Appendix 12A

Statewide Agricultural Production Model (SWAP) Documentation

This appendix provides information about the Statewide Agricultural Production (SWAP) model methodology, assumptions, and results used for the Remanded Biological Opinions on Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) Environmental Consequences analysis. More comprehensive SWAP model documentation can be found in the reference list, Section 12A.4.

This appendix is organized into three main sections:

- Section 12A.1: SWAP Model Methodology. The EIS uses SWAP to quantify effects of the alternatives on the long-term operations. This section provides information about the development history, methodology, and coverage.
- Section 12A.2: SWAP Model Assumptions. This section provides a brief description of the assumptions for the SWAP model simulations of the No Action Alternative, Second Basis of Comparison, and the other EIS alternatives.
- Section 12A.3: SWAP Model Results. This section provides model results used in the analysis and interpretation of modeling results for the alternatives impacts assessment. Also included is a discussion of model outputs used by other tools.

12A.1 SWAP Model Methodology

This section summarizes the SWAP development history, methodology, and coverage. It describes the overall analytical framework and contains descriptions of the key sources of input data used in the quantitative evaluation of the alternatives. The project alternatives include several major components that will have significant effects on CVP and SWP operations and the quantity of delivered water to agricultural contractors.

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers across 93 percent of agricultural land in California. It is the most current in a series of production models of California agriculture developed by researchers at the University of California at Davis under the direction of Professor Richard Howitt in collaboration with the California Department of Water Resources (DWR). The SWAP model has been subject to peer review and technical details can be found in “Calibrating Disaggregate Economic Models of Irrigated Production and Water Management” (Howitt et al. 2012).

12A.1.1 SWAP Model Development History

The SWAP model is an improvement and extension of the Central Valley Production Model (CVPM). The CVPM was developed in the early 1990s and was used to assess the impacts of the Central Valley Project Improvement Act (Reclamation and USFWS 1999). The SWAP model allows for greater flexibility in production technology and input substitution than CVPM does, and has been extended to allow for a range of analyses, including interregional water transfers and climate change effects. Its first application was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California, CALVIN (Draper et al. 2003). More recently, the SWAP model has been used to estimate the economic losses caused by salinity in the Central Valley (Howitt et al. 2009a), economic losses to agriculture in the Sacramento-San Joaquin Delta (Lund et al. 2007), and economic effects of water shortage to Central Valley agriculture (Howitt et al. 2009b). The model was updated and augmented for use by Bureau of Reclamation (Reclamation) in 2012 (Reclamation 2012). It is also being used in several ongoing studies of water projects and operations.

12A.1.1.1 Modeling Objectives

EIS modeling objectives accomplished with the SWAP model included the evaluation of the following potential impacts:

- Effects on irrigated agricultural acreage
- Effects on total production value
- Qualitative effects related to water transfers

12A.1.2 SWAP Model Methodology

The SWAP model assumes that growers select the crops, water supplies, and other inputs to maximize profit subject to resource constraints, technical production relationships, and market conditions. Growers face competitive markets, where no one grower can influence crop prices. The competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region. CES has four inputs: land, labor, water, and other supplies. CES production functions allow for limited substitution between inputs, which allows the model to estimate both total input use and input use intensity. Parameters are calculated using a combination of prior information and the method of Positive Mathematical Programming (PMP) (Howitt 1995a, Howitt 1995b).

- Marginal land cost functions are estimated using PMP. Additional land brought into production is assumed to be of lower value and thus requires a higher cost to cultivate. The PMP functions capture this cost by using acreage response elasticities, which relate change in acreage to changes in expected returns and other information.

- Groundwater pumping cost including depth to groundwater.
- Crop demand functions.
- Resource constraints on land, labor, water, and, if applicable, other input availability by region.
- Other agronomic and economic constraints. For example, a minimum regional silage production to meet dairy herd feeding requirements can be imposed if appropriate.

The model chooses the optimal amounts of land, water, labor, and other input use subject to these constraints and definitions. Profit is revenue minus costs, where revenue is price times yield per acre times total acres. Trade-offs among production inputs are described by the CES production functions. Costs are observable input costs plus the PMP cost function, which represents changes in marginal productivity of land. Downward-sloping crop demand curves guarantee that with all else constant, as production increases, crop price decreases (and vice-versa). Over time, crop demands may shift, driven by real income growth and population increases. External data and elasticities are used to estimate the magnitude of these shifts.

The SWAP model incorporates CVP and SWP agricultural water supplies, other local surface water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. Land will be fallowed when that is the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-run response of agriculture to potential changes in CVP and SWP agricultural water delivery, other surface or groundwater conditions, or other economic values or restrictions. Results from the CalSim II model are used as inputs into SWAP through a standardized data linkage tool, as described in Appendix 5A, CalSim II and DSM2 Modeling. Groundwater analysis conducted for the EIS with the Central Valley Hydrologic Model is used to develop assumptions and estimates on pumping lifts for use in the SWAP model. See Appendix 7A, Groundwater Model Documentation, for more information on the interfacing of the Central Valley Hydrologic Model and SWAP.

The model self-calibrates using PMP, which has been used in models since the 1980s (Vaux and Howitt 1984) and was formalized in 1995 (Howitt 1995a). PMP allows the modeler to infer the marginal cost and return conditions affecting decisions of farmers while only being able to observe limited average production cost and return data. PMP captures this information through a nonlinear cost or revenue function introduced to the model.

12A.1.3 SWAP Model Coverage

The SWAP model has 27 base regions in the Central Valley. The model is also able to include agricultural areas of the Central Coast, the Colorado River region that includes Coachella, Palo Verde and the Imperial Valley, and San Diego, Santa Ana, and Ventura and the South Coast; however, data for those regions have not been updated recently, so those regions were not analyzed for this report using SWAP. Figure 12A.1 shows the numbered California agricultural areas covered in SWAP. Table 12A.1 details the major water users in each of the regions.

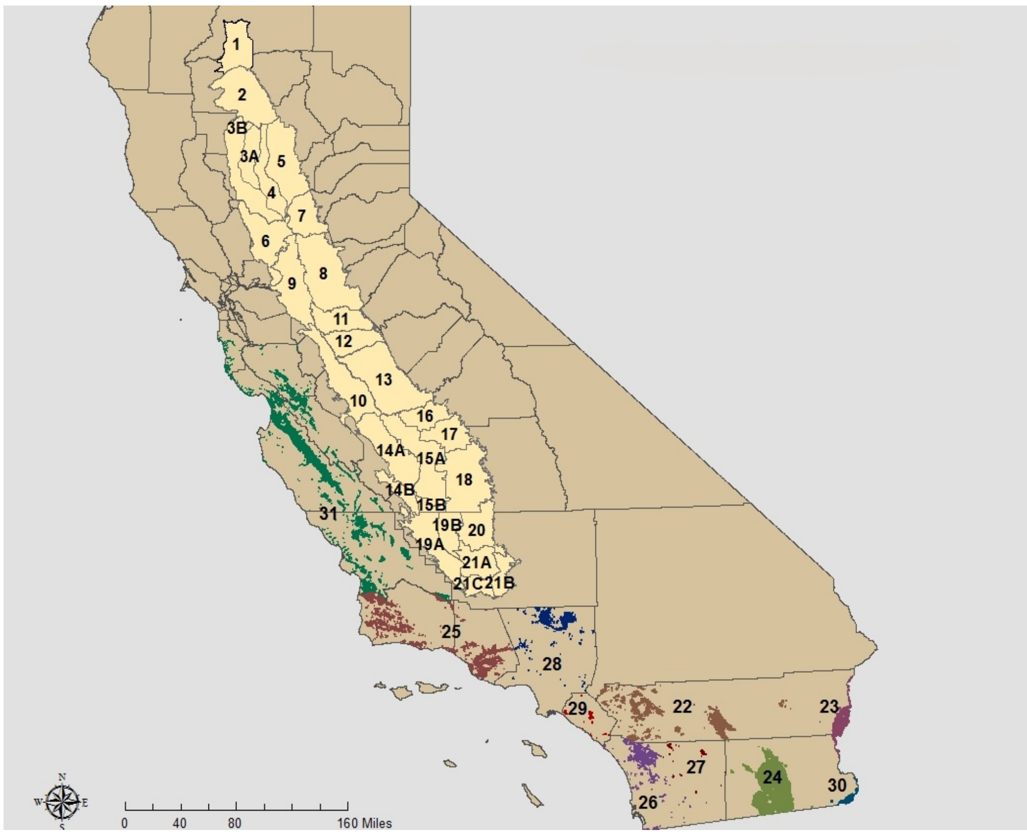

Figure 12A.1 SWAP Model Coverage of Agriculture in California

Table 12A.1 SWAP Model Region Summary

SWAP Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood I.D., Clear Creek C.S.D., Bella Vista W.D., and other Sacramento River Water Rights Settlement Contractors.
2	CVP Users: Corning Canal, Kirkwood W.D., Tehama, and other Sacramento River Water Rights Settlement Contractors.
3a	CVP Users: Glenn Colusa I.D., Provident I.D., Princeton-Codora I.D., Maxwell I.D., and Colusa Basin Drain M.W.C.
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois W.D., most of Colusa County, Davis W.D., Dunnigan W.D., Glide W.D., Kanawha W.D., La Grande W.D., and Westside W.D.
4	CVP Users: Princeton-Codora-Glenn I.D., Colusa I.C., Meridian Farm W.C., Pelger Mutual W.C., Reclamation District 1004, Reclamation District 108, Roberts Ditch I.C., Sartain M.D., Sutter M.W.C., Swinford Tract I.C., Tisdale Irrigation and Drainage Company, and other Sacramento River Water Rights Settlement Contractors.
5	Most Feather River Region riparian and appropriative users.
6	Yolo and Solano Counties. CVP Users: Conaway Ranch and other Sacramento River Water Rights Settlement Contractors.
7	Sacramento County north of American River. CVP Users: Natomas Central M.W.C., other Sacramento River Water Rights Settlement Contractors, Pleasant Grove-Verona W.M.C., and Placer County Water Agency.
8	Sacramento County south of American River and northern San Joaquin County.
9	Direct diverters within the Delta region. CVP Users: Banta Carbona I.D., West Side W.D., and Plainview W.D.
10	Delta Mendota service area. CVP Users: Panoche W.D., Pacheco W.D., Del Puerto W.D., Hospital W.D., Sunflower W.D., West Stanislaus W.D., Mustang W.D., Orestimba W.D., Patterson W.D., Foothill W.D., San Luis W.D., Broadview W.D., Eagle Field W.D., Mercy Springs W.D., San Joaquin River Exchange Contractors.
11	Stanislaus River water rights: Modesto I.D., Oakdale I.D., and South San Joaquin I.D.
12	Turlock I.D.
13	Merced I.D. CVP Users: Madera I.D., Chowchilla W.D., and Gravelly Ford W.D.
14a	CVP Users: Westlands W.D.
14b	Southwest corner of Kings County.
15a	Tulare Lake Bed. CVP Users: Fresno Slough W.D., James I.D., Tranquillity I.D., Traction Ranch, Laguna W.D., and Reclamation District 1606.
15b	Dudley Ridge W.D. and Devil's Den W.D. (Castaic Lake).

SWAP Region	Major Surface Water Users
16	Eastern Fresno County. CVP Users: Friant-Kern Canal Water Authority, Fresno I.D., Garfield W.D., and International W.D.
17	CVP Users: Friant-Kern Canal, Hills Valley I.D., Tri-Valley W.D., and Orange Cove I.D.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River I.D., Pixley I.D., portion of Rag Gulch W.D., Ducor I.D., County of Tulare, most of Delano-Earlimart I.D., Exeter I.D., Ivanhoe I.D., Lewis Creek W.D., Lindmore I.D., Lindsay-Strathmore I.D., Porterville I.D., Sausalito I.D., Stone Corral I.D., Tea Pot Dome W.D., Terra Bella I.D., and Tulare I.D.
19a	SWP Service Area, including Belridge W.S.D., Berrenda Mesa W.D.
19b	SWP Service Area, including Semitropic W.S.D.
20	CVP Users: Friant-Kern Canal Water Authority, Shafter-Wasco I.D.
21a	CVP Users: Cross Valley Canal water users and Friant-Kern Canal Water Authority.
21b	Arvin Edison W.D.
21c	SWP service area: Wheeler Ridge-Maricopa W.S.D.
23-30	Central Coast, Desert, and Southern California.

Notes:

The list above does not include all water users. It is intended only to indicate the major users or categories of users. All regions in the Central Valley also include private groundwater pumpers.

C.S.D. = Community Service District
I.C. = Irrigation Company
I.D. = Irrigation District
M.W.C. = Mutual Water Company
W.D. = Water District
W.S.D. = Water Storage District

Crops are aggregated into 20 crop groups, which are the same across all regions. Each crop group may represent a number of individual crops, but many are dominated by a single crop. Irrigated acres represent acreage of all crops within the group, while production costs and returns are represented by a single proxy crop for each group. The current 20 crop groups were defined in collaboration with Reclamation and DWR and updated in March 2011. For each group, the representative (proxy) crop is chosen based on four criteria:

- A detailed production budget is available from the University of California Cooperative Extension (UCCE).
- It is the largest or one of the largest acreages within a group.
- Its water use (applied water) is representative of water use of the crops in the group.
- Its gross and net returns per acre are representative of the crops in the group.

The relative importance of these criteria varies by crop. Crop group definitions and the corresponding proxy crop are shown in Table 12A.2.

Table 12A.2 SWAP Model Crop Groups

SWAP Definition	Proxy Crop	Other Crops
Almonds and Pistachios	Almonds	Pistachios
Alfalfa	Alfalfa hay	–
Corn	Grain corn	Corn silage
Cotton	Pima cotton	Upland cotton
Cucurbits	Summer squash	Melons, cucumbers, pumpkins
Dry Beans	Dry beans	Lima beans
Fresh Tomatoes	Fresh tomatoes	–
Grain	Wheat	Oats, sorghum, barley
Onions and Garlic	Dry onions	Fresh onions, garlic
Other Deciduous	Walnuts	Peaches, plums, apples
Other Field	Sudan grass hay	Other silage
Other Truck	Broccoli	Carrots, peppers, lettuce, other vegetables
Pasture	Irrigated pasture	–
Potatoes	White potatoes	–
Processing Tomatoes	Processing tomatoes	–
Rice	Rice	–
Safflower	Safflower	–
Sugar Beet	Sugar beets	–
Subtropical	Oranges	Lemons, misc. citrus, olives
Vine	Wine grapes	Table grapes, raisins

12A.2 SWAP Model Assumptions

This section is a non-technical overview of the SWAP model. It is important to note that SWAP, like any model, is a representation of a complex system and requires assumptions and simplifications to be made. All analyses using SWAP should be explicit about the assumptions and provide sensitivity analysis where appropriate.

12A.2.1 Calibration Using Positive Mathematical Programming

The SWAP model self-calibrates using a three-step procedure based on PMP (Howitt 1995a) and the assumption that farmers behave as profit-maximizing agents within a competitive market. In a traditional optimization model, profit-maximizing farmers would simply allocate all land, up until resource constraints become binding, to the most valuable crop(s). In other words, a traditional model would have a tendency for overspecialization in production activities relative to what is observed empirically. PMP incorporates information on the marginal production conditions that farmers face, allowing the model to replicate a base year of observed input use and output. Farm- and field-specific conditions that are unobserved in aggregated data may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and heterogeneity in soil and other physical capital. In the SWAP model, PMP is used to translate these unobservable marginal conditions, in addition to observed average conditions, into an exponential “PMP” cost function. This cost function allows the model to calibrate to a base year of observed input use and output.

The SWAP model assumes additional land brought into production faces an increasing marginal cost of production. The most fertile or lowest cost land is cultivated first; additional land brought into production is of lower “quality” because of poorer soil quality, drainage or other water quality issues, or other factors that cause it to be more costly to farm. This is captured through an exponential land cost function (PMP cost function) for each crop and region. The exponential function is advantageous because it is always positive and strictly increasing, consistent with the hypothesis of increasing land costs. The PMP cost function is both region- and crop-specific, reflecting differences in production across crops and heterogeneity across regions. Functions are calibrated using information from acreage response elasticities and shadow values of calibration and resource constraints. The information is incorporated in such a way that the average cost conditions (the observed cost data) are unaffected.

12A.2.2 Constant Elasticity of Substitution Production Function

Crop production in the SWAP model is represented by a CES production function for each region and crop with positive acres. In general, a production function captures the relationship between inputs and output. For example, land, labor, water, and other inputs are combined to produce a crop. CES production functions in the SWAP model are specific to each region; thus, regional input use is combined to determine regional production for each crop. The calibration routine in SWAP guarantees that both input use and output match a base year of observed data.

The SWAP model considers four aggregate inputs to produce each crop in each region: land, labor, water, and other supplies. All units are converted into monetary terms, e.g., dollars of labor per acre instead of worker hours. Land is simply the number of acres of a crop in any region. Land costs represent basic land investment, cash overhead, and (when applicable) land rent. Labor costs represent both machinery labor and manual labor. “Other supplies” is a broad category that captures a range of inputs including fertilizer, pesticides, chemicals, capital recovery, and interest on operating capital. Water costs and use per acre vary by crop and region.

The generalized CES production function allows for limited substitution among inputs (Beattie and Taylor 1985). This is consistent with observed farmer production practices (farmers are able to substitute among inputs in order to achieve the same level of production). For example, farmers may substitute labor for chemicals by reducing herbicide application and increasing manual weed control. Or, farmers can substitute labor for water by managing an existing irrigation system more intensively in order to reduce water use. The CES function used in Version 6 of the SWAP model is non-nested; thus, the elasticity of substitution is the same between all inputs.

12A.2.3 Crop Demand Functions

The SWAP model is specified with downward-sloping, California-specific crop demand functions. The demand curve represents consumers' willingness-to-pay for a given level of crop production. With all else constant, as production of a crop increases, the price of that crop is expected to fall. The extent of the price decrease depends on the elasticity of demand or, equivalently, the price flexibility, which is the percentage change in crop price due to a percent change in production. Demand functions are specific to a crop but not to a region. Therefore, large changes in production in one set of regions can, through the demand-induced price changes, lead to changes in production in other regions.

The SWAP model is specified with linear demand functions. The nature of the demand function for specific commodities can change over time due to tastes and preferences, population growth, changes in income, and other factors. The SWAP model incorporates linear shifts in the demand functions over time due to growth in population and changes in real income per capita. Changes in the demand elasticity itself, resulting from changing tastes and preferences, are not considered in the model, though they can be evaluated by changing demand function parameters in the model's input data.

12A.2.4 Water Supply and Groundwater Pumping

Total available water for agriculture is specified on a regional basis in the SWAP model. Each region has six sources of supply, although not all sources are available in every region:

- CVP water service contracts (including Friant-Kern Class 1 water service contracts)
- CVP Sacramento River settlement contracts and San Joaquin River exchange contracts
- Friant Kern Class 2 water service contracts
- SWP entitlement contracts
- Other local surface water

- Groundwater

Data sources and associated calculations are described in Reclamation (2012). State and Federal project deliveries are estimated from delivery records of DWR and Reclamation. Local surface water supplies are based on DWR estimates and reports of individual water suppliers, and, where necessary, are drawn from earlier studies.

Costs for surface water supplies are compiled from information published by individual water supply agencies. There is no central data source for water prices in California. Agencies that prepared CVP water conservation plans or agricultural water management plans in most cases included water prices and related fees charged to growers. Other agencies publish and/or announce rates on an annual basis. Water prices used in SWAP are intended to be representative for each region, but vary in their level of detail.

Groundwater availability is specified by region-specific maximum pumping estimates. These are determined by consulting the individual districts' records and information compiled by DWR. DWR analysts provided estimates of the actual pumping in the base year and the existing pumping capacity by region. The model determines the optimal level of groundwater pumping for each region, up to the capacity limit specified. In some studies using SWAP or CVPM, the model has been used interactively with a groundwater model to evaluate short-term and long-term effects on aquifer conditions and pumping lifts.

Pumping costs vary by region depending on depth to groundwater and power rates. The SWAP model includes a routine to calculate the total costs of groundwater. The total cost of groundwater is the sum of fixed, operation and maintenance (O&M), and energy costs. Energy costs are based on a blend of agricultural power rates provided by Pacific Gas and Electric Company (PG&E).

12A.2.5 SWAP Model Inputs and Supporting Data

Land use data in the SWAP model correspond to the year 2010 and were prepared by DWR analysts. DWR is now developing more detailed annual time series data on agricultural land use, but the current version of the SWAP model calibrates to 2010 as a relatively normal base year. All prices and costs in SWAP are in constant 2010 dollars for consistency with the land use data. Table 12A.3 summarizes input data and sources used in the SWAP model.

Table 12A.3 SWAP Model Input Data Summary

Input	Source	Notes
Land Use	DWR	Base year 2010.
Crop Prices	County agricultural commissioners	By proxy crop using 2010-2012 average prices, indexed to 2010 price level.
Crop Yields	UCCE crop budgets	By proxy crop for various years (most recent available).

Input	Source	Notes
Interest Rates	UCCE crop budgets	Crop budget interest costs adjusted to year 2010.
Land Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars.
Other Supply Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars
Labor Costs	UCCE crop budgets	By proxy crop for various years (most recent available). In 2010 dollars
Surface Water Costs	Reclamation, DWR, individual districts	By SWAP model region. In 2010 dollars.
Groundwater Costs	PG&E, individual districts	Total cost per acre-foot includes fixed, O&M, and energy cost. In 2010 dollars.
Irrigation Water	DWR	Average crop irrigation water requirements in acre-feet per acre.
Available Water	CVPM, DWR, Reclamation, individual districts	By SWAP model region and water supply source.
Elasticities	Russo et al. 2008	California estimates.

12A.2.6 2030 Assumptions

Analysis of alternatives assumed 2030 conditions. Projected CVP and SWP water deliveries were provided by CalSim II results as described in Appendix 5A, CalSim II and DSM2 Modeling. Future crop demand functions are based on shifts over time due to growth in population and changes in real income per capita (see Section 12A.2.3).

12A.3 SWAP Model Results

12A.3.1 Acreage and Agricultural Production Results

Modeling results are summarized and discussed in Chapter 12, Agricultural Resources. More detailed results by individual crop type are shown in Tables 12A.4 through 12A.11. All values of production are in 2010 dollars.

Table 12A.4 Sacramento and San Joaquin Valley Irrigated Acreage by Crop under the No Action Alternative and Alternative 2 over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (1000s acres)	Long-term Average, San Joaquin Valley (1000s acres)	Dry and Critically Dry, Sacramento Valley (1000s acres)	Dry and Critically Dry, San Joaquin Valley (1000s acres)
Alfalfa	97.2	572.0	96.4	571.5
Almond, Pistachio	164.3	920.3	163.4	918.6
Corn	48.7	678.7	48.3	678.3
Cotton	3.3	281.2	3.3	281.0
Cucurbits	40.1	68.8	40.1	68.8
Drybeans	19.9	55.9	19.9	55.9
Fresh Tomato	1.7	35.1	1.7	35.1
Grain	86.6	289.0	86.8	275.8
Onion, Garlic	4.0	60.4	4.0	60.4
Other Deciduous	246.6	392.6	246.6	392.4
Other Field	44.8	519.5	44.7	519.3
Other Truck	7.4	199.1	7.4	199.1
Pasture, Irrigated	102.0	162.7	100.3	163.0
Potato	–	16.9	–	16.9
Process Tomato	65.5	252.9	65.4	252.9
Rice	548.0	16.6	544.2	16.6
Safflower	11.0	26.5	11.0	26.5
Sugarbeet	–	0.6	–	0.6
Subtropical	37.2	238.5	37.2	238.5
Vineyard	8.4	604.1	8.4	604.1
Total	1,536.7	5,391.7	1,529.0	5,375.3

Table 12A.5 Sacramento and San Joaquin Valley Production Value by Crop under the No Action Alternative and Alternative 2, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Alfalfa	$161.7	$1,256.0	$160.6	$1,255.9
Almond, Pistachio	$737.9	$4,826.8	$737.4	$4,823.5
Corn	$60.6	$979.9	$60.3	$979.1
Cotton	$8.2	$697.1	$8.2	$696.7
Cucurbits	$593.8	$1,018.3	$593.8	$1,018.2
Drybeans	$23.9	$63.5	$23.9	$63.5
Fresh Tomato	$16.5	$404.8	$16.5	$404.8
Grain	$59.6	$278.2	$59.8	$265.1
Onion, Garlic	$31.5	$445.7	$31.5	$445.6
Other Deciduous	$1,759.1	$3,237.2	$1,759.1	$3,236.1
Other Field	$58.0	$664.1	$58.0	$663.9
Other Truck	$51.0	$1,459.2	$51.0	$1,459.1
Pasture, Irrigated	$74.7	$116.2	$73.6	$116.7
Potato	$-	$122.2	$-	$122.2
Process Tomato	$237.9	$999.3	$237.9	$999.1
Rice	$1,072.2	$30.3	$1,065.1	$30.3
Safflower	$8.1	$19.6	$8.1	$19.6
Sugarbeet	$-	$1.6	$-	$1.6
Subtropical	$525.1	$3,618.9	$525.1	$3,618.8
Vineyard	$49.6	$4,243.2	$49.8	$4,243.0
Total	$5,529.5	$24,482.1	$5,519.7	$24,462.8

Table 12A.6 Sacramento and San Joaquin Valley Irrigated Acreage by Crop under the Second Basis of Comparison and Alternative 1, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (1000s acres)	Long-term Average, San Joaquin Valley (1000s acres)	Dry and Critically Dry, Sacramento Valley (1000s acres)	Dry and Critically Dry, San Joaquin Valley (1000s acres)
Alfalfa	97.3	572.2	97.2	572.2
Almond, Pistachio	164.4	920.3	164.4	920.3
Corn	48.6	679.0	48.8	678.9
Cotton	3.3	281.2	3.3	281.2
Cucurbits	40.1	68.8	40.1	68.8
Drybeans	19.9	55.9	19.9	55.9
Fresh Tomato	1.7	35.1	1.7	35.1
Grain	85.6	288.8	86.8	288.8
Onion, Garlic	4.0	60.4	4.0	60.4
Other Deciduous	246.6	392.6	246.6	392.6
Other Field	44.8	519.6	44.9	519.5
Other Truck	7.4	199.1	7.4	199.1
Pasture, Irrigated	102.5	162.7	100.8	163.2
Potato	–	16.9	–	16.9
Process Tomato	65.5	252.9	65.5	252.9
Rice	548.5	16.6	548.0	16.6
Safflower	11.0	26.5	11.0	26.5
Sugarbeet	–	0.6	–	0.6
Subtropical	37.2	238.5	37.2	238.5
Vineyard	8.4	604.1	8.4	604.1
Total	1,536.7	5,392.2	1,535.8	5,392.2

Table 12A.7 Sacramento and San Joaquin Valley Production Value by Crop under the Second Basis of Comparison and Alternative 1, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Alfalfa	$162.0	$1,256.1	$161.7	$1,256.2
Almond, Pistachio	$738.8	$4,826.5	$738.9	$4,826.4
Corn	$60.5	$980.3	$60.8	$980.1
Cotton	$8.2	$697.3	$8.2	$697.3
Cucurbits	$593.8	$1,018.2	$593.8	$1,018.2
Drybeans	$23.9	$63.5	$23.9	$63.5
Fresh Tomato	$16.5	$404.8	$16.5	$404.8
Grain	$58.9	$277.9	$59.8	$277.9
Onion, Garlic	$31.5	$445.7	$31.5	$445.7
Other Deciduous	$1,759.1	$3,237.3	$1,759.1	$3,237.3
Other Field	$58.0	$664.3	$58.1	$664.2
Other Truck	$51.0	$1,459.2	$51.0	$1,459.1
Pasture, Irrigated	$75.0	$116.2	$73.9	$116.7
Potato	$-	$122.2	$-	$122.2
Process Tomato	$238.0	$999.2	$238.1	$999.2
Rice	$1,073.1	$30.3	$1,072.1	$30.3
Safflower	$8.1	$19.6	$8.2	$19.6
Sugarbeet	$-	$1.6	$-	$1.6
Subtropical	$525.1	$3,619.0	$525.3	$3,618.8
Vineyard	$49.6	$4,243.3	$49.8	$4,243.1
Total	$5,531.0	$24,482.6	$5,530.6	$24,482.3

Table 12A.8 Sacramento and San Joaquin Valley Irrigated Acreage by Crop under Alternative 3, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (1000s acres)	Long-term Average, San Joaquin Valley (1000s acres)	Dry and Critically Dry, Sacramento Valley (1000s acres)	Dry and Critically Dry, San Joaquin Valley (1000s acres)
Alfalfa	97.3	572.2	96.8	571.6
Almond, Pistachio	164.4	920.3	163.9	918.9
Corn	48.6	679.0	48.6	678.5
Cotton	3.3	281.2	3.3	281.1
Cucurbits	40.1	68.8	40.1	68.8
Drybeans	19.9	55.9	19.9	55.9
Fresh Tomato	1.7	35.1	1.7	35.1
Grain	85.8	288.8	86.6	286.5
Onion, Garlic	4.0	60.4	4.0	60.4
Other Deciduous	246.6	392.6	246.6	392.5
Other Field	44.8	519.6	44.8	519.4
Other Truck	7.4	199.1	7.4	199.1
Pasture, Irrigated	102.5	162.7	100.3	163.1
Potato	–	16.9	–	16.9
Process Tomato	65.5	252.9	65.5	252.9
Rice	548.4	16.6	547.2	16.6
Safflower	11.0	26.5	11.0	26.5
Sugarbeet	–	0.6	–	0.6
Subtropical	37.2	238.5	37.2	238.5
Vineyard	8.4	604.1	8.4	604.1
Total	1,536.7	5,392.0	1,533.2	5,386.9

Table 12A.9 Sacramento and San Joaquin Valley Production Value by Crop under Alternative 3, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Alfalfa	$161.9	$1,256.1	$161.3	$1,255.7
Almond, Pistachio	$738.8	$4,826.5	$739.2	$4,823.1
Corn	$60.5	$980.2	$60.6	$979.4
Cotton	$8.2	$697.3	$8.2	$696.9
Cucurbits	$593.8	$1,018.2	$593.7	$1,018.2
Drybeans	$23.9	$63.5	$23.9	$63.5
Fresh Tomato	$16.5	$404.8	$16.5	$404.8
Grain	$59.1	$278.0	$59.7	$275.9
Onion, Garlic	$31.5	$445.7	$31.5	$445.6
Other Deciduous	$1,759.1	$3,237.3	$1,759.2	$3,236.4
Other Field	$57.9	$664.3	$58.1	$664.0
Other Truck	$51.0	$1,459.2	$51.0	$1,459.1
Pasture, Irrigated	$75.0	$116.2	$73.7	$116.8
Potato	$-	$122.2	$-	$122.2
Process Tomato	$238.0	$999.2	$238.0	$999.1
Rice	$1,072.8	$30.3	$1,070.7	$30.3
Safflower	$8.1	$19.6	$8.1	$19.6
Sugarbeet	$-	$1.6	$-	$1.6
Subtropical	$525.1	$3,618.9	$525.3	$3,618.7
Vineyard	$49.6	$4,243.3	$49.8	$4,243.0
Total	$5,530.7	$24,482.4	$5,528.6	$24,473.7

Table 12A.10 Sacramento and San Joaquin Valley Irrigated Acreage by Crop under Alternative 5, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (1000s acres)	Long-term Average, San Joaquin Valley (1000s acres)	Dry and Critically Dry, Sacramento Valley (1000s acres)	Dry and Critically Dry, San Joaquin Valley (1000s acres)
Alfalfa	97.2	572.0	96.4	571.5
Almond, Pistachio	164.3	920.3	163.4	918.0
Corn	48.7	678.7	48.3	678.2
Cotton	3.3	281.2	3.3	280.9
Cucurbits	40.1	68.8	40.1	68.8
Drybeans	19.9	55.9	19.9	55.9
Fresh Tomato	1.7	35.1	1.7	35.1
Grain	86.6	289.0	86.6	275.7
Onion, Garlic	4.0	60.4	4.0	60.4
Other Deciduous	246.6	392.6	246.6	392.4
Other Field	44.8	519.5	44.7	519.3
Other Truck	7.4	199.1	7.3	199.1
Pasture, Irrigated	102.0	162.7	100.3	163.0
Potato	–	16.9	–	16.9
Process Tomato	65.5	252.9	65.4	252.9
Rice	548.1	16.6	544.3	16.6
Safflower	11.0	26.5	11.0	26.5
Sugarbeet	–	0.6	–	0.6
Subtropical	37.2	238.5	37.2	238.5
Vineyard	8.4	604.1	8.4	604.0
Total	1,536.7	5,391.6	1,529.0	5,374.4

Table 12A.11 Sacramento and San Joaquin Valley Production Value by Crop under Alternative 5, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crops	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Alfalfa	$161.7	$1,255.9	$160.6	$1,255.8
Almond, Pistachio	$738.0	$4,826.7	$737.9	$4,822.0
Corn	$60.6	$979.9	$60.3	$979.0
Cotton	$8.2	$697.1	$8.2	$696.5
Cucurbits	$593.8	$1,018.3	$593.7	$1,018.2
Drybeans	$23.9	$63.5	$23.9	$63.5
Fresh Tomato	$16.5	$404.8	$16.5	$404.8
Grain	$59.6	$278.2	$59.7	$265.1
Onion, Garlic	$31.5	$445.7	$31.5	$445.6
Other Deciduous	$1,759.1	$3,237.2	$1,759.1	$3,235.8
Other Field	$58.0	$664.1	$58.0	$663.8
Other Truck	$51.0	$1,459.2	$51.0	$1,459.0
Pasture, Irrigated	$74.7	$116.2	$73.7	$116.7
Potato	$-	$122.2	$-	$122.2
Process Tomato	$237.9	$999.3	$237.9	$999.1
Rice	$1,072.3	$30.3	$1,065.3	$30.3
Safflower	$8.1	$19.6	$8.1	$19.6
Sugarbeet	$-	$1.6	$-	$1.6
Subtropical	$525.1	$3,618.9	$525.2	$3,618.7
Vineyard	$49.6	$4,243.2	$49.8	$4,243.0
Total	$5,529.6	$24,482.0	$5,520.4	$24,460.2

12A.3.2 Cost of Groundwater Pumping for Irrigation

Table 12A.12 displays the cost of pumping groundwater in 2010 dollars, by region and alternative, for long-term average condition and for dry and critically dry years.

Table 12A.12 Groundwater Pumping Cost by Region and Alternative, over the Long-term Average Conditions and for Dry and Critically Dry Years

Alternative	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically, Sacramento Valley (Million $)	Dry and Critically, San Joaquin Valley (Million $)
No Action Alternative and Alternative 2	$58.3	$882.6	$66.3	$1,029.3
Second Basis of Comparison and Alternative 1	$57.6	$782.9	$66.3	$962.1
Alternative 3	$57.5	$813.0	$66.3	$990.2
Alternative 5	$58.3	$887.1	$66.3	$1,032.8

12A.3.3 Output Data for Use in IMPLAN Model

Production value estimates were summarized into more aggregated crop categories for use in regional economic impact analysis, as described in Chapter 19, Socioeconomics. All values below are in 2010 dollars.

Tables 12A.13 through 12A.16 display the aggregated production values. It should be noted that for the IMPLAN analysis, the values were indexed for 2012 dollars.

Table 12A.13 Production Value by Aggregated Crop Category under the No Action Alternative and Alternative 2, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crop Category	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Grains	$1,348	$1,498	$1,340	$1,483
Field Crops	$82	$1,532	$82	$1,531
Forage Crops	$262	$1,521	$260	$1,521
Vegetable, Truck	$1,031	$4,931	$1,031	$4,930
Orchards, Vineyards	$3,404	$17,649	$3,404	$17,644
Total	$6,128	$27,130	$6,117	$27,109

Table 12A.14 Production Value by Aggregated Crop Category under Second Basis of Comparison and Alternative 1, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crop Category	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Grains	$1,348	$1,498	$1,348	$1,498
Field Crops	$82	$1,532	$83	$1,532
Forage Crops	$263	$1,521	$261	$1,521
Vegetable, Truck	$1,031	$4,931	$1,032	$4,931
Orchards, Vineyards	$3,405	$17,649	$3,405	$17,648
Total	$6,129	$27,131	$6,129	$27,131

Table 12A.15 Production Value by Aggregated Crop Category under Alternative 3, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crop Category	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Grains	$1,348	$1,498	$1,346	$1,495
Field Crops	$82	$1,532	$82	$1,532
Forage Crops	$263	$1,521	$260	$1,521
Vegetable, Truck	$1,031	$4,931	$1,031	$4,930
Orchards, Vineyards	$3,405	$17,649	$3,406	$17,643
Total	$6,129	$27,131	$6,127	$27,121

Table 12A.16 Production Value by Aggregated Crop Category under Alternative 5, over the Long-term Average Conditions and for Dry and Critically Dry Years

Crop Category	Long-term Average, Sacramento Valley (Million $)	Long-term Average, San Joaquin Valley (Million $)	Dry and Critically Dry, Sacramento Valley (Million $)	Dry and Critically Dry, San Joaquin Valley (Million $)
Grains	$1,281	$412	$1,273	$398
Field Crops	$150	$2,618	$149	$2,616
Forage Crops	$262	$1,521	$260	$1,521
Vegetable, Truck	$1,031	$4,931	$1,031	$4,930
Orchards, Vineyards	$3,404	$17,649	$3,404	$17,641
Total	$6,128	$27,130	$6,118	$27,106

12A.3.4 Model Limitations and Applicability

The SWAP model is an optimization model that makes the best (most profitable) adjustments to water supply and other changes. Constraints can be imposed to simulate restrictions on how much adjustment is possible or how fast the adjustment can realistically occur. Nevertheless, an optimization model can tend to over-adjust and minimize costs associated with detrimental changes or, similarly, maximize benefits associated with positive changes.

SWAP does not explicitly account for the dynamic nature of agricultural production; it provides a point in time comparison between two conditions. This is consistent with the way most economic and environmental impact analysis is conducted, but it can obscure sometimes important adjustment costs.

SWAP also does not explicitly incorporate risk or risk preferences (e.g., risk aversion) into its objective function. Risk and variability are handled in two ways. First, the calibration procedure for SWAP is designed to reproduce observed crop mix, so to the extent that crop mix incorporates farmers' risk spreading and risk aversion, the starting, calibrated SWAP base condition will also. Second, variability in water delivery, prices, yields, or other parameters can be evaluated by running the model over a sequence of conditions or over a set of conditions that characterize a distribution, such as a set of water year types.

Groundwater is an alternative source to augment local surface, SWP, and CVP water delivery in all SWAP regions. The cost and availability of groundwater therefore has an important effect on how SWAP responds to changes in delivery. However, SWAP is not a groundwater model and does not include any direct way to adjust pumping lifts and unit pumping cost in response to long-run changes in pumping quantities. Economic analysis using SWAP must rely on an accompanying groundwater analysis.

12A.4 References

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