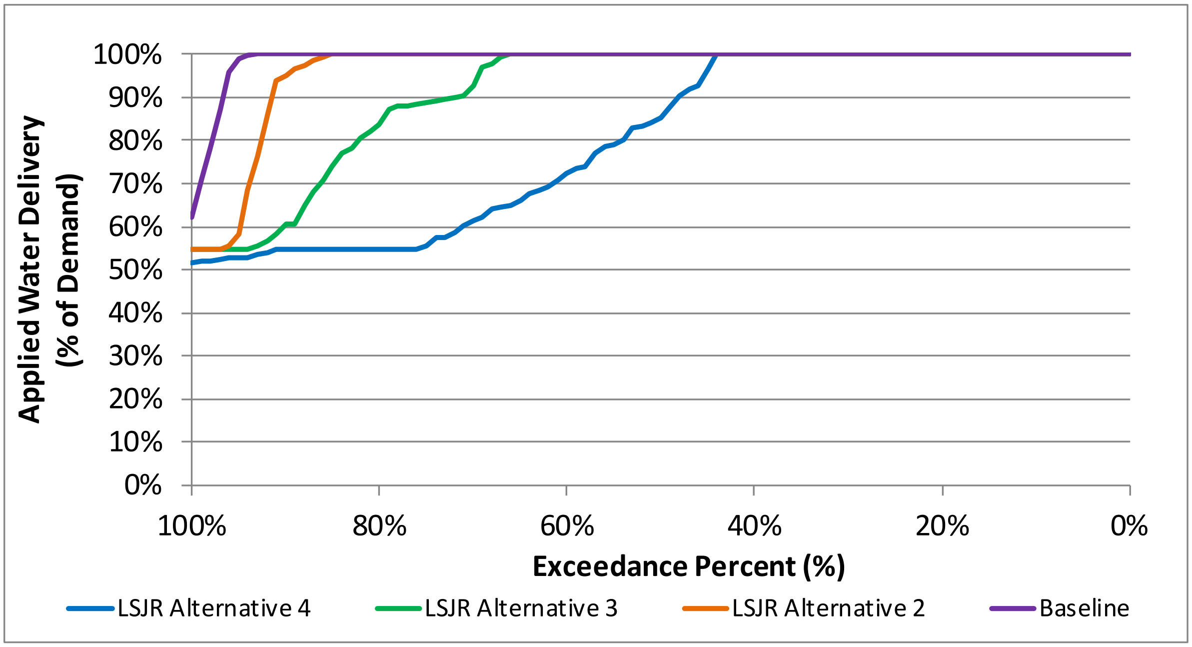

Figure 8.1-7. Exceedance Chart of Annual Applied Water Delivery as a Percent of Demand in SSJID

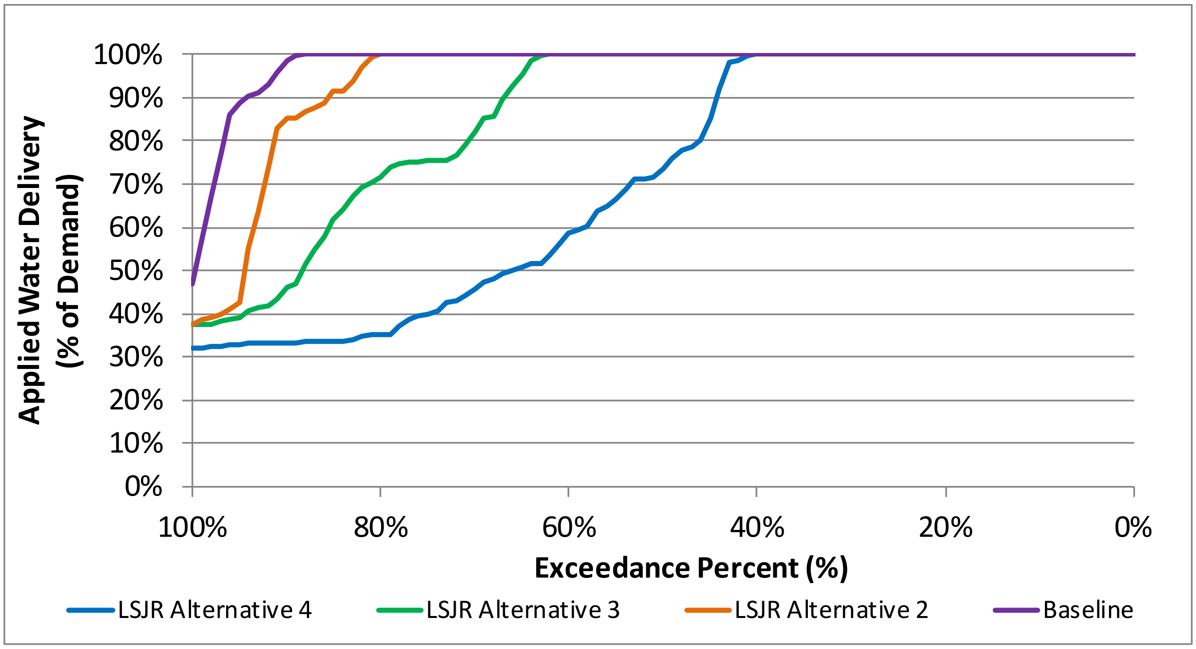

Figure 8.1-8. Exceedance Chart of Annual Applied Water Delivery as a Percent of Demand in OID

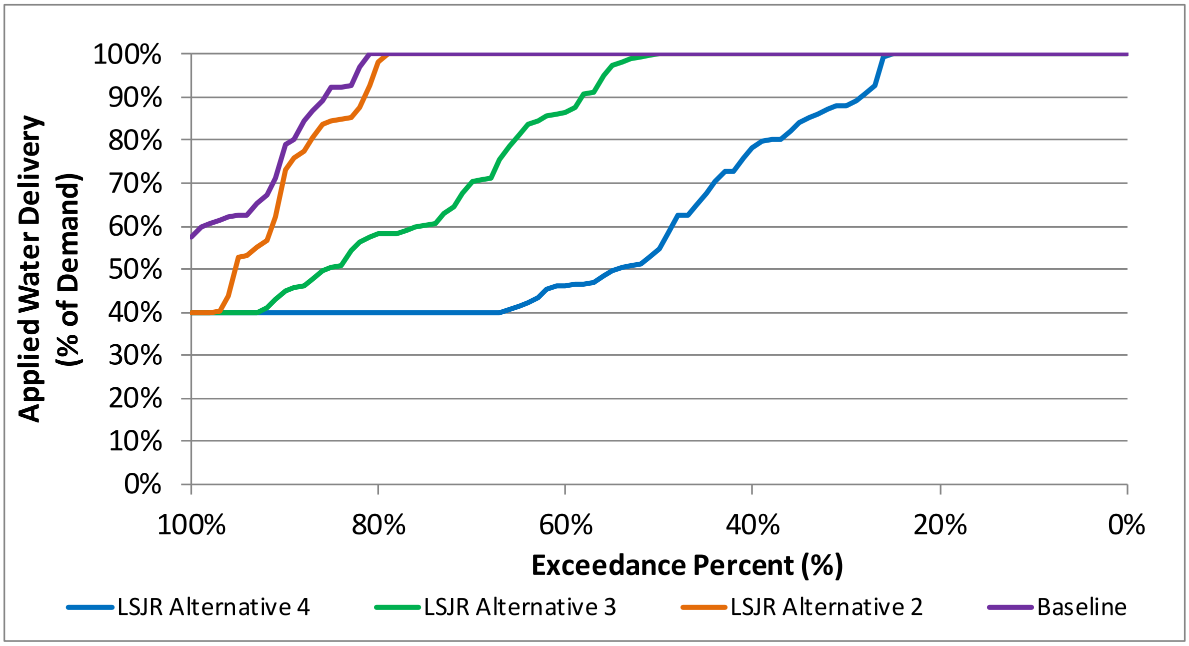

Figure 8.1-9. Exceedance Chart of Annual Applied Water Delivery as a Percent of Demand in MID

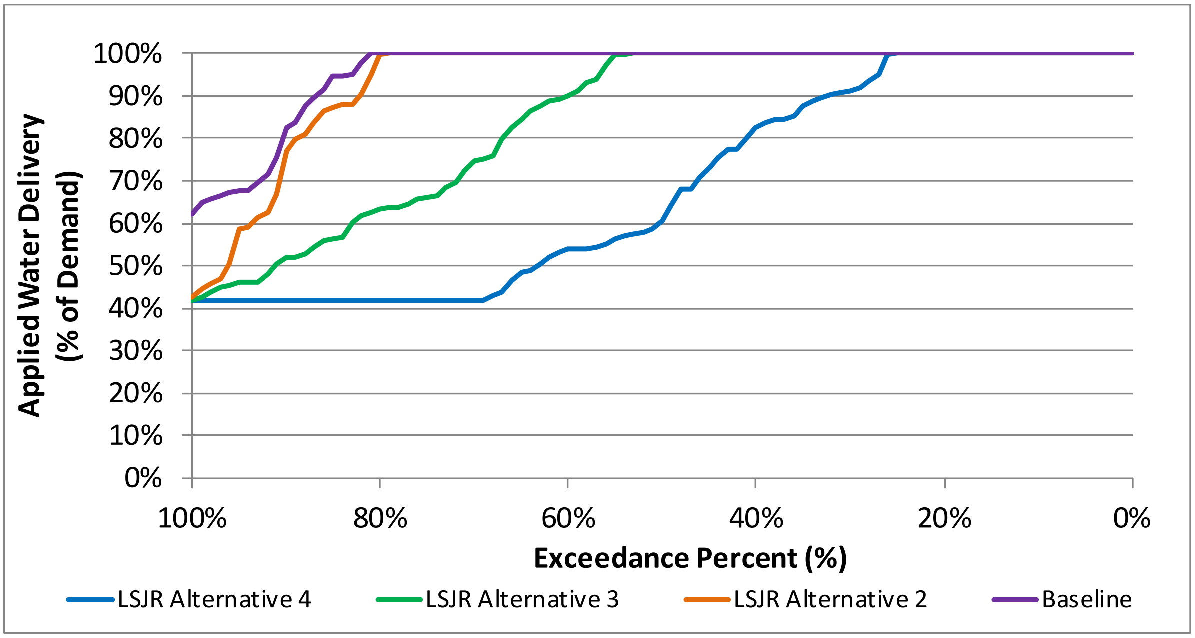

Figure 8.1-10. Exceedance Chart of Annual Applied Water Delivery as a Percent of Demand in TID

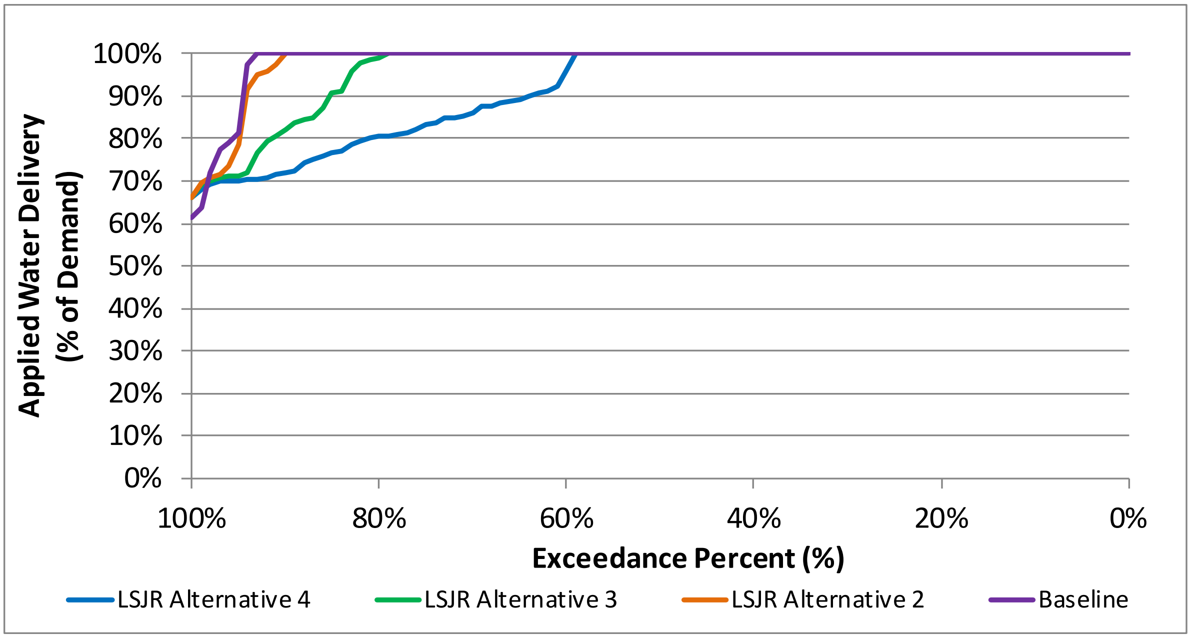

Figure 8.1-11. Exceedance Chart of Annual Applied Water Delivery as a Percent of Demand in Merced ID

Table 8.1-12 presents the average annual applied surface water deficit for baseline and the increase in the deficit under the LSJR alternatives, based on the revised groundwater scenario used for the revised SWAP analysis. This table is analogues to Tables G.2-10 and G.2-11 in Appendix G, which show the same results, but assume either 2009 or 2014 maximum groundwater pumping capacities.

Table 8.1-12. Average Annual Applied Surface Water Deficit Post-Groundwater Replacement

	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	6	15	34	5	13	33
OID	5	13	30	64	8	25	59
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	11	16	40	77	5	29	65
TID	23	35	86	173	12	63	150
Merced ID	7	7	15	31	1	8	25
All Districts	48	79	186	380	31	138	332
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	1	5	11	24	3	9	23
OID	2	7	15	32	4	13	30
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	5	8	20	38	3	14	32
TID	5	8	19	39	3	14	34
Merced ID	2	2	5	10	0	3	8
All Districts	3	6	13	27	2	10	23

TAF/y = thousand-acre feet per year.

Irrigated Crop Area

Table 8.1-13 presents the average annual fallowed acres for each crop across all irrigation districts under baseline conditions, averaged over all years and by water year type. Tables 8.1-14 through 8.1-16 present the increase in fallowed acres relative to baseline under the LSJR alternatives, again averaged over all years and by water year type. Crop results include 19 crop categories, as opposed to the 20 categories defined in the DWR classifications (see Table 8.1-1), because the DWR land use data did not show any acreage in the Potato crop category for the areas analyzed. Please note that all of the underlying annual data for crop acreage, water use, and crop revenues are available in the *Agricultural Economic Analysis* spreadsheet posted on the State Water Board website. Please see Chapter 11, *Agricultural Resources*, for presentation of exceedance charts describing the frequency and magnitude of annual fallowing impacts on specific crops and for the agricultural impact determinations of the LSJR alternatives.

Compared to the SWAP model run in the 2016 Recirculated SED, under baseline conditions, the average annual fallowed area increases by about 1,015 acres (5,887 acres in the 2016 Recirculated SED to 6,902 acres in the revised SWAP model results in this Final SED). The crops with the most fallowed acres are still pasture, other field crops, and alfalfa, as was discussed in the 2016 Recirculated SED. In Table 8.1-13, which examines average annual acres fallowed by year type, the table shows that wet, above normal, and below normal years have no fallowing. Dry years show a relatively low amount of fallowing. However, there is a sharp increase in fallowed acres between dry years and critical years. In critical years, 89 percent (30,975 acres of 34,745 acres) of the fallowed acres are from pasture, alfalfa, corn, and other field crops.

Under LSJR Alternative 2, the average annual increase in fallowed area relative to baseline in the revised SWAP model run is about the same as in the 2016 Recirculated SED model run (5,990 acres compared to 6,086 acres, respectively). Table 8.1-14 shows that on average, no fallowing occurs in wet and above normal years. During below normal and dry years, on average, fallowing increases by 419 and 1,490 acres, respectively, relative to baseline, primarily as more pasture is fallowed. Fallowed acres in critical years almost doubles over baseline, increasing by 29,150 acres, with more acres of other field crops, alfalfa, and corn coming out of production.

Under LSJR Alternative 3, the average annual increase in fallowed area relative to baseline in the revised SWAP model run is slightly larger than in the 2016 Recirculated SED model run (24,905 acres compared to 23,421 acres, respectively). Table 8.1-15 shows that on average, all year types now have some fallowed area. Fallowing in wet years is still relatively small compared to the overall acreage. The increase in fallowed area is larger for the other year types, particularly critical years. About 86 percent (68,316 acres of 79,114 acres) of the increase in fallowed area in critical years is from removing pasture, alfalfa, corn, and other field crops.

Under LSJR Alternative 4, the average annual increase in fallowed area relative to baseline in the revised SWAP model run is smaller than in the 2016 Recirculated SED model run (64,038 acres compared to 70,640 acres, respectively). This decrease is primarily because there are fewer acres of corn fallowed in the revised model run. Table 8.1-16 shows still greater fallowing in each year type, although it is dry years that have the greatest increase in fallowed acres over baseline rather than critical years. However, the overall fallowed acreage is still greater in critical years.

Table 8.1-13. Average Annual Fallowing over All Irrigation Districts under Baseline, by Crop and Water Year Type Conditions

		Average Annual Fallowing					
	Total Irrigated Area	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Alfalfa	34,642	637	0	0	0	62	3,212
Almond and Pistachio	116,016	178	0	0	0	28	887
Corn	106,783	418	0	0	0	65	2,088
Cotton	2,619	22	0	0	0	0	113
Cucurbits	2,691	13	0	0	0	1	67
Dry Bean	2,471	31	0	0	0	5	153
Fresh Tomato	10,422	3	0	0	0	0	17
Grain	14,435	18	0	0	0	1	91
Onion and Garlic	781	0	0	0	0	0	1
Other Deciduous	78,660	54	0	0	0	10	269
Other Field	54,271	2,353	0	0	0	137	11,951
Other Truck	28,798	129	0	0	0	18	647
Pasture	35,903	2,747	0	0	0	435	13,724

	Total Irrigated Area	Average Annual Fallowing					
		All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Processing Tomato	1,916	16	0	0	0	0	82
Rice	6,409	257	0	0	0	10	1,309
Safflower	162	4	0	0	0	0	19
Sugar Beets	292	1	0	0	0	0	3
Subtropical	1,994	6	0	0	0	0	29
Vine	22,962	16	0	0	0	2	82
Total	522,227	6,902	0	0	0	774	34,745

Table 8.1-14. Increase in Average Annual Fallowing over All Irrigation Districts LSJR Alternative 2 relative to Baseline, by Crop and Water Year Type Conditions

	Increase in Average Annual Fallowing					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres
Alfalfa	1,004	0	0	36	46	5,076
Almond and Pistachio	191	0	0	16	29	945
Corn	850	0	0	38	51	4,283
Cotton	2	0	0	0	0	12
Cucurbits	37	0	0	1	2	188
Dry Bean	74	0	0	3	4	376
Fresh Tomato	2	0	0	0	0	10
Grain	21	0	0	1	2	104
Onion and Garlic	1	0	0	0	0	3
Other Deciduous	63	0	0	6	10	309
Other Field	2,120	0	0	80	95	10,720
Other Truck	174	0	0	11	14	874
Pasture	1,128	0	0	220	1,190	4,638
Processing Tomato	25	0	0	0	1	128
Rice	266	0	0	6	40	1,326
Safflower	9	0	0	0	1	46
Sugar Beets	0	0	0	0	0	1
Subtropical	7	0	0	0	3	32
Vine	16	0	0	1	3	81
Total	5,990	0	0	419	1,490	29,150

Table 8.1-15. Increase in Average Annual Fallowing over All Irrigation Districts LSJR Alternative 3 relative to Baseline, by Crop and Water Year Type Conditions

	Increase in Average Annual Fallowing					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres
Alfalfa	3,551	13	334	1,084	3,490	14,128
Almond and Pistachio	674	12	135	346	845	2,332
Corn	2,424	14	261	838	2,065	9,783
Cotton	19	0	0	0	18	82
Cucurbits	96	1	9	20	56	417
Dry Bean	213	1	21	68	181	865
Fresh Tomato	8	0	1	4	11	28
Grain	66	2	11	21	63	254
Onion and Garlic	2	0	1	1	1	7
Other Deciduous	219	4	46	117	276	750
Other Field	9,063	15	1,526	5,168	13,895	29,412
Other Truck	572	6	67	218	551	2,229
Pasture	6,931	362	3,155	6,785	13,932	14,993
Processing Tomato	72	1	7	7	64	304
Rice	887	18	159	266	1,227	3,145
Safflower	25	1	4	4	27	99
Sugar Beets	1	0	0	0	1	3
Subtropical	27	2	15	18	30	80
Vine	58	1	12	28	71	203
Total	24,905	451	5,762	14,994	36,805	79,114

Table 8.1-16. Increase in Average Annual Fallowing over All Irrigation Districts LSJR Alternative 4 relative to Baseline, by Crop and Water Year Type Conditions (Revised SWAP Model Scenario)

	Increase in Average Annual Fallowing					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres
Alfalfa	9,757	1,197	4,125	10,943	19,869	19,049
Almond and Pistachio	1,884	255	938	1,949	3,507	3,900
Corn	8,926	770	3,434	6,876	15,987	22,581
Cotton	63	0	12	11	127	198
Cucurbits	291	37	134	202	476	750
Dry Bean	664	54	235	583	1,358	1,508
Fresh Tomato	23	2	11	20	46	52

	Increase in Average Annual Fallowing					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Crop Category	Acres	Acres	Acres	Acres	Acres	Acres
Grain	194	25	80	161	356	456
Onion and Garlic	5	1	2	5	8	10
Other Deciduous	615	86	308	647	1,141	1,261
Other Field	21,606	2,332	10,648	31,592	42,663	36,251
Other Truck	2,358	145	826	1,843	4,365	5,999
Pasture	14,768	2,542	11,915	23,008	28,608	18,019
Processing Tomato	202	51	91	153	339	470
Rice	2,395	588	1,181	2,420	4,476	4,608
Safflower	67	20	30	65	119	134
Sugar Beets	2	0	1	0	5	7
Subtropical	58	15	26	84	110	89
Vine	161	22	78	162	302	338
Total	64,038	8,143	34,073	80,724	123,860	115,682

Agricultural Gross Revenues

Table 8.1-17 presents gross revenue losses for each district under baseline conditions, averaged over all years and by water year type. Tables 8.1-18 through 8.1-20 present how the LSJR alternatives could further reduce gross revenue relative to baseline, again averaged over all years and by water year type. Please note that all of the underlying annual data for crop acreage, water use, and crop revenues are available in the *Agricultural Economic Analysis* spreadsheet posted on the State Water Board website. Please see Chapter 20, *Economic Analyses*, and Appendix G for further discussion of agricultural revenues and the effects of the LSJR alternatives.

Compared to the SWAP model run in the 2016 Recirculated SED, the revised results show a relatively small increase in maximum annual gross revenue over all the irrigation districts, from $1,487 million to $1,531 million. Under baseline conditions, average annual revenue decreases by about $11 million in the revised SWAP model run compared to $10 million in the 2016 Recirculated SED model run. In Table 8.1-17, wet, above normal, and below normal year types average no loss in revenue. For dry years, the average annual reduction in revenue is relatively small compared to the maximum gross revenue. In critical years, revenue is reduced by about 4 percent of the maximum gross revenue.

Under LSJR Alternative 2, average annual gross revenue decreases by about $10 million in the revised SWAP model run compared to $9 million in the 2016 Recirculated SED model run. Table 8.1-18 shows that for wet and above normal years, there is no reduction in revenue, and for below normal and dry years, there is only a relatively small decrease in revenue. The average annual revenue lost under LSJR Alternative 2 in critical years amounts to an additional 3 percent of the maximum gross revenue.

Under LSJR Alternative 3, average annual gross revenue decreases by about $39 million in the revised SWAP model run compared to $36 million in the 2016 Recirculated SED model run. Table 8.1-19 shows greater revenue losses than under LSJR Alternative 2 in all year types. In wet, above normal, and below normal years, the reduction in average annual revenue is only about 1.5 percent or less of the maximum gross revenue. The average annual revenue lost under LSJR Alternative 3 in dry and critical years is an additional 4 and 9 percent of the maximum gross revenue, respectively.

Under LSJR Alternative 4, average annual gross revenue decreases by about $108 million in the revised SWAP model run compared to $117 million in the 2016 Recirculated SED model run. The reduction in revenue is not as high as in the 2016 Recirculated SED primarily because fewer acres of corn are fallowed, particularly in TID. Table 8.1-20 shows that average annual gross revenue decreases in all year types. The average annual revenue lost under LSJR Alternative 4 ranges from an additional 1 to 14 percent of the maximum gross revenue, depending on the year type.

Table 8.1-17. Reduction in Average Annual Gross Agricultural Revenue under Baseline, by Irrigation District and Water Year Type Conditions

	Maximum Gross Revenue	Reduction in Avg. Annual Gross Revenue					
		All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)
SSJID	222	1	0	0	0	0	4
OID	135	1	0	0	0	0	4
SEWD/ CSJWCD	335	0	0	0	0	0	0
MID	180	2	0	0	0	1	11
TID	338	5	0	0	0	1	26
Merced ID	322	2	0	0	0	0	9
Total	1,531	11	0	0	0	2	55

Table 8.1-18. Reduction in Average Annual Gross Agricultural Revenue under LSJR Alternative 2 relative to Baseline, by Irrigation District and Water Year Type Conditions

	Reduction in Avg. Annual Gross Revenue, Relative to Baseline					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)
SSJID	2	0	0	0	0	12
OID	2	0	0	0	1	9
SEWD/ CSJWCD	0	0	0	0	0	0
MID	2	0	0	0	0	10
TID	4	0	0	1	1	18
Merced ID	0	0	0	0	0	1
Total	10	0	0	1	2	50

Table 8.1-19. Reduction in Average Annual Gross Agricultural Revenue under LSJR Alternative 3 relative to Baseline, by Irrigation District and Water Year Type Conditions

	Reduction in Avg. Annual Gross Revenue, Relative to Baseline					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million , 2008/y)
SSJID	6	0	1	1	4	26
OID	5	0	2	2	4	19
SEWD/ CSJWCD	0	0	0	0	0	0
MID	9	0	1	6	14	27
TID	17	0	3	13	30	51
Merced ID	2	0	0	0	2	7
Total	39	1	8	22	55	130

Table 8.1-20. Reduction in Average Annual Gross Agricultural Revenue under LSJR Alternative 4 relative to Baseline, by Irrigation District and Water Year Type Conditions

	Reduction in Avg. Annual Gross Revenue, Relative to Baseline					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critical Years
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million, 2008/y)	($Million , 2008/y)
SSJID	17	4	8	15	27	38
OID	15	4	7	13	24	34
SEWD/ CSJWCD	0	0	0	0	0	0
MID	22	2	13	30	45	37
TID	48	4	27	64	96	85
Merced ID	6	0	2	1	13	16
Total	108	14	56	123	205	210

Other Costs Associated with Crop Production

Commenters suggested other costs related to agricultural production that they believed should have been estimated as part of considering agricultural economic effects. Some specific costs mentioned included operation and maintenance costs for district canals, district administration costs, and maintenance costs for fallowed acres. However, the purpose of the agricultural economic analysis is to consider economics related to the LSJR flow objectives, in particular how agricultural net revenue would be reduced in response to reduced surface water deliveries. Estimating other costs would require detailed, project-level analysis of baseline costs for internal district operations, including age and types of infrastructure, current management and maintenance practices for individual fields, and projected future changes. Therefore, it would be speculative to assume the incremental changes to such operations under the LSJR alternatives when compared to potentially larger effects driven by potential crop fallowing. Furthermore, the appropriate range of potential economic effects under the LSJR alternatives, based on changes in crop production, has been provided to decision makers and the public.

Potential Reoptimization of Cropping Patterns and Contraction of the Agricultural Industry

Many commenters were concerned that the scope of the analysis did not include potential future actions that growers may take in response to reduced long-term water supply reliability. In particular, commenters asserted that reduced water supply reliability would lead to reoptimization of cropping patterns away from permanent crops and a long-term contraction in related agricultural industries. However, it would be speculative to assume growers would reduce acreage of permanent crops in the future. Over history, agriculture in the plan area has expanded and shifted toward higher net revenue, permanent crops. Recent drought studies from UC Davis (Howitt et al. 2015; Medellin-Azuara et al. 2016), ground-truthed with satellite information and statistics from the US Department of Agricultural (USDA), corroborate that during the last drought, permanent crops and vegetables tended to displace other crop classes due to market factors. The future decisions of growers will also depend on many factors in addition to water supply, including crop prices, input costs, and market conditions. Furthermore, there is still room for adaptation to take place in how water is managed and used and how markets operate. Distribution and field efficiencies can be improved, and permanent crops can be deficit irrigated to avoid losing investment. Feed crops, like alfalfa, can be imported from other areas. Though these possibilities could represent some loss in revenue, they would help avoid large-scale contraction of the industry. Please see Master Response 3.5, *Agricultural Resources*, for discussion of agricultural and dairy water management options.

Property Values

Some commenters asserted that property values for agricultural land would decrease in response to reduced water supply reliability and increases in operational costs. Furthermore, some commenters connected a potential reduction in property values to a reduction in property taxes for local governments and, in turn, potential funding cuts for essential services. Analyzing the effects of the LSJR alternative on individual properties is beyond the scope of the analysis because it is unknown where these properties are located and what other factors may affect their value. As reported by the Western Farm Press, while the American Society of Farm Managers and Rural Appraisers acknowledged that water cost during the drought had an impact on some California agricultural land values, it also suggested that in some circumstances, the impact of water cost might not be as large on property values as the effect of changing crop prices, stating: "a 'stomach-wrenching' free fall in almond prices fundamentally altered land values in 2016" (Cline 2016). This is an example of how property values will depend on several factors in addition to water supply including markets, type of crop, location, soil type and quality, and structures present. Such detailed, site-specific analysis is not required to consider economic effects of the plan amendments.

Commercial properties account for approximately 28 percent of the state's property tax base. In addition to agricultural properties, this category includes retail, industrial, and office properties (such as stores, gas stations, manufacturing facilities, and office buildings) as well as gas, oil and mineral properties (LAO 2012). Population growth and housing shortages in California are large market forces that will also affect (minimize or prevent declines in) land values. Given the diversity and complexity of these factors, it is speculative to assume how much the plan amendments would cause a change in agricultural land values. Likewise, it is speculative to assume that any changes would be large enough to reduce the tax base for municipal budgets and impact essential services.

Bank Loans and Loan Interest Rates

Some commenters worried that if the water supply becomes less reliable that it would become more difficult for individual growers to obtain loans or it would force creditors to apply higher interest rates to their loans. However, analyzing the effects of the LSJR alternative on local lenders and individual growers would require information on the specific conditions associated with the lenders and growers. There are many factors that affect the ability of lenders to give out loans and the ability of individual growers to receive loans, including credit scores, agricultural experience, and grower income. Such detailed, individual-specific analysis is not required to estimate the general economic effects of the plan amendments for the programmatic analysis in the SED.

Irrigation District Water Rates

Commenters were also concerned that district water rates might increase in response to reduced water supply reliability. They argued that the irrigation districts would still need to cover their expenses, despite having less water to deliver, and this would require raising water rates. It is reasonable to expect that if expenses for the irrigation districts were to exceed their revenues, then they could make a decision to change their irrigation water rates so they could remain economically viable. However, it is speculative to assume how district water rates would change in the future. Water rates will be decided by individual irrigation districts based on their expenses.

Economic Investment and Business Relocation

Other commenters asserted that reduced water supply reliability would drive away investment in the regional economy. With questions about water supply, commenters argued, agricultural related industries and businesses would look to move elsewhere, possibly out of state. However, one of the main attractions in California is its mild climate (PPIC 2011). The state’s combination of climate and soils is difficult or nearly impossible to replicate elsewhere. Almonds, for example, thrive in mild, wet winters and hot, dry summers. That is why nearly all of the almonds sold inside the United States come from California (WIFSS 2016). In addition, predicting future investment is highly speculative as it is unknown when and where investors will appear or what industries will expand. Furthermore, it is also speculative to assume if and where businesses will relocate given that decisions such as business location are dependent on many factors. Business owners and investors must plan their decisions carefully to put themselves in the best position to be successful. Though water is an important factor in these decisions, so is the strength of local and regional markets, of which California has some of the strongest in the country and the world. In addition, it is possible that farming activities would be replaced with other types of investment; for example, some farmland may be converted to solar power collection or housing.

References Cited

Akram, M. 2011. *Growth and Yield Components of Wheat Stress under Water Stress at Different Growth Stages*. Available: https://pdfs.semanticscholar.org/4d0d/5cb2c47cd012c06cbf4523ad17d93e7419b5.pdf. Accessed: May 4, 2018.

Aredas, A. 2015. *"TID, farmers debate selling district water for individual profit"*. Last revised: August 4, 2014. Available: https://www.turlockjournal.com/news/local/tid-farmers-debate-selling-district-water-for-individual-profit/. Accessed: May 4, 2018.

Carter, J., M. E. Jensen, and D. J. Traveller. 1980. Effect of Mid- to Late-Season Water Stress on Sugarbeet Growth and Yield. *Journal of Agronomy* 72:805–815. Available: https://eprints.nwisrl.ars.usda.gov/365/1/449.pdf. Accessed: May 4, 2018.

Celebi, M. 2014. The Effect of Water Stress on Tomato under Different Emitter Discharges and Semi-Arid Climate Condition. *Bulgarian Journal of Agricultural Science* 20(5):1151–1157. Available: http://agrojournal.org/20/05-21.pdf. Accessed: May 4, 2018.

Central San Joaquin Water Conservation District (CSJWCD). 2013. *Water Management Plan 2009 Criteria*. July 10.

Cline, H. 2016. *ASFMRA report: Will increasing California farm land prices slow, falter?* June 8. Available: https://www.proag.com/news/asfmra-report-will-increasing-california-farm-land-prices-slow-falter/. Accessed May 4, 2018.

Department of Water Resources (DWR). 2009. California Water Plan Update, 2009. Bulletin 160-09. Sacramento, California.

Department of Water Resources (DWR). 2010. Agricultural Land and Water Use. Available: https://www.water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates. Accessed: May 4, 2018.

Department of Water Resources (DWR). 2017. *A Water Resources System Planning Model For State Water Project (SWP) & Central Valley Project (CVP), CalSim 3.0 Draft Report*. Available: https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Library/Modeling-And-Analysis/CalSim3/Files/MainReport.pdf?la=en&hash=891FCF288374FEBFEA025FDCAD878E277A1548AC. Accessed: May 7, 2018.

Emam, Y., A. Shekoofa, F. Salehi, and A.H. Jalali. 2010. Water Stress Effects on Two Common Bean Cultivars with Contrasting Growth Habits. *American-Eurasian Journal of Agricultural & Environmental Sciences* 9(5):495–499. Available: http://idosi.org/aejaes/jaes9(5)/6.pdf. Accessed: May 4, 2018.

Esendal, E., A. Istanbulluoglu, B. Arslan, and C. Paşa 2008. *Effect of Water Stress on Growth Components of Winter Safflower (*Carthamus tinctorius L.*)*. 7th International Safflower Conference. Wagga Wagga Australia. Available: http://www.australianoilseeds.com/__data/assets/pdf_file/0005/6773/final_Esendal_oral_paper.pdf. Accessed: May 4, 2018.

Faber, B. 2015. *Drought Tip: Irrigating Citrus with Limited Water*. University of California Agriculture and Natural Resources Publication 8549. Available: http://anrcatalog.ucanr.edu/pdf/8549.pdf. Accessed: May 4, 2018.

Fulton, A., R. Buchner, and F. Niederholzer. 2015. *Drought Tip: Drought Strategies for California Prune Production*. University of California Agriculture and Natural Resources Publication 8520. Available: http://anrcatalog.ucanr.edu/pdf/8520.pdf. Accessed: May 4, 2018.

Goldhamer DA, Viveros M, Salinias M. 2005. Regulated deficit irrigation in almonds: effects of variations in applied water and stress timing on yield and yield components. Irrig. Sci. 24(2):101-114.

Hansen, B., D. May, T. Turini, and L. Schwankl. No date. *Coping with Drought: Strategies for Irrigating Processing Tomatoes*. University of California. Available: http://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Processing_Tomatoes/. Accessed: May 31, 2018.

Holland, J. 2014. *"Large almond crop projected despite drought"*. Last revised: May 2, 2014. Available: http://www.modbee.com/latest-news/article3164093.html. Accessed: May 3, 2018.

Holland, J. 2015. *"SSJID caps water deliveries for first time"*. Last revised: March 10, 2015. Available: http://www.fresnobee.com/news/local/water-and-drought/article19539333.html. Accessed: May 3, 2018.

Howitt, R. E., J. Medellín-Azuara, D. MacEwan, and J. R. Lund. 2012. *Calibrating disaggregate economic models of agricultural production and water management*. *Environmental Modelling & Software*, *38*, pp.244-258.

Howitt, R. E., D. MacEwan, J. Medellín-Azuara, J. R. Lund, and D. A. Sumner. 2015. *Economic Analysis of the 2015 Drought for California Agriculture*. Center for Watershed Sciences, University of California, Davis, CA. 16 pp. Available: https://watershed.ucdavis.edu/files/biblio/Economic_Analysis_2015_California_Drought__Main_Report.pdf. Accessed: May 4, 2018.

Hutmacher B., M. Keeley, R. Delgado, S. Wright, G. Banuelos, and B. Marsh. No date. *Deficit Drip Irrigation Management Practices—Role of Deficit Irrigation, Varieties*. PowerPoint presentation. University of California Cooperative Extension. Available: http://ucanr.edu/sites/Irrigation_and_Soils_/files/93372.pdf. Accessed: May 4, 2018.

Imperial Irrigation District (IID) 1994. *Test Water Savings Program—Final Environmental Assessment*. Imperial County, CA.

Kemble, J. K., and D. C. Sanders. No date. *Basics of Vegetable Crop Irrigation*. ANR-1169. Alabama Cooperative Extension System. Alabama A&M and Auburn Universities.

Legislative Analyst's Office (LAO). 2012. Understanding California's Property Taxes. November 29. Accessed: http://www.lao.ca.gov/reports/2012/tax/property-tax-primer-112912.aspx. Available: May 4, 2018.

Lundy, M. 2015. *Drought Tip: Managing Irrigated Corn during Drought*. University of California Agriculture and Natural Resources Publication 8551. Available: http://anrcatalog.ucanr.edu/pdf/8551.pdf. Accessed: May 4, 2018.

Medellin-Azuara, J., MacEwan, D., Howitt, Richard E., Medellín-Azuara, Sumner, D.A. Lund, J.R. 2016. *Economic Analysis of the 2016 California Drought on Agriculture*. Center for Watershed Sciences, UC Davis. Davis, CA, 17 pp. Available: https://watershed.ucdavis.edu/files/DroughtReport_20160812.pdf. Accessed: May 4, 2018.

Merced Irrigation District (Merced ID). 2013. *Agricultural Water Management Plan*. September 3. Available: http://www.mercedid.com/default/assets/File/Merced%20ID%20Ag%20Water%20Management%20Plan%20Final.pdf. Accessed: May 4, 2018.

Merced Irrigation District (Merced ID). 2016. *Merced Irrigation District Agricultural Water Management Plan.* Developed for the Department of Water Resources. Adopted July 5, 2016. Available: http://www.mercedid.com/default/assets/File/Merced%20ID%202015%20AWMP%20Final%20Board%20Approved%20070516(1).pdf. Accessed: May 4, 2018.

Modesto Irrigation District (MID). 2012. *Agriculture Water Management Plan*. December. Modesto, CA. Available: http://www.mid.org/water/irrigation/documents/AgWaterManagementPlan_2012.pdf. Accessed: May 4, 2018.

Modesto Irrigation District (MID). 2015. Agricultural Water Management Plan 2015 Update. Prepared by Provost & Pritchard Consulting Group. Available: http://www.mid.org/water/irrigation/documents/MID2015AWMPFinal.pdf. Accessed May 4, 2018.

Oakdale Irrigation District (OID). 2016. *Oakdale Irrigation District Agricultural Water Management Plan*. March. Prepared by Davids Engineering, Inc. Available: https://www.oakdaleirrigation.com/files/52c08212b/OID+2015+AWMP.pdf. Accessed: May 4, 2018.

Orloff, S., D. Putnam, and K. Bali. 2015a. *Drought Tip: Drought Strategies for Alfalfa*. University of California Agriculture and Natural Resources Publication 8522. Available: http://anrcatalog.ucanr.edu/pdf/8522.pdf. Accessed: May 4, 2018.

Orloff, S., C. Brummer, and D Putnam. 2015b. *Drought Tip: Managing Irrigated Pasture during Drought*. University of California Agriculture and Natural Resources Publication 8537. Available: http://anrcatalog.ucanr.edu/pdf/8537.pdf. Last Accessed: May 4, 2018.

Prichard, T., No date. *Irrigation Management of Winegrapes with a Limited Water Supply*. Available: http://caff.org/wp-content/uploads/2014/05/Winegrape_Irrigation-1.pdf. Accessed: May 4, 2018.

Public Policy Institute of California (PPIC). 2011. *Business Climate Rankings and the California Economy*. Available: http://www.ppic.org/content/pubs/report/R_411JKR.pdf. Accessed: May 4, 2018.

Recede, K. 2015. *"Oakdale's Water Conservation Efforts Meet State Enforced Challenge"*. Last revised: April 21, 2015. Available: http://fox40.com/2015/04/21/oakdales-water-conservation-efforts-meets-state-enforced-challenge/. Accessed: May 3, 2018.

Shackel, K., 2008. *Almond Irrigation, Water Stress and Productivity: Where do Drought & Deficit Irrigation Research Fit In?* University of California, Davis, Plant Sciences. Available: http://cestanislaus.ucanr.edu/files/111574.pdf. Accessed: May 3, 2018.

South San Joaquin Irrigation District (SSJID). 2015. *2015 Agricultural Water Management Plan.* December. Prepared by Davids Engineering, Inc. Available: http://www.ssjid.com/assets/pdf/2015-Ag-Water-Management-Plan.pdf. Accessed: May 4, 2018.

Stockton East Water District (SEWD). 2014. *Final Stockton East Water District Water Management Plan*. January 20. Available: https://www.water.ca.gov/LegacyFiles/wateruseefficiency/sb7/docs/2014/plans/Stockton-Eeast_WD_WMP-Final_012014.pdf. Accessed: May 4, 2018.

Stockton East Water District (SEWD). 2017. *Stockton East Water District 2015 Water Management Plan*. July. Available: https://www.water.ca.gov/LegacyFiles/wateruseefficiency/sb7/docs/2017/Stockton-East%20WD_2015_AWMP%202017_08_01.pdf. Accessed: May 4, 2018.

Turlock Irrigation District (TID). 2012. *Turlock Irrigation District 2012 Agricultural Water Management Plan.* November. Turlock, CA. Available: https://www.water.ca.gov/LegacyFiles/wateruseefficiency/sb7/docs/2014/plans/Turlock%20ID%20Final%20AWMP%2012-11-2012.pdf. Accessed: May 4, 2018.

Turlock Irrigation District (TID). 2015. *Turlock Irrigation District 2015 Agricultural Water Management Plan.* November. Turlock, CA. Available: https://www.tid.org/irrigation/irrigation-information/ag-water-management-plan/. Accessed: May 4, 2018.

University of California Cooperative Extension (UCCE). 2009. California Rice Workshop, March 25. Yuba City, CA.

U. S. Bureau of Reclamation (USBR). 2011. *Madera Irrigation District Water Supply Enhancement Project, Final Environmental Impact Statement*. EIS-06-127. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/STCDA%20et%20al/scda_47.pdf. Accessed: May 4, 2018.

U. S. Bureau of Reclamation (USBR). 2015. Modeling Appendix, Shasta Lake water resources investigation, California. United States Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA. Available: https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=22615. Accessed: May 4, 2018.

U.S. Department of Agriculture (USDA). 2018. California County Agricultural Commissioners' Data for 2010. Prepared by the National Agricultural Statistics Service California Field Office. Available: https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/. Accessed: May 4, 2018.

U.S. Office of Technology Assessment (OTA). 1982. *Use of Models for Water Resource Management, Planning, and Policy*. Chapter 3. Washington, DC.

Weiser, M. 2016. *Despite Drought, California Farming Prospered*. Published: August 1, 2016. Available: https://www.newsdeeply.com/water/articles/2016/08/01/despite-drought-california-farming-prospered. Accessed: May 4, 2018.

Western Institute for Food Safety & Security (WIFSS). 2016. *Almonds*. Presented by FDA. Available: https://www.wifss.ucdavis.edu/wp-content/uploads/2016/10/Almonds_PDF.pdf. Accessed: May 4, 2018.