APPENDIX K

IRRIGATION WATER REQUIREMENTS

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INTRODUCTION

Representation of Agricultural Demand

The Capitalization[1] study is an economic evaluation of the use of water delivered by California's integrated supply network that stretches from Lake Shasta at the head of the Central Valley to the Colorado River in the southeast of the state. 24 modeling units represent agricultural users supplied from this network. Each modeling unit is assumed to be homogeneous, in which farmers face identical production decisions. For each modeling unit, the Statewide Agricultural Production Model (SWAP) calculates the net cost of lost production for various water supply levels. These relationships are subsequently incorporated into the CALVIN network flow model that operates the water supply system and allocates water to minimize the total cost of shortage. Twenty-one of the agricultural modeling units are located within the Central Valley and follow the delineation used by the CVPIA PEIS (USBR 1997). The other three regions represent agriculture in the Colorado River Hydrologic Region: Imperial Valley; Coachella Valley; and Palo Verde. A further modeling unit to represent agriculture in San Diego County will be added at a future date. The different regions are summarized in Table K-1.

Figure K-1 illustrates how the agricultural modeling units are represented in CALVIN. Each unit or region is divided into two demand nodes, which sum to the total agricultural land area of the region. One node has return flows to groundwater (deep percolation), the other node has return flows to the surface water system (tailwater). Both demand nodes are supplied from a common upstream node. This upstream node represents water supplies available to the region, i.e. the sum of surface water diversions and groundwater pumping. This node is referred to as the 'regional water supply node.' Gain factors, that express the ratio of outflow to inflow along a link, are applied to the links to account for various losses and return flows. These include:

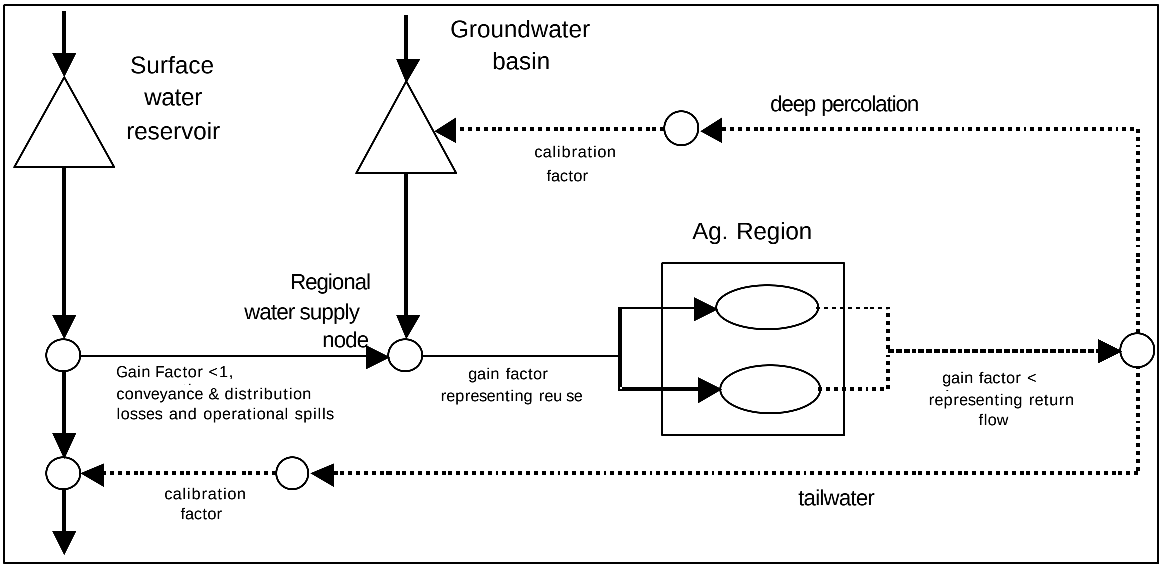
- Main canal conveyance losses,
- Operational spills,
- In-district distribution losses,
- In-district reuse of tailwater, and
- Recoverable fraction of applied water

These factors are described in greater detail later in the appendix.

[1] The study is entitled "Quantitative Analysis of Finance Options for California's Future Water Supply," or, the "Capitalization Project" for short.

The CALVIN optimization engine is driven by penalty functions (see Chapter 6). To model agricultural demand, a penalty function is associated with the link between the regional water supply node and the two demand nodes. Each unit of flow through these links incurs a penalty that varies as a function of the total flow through the link. This penalty represents the cost of water shortage to the region. The penalty is zero for deliveries equal to the maximum or target demand.

Figure K-1. Representation of Agricultural Regions in CALVIN



Target Demand

The maximum or target demand for agricultural water is a somewhat artificial reference point. In line with microeconomic theory, SWAP predicts diminishing economic returns to applied water. The point where the value of the marginal product of water is zero defines the maximum demand. This would be the demand if water had zero variable cost. The water demand from SWAP should therefore exceed estimates of applied water demand used by DWR for Bulletin 160-98. Water demand in SWAP is at the level of the farm gate. It does not include inter and intra-district conveyance losses, operational losses or reuse of tailwater.

Requirements for SWAP

SWAP is used to develop the agricultural value functions for CALVIN. The model is described in Chapter 6 and Appendix D. Required inputs to SWAP for each modeling region are: (a) total seasonal applied water (AW) for each crop in ac-ft/ac; (b) the monthly distribution of the seasonal applied water in percent; and (c) total seasonal consumptive use of applied water (ETAW) for each crop in ac-ft/ac. The model is formulated in terms of applied water, but the ratio of AW/ETAW is used to determine the optimal investment in irrigation technology.

Table K-1. Agricultural Model Regions

Region	County	DAU	CVP Agricultural Contractors	SWP Agricultural Contractors	Others
CVPM 1	Shasta, Tehema	137,141, 143,145	Anderson Cottonwood ID, Bella Vista WD, Clear Creek CSD, Keswick CSD, Shasta CSD, Shasta Co. Water Ag, Shasta Dam PUD, Mountain Gate CSD		Sac R. Misc Users
CVPM 2	Butte, Glenn, Tehema	142,144	Corning WD, Kirkwood WD, Tehema WD, Sac R. Misc Users		
CVPM 3	Colusa, Glenn, Yolo	163	Glenn Colusa ID, Provident, Princeton-Codora, Maxwell, and Colusa Basin Drain, Orland-Artois WD, most of County of Colusa, Davis, Dunnigan, Glide, Kanawha, La Grande, Westside WD		Glenn Colusa ID, Tehama Colusa Canal Service Area
CVPM 4	Butte, Colusa, Glenn, Sutter, Yolo	164,165, 167	Princeton-Codora-Glenn, Colusa Irrigation Co., Meridian Farm WC, Pelger Mutual WC, Recl. Dist. 1004, Recl. Dist. 108, Roberts Ditch, Sartain M.D., Sutter MWC, Swinford Tract IC, Tisdale Irrigation, Sac River miscellaneous users.		Rec. Dist. 108, Rec. Dist. 1004, Sutter MWC
CVPM 5	Butte, Glenn, Sutter, Yuba	159,160, 166,168, 170,171			Most Feather River Region riparian and appropriative users Richvale ID, Butte WD
CVPM 6	Solano, Yolo	162,191, part 41	Conaway Ranch, Sac River Miscellaneous users		Solano ID, Yolo Co FCWCD
CVPM 7	Placer, Sacramento, Sutter	161,172			Natomas Central MWC, Sac River miscellaneous users, Pleasant Grove-Verona, San Juan Suburban Nevada ID, South Sutter WD, Pleasant Grove-Verona MWC, Placer Co WA

Table K-1. Agricultural Model Regions (cont.)

Region	County	DAU	CVP Agricultural Contractors	SWP Agricultural Contractors	Others
CVPM 8	Amador, Calaveras, Sacramento, San Joaquin, Stanislaus	173,180, 181,182, 184			North San Joaquin WCD, Stockton-East WD, Central San Joaquin WCD
CVPM 9	Alameda, Contra Costa, Sacramento, San Joaquin Solano, Yolo,	185,186	Banta Carbona, West Side, Plainview		North Delta WA, Central Delta WA
CVPM 10	Madera, Merced, San Joaquin, Stanislaus	216	Central California ID, Panoche WD, Pacheco WD, Del Puerto, Hospital, Sunflower, West Stanislaus ID, Mustang, Orestimba, Patterson WD, Foothill, San Luis WD, Broadview, Eagle Field, Mercy Springs, Pool Exchange Contractors, Schedule II water rights, Grasslands WD	Oak Flat WD	
CVPM 11	San Joaquin, Stanislaus	205,206, 207			Stanislaus River water rights: Modesto ID, Oakdale ID, South San Joaquin ID
CVPM 12	Merced, Stanislaus	208,209			Turlock ID, part of Stevinson WD, part of Merced ID
CVPM 13	Madera, Merced	210,211, 212,213, 214,215	Chowchilla WD, Gravely Ford WD, Madera ID		majority Merced ID
CVPM 14	Fresno, Kings, San Benito	244	Westlands WD		
CVPM 15	Fresno, Kings, Tulare	235,237, 238,241, 246	Fresno Slough WD, James ID, Laguna ID, Real. Dist. 1606, Traction Ranch, Tranquillity ID	Dudley Ridge WD, Empire West Side ID, Part of Kings Co WD, Tulare Lake Bed WSD	Corcoran ID, Part of Devils Den WD, Farmers WD, Hacienda WD, Heinlen MWC, part of Kings Co WD, Mid-Valley WD, Murphy Slough Association, Raisin City WD, Riverdale ID, Stinson WD, Stratford PUD

Table K-1. Agricultural Model Regions (cont.)

Region	County	DAU	CVP Agricultural Contractors	SWP Agricultural Contractors	Others
CVPM 16	Fresno	233,234,	Fresno ID, Garfield WD, International WD		
CVPM 17	Fresno, Kings, Tulare	236,239, 240	Hills Valley ID*, Orange Cove ID, Tri-Valley WD*		Alta ID, Consolidated ID, Kings River WD
CVPM 18	Kings, Tulare	242,243	Alpaugh ID*, Atwell Island WD*, Corral ID, Co of Fresno*, Co of Tulare*, most of Delano Earlimart ID, Ducor ID, Exeter ID, Ivanhoe ID, Lewis Creek WD, Lower Tule River ID*, Lindmore ID, Lindsay-Strathmore ID, Pixley ID*,Porterville ID, portion of Rag Gulch WD*, Saucelito, Stone Tea Pot Dome, Terra Bella ID, Tulare ID,	Part of Kings Co WD	Kaweah Delta WCD
CVPM 19	Kern (West side)	255,259, 260	Part of Delano Earlimart, Part of Rag Gulch WD	Belridge WSD, Berrenda Mesa WD, Buena Vista WSD, Buttonwillow ID, Lost Hills WD, Pond Poso ID, Semitropic WSD, West Kern WD	Part of Devils Den WD
CVPM 20	Kern (East Side), Tulare	256,257	Shafter-Wasco ID, South San Joaquin MUD	Cawelo WD	Kern-Tulare WD, North Kern WSD, Olcese WD
CVPM 21	Kern (South Side)	254,258, 261	Arvin Edison WSD	Tehachapi-Cummings Co WD, Kern Delta WD, Wheeler Ridge-Maricopa WSD, Rosedale Rio-Bravo WSD, Improvement District #4, Tejon-Castac WD, Henry Miller WD	Palmdale WD
Imperial Valley	Imperial	351,352, 353			Imperial ID
Coachella Valley	Riverside, Imperial	348,349			Coachella Valley ID
Colorado River	Riverside, Imperial	345, 346, 347			Bard Valley WD, Palo Verde ID
San Diego	San Diego	120			
* Cross Valley Canal Exchange Contractors					

Requirements for CALVIN

In contrast to SWAP, CALVIN's accounting for water is at the regional level. CALVIN must account for conveyance losses both to and within a service area and also for reuse of tailwater within the service area.

WATER SUPPLY AND WATER USE DEFINITIONS

The following water supply and water use definitions are based on DWR's Bulletin 160-98 classification (DWR 1998, p 3-12). Additional water supply definitions have been added where required.

Evapotranspiration (ET)

Evapotranspiration (ET) is the volume or depth of water that is transpired by a crop, evaporated from the adjacent soil surface or retained within the plant tissue.

Reference Evapotranspiration (ETo)

Evapotranspiration rates vary from crop to crop and with the crop growth stage. Reference evapotranspiration (ETo) provides a constant reference point. It is the evapotranspiration rate of a reference crop at a particular growth stage. For California, grass is used as the reference and ETo is defined as:

> '*the rate of evapotranspiration from an extended surface of 8-15 cm tall green grass of uniform height, actively growing, completely shading the ground and not short of water*' *(FAO 1977)*

Evapotranspiration for a particular crop is calculated by multiplying ETo by a crop coefficient or K_c value. K_c values are crop specific and vary from day to day as a function of the crop growth stage or crop development.

Effective Precipitation (P_e)

Effective precipitation (P_e) is the part of precipitation that contributes to ET. It is the precipitation stored in the root zone both before and during the growing season that is subsequently used consumptively by the crop. It excludes precipitation that is 'lost' either through surface runoff or deep percolation.

Evapotranspiration of Applied Water (ETAW)

Crop ET can be supplied from either precipitation, soil moisture or applied water. The evapotranspiration of applied water (ETAW) is the volume of irrigation water that is consumptively used by the crop. The rest of the applied water contributes to runoff or deep percolation.

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[3] Net water use may be larger or smaller than applied water depending on the treatment of the non-recoverable losses and the importance of reapplication of return flows. DWR in Bulletin 160-98 (Fig. 3-8) attributes non-recoverable losses to a point downstream on the "farmgate." The applied water therefore includes these losses. However, there may be conveyance losses in the canal system upstream of an irrigation district that are not included in the applied water.

Applied Water (AW)

Applied water is the volume of water required to meet the demand of the user. For instream use it is the portion of the stream flow dedicated to that purpose. For non-instream use, it is equal to the volume of water delivered to:

- The intake to a city's water system,
- The farm headgate, or
- A managed wetland

Particular care must be taken with this term, as in some documents it refers to water delivered to either the district or the basin.

Non-Recoverable Losses

Non-recoverable losses are the portion of diverted water that is lost from the conveyance system and is not available for reuse. It consists of water lost through: (a) channel evaporation; and (b) seepage that flows to a salt sink or is used consumptively by non-agricultural crops.

Net Water

Net water is the volume of water required by a service area and corresponds to the total surface water diversion and net groundwater extraction. It equals the sum of ETAW, non-recoverable losses and return flows leaving the area. Net water is the volume of water no longer available to the service area.[3] Net water excludes the portion of demand met by reapplication of surface runoff and by groundwater derived from deep percolation of previously applied water.

Irrigation Efficiency (IE)

Irrigation efficiency is often used to quantify irrigation performance and as such has been open to many definitions. Typically it is defined as the percentage of applied water that is used beneficially for crop production. Beneficial uses include consumptive use, leaching, frost protection and soil preparation. Irrigation efficiency (IE) and Irrigation Consumptive Use Coefficient (ICUC) are defined as follows (Burt et al. 1997):

$$IE = \frac{\text{volume of irrigation water beneficially used}}{\text{volume of irrigation water applied}} * 100\%$$

$$ICUC = \frac{\text{volume of irrigation water used consumptively}}{\text{volume of irrigation water applied}} * 100\%$$

Both IE and ICUC can be used at any geographic scale: basin, district, farm, or field. The farm scale ICUC ($ICUC_{farm}$) differs from the ETAW/AW ratio as it includes in the numerator any additional evaporative losses that occur within the farm boundary (e.g. evaporation from farm reservoirs and field ditches). Neither ETAW/AW nor ICUC are measures of performance. DWR (1994, p164) defines the agricultural water use efficiency as the ratio of ETAW plus the leaching requirement to applied water. DWR also refers to this as the seasonal application efficiency.

$$SAE = \frac{\text{consumptive use of applied water} + \text{leaching requirement}}{\text{volume of irrigation water applied}} * 100\%$$

For water use accounting, DWR's depletion analysis uses the term 'basin efficiency factor:'

$$Basin\ efficiencyFactor = \frac{\text{consumptive use of applied water}}{\text{total water requirement to supply the basin}} * 100\%$$

The total water requirement is referred to as the prime supply (DWR, 1976). The prime supply has both a surface water and groundwater element. The surface water portion is surface water (including local accretions) entering the basin that is diverted for irrigation. The groundwater portion is the net groundwater pumping which is the sum of groundwater recharge from natural sources plus overdraft. It is estimated from changes in groundwater levels and specific yield.

Depletion

Depletion is the volume of water within a service or study area that is no longer available for reuse. Within an agricultural area, depletion is the sum of ETAW and non-recoverable losses. For wetlands, the depletion is the sum of water consumed by wetland vegetation and open water surface evaporation. For the urban sector, the depletion consists of landscape water that is consumptively used flows to a salt sink. For environmental in-stream use, the depletion is the volume of water that flows to the ocean or other salt sink.

DATA SOURCES FOR ESTIMATING IRRIGATION REQUIREMENTS

DWR – Bulletin 160-98 Calculations

For the Bulletin 160 series, DWR's four district offices compile detailed estimates of AW and ETAW for a range of crops at the level of the DAU and county. These figures reflect normal or average year conditions. For Bulletin 160, these figures are combined with projected land use to obtain aggregated agricultural demand for each hydrologic region. The methodology used by the district offices to calculate AW and ETAW is not known. It is believed that these figures are based on field measurements, pan evaporation data and crop coefficients.

DWR - Consumptive Use Model

The Consumptive Use (CU) Model was developed by DWR in association with Water Resources Management Inc. (WRMI) to develop input for DWR's water resources planning model DWRSIM. For a given land use, the model calculates monthly agricultural and urban water demands. Demand for irrigation water is based on a root zone soil moisture budget and is described in greater detail later in this chapter. The model has been applied by DWR to the Sacramento and San Joaquin Valleys.

USBR - CVPIA PEIS

In 1987, USBR published the Draft Programmatic Environmental Impact Statement (PEIS) for the Central Valley Project Improvement Act (CVPIA). The PEIS uses a series of computer planning models to assess the impacts of implementing provisions of the Act. The models consist of two reservoir simulation models, a groundwater model, and an economic production model. The models are described in Volumes 7 and 8 of the technical appendices to the PEIS.

Input and output files for the models are published on a CD-Rom (disc 2) accompanying the report. The PEIS analyzes the impacts of various alternative scenarios. Data and results developed for the "No Action Alternative" (NAA) are considered most appropriate for use with CALVIN. A mistake in the input hydrology made absolute figures used by the draft PEIS incorrect. The analysis was partially reworked for the final PEIS.

The Central Valley Production Model (CVPM) is a regional model of irrigated agricultural production within the Central Valley. Twenty-two[4] production regions are defined. The CVPM includes a database of agricultural information for the period 1985-1992 (CD-ROM disc 2, Ag-Econ\Naa\Model\Cesdat95.gms). The database includes observed crop acreage, annual estimates of ETAW and AW by crop and by region, tailwater reuse factors and conveyance losses. The annual AW and ETAW are based on figures obtained from DWR and reflect 1990 base year conditions.

The Central Valley Groundwater Surface Water Model (CVGSM) is a quasi 3-dimensional finite element model of the groundwater aquifers underlying the agricultural production regions within the Central Valley. It includes a surface stream network and a root zone soil moisture layer to determine surface water-groundwater interaction. Input files for the model contain for each region: monthly estimates of crop evapotranspiration (CD-ROM disc 2, CVGSM\input\naa\cnjet.dat), monthly precipitation (...\naa\cnjprcp1.dat), soil parameters (...\pass1\cnjchrc.dat), water use parameters (...\naa\cnjparm.dat), and conveyance losses (...\naa\cnjdvsp.dat).

Hydrologic-Economic Model of the San Joaquin Valley

In the early 1980s DWR initiated a study to analyze the hydrologic and economic impacts of groundwater overdraft in the San Joaquin Valley. DWR contracted with Auslem & Associates Inc. to develop a modeling system composed of four linked models: a surface water allocation model (SWAM), a groundwater model (GWM), the San Joaquin Valley Production Model (SJVPM) and a Linear Quadratic Control Model (LQCM). SWAM and GWM were subsequently subcontracted to and developed by Resource Management Associates (RMA). Collectively the set of models is known as the Hydrologic-Economic Model (HEM) and is described in Bulletin 214 (DWR 1982). Considerable data was collected for the study, chiefly by the San Joaquin District of DWR. This included a hydrologic water balance by DAU for the base period of 1970-1982. Since the end of the contract in 1982, DWR has revised the input data and assumptions. These changes are documented in DWR's district reports (DWR 1985 and 1989). DWR also developed a preprocessor to SWAM, known as SWUSE, to estimate crop water use (DWR 1989).

CIMIS

The California Irrigation Management Information System (CIMIS) was developed by DWR and the University of California at Davis. It is a repository of climate data collected from a statewide network of automated weather stations. Operational since 1982, its purpose is to improve irrigation efficiency by providing growers with data to aid irrigation scheduling. Reference crop

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[4] CVPM Region 3 is sub-divided into 3 and 3B.

evapotranspiration is calculated daily for over 100 CIMIS weather stations from measurements of net radiation, air temperature, wind speed and humidity.

Other Sources

There are many individual publications that provide the base data needed to calculate crop ET: typical planting dates; length of growing season; Kc values; ETo; and precipitation. Much agriculture water use data collected by DWR is summarized in the Bulletin 113 series (1975 & 1984). The 1984 Bulletin is currently being revised and should be available in 2001. Crop coefficients are listed by Snyder et al. (1987 & 1989). In addition, various studies have published crop ET and ETAW for specific areas and irrigation districts within California.

METHODOLOGY

To reiterate, monthly values of farm AW and ETAW are required as input to SWAP. It would be possible to calculate ETAW from 'first principles' using published climatic and agronomic data. However, this approach is beyond the resources of the present study. It was, therefore, decided to use directly published values of ETAW wherever possible.

Central Valley

DWR has established annual values of ETAW and AW by DAU and by crop. These values have been used to obtain aggregated values for each crop for each CVPM region. The DAU values were weighted by DWR's 2020 projected land use. The resulting values were compared to values established for CVPM and found to be in good agreement. The CU model was used to estimate the monthly distribution of ETAW. This ensures that inputs for CALVIN are consistent with agricultural demands calculated for Bulletin 160-98. However, significant differences were found between Bulletin 160 data and average annual values predicted by the CU model. As both DWRSIM and CVGSM use the results from the CU model directly to calculate irrigation demand, there will be some differences between CALVIN and these two models.

The monthly variation in AW was obtained by assuming a constant monthly ETAW/AW ratio. The basin efficiency factors used in the depletion analysis suggest that irrigation efficiencies rise in the summer and are lower in the spring and fall. If this is true, CALVIN will over estimate irrigation demand in the summer and under estimate demand in the spring and fall. The summer season over estimate of demand will be compounded by too low an efficiency resulting in a substantial over estimate of summer return flows. Revisions are currently being made to HEC-PRM to allow variable monthly gain factors to be used.

Southern California

Unlike the Central Valley, there is no single model for agricultural demand in Southern California. However, numerous reports have been published on irrigation water requirements for the Imperial Irrigation District (IID). Values of monthly ETAW for Imperial Valley are based on figures published in these reports. For Coachella Valley and Palo Verde, these figures have been adjusted to account for minor differences in monthly ETo and precipitation.

Consumptive Use Model

The CU model has already been applied to CVPM regions 1-13 by DWR to develop inputs for the depletion analysis and DWRSIM (DWR 1991)[5]. This study extends its use to the remaining eight CVPM regions to the south. The methodology of the CU model was reproduced in Excel using Visual Basic for Applications (VBA). The CU model uses a simple soil-water budget to calculate ETAW. For this study, only the first six 'columns' of the CU model are used. They are:

(1) monthly precipitation

The values reflect average precipitation over the developable area of the particular DA (CVPM) region.

(2) monthly evapotranspiration

During the growing season this column contains monthly crop evapotranspiration. Outside of the growing season, the figures are for bare soil evaporation.

(3) consumptive use of precipitation

This is the part of precipitation that is used to meet ET demand in the current month. It does not include precipitation that is stored in the soil profile for use in subsequent months. *The title of this column is confusing, as it would normally be interpreted as including precipitation stored in the soil profile.*

(4) change in soil moisture

This column contains the change in available soil moisture in the root zone. Available soil moisture is always calculated using the maximum rooting depth at crop maturity. Moisture stored in the root zone will become available to the growing plant at some point during the season.

(5) soil moisture accumulation

This value is the available soil moisture in the root zone at the end of the month. It is bounded by a lower limit during the growing season that is used to trigger irrigation and an upper limit determined by an assumed water holding capacity of 1.5 inches per foot of rooting depth.

(6) consumptive use of applied water

Irrigation water is applied during the growing season to ensure that the soil moisture does not drop below the monthly minimum value. These minimum values, determined for each month and for each crop, are based on observed irrigation practice and include pre-irrigation.

Irrigation water stored in the soil profile is always considered consumptive use. For rice, irrigation water used to flood the paddy is drained in September so that some of what is calculated as consumptive use is returned to the system. Currently, this drainage water is not

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[5] CVPM regions in the Sacramento Valley are identical to the Depletion Areas Units defined by DWR for the depletion analysis. See Appendix I – Surface Water Hydrology for more details.

represented in CALVIN. The ability of farmers to vary the timing of pre-irrigation according to the availability of water could be represented in CALVIN by a reservoir for soil moisture. In a similar manner, a reservoir could be used to represent the flooding and draining of rice paddies.

A monthly soil moisture budget is calculated for the historic period-of-record. For CVPM Regions 1 through 8, this is October 1921- September 1993. For the rest of the Central Valley, a shorter period ending in October 1990 was used due to the availability of precipitation data in CVGSM. The ET data are from 1976 and the soil moisture data from 1969. The following assumptions are built into the CU model.

1. There is no inter-annual variation in crop ET.
2. There is no inter-annual variation of crop agronomic factors or growing season.
3. Maximum crop rooting depths do not vary by region.
4. For most crops, there is no annual carry-over storage of soil moisture. Initial (October) soil moisture is equal to the end of year (September) soil moisture for that crop. Given the small amount of precipitation during the summer, the soil moisture in September is always at the minimum specified value.
5. Minimum monthly soil moisture requirements for a crop do not vary by region.
6. Available soil moisture storage capacity is 1.5 inches of water per foot of rooting depth.
7. During a non-irrigation month, if precipitation and soil moisture do not meet soil ET, then the demand is unsatisfied.
8. Crops are grown under good farm management practices and are not subject to water stress or deficit irrigation.
9. No runoff or deep percolation occurs unless the soil profile is at the upper limit (i.e., field capacity).
10. Consumptive use of applied water does not include other beneficial uses of water (e.g., leaching requirements).

CROP CATEGORIES

Over 250 different crops are grown in California (DWR 1994). For planning purposes, crops are aggregated into groups or categories. Crops in each category are represented by common characteristics such as production costs, prices, yields and water use.

Central Valley

Table K-2 lists the different crops or crop categories used by different. The codes for the different crops are those used in CVGSM and the CU model. For the Bulletin 160 series, DWR uses 14 crop types. Field crops are divided into ‘corn’ and ‘other field’ crops. Orchards are divided into ‘almonds/pistachios’, ‘other deciduous orchard’ and ‘subtropical’. Subtropical includes olives, citrus, avocados and dates.

In DWR's CU model, the category 'tomatoes' is used where the tomato acreage has been reported without distinguishing between handpicked and machine-picked. For 2020-projected acreage, DWR assumes that all tomatoes are machine-picked, except for the Delta, where they do not distinguish between the two. In the CU model, it is assumed that the 'sub-orchard' category represents 'sub-tropical.' It appears only for Region 5 and is relatively minor.

CVGSM uses the same crop types as the CU model.

CVPM uses the greatest number of crop categories. Table I-2 of Technical Appendix 8 and input file '\ag-econ\model\cesdat.gms' define 26 different crop categories. The table also lists the proxy and additional crops for each crop category. The proxy crop is used to define production costs, yields and prices for the crop category. Crop acreage for the additional crops is summed with the proxy crop to give base acreage for model calibration. In Table K-2, crop categories have been grouped together for cases where the annual estimate of ETAW is identical for all regions. This reduces the number of categories to 16.

For the Central Valley, SWAP uses nine basic crop types. These are listed in Table K-3. The sub-tropical orchard category (SO) of the CU model consists of citrus and olives. This is equated to both "citrus" (oranges, lemons, grapefruit) and the "subtropical" (figs, kiwis, avocados, pomegranates) crop categories of SWAP. The SWAP "fodder" category (alfhay, misc hay, pasture) is equated to alfalfa in the CU model. ETAW for alfalfa and irrigated pasture results are generally similar. Typically in the Central Valley, ETAW for pasture is 3-6% greater (DWR 1974). In SWAP, no distinction is made between almonds/pistachios and other deciduous orchard crops. ETAW for almonds and pistachios is approximately 75% of that for other deciduous orchards.

Southern California

Detailed estimates of irrigation water requirements are available for IID. Table K-4 shows how estimates for particular crops have been grouped together to form the ten crop categories that are used in SWAP. The 'weights' column gives the assumed composition of each crop category. The weights are based on IID observed average crop acreage for the years 1995-96.

Table K-2. Crop Categories for the Central Valley

Code	DWR Bulletin 160-98	DWR CU Model	CVGSM (cnjet.dat)	CVPM (cesdat.gms)
AL	alfalfa	alfalfa	alfalfa	alfalfa
CO	cotton	cotton	cotton	cotton
FI	corn	gen. field	field crops	field corn, alfalfa seed
	other field			
GR	grain	grain	grains	wheat, misc. grain
OR	other deciduous	orchard	orchard	peaches, prunes, walnuts
	almond/pistachios			almonds
		sub-orchard		
PA	pasture	pasture	pasture	pasture (irrigated)
RI	rice	rice	rice	rice
SB	sugar beets	sugar beets	sugar beet	sugar beets
SO	subtropical	citrus/olives	citrus and olives	citrus, olives
TO	tomatoes	tomatoes	tomato	
TH		tomato hand	tomato hand picked	
TM		tomato machine	tomato machine picked	fresh & processed tomatoes
TR	other truck	misc. truck	truck crops	melon, onions, potatoes, misc. veg
				dry beans
				oilseed
VI	grapes	vineyard	vineyard	raisins, wine grapes

Notes: For the CVPM crop categories, the following additional information is given:

- misc. grain includes barley, oats, sorghum
- cornfld includes all corn except fresh sweet corn
- mischay includes grain hay, sudan grass, other silage
- drybean includes dry beans and limabeans
- oilseed includes safflower and sunflower
- alfseed includes alfalfa seed, wild rice, misc. seed crops
- melon includes canteloupe, honeydew, watermelon
- onions includes dry and fresh onions, and garlic
- miscveg includes carrots, cauliflower, lettuce, peas, spinach, broccoli, asparagus, peppers, sweet potatoes, other truck
- almonds also includes pistachios
- prunes also includes plums and apricots
- peaches includes nectarines, pears, cherries, apples, misc deciduous fruit
- citrus includes oranges, lemons, gapefruit, misc subtropical
- olives also includes figs, kiwi, avocados, pomegranates
- raisins also includes table grapes

Table K-3. SWAP Crop Categories for the Central Valley

Code	Description	CU/CVGSM Model Equivalent	Crops
CITR	citrus	citrus/olives (SO)	oranges, lemons, grapefruit,
COTT	cotton	cotton (CO)	cotton
DRCE	rice	rice (RI)	rice
FDDR	fodder	alfalfa (AL), pasture (PA)	alfalfa hay, pasture, miscellaneous grasses
FTOM	market tomatoes	tomato machine (TM)	fresh market tomatoes
GRPS	grapes	vineyard (VI)	table grapes, wine grapes, raisins
MFLD	misc. field	general field (FI)	field corn
MGRN	misc. grain	grain (GR)	wheat
ORCH	orchard	orchard (OR)	almonds, walnuts, prunes, and peaches
PTOM	processing tomatoes	tomato machine (TM)	processing tomatoes
SBTS	sugar beets	sugar beets (SB)	sugar beets
STRP	subtropical	citrus/olives (SO)	olives, figs, pomegranates
TRCK	truck	truck (TR)	melons, onions, potatoes, and miscellaneous vegetables

Table K-4. SWAP Crop Categories for Southern California

Code	Description	Crops	IID equivalent and weights
CITR	citrus	lemons, oranges – navel, valencia, and mandarin	citrus (1)
COTT	cotton	cotton	cotton (1)
FDDR	fodder	alfalfa hay	alfalfa (0.55), sudan grass (0.26), alfalfa seed (0.04), bermuda grass (0.07), bermuda grass seed (0.07), rye grass (0.01)
GRPS	grapes	wine grapes	
FTOM	market tomatoes	fresh market tomatoes	tomatoes(1)
MGRN	multi-grain	wheat	wheat (0.98), oats (0.02)
ORCH	orchard	dates, walnuts, and peaches	peaches (1)
STRP	subtropical	avocado	
SBTS	sugar beets	sugar beets	sugar beets (1)
TRCK	truck	broccoli, cabbage, cauliflower, onion, lettuce, melon, and potato	broccoli (0.14), cabbage (0.02), cauliflower (0.06), onions (0.29), lettuce spring (0.19), lettuce fall (0.19), watermelon (0.06), carrots (0.37), asparagus (0.12), cantaloupe spring (0.32), cantaloupe fall (0.01), onion seed (0.04), corn ear (0.10), potatoes (0.05)

LAND USE

Land use is based on Bulletin 160 forecasts. DWR's 1995 agricultural acreage is based on 1995 values but adjusted to represent average year water supplies and 1990s average market conditions. The resulting base year values are called '1995 normalized' figures. Projected 2020 land use is based on forecast rates of urbanization and changing market conditions. Land use estimates by DAU were obtained from DWR's district offices and aggregated to obtain estimates for each agricultural modeling unit used by SWAP/CALVIN. The results are given in Table K-5 and K-6.

Table K-8 below compares acreage modeled in CALVIN with total acreage within the Hydrologic Regions. Within the Sacramento Valley HR, CALVIN excludes agricultural areas upstream of Shasta Reservoir and upstream of the Sierra Foothill and Coastal Range Reservoirs. For the San Joaquin River HR and Tulare Lake HR, CALVIN explicitly models almost all agricultural areas within the hydrologic region. In the Colorado River HR, CALVIN excludes desert areas that rely on groundwater and are not supplied from the Colorado River. In the South Coast HR, CALVIN only represents agricultural within San Diego County.

Table K-8. Projected 2020 Agricultural Land Use by Hydrologic Region

HR	Bulletin 160-98 irrigated acreage	Area represented by CALVIN (acres)	Area represented by CVPM/CVGSM (NAA) (acres)	Percentage of HR represented by CALVIN	Comments
Sacramento River	2,150,000	1,834,836	1,805,866	85.3	Excludes all irrigated land in Shasta Lake-Pit River PSA (139,400 ac) and land in DAUs 147,154,156,158,174 & 175 (82,600 ac)
San Joaquin River	1,935,000	1,896,664	1,858,285	98.0	Excludes lands in PSAs Sierra Foothills (10,700), Western Uplands (11,800) and Eastside Uplands (2,300)
Tulare Lake	2,985,000	2,975,100	2,922,780	99.7	Excludes land in PSA Uplands (8,000)
Colorado River	750,000	725,160	0	96.7	Excludes lands in PSAs Borrego (13,580), Twenty-Nine Palms-Lanfair (7,180) and Chuckwalla (3,700)
South Coast	190,000	66,100	0	34.8	Represents San Diego County DAU 120

Data from DWR's head office do not agree exactly with that of District offices. Data are collected by the head office and adjusted to meet target acreage. This involves minor changes to the acreage of alfalfa, pasture and field crops.

Table K-5. 1995 Normalized Agricultural Land Use (acres)

Region	Alfalfa	Cotton	Field	Grain	Orchard	Pasture	Rice	Sub-Tropical	Sugar Beets	Tomato	Truck	Vine-yard	Total Crop	Double Cropping	Total Land
CVPM 1	1,200	0	600	1,400	4,100	27,900	0	800	0	0	1,200	200	37,400	0	37,400
CVPM 2	8,000	0	14,300	15,400	79,200	43,100	3,500	20,400	3,400	100	2,100	100	189,600	1,600	188,000
CVPM 3	10,100	0	7,800	11,100	4,300	100	3,700	0	1,100	14,000	5,100	700	58,900	2,200	56,700
CVPM 4	3,800	1,000	41,400	30,600	15,400	700	60,000	0	4,200	26,600	13,000	0	196,700	10,100	186,600
CVPM 5	2,300	0	13,500	10,300	77,500	14,300	62,900	0	1,200	1,400	5,500	100	189,000	1,900	187,100
CVPM 6	34,900	0	54,100	69,800	30,100	15,000	9,400	0	14,500	51,300	5,500	2,400	287,500	13,400	274,100
CVPM 7	3,400	0	7,500	11,600	8,900	15,900	57,400	0	3,000	1,400	400	200	109,700	400	109,300
CVPM 8	15,900	0	56,000	32,000	44,000	50,000	5,800	0	10,800	12,300	10,700	57,700	290,200	4,800	285,400
CVPM 9	59,300	0	157,900	72,300	21,300	26,100	900	0	22,400	44,100	29,500	6,400	440,200	11,300	428,900
CVPM 10	61,000	110,000	53,000	21,000	36,000	20,000	8,000	200	17,000	33,000	72,000	1,100	432,300	8,000	424,300
CVPM 11	6,400	0	11,200	1,900	44,600	15,800	2,500	0	400	800	3,600	5,400	92,600	500	92,100
CVPM 12	30,900	0	52,900	32,300	91,800	22,600	0	200	0	0	4,400	13,800	248,900	20,000	228,900
CVPM 13	63,400	75,000	48,400	50,400	129,000	47,200	4,300	7,800	7,000	10,000	12,300	96,200	551,000	11,000	540,000
CVPM 14	10,000	268,000	22,000	38,000	24,500	1,000	0	500	7,000	100,000	80,000	6,000	557,000	10,000	547,000
CVPM 15	91,000	281,000	65,500	63,100	32,200	16,100	200	300	10,100	5,200	5,500	48,900	619,100	4,000	615,100
CVPM 16	9,500	8,500	3,700	5,100	26,700	9,800	0	12,500	0	0	9,300	76,000	161,100	200	160,900
CVPM 17	8,700	9,000	7,800	5,800	78,600	8,700	0	33,700	100	0	7,500	106,800	266,700	1,000	265,700
CVPM 18	85,800	158,500	88,500	93,000	77,000	7,500	0	103,500	2,800	800	12,700	53,300	683,400	24,800	658,600
CVPM 19	33,700	122,000	7,300	21,900	46,800	500	0	3,000	4,400	1,400	9,000	7,700	257,700	2,000	255,700
CVPM 20	16,500	34,000	4,200	7,800	58,400	300	0	28,000	1,500	500	14,000	45,900	211,100	2,000	209,100
CVPM 21	39,800	144,000	13,500	25,300	21,800	1,700	0	19,000	3,100	3,100	57,000	35,400	363,700	19,000	344,700
Coachella	3,030	360	6,650	790	440	1,500	0	21,260	0	190	20,400	18,800	73,420	14,310	59,110
Colorado	56,000	16,310	7,740	9,430	10	4,450	0	5,450	0	1,660	28,700	0	129,750	24,700	105,050
Imperial	191,090	7,670	63,900	59,520	640	36,590	0	4,410	38,350	6,580	117,030	0	525,780	63,200	462,580
San Diego	340	0	500	160	12,880	1,630	0	0	62,750	0	3,010	220	84,630	2,770	81,860

Table K-6. Projected 2020 Agricultural Land Use (acres)

Region	Alfalfa	Cotton	Field	Grain	Orchard	Pasture	Rice	Sub-Tropical	Sugar Beets	Tomato	Truck	Vine-yard	Total Crop	Double Cropping	Total Land
CVPM 1	1,100		400	1,300	4,000	24,700		400			1,700	100	33,700		33,700
CVPM 2	9,500		14,300	15,500	88,900	32,500	4,500	24,500	3,300	200	11,700	200	205,100	5,500	199,600
CVPM 3	29,100	11,300	29,000	48,300	44,600	10,500	153,700	3,500	9,900	33,200	29,100	5,700	407,900	22,100	385,800
CVPM 4	6,900	3,100	37,200	44,700	32,100	1,200	88,600		7,100	35,300	39,900		296,100	16,300	279,800
CVPM 5	4,700	800	18,000	23,200	128,300	26,100	170,500	4,000	1,900	1,500	10,200	400	389,600	4,400	385,200
CVPM 6	33,900		45,900	59,600	31,000	13,100	10,400		14,300	51,100	11,700	2,000	273,000	17,400	255,600
CVPM 7	3,100		4,800	7,000	10,700	30,600	48,600		2,500	500	500	200	108,500	400	108,100
CVPM 8	11,500		52,800	30,900	48,600	45,300	4,500		1,300	12,300	17,100	60,800	285,100	7,000	278,100
CVPM 9	43,900		159,000	69,500	22,700	26,000	900		11,400	43,700	48,200	9,500	434,800	17,200	417,600
CVPM 10	45,000	100,000	51,800	13,300	39,100	15,000	5,000	500	13,000	43,400	110,000	3,000	439,100	11,000	428,000
CVPM 11	8,400	0	26,700	5,900	83,000	41,800	3,100	0	0	800	6,100	9,400	185,200	12,000	174,200
CVPM 12	26,400	0	48,400	24,300	96,800	17,600	0	200	0	0	5,900	12,800	232,400	20,000	212,400
CVPM 13	56,500	71,000	44,900	41,900	137,500	38,200	2,800	9,800	4,000	12,000	16,300	93,200	528,100	15,500	512,600
CVPM 14	4,000	210,400	22,500	30,000	37,000	1,000	0	500	4,900	113,000	116,000	7,000	546,300	25,000	521,300
CVPM 15	75,200	265,200	63,500	57,100	36,200	15,100	200	800	8,200	11,200	10,000	68,900	611,600	6,900	604,700
CVPM 16	4,100	3,000	2,500	2,900	13,000	5,300	0	9,500	0	0	9,300	48,300	97,900	1,000	96,900
CVPM 17	4,700	4,500	5,300	5,300	82,000	7,700	0	35,700	100	0	7,500	86,100	238,900	1,000	237,900
CVPM 18	85,800	151,000	87,200	70,000	81,000	7,500	0	112,500	2,800	800	19,700	55,200	673,500	32,000	641,500
CVPM 19	32,700	118,000	5,800	21,900	52,800	500	0	3,000	4,400	1,400	12,000	7,700	260,200	4,500	255,700
CVPM 20	15,200	31,800	1,700	8,800	58,400	300	0	28,000	0	500	20,000	43,400	208,100	4,000	204,100
CVPM 21	29,300	115,100	12,500	18,200	20,800	800	0	19,000	1,000	2,700	82,800	36,400	338,600	28,000	310,600
Coachella	500	0	500	200	400	2,000	0	17,900	0	350	5,150	11,300	38,300	3,900	34,400
Colorado	44,000	26,000	7,260	9,000	200	4,000	0	6,400	0	1,700	35,200	0	133,760	30,660	103,100
Imperial	168,400	20,000	27,500	86,300	500	24,500	0	1,700	29,300	12,000	182,900	0	553,100	107,500	445,600
San Diego	300	0	300	100	1,600	2,000	0	51,800	0	2,000	7,800	200	66,100	600	65,500

Notes:

1 CVPM3 – CU model gives 11,500 ac compared with 11,300 ac for cotton
2 CVPM3 – CU model gives 48,100 ac orchard & 0 ac subtropical compared with 44,600 ac and 3,500 ac
3 CVPM5 – CU model gives 0 ac compared with 400 ac vineyard
4 CVPM5 – CU model gives 128,400 ac compared with 128,300 ac for orchard
5 CVPM 8 – CU model gives 11,900 ac compared with 11,500 ac for alfalfa
6 CVPM 8 – CU model gives 1,400 ac compared with 1,300 ac for sugar beets
6 CVPM9 – CU model gives 48,300 ac compared with 48,200 ac for truck
7 Many differences for field, grain, pasture, tomato, truck

Table K-7. Projected 2020 Agricultural Land Use in CU Model/DWRSIM (acres)

Region	Alfalfa	Cotton	Field	Grain	Orchard	Pasture	Rice	Sub-Tropical	Sugar Beets	Tomato	Truck	Vine-yard	Total Crop	Double Cropping	Total Land
CVPM 1	1,100	0	500	1,300	4,000	24,700	0	400	0	0	1,600	100			33,700
CVPM 2	9,500	0	17,200	11,500	88,900	34,500	4,500	24,500	3,300	200	5,300	200			199,600
CVPM 3	29,100	11,500	29,600	30,900	48,100	14,500	153,700	0	9,900	31,700	21,300	5,700			386,000
CVPM 4	6,900	3,100	40,400	46,600	32,100	1,200	88,600	0	7,100	35,300	18,500	0			279,800
CVPM 5	4,700	800	19,700	20,300	128,400	26,100	170,500	0	1,900	1,500	6,900	4,000			384,800
CVPM 6	33,900	0	45,900	57,400	31,000	13,100	10,400	0	14,300	47,600	0	2,000			255,600
CVPM 7	3,100	0	4,800	6,600	10,700	30,600	48,600	0	2,500	500	500	200			108,100
CVPM 8	11,900	0	53,100	24,100	48,900	46,700	4,500	0	1,400	12,900	17,100	60,800			281,400
CVPM 9	43,900	0	141,800	69,500	22,700	26,000	900	0	11,400	43,700	48,300	9,500			417,700

Note: Land use in the depletion analysis is based on an assumed cropping intensity of 100%. The total area of crops equals the total land area.

AGRONOMIC FACTORS

This section gives details of the agronomic data used to generate crop consumptive use values.

Central Valley

Required input to the CU model includes months when crops are irrigated, crop rooting depths, and minimum required soil moisture levels for each crop.

Growing Season

For many annual crops, the growing season is determined by cultural and management practices. In contrast, the active growing season for perennial crops such as alfalfa, orchards and vineyards is a function of climate rather than management. For the CU model, average ET for annual crops is calculated as the integrated average of early, mid-season and late planting. The planting dates are based on figures quoted by DWR in Bulletin 113-3. Table K-9 gives the assumed planting dates for different regions within the Central Valley. The irrigation season often differs from the growing season due to the need to pre-irrigate and the cessation of irrigation before harvest. The cut-off date may be as much as two months prior to harvest.

Table K-9. Central Valley Crop Growing Season

Crop	Sacramento Valley	Delta	San Joaquin River HR	Tulare Lake HR
Alfalfa (AL)	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31
Citrus/Olives (SO)	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31
Cotton (CO)			4/15 – 10/15	4/15 – 10/15
Field (FI)	varies	varies	varies	varies
Grain (GR)	12/15 – 6/1	3/1 – 6/30	11/15 – 5/31	11/15 – 5/15
Orchard (OR)	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31
Pasture (PA)	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31	3/1 – 10/31
Rice (RI)	4/15 – 10/1	4/15 – 10/31	4/15 – 10/31	4/15 – 10/15
Sugar Beets (SB) annual	3/15 – 9/15 4/15-10/15 5/1 - 10/31	3/1 – 11/1 3/15 – 11/15 4/1 – 12/15	3/1 – 8/31 3/15 – 9/15 4/1 – 10/15	10/15 – 7/15 12/15 – 8/31 2/15 – 10/15
Sugar Beets (SB) overwintered	4/1 - 3/1 5/1 - 3/15 6/1 - 4/31		4/15 – 2/15 5/1 – 4/1 5/15 – 4/15	
Tomato (TM)	4/1 – 8/15 4/15 – 9/15 5/1 – 9/30	4/1 – 8/15 4/15 – 9/15 5/1 – 9/30	4/1- 8/31 4/15 – 9/15 5/1 – 9/30	2/15 – 7/15 3/1 – 8/1 3/15 – 8/15
Truck (TR)	varies	varies	varies	varies
Vineyard (VI)	5/1 – 10/31	4/15 – 10/31	5/1 – 10/31	5/1 – 10/31
Notes: In the Sacramento Valley, 1/3 beet crop overwintered in Yolo Co. and south, no overwinter crop to north. In the San Joaquin Valley, ¼ beet crop overwintered. Truck and field categories consist of several crops with different planting dates.				

Source: MacGillivary (1976)

Rooting Depths

Maximum rooting depths for 12 crop categories are given in Table K-10. Figures used in DWR's CU model are compared with figures published by DWR in Bulletin 113-3. In general, Bulletin 113-3 figures tend to be lower. It should be noted that root depths for truck crops vary considerably (lettuces 1.0 ft, potatoes 2.0 ft, carrots 4.0 ft) and the figures represent a weighted average. Rooting depths given in CVGSM input file (CVGSM\input\naa\cnjparm.dat) are taken from the CU model.

Table K-10. Maximum Crop Rooting Depths (feet)

Crop	AL	CO	FI	GR	OR	PA	RI	SB	SO	TO	TR	VI
Bulletin 113-3	5.0	5.0	3.0	3.0	6.0	2.0	2.0	5.0	3.0	5.0	2.0	5.0
CU model	6.0	6.0	4.0	4.0	6.0	2.0	2.0	5.0	4.0	5.0	3.0	5.0

<u>Minimum Soil Moisture</u>

Minimum required soil moisture in the root zone is given in Table K-11.

Table K-11. Minimum Soil Moisture (inches)

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Alfalfa (AL)	4.0	2.0	2.0	2.0	2.0	6.0	8.0	9.0	8.0	7.0	6.0	5.0
Citrus/Olives (SO)	2.0	1.0	1.0	1.0	1.0	3.0	4.0	6.0	6.0	6.0	5.0	4.0
Cotton (CO)	1.0	1.0	1.0	1.0	1.0	8.0	<6.9	<5.4	9.0	8.0	8.0	<2.6
Field (FI)	1.0	1.0	1.0	1.0	1.0	4.0	4.0	4.0	5.0	4.5	3.0	2.0
Grain (GR)	1.0	1.0	2.0	3.0	3.0	3.0	3.0	1.0	1.0	1.0	1.0	1.0
Orchard (OR)	4.0	2.0	2.0	2.0	2.0	5.0	8.0	9.0	8.0	7.0	6.0	5.0
Pasture (PA)	1.5	1.0	1.0	1.0	1.0	2.0	3.0	3.0	2.5	2.0	2.0	2.0
Rice (RI)	1.0	1.0	1.0	1.0	1.0	1.0	9.0	10.5	12.0	12.0	10.5	3.0
Sugar beets (SB)	3.0	2.0	2.0	2.0	2.0	4.0	4.0	4.5	7.5	6.0	5.0	4.0
Tomato (TH & TM)	1.0	1.0	1.0	1.0	1.0	1.0	3.0	7.5	7.5	6.5	5.5	3.0
Truck (TR)	1.0	1.0	1.0	1.0	1.0	1.0	3.0	4.0	4.5	4.0	4.0	2.0
Vineyard (VI)	3.0	2.0	2.0	2.0	2.0	2.0	5.0	7.5	7.0	6.0	5.0	4.0
Note: For rice, this includes flooding.												

Southern California

The CU model will eventually be extended to Southern California. In the interim period crop water requirements are bases on studies completed for IID.

CLIMATE

Reference Evapotranspiration (ETo)

Statewide estimates of ET were first made by DWR in 1954 using USWB Standard Class "A" evaporation pans (DWR 1986). Later, DWR (1975) divided the state into 11 zones of similar evaporative demand and gave estimates of monthly evapotranspiration for the principal crops grown in each zone. The floor of the Central Valley was divided into just two zones: Sacramento Valley and San Joaquin Valley. These ET rates were subsequently revised by MacGillivary (1976) for use in DWR's Consumptive Use Model. In 1987, maps depicting isolines of monthly ETo were developed by researchers at UC Davis (Pruitt et al. 1987).

Within the floor of the Central Valley, variations of ETo are relatively minor. DWR (1974) gives normal ETo values of 49.2 inches for the Sacramento Valley compared to 49.0 inches for the San Joaquin Valley. By comparison, ETo in the Colorado River Region is much higher. Normal year ETo calculated from CIMIS data for the Imperial Valley is 75.2 inches, approximately 53% higher. Table K-12 gives normal (average) year ETo for representative

Table K-12. Average Monthly Evapotranspiration (in)

Region	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
CVPM 1	Redding	1.2	1.4	2.6	4.1	5.6	7.1	8.5	7.3	5.3	3.2	1.4	0.9	48.8
CVPM 2	Corning	1.2	1.8	2.9	4.5	6.1	7.3	8.1	7.2	5.3	3.7	1.7	1.1	50.7
CVPM 3	Williams	1.2	1.7	2.9	4.5	6.1	7.2	8.5	7.3	5.3	3.4	1.6	1.0	50.8
CVPM 4	Colusa	1.1	1.7	2.8	4.8	6.6	7.4	8.2	7.0	5.7	3.5	1.7	1.0	51.4
CVPM 5	Gridley	1.2	1.8	3.0	4.7	6.1	7.7	8.5	7.1	5.4	3.7	1.7	1.0	51.9
CVPM 6	Winters	1.7	1.7	2.9	4.4	5.8	7.1	7.9	6.7	4.3	3.3	1.6	1.0	49.4
CVPM 7	Roseville	1.1	1.7	3.1	4.7	6.2	7.7	8.5	7.3	5.6	3.7	1.7	1.0	52.2
CVPM 8	Lodi	0.9	1.5	2.9	5.1	6.5	7.0	7.7	7.7	5.2	3.1	1.3	0.7	49.5
CVPM 9	Brentwood	1.0	1.5	2.9	4.5	6.1	7.1	7.9	6.7	5.2	3.2	1.4	0.7	48.3
CVPM 10	Los Banos	1.0	1.5	3.2	4.7	6.1	7.4	8.2	7.0	5.3	3.4	1.4	0.7	50.0
CVPM 11	Modesto	0.9	1.4	3.2	4.7	6.4	7.7	8.1	6.8	5.0	3.4	1.4	0.7	49.7
CVPM 12	Turlock	0.9	1.5	3.2	4.7	6.5	7.7	8.2	7.0	5.1	3.4	1.4	0.7	50.2
CVPM 13	Merced	1.0	1.5	3.2	4.7	6.6	7.9	8.5	7.2	5.3	3.4	1.4	0.7	51.5
CVPM 14	Five Points	0.9	1.7	3.3	5.0	6.6	7.7	8.5	7.3	5.4	3.4	1.5	0.9	52.1
CVPM 15	Lemoore	0.9	1.5	3.4	5.0	6.6	7.7	8.3	7.3	5.4	3.4	1.4	0.7	51.7
CVPM 16	Fresno	0.9	1.7	3.3	4.8	6.7	7.8	8.4	7.1	5.2	3.2	1.4	0.6	51.1
CVPM 17	Reedley	1.1	1.5	3.2	4.7	6.4	7.7	8.5	7.3	5.3	3.4	1.4	0.7	51.3
CVPM 18	Visalia	1.0	1.8	3.4	5.4	7.0	8.2	8.4	7.2	5.7	3.8	1.7	0.9	54.3
CVPM 19	Lost Hills	1.0	1.8	3.2	4.7	6.6	7.7	8.5	7.3	5.4	3.4	1.5	0.9	52.0
CVPM 20	Delano	0.9	1.8	3.4	4.7	6.6	7.7	8.5	7.3	5.4	3.4	1.4	0.7	52.0
CVPM 21	Arvin	1.2	1.8	3.5	4.7	6.6	7.4	8.1	7.3	5.3	3.4	1.7	1.0	51.9
Coachella	Coachella	2.9	4.4	6.2	8.4	10.5	11.9	12.3	10.1	8.9	6.2	3.8	2.4	88.0
Colorado	Blythe	3.2	4.2	6.7	8.9	11.1	12.4	12.8	11.1	9.1	6.7	4.0	2.7	92.9
Imperial	Calipatria	2.9	3.9	6.1	8.3	10.5	11.8	12.0	10.4	8.6	6.5	3.8	2.3	87.1
San Diego	Chula Vista	2.2	2.7	3.4	3.8	4.9	4.7	5.5	4.9	4.5	3.4	2.4	2.0	44.2

Source: http://wwwdla.water.ca.gov/cimis/cimis/hq locations within each agricultural region based on the UC Davis work. Regions close to the Delta show significant variation in ETo.

DWR still uses pan data for much of its prediction of crop evapotranspiration rather than CIMIS data. CIMIS ETo is significantly higher.

Precipitation

Average monthly precipitation for CALVIN's agricultural regions is given in Table K-16. Data for CVPM Regions 1-8 are taken from the CU model. Data for CVPM Regions 9-21 are calculated from input files for CVGSM (cvgsm\naa\input\cnjprcp1.dat). For Southern California, the data were obtained from either CIMIS or the Western Regional Climate Center (http://www.wrcc.sage.dri.edu).

Precipitation values developed for the CU model represent average monthly precipitation over the portion of the depletion area that is subject to future development (DWR 1991). This has been calculated using isohyetal maps and point data from selected rainfall gages termed 'index stations'. Values from the index stations are multiplied by a weighting factor to convert measured point precipitation into a value that represents precipitation over the developable area. The index stations and weights are given in Table K-15.

For CVGSM, 32 representative stations were chosen (/pass1/input/cnjchr.dat). The area of influence for each station was determined using Theissen polygons. To obtain a spatial variation for the elements within each polygon, the station rainfall was multiplied by a factor representing the ratio of the annual element precipitation to station precipitation. The element precipitation was estimated from an isohyetal map of mean annual precipitation for California (Rantz 1969). Precipitation values used in CALVIN are the average of the elements within each CVPM region, weighted by the percentage area within the element. *The station weights and resulting average precipitation for each CVPM region were calculated from CVGSM input data. The results differ from summary precipitation values given in the model output. The reason for this difference is not known.* Table K-17 compares values used in the CU model compared to the CVGSM. These differences are significant and are cause for concern.

For Southern California, precipitation for each agricultural region was calculated as the average of gage data weighted by the relative area of influence of Thiessen polygons.

Table K-14. Average Monthly Precipitation (in)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
CVPM 1	6.4	5.6	4.6	2.6	1.5	0.8	0.1	0.2	0.8	2.1	4.3	6.1	35.2
CVPM 2	4.1	3.6	2.9	1.6	0.9	0.5	0.1	0.1	0.5	1.3	2.8	3.9	22.2
CVPM 3	3.5	3.3	2.4	1.3	0.5	0.3	0.0	0.1	0.3	1.0	2.2	3.3	18.1
CVPM 4	3.2	3.0	2.2	1.2	0.5	0.2	0.0	0.1	0.2	0.9	2.0	3.0	16.5
CVPM 5	4.3	4.0	3.1	1.7	0.7	0.3	0.0	0.1	0.3	1.3	2.9	4.1	22.9
CVPM 6	4.3	3.9	2.8	1.5	0.5	0.2	0.0	0.0	0.2	1.1	2.5	3.8	20.9
CVPM 7	4.1	3.9	3.2	1.7	0.6	0.2	0.0	0.0	0.3	1.2	2.7	3.8	21.8
CVPM 8	3.1	3.0	2.7	1.5	0.5	0.1	0.0	0.0	0.2	0.9	2.1	2.9	17.3
CVPM 9 uplands	2.6	2.4	1.9	1.1	0.4	0.1	0.0	0.0	0.2	0.7	1.6	2.3	13.3
CVPM 9 lowlands	3.5	3.3	2.7	1.8	1.0	0.8	0.6	0.6	0.8	1.4	2.4	3.2	22.1
CVPM 10	1.5	1.4	1.2	0.8	0.3	0.1	0.0	0.0	0.2	0.4	1.0	1.4	8.2
CVPM 11	2.3	2.1	2.0	1.2	0.4	0.1	0.0	0.0	0.2	0.7	1.5	2.2	12.6
CVPM 12	2.2	2.1	1.9	1.2	0.4	0.1	0.0	0.0	0.2	0.6	1.5	2.1	12.5
CVPM 13	1.8	1.8	1.6	1.1	0.3	0.1	0.0	0.0	0.1	0.5	1.3	1.7	10.3
CVPM 14	1.0	1.0	0.8	0.5	0.2	0.0	0.0	0.0	0.1	0.2	0.6	0.8	5.4
CVPM 15	1.2	1.2	1.1	0.7	0.2	0.1	0.0	0.0	0.1	0.3	0.7	1.0	6.6
CVPM 16	1.7	1.7	1.6	1.0	0.3	0.1	0.0	0.0	0.1	0.5	1.0	1.5	9.6
CVPM 17	2.3	2.2	2.0	1.3	0.4	0.1	0.0	0.0	0.2	0.6	1.3	2.0	12.5
CVPM 18	1.9	2.0	1.8	1.1	0.3	0.1	0.0	0.0	0.2	0.6	1.2	1.7	10.9
CVPM 19	1.0	1.0	1.0	0.6	0.2	0.1	0.0	0.0	0.1	0.3	0.5	0.8	5.7
CVPM 20	1.3	1.4	1.3	0.9	0.3	0.1	0.0	0.0	0.2	0.4	0.7	1.1	7.7
CVPM 21	1.2	1.3	1.4	0.9	0.3	0.1	0.0	0.0	0.2	0.4	0.8	1.1	7.7
Coachella													
Colorado													
Imperial	0.6	0.4	0.3	0.0	0.1	0.0	0.5	0.2	0.2	0.2	0.2	0.5	3.3
San Diego													

Table K-15. Comparison of CU Model & CVGSM Precipitation
Average Annual Precipitation 1921-1990 (inches)

Region	DA58	DA10	DA12	DA15	DA69	DA65	DA70	DA59	DA54/55
	CVPM1	CVPM2	CVPM3	CVPM4	CVPM5	CVPM6	CVPM7	CVPM8	CVPM9
CU	35.4	22.2	18.1	16.41	22.9	20.9	21.9	17.3	19.4
CVGSM	27.1	21.5	15.6	17.9	19.8	15.1	15.7	16.2	16.3

Table K-13. CU and CVGSM Selected Rain Gages

Region	Factor	Station
(A) Consumptive Use Model		
CVPM 1	0.565, 0.565	Redding (a07296), extended Red Bluff (a07292)
CVPM 2	0.51, 0.51	Orland (a06506), extended Red Bluff (1.15*red bluff airport, beginning 10/49)
CVPM 3	0.36, 0.36, 0.36	Colusa (a01948), extended Knights Landing, Willows (a09699)
CVPM 4	0.327, 0.327, 0.327	Colusa (a01948), extended Knights Landing, Willows (a09699)
CVPM 5	0.37, 0.37, 0.37	Colusa 1ssw (a01948), Chico(a01714), Marysville(a05385)
CVPM 6	0.353, 0.353, 0.353	Davis 2wsw (a02294), Woodland 1wnw (a09781), Vacaville (a09200)
CVPM 7	0.55, 0.55	Knights Landing (a04591), Rocklin (a07516)
CVPM 8	0.33, 0.33, 0.33	Galt (b03301), Lodi (b05032), Oakdale (b06303)
(B) CVGSM		
CVPM 1	0.66, 0.16	Redding (7300), Red Bluff (7292)
CVPM 2	0.19,0.35,0.41	Red Bluff (7292), Orland (6506), Chico Univ Farms (1715)
CVPM 3	0.31,0.50,0.10,0.03	Orland (6506), Colusa (1948), Winters (9742), Sacramento (7633)
CVPM 4	0.17,0.48,0.23,0.12	Chico Univ Farm (1715), Colusa (1948), Marysville (5385), Sacramento (7633)
CVPM 5	0.33,0.04,0.53,0.01	Chico Univ Farm (1715), Colusa (1948), Marysville (5385), Sacramento (7633)
CVPM 6	0.65,0.20,0.02	Winters (9742), Sacramento (7633), Lodi (5032)
CVPM 7	0.06,0.81,	Marysville (5385), Sacramento (7633)
CVPM 8	0.24,0.39,0.37,0.02	Sacramento (7633), Lodi (5032), Camp Pardee (1428), Modesto (5738)
CVPM 9	0.08,0.17,0.44,0.34	Winters (9742), Sacramento (7633), Lodi (5032), Tracy Carbona (8999)
CVPM 10	0.11,0.07,0.02,0.05 ,0.69	Tracy Carbona (8999), Modesto (5738), Merced (5532), Madera (5233), Los Banos (5120)
CVPM 11	0.11,0.99	Tracy Carbona (8999), Modesto (5738)
CVPM 12	0.60,0.42	Modesto (5738), Merced (5532)
CVPM 13	0.44,0.36,0.04,0.10	Merced (5532), Madera (5233), Friant Gov. Camp (3261), Los Banos (5120)
CVPM 14	0.07,0.04,0.08,0.56	Madera (5233), Hanford 2 S (3747), Los Banos (5120), Kettleman (4536)
CVPM 15	0.09,0.09,0.25,0.16 ,0.01,0.25	Madera (5233), Fresno Wso Ap (3257), Hanford 2 S (3747), Corcoran (2012), Delano (2346), Kettleman (4536)
CVPM 16	0.06,0.05,0.68,0.02 ,0.15	Madera (5233), Friant Gov. Camp (3261), Fresno Wso Ap (3257), Pine Flat Dam (6896), Kettleman (4536)
CVPM 17	0.26,0.02,0.64,0.02 ,0.07,0.18	Fresno Wso Ap (3257), Pine Flat Dam (6896), Orange Cove (6476), Hanford 2 S (3747), Visalia (9367), Kettleman (4536)
CVPM 18	0.04,0.04,0.39,0.23 ,0.27,0.20,0.03	Orange Cove (6476), Hanford 2 S (3747), Visalia (9367), Corcoran (2012), Porterville (7077), Delano (2346), Kettleman (4536)
CVPM 19	0.03,0.29,0.36,0.01 ,0.11,0.11	Delano (2346), Wasco (9452), Buttonwillow (1244), Bakersfield (442), Maricopa (5338), Kettleman (4536)
CVPM 20	0.43,0.14,0.23,0.24 ,0.13	Delano (2346), Wasco (9452), Buttonwillow (1244), Bakersfield (442), Kettleman (4536)
CVPM 21	0.05,0.28,0.28,0.34	Buttonwillow (1244), Bakersfield (442), Maricopa (5338), Tejon Rancho (8839)
Coachella		
Palo Verde		
Imperial	0.47, 0.18, 0.35	Calipatria (41), Meloland (87), Seeley (68)
San Diego		

CROP EVAPOTRANSPIRATION

Central Valley

DWR's CU model uses monthly crop evapotranspiration estimates developed by MacGillivary (1976). For CVGSM, these data were extended to include the Tulare Lake basin based on MacGillivary's (1976) tables. A comparison was made between data used in the two models. As discussed in an earlier section, the CU model considers a range of planting dates for annual crops to calculate average monthly ET. The CU model lists irrigation months rather than the growing season. However, the growing season was inferred and found to match CVGSM figures based on the following assumptions:

- Pre-irrigation for sugar beets occurs in March,
- Rice is not irrigated during October,
- Orchards are not irrigated between November and February,
- Pre-irrigation of field crops occurs in March,
- Truck crops are not irrigated in October,
- Grain is not irrigated in May and June, and
- Cotton is pre-irrigated in March, followed by two months when the crop is not irrigated.

The figures agreed for all crops and regions except for minor differences for sugar beets in three regions. Table K-16 gives the total crop ET for each region within the Central Valley used in CALVIN. This is taken from CVGSM data (file: cvgsm\naa\input\cnjet.dat).

Table K-16. CALVIN Crop Evapotranspiration (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	3.6	0.0	2.0	1.3	3.7	3.8	0.0	0.0	2.4	0.0	1.9	2.5
CVPM 2	3.6	0.0	1.9	1.3	3.5	3.8	3.7	2.7	2.4	2.4	1.7	2.4
CVPM 3	3.6	2.5	1.9	1.3	3.4	3.8	3.7	2.7	0.0	2.4	1.7	2.3
CVPM 4	3.5	2.5	1.9	1.3	3.3	3.8	3.7	2.7	0.0	2.4	1.7	0.0
CVPM 5	3.6	2.5	1.9	1.3	3.6	3.8	3.7	2.7	2.4	2.4	1.8	0.0
CVPM 6	3.6	0.0	1.9	1.3	3.5	3.8	3.7	2.7	0.0	2.4	1.7	2.2
CVPM 7	3.6	0.0	1.9	1.3	3.7	3.8	3.7	2.8	0.0	2.4	1.8	2.4
CVPM 8	3.5	0.0	1.7	1.3	3.4	3.7	3.9	2.8	0.0	2.3	1.4	2.3
CVPM 9	3.4	0.0	2.0	1.3	3.3	3.5	3.5	2.8	0.0	2.3	2.3	2.2
CVPM 10-13	3.6	0.0	1.9	1.3	3.7	3.8	3.8	2.8	2.4	2.4	1.4	2.5
CVPM 14-21	3.6	2.7	1.9	0.9	3.1	3.8	3.8	2.4	2.3	2.2	1.4	2.3
Note: Nov. ET for sugar beets in the CU model are higher for CVPM 3,4 and 10, respectively 0.10, 0.20, and 0.3 feet.												

BARE SOIL EVAPORATION

Estimates of bare soil evaporation are required to estimate soil moisture loss outside the growing season. Winter and spring evaporation prior to planting will affect the depth of pre-irrigation required. Unfortunately, it is difficult to determine, being dependent on soil moisture, depth to the water table, soil texture and the presence of weeds. For the CU model, the following assumptions are made:

- For fallow land, deciduous orchards, and vineyards, ET in the non-growing season equals monthly precipitation up to a maximum of potential ET (for pasture);

- For perennial crops that maintain green vegetation (sub-tropical orchards, pasture, alfalfa), the non-growing ET is assumed equal to potential ET (for pasture);

- For annual crops, a monthly minimum ET of 1 inch is assumed for periods of fallow after harvest and before planting, but outside the rainy season, to account for continued surface evaporation from pre-irrigation, weed growth and evaporation from moist soil turned up through tillage operations.

From the CVGSM input data, it appears that bare soil evaporation greatly exceeds values used in the CU model, resulting in higher ETAW estimates for the San Joaquin Valley.

EVAPOTRANSPIRATION OF APPLIED WATER

Table K-17 gives values for crop ETAW averaged over a hydrologic region, as quoted by DWR in Bulletin 160-93.

Table K-17. ETAW from Bulletin 160-93 (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
Sacramento River HR	2.3		1.7	0.6	2.3	2.3	3.0	1.9	2.2	2.5	1.2	1.6
San Joaquin HR	2.9	2.5	1.6	0.7	2.3	3.1	3.6	1.8	2.5	2.0	1.2	2.0
Tulare Lake HR	3.0	2.5	2.0	1.0	2.5	3.2	3.0	1.9	2.6	2.3	1.3	2.1
Colorado River HR	6.2	3.3	2.6	2.0	5.0	5.5		4.2	3.8	2.5	1.7	3.3
South Coast HR	2.6		1.7	0.2	2.7	2.8		1.7		2.2	1.4	1.5
Note: Blank values indicate that the crop is not grown in the region.												

Central Valley

Both DWRSIM and the CVPM/CVGSM models for the CVPIA PEIS use the CU model to calculate ETAW. Demand at the field level is determined as the depth of water required to maintain the soil profile at a minimum moisture level. This can be formulated as:

$$ETAW = \max\left\{0, S_{\min} - \left(S_m^t + P_e^t - E_a^t\right)\right\}$$

where:

ETAW = evapotranspiration of applied water
S_{min} = minimum soil moisture requirement
P_e^t = effective rainfall in month *t*
S_m^t = soil moisture at the beginning of month *t*
E_a^t = actual evapotranspiration in month *t*

The CU model was programmed in Excel and run using agronomic factors and evapotranspiration given in Tables K-9, K-10, K-11 and K-16. Annual average values from the model for the October 1921-September 1993 period are given in Table K-18.

Annual average figures were also calculated for each CVPM region from DWR's supporting data for Bulletin 160-98. Values by county and DAU were aggregated and weighted by

DWR's projected 2020 land use. Some minor adjustments were made where specific values seemed either too low or too high. Results from the CU model were compared with values from Bulletin 160-98 supporting data. The values varied significantly. In particular, values for grain predicted by the CU model are typically only 50% of those estimated by DWR. In contrast, values used for the CVPM model for the CVPIA PEIS[6] agreed well with DWR data. Annual values were generally within 10%, with the exception of grain and field crops. CVPM's ETAW values for grain in the Sacramento Valley are typically 20% higher and CVPM values for field crops in the lower Sacramento Valley and upper San Joaquin Valley are typically 15% higher.

[6] Values for the CVPM model are based on aggregated crop types weighted by 1987-1990 average observed crop acreage. An apparent error for walnuts and prunes in CVPM 16 has been corrected.

Table K-18. ETAW from CU Model (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	2.52		1.43	0.16	2.26	2.88			1.56		1.31	1.80
CVPM 2	2.63		1.43	0.23	2.17	2.98	3.52	2.01	1.61	1.92	1.27	1.80
CVPM 3	2.82	1.97	1.53	0.39	2.23	3.10	3.62	2.11		2.02	1.34	1.88
CVPM 4	2.77	2.01	1.47	0.26	2.15	3.13	3.57	2.07		1.94	1.32	
CVPM 5	2.72	2.00	1.50	0.22	2.31	3.07	3.55	2.10	1.67	1.97	1.35	
CVPM 6	2.85		1.61	0.47	2.33	3.07	3.63	2.18		2.10	1.37	1.76
CVPM 7	2.88		1.63	0.31	2.54	3.19	3.63	2.24		2.10	1.45	2.01
CVPM 8	2.72		1.36	0.24	2.25	3.05	3.77	2.22		1.90	1.11	1.83
CVPM 9	2.72		1.57	0.23	2.26	2.95	3.54	1.76		1.88	1.71	1.79
CVPM 10	3.29	2.33	1.72	0.61	2.67	3.45	3.79	2.51	1.99	2.25	1.19	2.06
CVPM 11	3.02	2.17	1.59	0.42	2.45	3.29	3.73	2.34	1.82	2.10	1.11	1.94
CVPM 12	3.02	2.18	1.59	0.42	2.45	3.29	3.73	2.34	1.82	2.10	1.11	1.94
CVPM 13	3.14	2.27	1.65	0.50	2.55	3.36	3.75	2.41	1.89	2.17	1.14	1.99
CVPM 14	3.50	2.54	1.91	0.63	2.66	3.59	3.85	2.35	2.16	2.22	1.31	2.20
CVPM 15	3.40	2.47	1.84	0.55	2.56	3.52	3.81	2.26	2.06	2.13	1.26	2.12
CVPM 16	3.20	2.40	1.74	0.40	2.41	3.39	3.77	2.12	1.93	2.02	1.17	2.05
CVPM 17	2.99	2.21	1.59	0.25	2.23	3.27	3.70	1.95	1.79	1.88	1.07	1.90
CVPM 18	3.12	2.34	1.71	0.38	2.34	3.36	3.83	2.08	1.90	2.01	1.20	2.00
CVPM 19	3.46	2.51	1.87	0.61	2.62	3.55	3.82	2.31	2.12	2.19	1.28	2.16
CVPM 20	3.31	2.44	1.78	0.48	2.50	3.45	3.78	2.19	2.01	2.08	1.21	2.09
CVPM 21	3.31	2.44	1.79	0.49	2.49	3.45	3.78	2.19	2.01	2.07	1.21	2.09

Note: Blank values indicate that the crop is not grown in the region.

Table K-19. ETAW from CVPM (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	2.92	2.08	1.82	0.68	2.59	3.33	3.54	2.40	1.98	2.08	1.25	1.98
CVPM 2	3.10	2.27	1.90	0.71	2.65	3.63	3.75	2.61	2.10	2.27	1.36	2.10
CVPM 3	2.93	2.29	1.76	0.68	2.37	3.31	3.65	2.39	1.98	2.08	1.25	1.94
CVPM 4	2.95	2.11	1.71	0.69	2.43	3.37	3.58	2.42	2.01	2.11	1.27	2.01
CVPM 5	2.87	2.04	1.71	0.66	2.46	3.28	3.48	2.36	1.94	2.04	1.22	1.94
CVPM 6	2.81	2.00	1.71	0.65	2.38	3.21	3.40	2.30	1.90	2.00	1.20	1.90
CVPM 7	2.85	2.03	1.69	0.66	2.63	3.25	3.46	2.34	1.93	2.03	1.22	1.93
CVPM 8	3.04	2.53	1.71	0.71	2.21	3.24	3.65	2.76	1.93	2.14	1.17	1.93
CVPM 9	2.99	2.63	1.59	0.74	2.49	3.15	3.78	2.42	2.00	2.11	1.79	1.91
CVPM 10	3.10	2.45	1.79	1.00	2.48	3.30	3.60	2.50	2.00	2.20	1.10	2.10
CVPM 11	2.63	2.35	1.63	0.49	2.10	2.92	3.26	2.24	1.94	2.04	1.07	1.75
CVPM 12	2.99	2.54	1.81	0.68	2.35	3.20	3.51	2.51	1.83	2.20	1.31	2.04
CVPM 13	3.01	2.47	1.97	0.77	2.33	3.22	3.47	2.49	1.82	2.18	1.31	2.06
CVPM 14	3.31	2.55	1.80	1.02	2.58	3.46	3.67	2.65	2.04	2.34	1.43	2.24
CVPM 15	3.10	2.50	1.60	1.00	2.72	3.43	3.60	2.60	2.00	2.30	1.40	2.20
CVPM 16	2.85	2.35	1.89	0.69	2.39	3.04	3.43	2.35	1.77	2.06	1.37	1.96
CVPM 17	2.85	2.35	1.84	0.65	2.45	3.05	3.50	2.40	1.75	2.05	1.35	1.95
CVPM 18	3.14	2.53	1.94	0.91	2.74	3.34	3.54	2.53	1.92	2.23	1.32	2.13
CVPM 19	3.35	2.54	1.52	1.15	2.63	3.55	3.76	2.74	2.23	2.33	1.37	2.23
CVPM 20	3.21	2.51	1.88	1.00	2.50	3.42	3.72	2.61	2.01	2.31	1.41	2.21
CVPM 21	3.36	2.60	1.93	1.11	2.61	3.57	3.85	2.73	2.15	2.39	1.42	2.29

Table K-20. ETAW from Bulletin 160-98 Supporting Data (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	3.09		2.00	0.64	2.71	2.93			2.00		1.19	2.00
CVPM 2	3.19		1.95	0.50	2.70	3.22	3.31	2.70	1.92	2.00	1.32	2.00
CVPM 3	3.13	2.89	1.83	0.52	2.63	3.05	3.30	2.66	2.01	2.10	1.33	1.99
CVPM 4	3.13	2.88	1.39	0.55	2.68	3.26	3.35	2.63		2.10	1.29	
CVPM 5	3.12	2.80	1.50	0.55	2.56	3.08	3.34	2.46	2.00	2.09	1.20	1.75
CVPM 6	2.99		1.42	0.60	2.24	3.32	3.42	2.31		2.10	1.19	1.89
CVPM 7	2.99		1.50	0.60	2.51	2.96	3.42	2.31		2.10	1.19	1.89
CVPM 8	2.99		1.54	0.69	2.52	3.20	3.58	2.33		2.10	1.12	1.89
CVPM 9	2.72		1.37	0.60	2.42	2.99	3.30	2.31		1.89	1.70	1.79
CVPM 10	3.10	2.50	1.59	0.99	2.59	3.30	3.60	2.50	2.00	2.20	1.10	2.10
CVPM 11	3.01		1.77	0.62	2.04	3.10	3.46			2.10	1.18	1.89
CVPM 12	2.88		1.92	0.68	2.21	3.08			1.80		1.29	1.93
CVPM 13	3.00	2.45	1.87	0.74	2.32	3.12	3.40	2.41	1.82	2.10	1.30	2.07
CVPM 14	3.40	2.31	2.10	1.00	2.59	3.40		2.60	2.00	2.00	1.30	1.90
CVPM 15	2.84	2.50	2.05	1.00	2.66	3.41	3.60	2.60	2.00	2.30	1.38	2.20
CVPM 16	2.90	2.40	1.96	0.67	2.32	3.08			1.77		1.40	2.00
CVPM 17	2.83	2.33	1.79	0.62	2.51	3.08		2.40	1.76		1.33	2.06
CVPM 18	3.10	2.50	1.97	0.90	2.69	3.30		2.50	1.90	2.00	1.30	2.10
CVPM 19	3.30	2.50	1.73	1.20	2.54	3.50		2.70	2.20	2.30	1.35	2.20
CVPM 20	3.20	2.50	1.82	1.00	2.46	3.40			2.00	2.30	1.40	2.20
CVPM 21	3.29	2.50	1.88	1.13	2.59	3.46		2.70	2.00	2.30	1.38	2.20
Note: Blank values indicate that the crop is not grown in the region.												

Table K-21. Comparison of ETAW: CVPM to Bulletin 160-98 (%)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	94		91	106	96	114			99		105	94
CVPM 2	97		97	142	98	113	113	97	109	114	103	97
CVPM 3	94	79	96	131	90	109	111	90	99	99	94	94
CVPM 4	94	73	123	125	91	103	107	92		100	98	94
CVPM 5	92	73	114	120	96	106	104	96	97	98	102	92
CVPM 6	94		120	108	106	97	99	100		95	101	94
CVPM 7	95		113	110	105	110	101	101		97	103	95
CVPM 8	102		111	103	88	101	102	118		102	104	102
CVPM 9	110		116	123	103	105	115	105		112	105	110
CVPM 10	100	98	113	101	96	100	100	100	100	100	100	100
CVPM 11	87		92	79	103	94	94			97	91	87
CVPM 12	104		94	100	106	104			102		102	104
CVPM 13	100	101	105	104	100	103	102	103	100	104	101	100
CVPM 14	97	110	86	102	100	102		102	102	117	110	97
CVPM 15	109	100	78	100	102	101	100	100	100	100	101	109
CVPM 16	98	98	96	103	103	99			100		98	98
CVPM 17	101	101	103	105	98	99		100	99		102	101
CVPM 18	101	101	98	101	102	101		101	101	112	102	101
CVPM 19	102	102	88	96	104	101		101	101	101	101	102
CVPM 20	100	100	103	100	102	101			101	100	101	100
CVPM 21	102	104	103	98	101	103		101	108	104	103	102

Table K-22. Comparison of ETAW: CU Model to Bulletin 160-98 (%)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
CVPM 1	82		72	25	83	98			78		110	90
CVPM 2	82		73	46	80	93	106	74	84	96	96	90
CVPM 3	90	68	84	75	85	102	110	79	0	96	101	94
CVPM 4	88	70	106	47	80	96	107	79		92	102	
CVPM 5	87	71	100	40	90	100	106	85	84	94	113	
CVPM 6	95		113	78	104	92	106	94		100	115	93
CVPM 7	96		109	52	101	108	106	97		100	122	106
CVPM 8	91		88	35	89	95	105	95		90	99	97
CVPM 9	100		115	38	93	99	107	76		99	101	100
CVPM 10	106	93	108	62	103	105	105	100	100	102	108	98
CVPM 11	100		90	68	120	106	108			100	94	103
CVPM 12	105		83	62	111	107			101		86	101
CVPM 13	105	93	88	68	110	108	110	100	104	103	88	96
CVPM 14	103	110	91	63	103	106		90	108	111	101	116
CVPM 15	120	99	90	55	96	103	106	87	103	93	91	96
CVPM 16	110	100	89	60	104	110			109		84	103
CVPM 17	106	95	89	40	89	106		81	102		80	92
CVPM 18	101	94	87	42	87	102		83	100	101	92	95
CVPM 19	105	100	108	51	103	101		86	96	95	95	98
CVPM 20	103	98	98	48	102	101			101	90	86	95
CVPM 21	101	98	95	43	96	100		81	101	90	88	95

Note: Blank values indicate the crop is not grown in the region.

Southern California

Table K-23 gives ETAW values from Bulletin 160-98 supporting data.

Table K-23. ETAW from Bulletin 160-98 Supporting Data (ft)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TM	TR	VI
Coachella	7.0		3.3	2.1	4.4	6.6			4.1	2.9	2.3	3.6
Colorado	6.0	3.6	3.5	1.8	4.4	5.5			3.8	2.9	1.6	3.3
Imperial	5.4	3.3	4.2	2.1	4.4	5.5		3.6	3.6	2.9	1.5	
San Diego	2.7			0.3	2.3	2.7			1.8	1.8	1.4	1.2

DEMAND AT THE FARM GATE

For the SWAP model, it is necessary to convert consumptive use of applied water into the total quantity of water required at the farm gate. In addition to crop evapotranspiration, water may be beneficially used for seedbed preparation, leaching and frost protection. Additional water is required due to surface runoff (tailwater) and deep percolation losses resulting from the non-uniform distribution of applied water.

Central Valley

Three methods were explored for estimating the ratio of ETAW/AW:

- Using a constant ‘efficiency’ for all regions and crops,
- Using crop and region specific values, and
- Using economic optimal values.

Constant Efficiency

For Bulletin 160-98, DWR uses ‘seasonal application efficiency’ (SAE) to calculate applied water for the year 2020. SAE is defined as:

$$SAE = \frac{\text{ETAW + Leaching Requirement}}{\text{volume of applied water}} * 100\%$$

Seasonal application efficiencies are measured by DWR as part of the DWR/local agency Cooperative Mobile Irrigation Laboratory Program. Over 1,000 field studies have been conducted in the San Joaquin Valley, the Tulare Basin and in Southern California. In Bulletin 160-98 (Vol 1, p. 4-21), DWR states:

> *"It is assumed that by 2020 seasonal application efficiency will reach 73 percent in all regions of California, averaged across crop types, farm land characteristics, and management practices. The DU [distribution uniformity] of irrigation methods limits SAE. ....By 2020, the DU is expected to be about 80 percent. An irrigation method with a distribution uniformity of 80 percent can achieve a maximum SAE of about 73 percent, assuming that irrigation events are properly timed, the soil is well drained, and none of the field is under-irrigated."*

The use of a constant SAE value of 73% has several advantages. It provides a simple constant value statewide. Sensitivity analysis of CALVIN’s results would determine the value of further efforts to improve the distribution efficiency. However, leaching requirements would need to be calculated for each region. Leaching is particularly important in the west side of the San Joaquin Valley due to the salinity of pumped groundwater and in Southern California due to the low water quality of the Colorado River.

The price of water varies considerably between districts and regions. This leads to different levels of investment in irrigation technology. Efficiencies will also vary regionally with soil type and cropping pattern.

Crop and Region Specific Values

As part of the California Water Plan, DWR’s district offices prepare estimates of AW and ETAW for 14 crop categories by DAU. In all but a few cases these figures are used as a basis to estimate ETAW/AW values for CVPM (USBR 1987, V8, pII-9). A few of the estimates were adjusted downward where considered unrealistically high. The AW figures used to calibrate CVPM correspond to a 1995 level of irrigation technology[7]. Table K-24 gives the ICUC values for 12 crop categories for the 21 CVPM regions based on CVPM input data (USBR 1987, V8,

[7] “Irrigation efficiency for 2020 projected-level conditions were assumed to be the same as 1995 conditions. For Bulletin 160-93, DWR reported agricultural demands for both Level 1 conservation in place and without. Level 1 conservation assumes various agricultural programs are in place; however, at the time of publication of the bulletin, these agricultural programs were not firmly established and were only in a working phase. This preliminary status does not meet the No-Action Alternative criteria adopted for the PEIS.”

Tables II-5 and II-6 and CD-ROM disc 2, Ag-Econ\Naa\Model\Cesdat95.gms). Values for field crops, deciduous orchards and CVPM Region 3 are averages weighted by crop acreage. The crop acreages are the observed 1987-90 crop data given in CVPM input files (Cesdat95.gms). These figures are therefore appropriate for base year calibration of the SWAP model.

Table K-24. Base Year ETAW/AW (%)

Region	AL	CO	FI	GR	OR	PA	RI	SB	SO	TO	TR	VY	Average
CVPM 1	72.3	68.6	72.3	74.7	69.4	65.8	53.9	69.8	75.3	66.5	65.1	75.3	66.9
CVPM 2	78.7	76.7	80.9	79.8	78.6	73.6	58.6	77.9	80.8	74.4	72.7	80.8	77.3
CVPM 3	75.6	73.4	77.6	79.0	75.2	73.4	58.9	77.0	78.0	71.0	71.8	75.5	68.7
CVPM 4	74.7	71.0	76.4	77.5	72.8	68.1	55.7	72.0	78.2	68.7	67.6	78.2	68.0
CVPM 5	74.9	71.1	76.1	76.7	72.6	68.6	55.9	72.4	78.2	68.7	67.4	78.2	65.3
CVPM 6	69.7	66.2	69.8	71.4	67.4	63.7	51.8	67.3	72.5	64.1	62.8	72.5	67.9
CVPM 7	69.5	65.9	70.5	71.7	62.3	63.4	51.9	67.0	72.3	63.8	62.6	72.3	59.3
CVPM 8	67.7	75.3	67.5	69.6	68.6	61.6	51.8	66.3	72.8	67.7	65.4	65.0	66.0
CVPM 9	68.0	76.2	69.7	70.5	68.2	62.6	52.2	68.0	73.5	69.2	68.3	64.7	68.9
CVPM 10	67.4	74.2	63.6	71.4	75.6	66.0	53.7	75.8	80.0	66.7	61.1	75.0	67.9
CVPM 11	62.5	73.7	60.5	65.3	68.9	70.2	48.5	72.0	77.3	75.3	59.1	71.1	67.1
CVPM 12	62.8	74.7	67.0	63.6	75.6	67.9	49.0	73.4	69.8	76.1	64.5	76.4	70.3
CVPM 13	66.3	75.1	66.8	68.8	74.4	70.8	50.0	76.6	71.7	72.7	62.4	71.5	71.2
CVPM 14	83.6	84.4	81.8	79.1	78.4	83.2	55.4	81.0	76.4	76.2	67.1	83.9	78.1
CVPM 15	72.9	75.1	67.1	64.9	77.3	73.1	52.4	73.4	67.3	67.4	61.9	74.1	72.5
CVPM 16	61.7	77.0	65.2	63.9	77.6	65.8	52.1	74.6	75.0	67.5	60.6	74.0	71.9
CVPM 17	60.6	74.6	65.4	54.2	77.0	64.9	52.2	75.0	74.5	66.1	67.5	75.0	74.2
CVPM 18	68.4	80.1	64.2	63.6	77.9	72.8	51.8	75.1	75.3	68.4	71.7	74.5	72.9
CVPM 19	76.1	75.1	67.6	68.9	76.7	77.0	54.8	75.3	79.1	68.9	70.3	75.1	74.7
CVPM 20	67.0	74.5	64.2	67.6	77.4	71.4	54.5	71.1	73.1	68.5	72.7	74.7	73.8
CVPM 21	71.0	76.2	66.8	68.5	77.0	73.9	55.6	74.8	76.2	70.7	73.2	76.3	74.2
Note: The average is the weighted average by crop													

Source: CVPEIS CD-ROM disc 2, Ag-Econ\Naa\Model\Cesdat95.gms

CVPM is an annual model. There are no data on how ETAW/AW varies on a monthly basis. The weighted average value of ETAW/AW for the Central Valley is 71.2%.

Economic Optimal Values

By 2020, it is expected that irrigation technology and management practices will have improved. In the CVPM model, the ratio of ETAW/AW is referred to as 'irrigation efficiency.' To estimate the improvement in efficiencies and corresponding reduction in AW, the CVPM considers a trade-off between water use and irrigation technology costs. The level of technology for each crop in each region is optimally chosen so that the values of the marginal product of water and irrigation technology are equal. The CVPM and CVGSM models are run iteratively for 2020 conditions until the projected crop area, ground water pumping and long-run irrigation 'efficiencies' between the two models converge. The initial run of the CVGSM uses AW calculated from DWR's Bulletin 160-93 supporting information. Subsequent runs of the CVGSM model use revised crop acreage and AW figures from CVPM output.

The changes in efficiencies between different CVPM model runs are small. Valley-wide average efficiencies vary from 72.5% for the calibration run to 70.4% for the 2020 No-Action-

Alternative. These small changes in efficiency are a result of changes in cropping pattern in response to a reduction of surface water deliveries rather than changes in irrigation technology.

The CVPM is an annual model. All parameters, such as efficiencies and AW, are annual values. CVGSM is a monthly model. For the CVGSM, initial irrigation efficiencies derived from DWR data are distributed monthly using data from the CU model and depletion analysis (USBR 1997, V8, pIII-11). It is not known how subsequent efficiencies obtained from the CVPM are distributed.

Table K-25 gives the aggregated ETAW and AW demand for the 21 regions of the Central Valley based on DWR's 2020 projected land use and DWR's estimates of crop water requirements.

Table K-25. Aggregated ETAW and AW at the Farm Gate

Region	ETAW (taf)	AW (taf)	Eff. (%)
CVPM 1	91	134	68
CVPM 2	504	686	73
CVPM 3	1,021	1,525	67
CVPM 4	640	958	67
CVPM 5	1,065	1,609	66
CVPM 6	527	744	71
CVPM 7	312	495	63
CVPM 8	592	869	68
CVPM 9	724	1,034	70
CVPM 10	910	1,256	72
CVPM 11	413	600	69
CVPM 12	486	667	73
CVPM 13	1,174	1,617	73
CVPM 14	1,080	1,382	78
CVPM 15	1,426	1,918	74
CVPM 16	199	272	73
CVPM 17	516	694	74
CVPM 18	1,485	1,987	75
CVPM 19	630	802	79
CVPM 20	465	610	76
CVPM 21	726	967	75
Total	14,984	20,825	72

Southern California

For Southern California efficiencies are based on a studies completed for IID.

DEMAND AT THE HEAD OF THE REGION

SWAP's analysis of agricultural water demand is at the level of the farm gate and represents the aggregated demand of all farms within each modeling unit. SWAP does not distinguish between surface water and groundwater supplies. In contrast, CALVIN must distinguish between surface water and groundwater and distinguish between aggregated applied water demand at the farm gate and demand for the region. Several factors need to be considered to undertake this conversion:

- Conveyance losses from the principal points of diversion to water districts within the region;
- Distribution losses within a district from district laterals; and
- Tailwater reuse within a district and between districts within the region.

Within an agricultural region, field runoff and tailwater may be reused to supplement water supplies of downstream farms. The amount of reuse tends to increase as larger agricultural areas are considered. Corresponding gains in water use efficiency are off-set by increasing conveyance losses. Net water use in an area is usually lower than the sum of applied water. However in some areas, such as the Colorado River region where losses from the All-American Canal are high and reuse is limited due to poor water quality, net water use is higher than applied water (DWR 1994). *It is assumed that tailwater reuse within a farm has already been accounted for in the estimate of applied water demand*. Figures K-2 and K-3 show a conceptual model for the interaction of these different factors. Several points arise from the analysis shown in the figures.

- Reuse affects water available to the farmer, so that farm efficiencies used or calculated from a farm production model differ from efficiencies at the head of the district or at the head of the region,
- DWR's Bulletin 160 values for applied water are assumed to represent (d+g)/(1-rs),
- It is assumed that groundwater is pumped from on-farm wells and is not subject to district distribution losses[8].

Tailwater Reuse

Reuse occurs at many different levels. For fields where surface runoff is collected and returned to the on-farm irrigation supply, the amount of water returned is not considered to be an additional supply. Thus applied water use estimated by DWR includes on-farm reuse. The farmer in SWAP 'sees' a volume of water (d+g)/(1-rs). In contrast, the water available at the regional supply node is (d + g). To account for reuse a gain factor of 1/(1-rs) is applied to the links downstream of the regional supply node. The value function is applied to the outflow from this link. For calibration of CVPM, reuse factors were used to calculate water available to the farmer. These factors are given in Table K-26. For modeling purposes the reuse factor is assumed to be constant throughout the growing season. The value for CVPM 6 is very high. This suggests a combination of high surface runoff and an efficient tailwater recovery program.

[8] Data from the CVPM model suggest that some groundwater pumping does occur at district level. For CVPM Regions 6 and 8, groundwater pumping by the district accounts for 20% of the total pumping. For CVPM Regions 10, 15, 19, 20, and 21, district pumping is 10% of the total pumping.

Table K-26. Reuse Factors

Region	Reuse Factor	Region	Reuse Factor
CVPM 1	1.00	CVPM 11	1.10
CVPM 2	1.00	CVPM 12	1.10
CVPM 3A	1.08	CVPM 13	1.10
CVPM 3B	1.10	CVPM 14	1.03
CVPM 4	1.13	CVPM 15	1.05
CVPM 5	1.06	CVPM 16	1.10
CVPM 6	1.34	CVPM 17	1.10
CVPM 7	1.08	CVPM 18	1.10
CVPM 8	1.10	CVPM 19	1.01
CVPM 9	1.10	CVPM 20	1.10
CVPM 10	1.05	CVPM 21	1.01

Source: CVPEIS CD-ROM disc 2, Ag-Econ\Naa\Model\Cesdat95.gms

Conveyance and Distribution Losses

Losses from the conveyance and distribution systems are caused through evaporation and seepage. Seepage may be subsequently used consumptively through evaporation and evapotranspiration or contribute to groundwater percolation. In CALVIN, conveyance and distribution losses are combined and modeled using a gain factor on the link supplying the regional supply node from the principal point(s) of diversion. It is assumed that all groundwater is extracted by local farm wells and is not subject to conveyance losses.

Distribution Losses

Distribution losses are those associated with the transport of water from the edge of the region to the individual irrigation districts and within the district to the farm gates. There are relatively little data available on distribution losses from laterals within irrigation districts. Losses will depend on the type of distribution system and for unlined open canal systems the soil texture. Westlands WD, for example, uses a piped distribution system, partly pressurized, partly flowing under gravity. Distribution losses from this system are estimated at 2.5% (DWR SWAM input data). In contrast, the older districts in CVPM regions 15 and 17, located on the lighter soils of the Kings River alluvial fan have distribution losses from an unlined canal system of approximately 20%. Table K-27 gives a breakdown of losses in the San Joaquin Valley. These estimates were developed by the San Joaquin District of DWR in the 1980s for SWAM – a component of the Hydrologic–Economic Model of the San Joaquin Valley.

Table K-27. San Joaquin Valley Distribution Losses

Region	DAU	Non-Recov Loss (%)	Recov Loss (%)	Projected 2020 AW (taf)	Av Non-Recov Loss (taf)	Av Recov Loss (taf)	Av Total Loss for Region (%)
CVPM 10	216	2.0	15.0	655	2.0	15.0	17.0
CVPM 11	205	-	-	278	3.0	15.0	18.0
	206	3.0	15.0	306			
	207	3.0	15.0	219			
CVPM 12	208	3.0	15.0	376	2.6	14.2	16.7
	209	2.0	13.0	274			
CVPM 13	210	2.0	13.0	291	2.0	2.0	12.4
	211	2.0	15.0	231			
	212	2.0	10.0	339			
	213	2.0	15.0	348			
	214	2.0	5.0	290			
	215	2.0	5.0	306			
CVPM 14	244	0.5	2.0	761	0.5	0.5	2.2
	245	0.5	1.0	275			
CVPM 15	235	2.0	5.0	369	1.8	6.3	8.1
	237	2.0	20.0	386			
	238	2.0	2.0	358			
	241	2.0	2.0	430			
	246	0.5	1.0	265			
CVPM 16	233	2.0	13.0	326	1.4	9.6	8.1
	234	0.5	5.0	239			
CVPM 17	236	2.0	20.0	345	1.6	13.1	14.7
	239	2.0	15.0	338			
	240	0.5	2.0	271			
CVPM 18	242	2.0	2.0	596	2.0	8.3	10.3
	243	2.0	15.0	562			
CVPM 19	255	2.0	15.0	409	1.3	8.4	9.7
	259	0.5	1.0	364			
	260	-	-	261			
CVPM 20	256	1.0	15.0	443	0.8	10.0	10.8
	257	0.5	2.0	279			
CVPM 21	254	2.0	13.0	416	1.2	6.1	7.3
	258	1.0	2.0	368			
	261	0.5	2.0	327			

Source: SWAM input data file: swmbpa1.dat

For the Colorado River Region, agriculture is aggregated into large distinct irrigation districts. An analysis of deliveries to and within IID shows that losses from the mixture of lined and unlined canals and laterals accounts for 6.5 % of the supply. Combined conveyance and distribution losses are estimated by USBR (quoted in IID 1998) to be 87% for CVWD, 90% for IID and 89% for the Bard Reservation Unit. Based on IID data, a figure of 7% has been assumed to be representative for all agricultural regions within Southern California.

Conveyance Losses

Conveyance losses are those associated with the transport of water from the point of diversion to the edge of the CVPM region. Table K-27 summarizes the assumed conveyance losses used in CALVIN for the Central Valley. Loss factors are taken from CVGSM input data (cvgsm/input/cnjdvsp2.nda). It was originally assumed that CVGSM conveyance losses include district distribution losses as agriculture water demand is estimated from crop ETAW and on-farm efficiencies. However, this assumption is contrary to the explanation given by Montgomery Watson (1990 p3-19). It is now assumed that losses from district laterals, in the form of seepage to groundwater, are included implicitly as part of the soil water budget for a CVPM region. For example, deliveries from the Friant-Kern canal are subject to a 9% loss conveyance loss but no explicit distribution loss. However some 'conveyance' losses seem to be very high. Deliveries from the Kings River to adjacent land are subject to a 20% loss. It is believed that data from SWAM provide a more reliable estimate of combined distribution and conveyance losses outside of project canals (DMC, California Aqueduct, Friant-Kern Canal, Cross-Valley Canal).

For IID, conveyance and distribution losses have been combined and are described in the previous section. The Palo Verde ID is located on the right bank of the Colorado River. It is assumed that there are no conveyance losses from the point of diversion to the edge of the district.

Losses from Inter-Regional Water Transfers

CALVIN explicitly represents several major canals, pipelines and aqueducts that are used for inter-regional transfers and supply more than one agricultural unit. These conveyance systems include the:

- California Aqueduct/San Luis Canal (including south, west and east branches),
- Delta Mendota Canal,
- Friant-Kern Canal,
- Cross-Valley Canal,
- Los Angeles Aqueduct,
- Colorado Aqueduct, and
- All American Canal

Conveyance losses for the California Aqueduct and the Delta Mendota Canal are taken from DWRSIM (run 2020D09B-CALFED-514). Losses for these canals have been preprocessed and are represented as a fixed time series with return flows to the sink. This approach is preferable to the use of gains where losses are a non-linear function of flow. Control structures along the canals maintain a relatively constant head. Losses for the other canals and aqueducts are modeled using gain factors.

DWRSIM represents losses for the DMC at Control Point 703 (Upper DMC losses) and at Control Point 733 – (Mendota Pool losses). The average loss at these two nodes represents 4.3% (115taf/yr) of the diversion at Tracy Pumping Station. This compares with 120 taf/yr assumed by both PROSIM (Node 52 –Upper DMC and Node 55-Lower DMC) and CVGSM for the total DMC loss. Losses associated with diversions at Mendota Pool in CVGSM are 20% or 172 taf/yr. It is assumed that these represent conveyance losses the district and are not part of the DMC conveyance loss.

A gain of 0.91 for the Friant-Kern Canal is taken from CVGSM input data.

The All-American Canal stretches 82 miles from Imperial Dam on the Colorado River to the head of the Westside Main Canal on the west side of IID. At Pilot Knob water is returned to the Colorado River for delivery to Mexico. The Coachella Canal headworks are located downstream at Drop No1. For the conceptual framework developed for CALVIN, losses on the All-American Canal upstream of the East Highline Canal, the first point of diversion for IID, are attributed to the All-American Canal. Downstream losses on the All-American are combined with in-district canal and lateral losses for IID. A 1998 water use assessment study estimated seepage and evaporation losses between Pilot Knob and the East Highline Canal to be approximately 3%.

Operational Spills

Operational spills return directly to the surface water system and do not affect agricultural production. Due to the difficulty of representing them in CALVIN, they should be excluded from the surface water diversions. Ideally the canal loss fraction should be increased to account for conveyance losses associated with the transport of this 'operational' water. However little information has been collected on the magnitude of operational spills. Currently operational spills have been ignored. It is believed that they are not included in the CVGSM deliveries.

> *"Special considerations were given to subregion 1 and subregion 9. In subregion 1 PROSIM provides CVP project surface water deliveries to this region at PROSIM node 5. These deliveries include large quantities of water that never reaches the farm, but is needed to effectively transport the project water that is used on the farms. The transport water runs parallel with the Sacramento River and eventually returns to the river. Hence, the stream diversions used in PROSIM are reduced to represent actual water for crop needs." (USBR 1997, Draft Methodology/Modeling Technical Appendix CVGSM M/M, p III-12)*

Table K-28. Conveyance Loss Factors for Agricultural Deliveries

Region	Canal	CVGSM Av Annual delivery (taf)	Recoverable Loss	Non-Recoverable Loss	Gain Factor	Total Average Loss
CVPM 1	Whiskeytown Conduit	14.2	0.00	0.03	0.97	
	Bella Vista Conduit	22.2	0.00	0.03	0.97	
	Sacramento River (Keswick to Red Bluff) to DSA 58	111.7	0.00	0.03	0.97	
	Sub-total CVPM 1	**148.1**			**0.97**	0.030
CVPM 2	Corning Canal	34.7	0.10	0.02	0.88	
	Stony Creek (total for North and South Canals)	99.8	0.04	0.01	0.95	
	Tehama-Colusa Canal to DSA 10 (Irrigation Supply)	1.9	0.04	0.01	0.95	
	Sacramento River (Red Bluff to Ord Ferry) to DSA 10	5.5	0.00	0.03	0.97	
	Sub-total CVPM 2	**141.9**			**0.934**	0.066
CVPM 3	Tehama-Colusa Canal to DSA 12 (Irrigation Supply)	267.7	0.04	0.01	0.95	
	Glenn Colusa Canal (Iinc Stony Creek diversion)	778.4	0.00	0.04	0.96	
	Colusa Basin Drain for Irrigation Supply	58.1	0.15	0.05	0.8	
	Sacramento River Right Bank Diverters to DSA 12	205.7	0.00	0.03	0.97	
	Sub-total CVPM 3	**1309.9**			**0.952**	0.048
CVPM 4	Sacramento River (Ord Ferry to Knights Landing) to DSA 15	**697.5**	0	0.03	**0.97**	0.030
CVPM 5	Tarr Ditch	16	0.08	0.02	0.9	
	Bear River Diversion by Camp Far West ID	6	0.00	0.03	0.97	
	Palermo Canal	8	0.10	0.02	0.88	
	Forbestown (Oroville-Wyandotte) Ditch	6	0.16	0.04	0.8	
	Miners Ranch Canal (Irrigation Only)	8	0.10	0.02	0.88	
	Feather River Diversions to DSA 69	991.3	0.00	0.03	0.97	
	Riparian Diversions from Yuba River (Total)	173	0.00	0.03	0.97	
	Sacramento River (Ord Ferry to Knights Landing) to DSA 69	19.5	0.00	0.03	0.97	
	Sub-total CVPM 5	**1227.8**			**0.967**	0.033
CVPM 6	Sacramento River Right Bank (Knights Lnd to Sacramento) to DSA 65	72.9	0.00	0.03	0.97	
	Knights Landing Ridge Cut Diversions for Irrigation Supply	24	0.00	0.03	0.97	
	Capay Irrigation	127.9	0.00	0.03	0.97	
	Putah South Canal to DSA 65	149.9	0.10	0.02	0.88	
	Sub-total CVPM 6	**374.7**			**0.934**	0.066
CVPM 7	Feather River Left Bank Diversions to DSA 70	9.9	0.00	0.03	0.97	
	South Sutter Diversions Exported to DSA 70	106.7	0.10	0.02	0.88	
	DSA 70 Sacramento River (Knights Lnd to Sac) not incl. City of Sac	146.1	0.00	0.03	0.97	
	Sub-total CVPM 7	**262.7**			**0.933**	0.067
CVPM 8	Folsom South Canal	48.8	0.10	0.02	0.88	
	Riparian Diversions from Cosumnes River	11.8	0.00	0.03	0.97	
	Riparian Diversions from Mokelumne River	86.8	0.00	0.03	0.97	
	Central San Joaquin ID - Supply from Stanislaus River	19.1	0.15	0.03	0.82	
	Sub-total CVPM 8	**166.5**			**0.926**	0.074

Table K-28. Conveyance Loss Factors for Agricultural Deliveries (cont.)

Region	Canal	CVGSM Av Annual delivery (taf)	Recoverable Loss	Non-Recoverable Loss	Gain Factor	Total Average Loss
CVPM 9	Delta Mendota Canal to DSA Subregion 49a	54.0	0.00	0.00	1	
	Total Surface Water Diversions to DSA 55	966.0	0.00	0.00	1	
	Sub-total CVPM 9	**1020.00**			**1.000**	0.000
CVPM 10	Riparian Diversions from San Joaquin River (Fremont Ford to Vernalis)	168.3	0.00	0.03	0.97	
	Delta Mendota Canal to DSA Subregion 49a	508.4	0.00	0.00	1	
	Mendota Pool to DSA Subregion 49a	700.8	0.16	0.04	0.8	
	San Luis Canal to San Luis, Panoche & Pacheco WDs	110.5	0.00	0.00	1	
	San Luis Canal Miscellaneous	1.9	0.00	0.00	1	
	California Aqueduct to Oak Flat Wd in DSA 49a	4.6	0.00	0.00	1	
	Sub-total CVPM 10	**1494.51**			**0.903**	0.097
CVPM 11	Riparian Diversions from San Joaquin River (Fremont Ford to Vernalis)	12.5	0.00	0.03	0.97	
	Oakdale Canal Diversion from Stanislaus River (for OID South)	164.9	0.15	0.03	0.82	
	Oakdale ID North	127.4	0.15	0.03	0.82	
	South San Joaquin ID - Supply from South San Joaquin Main Canal	291.4	0.15	0.03	0.82	
	Riparian Diversions from Stanislaus River	48.0	0.00	0.03	0.97	
	Riparian Diversions from Tuolumnne River Right Bank	9.5	0.00	0.03	0.97	
	Modesto ID - Supply from Modesto Canal	354.9	0.15	0.03	0.82	
	Sub-total CVPM 11	**1008.6**			**0.830**	0.170
CVPM 12	Riparian Diversions from San Joaquin River (Fremont Ford to Vernalis)	18.7	0.00	0.03	0.97	
	Riparian Diversions from Tuolumnne River Left Bank	7.4	0.00	0.03	0.97	
	Merced ID Northside Canal Diversions from Merced River	23.1	0.15	0.03	0.82	
	Riparian Diversions from Merced River Right Bank	60.6	0.00	0.03	0.97	
	Turlock ID - Supply from Turlock Canal	564.1	0.15	0.03	0.82	
	Sub-total CVPM 12	**673.9**			**0.839**	0.161
CVPM 13	Riparian Diversions from San Joaquin River (Fremont Ford to Vernalis)	2.1	0.00	0.03	0.97	
	Mendota Pool to DSA Subregion 49d	58.4	0.16	0.04	0.8	
	Riparian Diversions from Merced River Left Bank	21.2	0.00	0.03	0.97	
	Merced ID Main Canal Diversion from Merced River	504.8	0.15	0.03	0.82	
	Madera Canal	253.6	0.072	0.018	0.91	
	Diversions from Chowchilla River (not including Madera Canal)	56.4	0.00	0.03	0.97	
	Diversions from Fresno River (not including Madera Canal)	52.8	0.00	0.03	0.97	
	Riparian Diversions from San Joaquin River (Friant to Gravelly Ford)	5.9	0.00	0.04	0.48	
	Riparian Diversions from San Joaquin River (Mendota to Merced)	0	0.00	0.04	0.96	
	Sub-total CVPM 13	**955.2**			**0.861**	0.139

Table K-28. Conveyance Loss Factors for Agricultural Deliveries (cont.)

Region	Canal	CVGSM Av Annual delivery (taf)	Recoverable Loss	Non-Recoverable Loss	Gain Factor	Total Average Loss
CVPM 14	Mendota Pool to DSA Subregion 60a	22.3	0.16	0.04	0.8	
	San Luis Canal to Westlands Water District	880	0.00	0.00	1	
	Sub-total CVPM 14	**902.3**			**0.995**	0.005
CVPM 15	Mendota Pool to DSA Subregion 60b	78.3	0.16	0.04	0.8	
	Friant-Kern Canal to DSA Subregion 60b	1.7	0.072	0.018	0.91	
	Kaweah River to Corcoran ID	7.2	0.14	0.03	0.83	
	California Aqueduct to DSA Subregion 60b	216.4	0.00	0.00	1	
	Diversion A from Main Stem of Kings River	420.5	0.16	0.04	0.8	
	Diversion B from South Fork Kings River	29.7	0.16	0.04	0.8	
	Diversion C from North Fork Kings River	25.3	0.16	0.04	0.8	
	Sub-total CVPM 15	**779.1**			**0.856**	0.144
CVPM 16	Riparian Diversions from San Joaquin River (Friant to Gravelly Ford)	5.9	0.00	0.04	0.96	
	Friant-Kern Canal to DSA Subregion 60c	25.6	0.072	0.018	0.91	
	Kings River to Fresno ID (not including CVP)	437.6	0.12	0.03	0.85	
	Sub-total CVPM 16	**469.1**			**0.844**	0.156
CVPM 17	Friant-Kern Canal to DSA Subregion 60d	48.2	0.072	0.018	0.91	
	Kings River to Consolidated ID (not including CVP)	231.5	0.16	0.04	0.8	
	Kings River to Alta ID (not including CVP)	154.8	0.16	0.04	0.8	
	Sub-total CVPM 17	**434.5**			**0.812**	0.188
CVPM 18	Friant-Kern Canal to DSA Subregion 60e	678.3	0.072	0.018	0.91	
	Kaweah River - Partition A, B, C & D	359	0.14	0.03	0.83	
	Tule River	41.6	0.12	0.03	0.85	
	Sub-total CVPM 18	**1078.9**			**0.881**	0.119
CVPM 19	Friant-Kern Canal to DSA Subregion 60f	13.4	0.072	0.018	0.91	
	California Aqueduct to DSA Subregion 60f	508.9	0.00	0.00	1	
	Cross Valley Canal to DSA Subregion 60f	6.7	0.08	0.02	0.9	
	Kern River to DSA Subregion 60f (Irrigation Supply)	65.6	0.07	0.01	0.92	
	Sub-total CVPM 19	**594.6**			**0.988**	0.012
CVPM 20	Friant-Kern Canal to DSA Subregion 60g	260.9	0.072	0.018	0.91	
	Cross Valley Canal to DSA Subregion 60g	14.7	0.03	0.02	0.95	
	Kern River to Subregion DSA 60g (Irrigation Supply)	121.7	0.13	0.03	0.84	
	Sub-total CVPM 20	397.3			**0.890**	0.110
CVPM 21	Friant-Kern Canal to DSA Subregion 60h	108.5	0.072	0.018	0.91	
	California Aqueduct to DSA Subregion 60h	326.4	0.00	0.00	1	
	Cross Valley Canal to DSA Subregion 60h	90.7	0.04	0.02	0.96	
	Kern River to DSA Subregion 60h (Irrigation Supply)	178	0.08	0.02	0.9	
	Sub-total CVPM 21	**703.6**			**0.956**	0.044

Figure K-2. Conceptual Model of Water Use

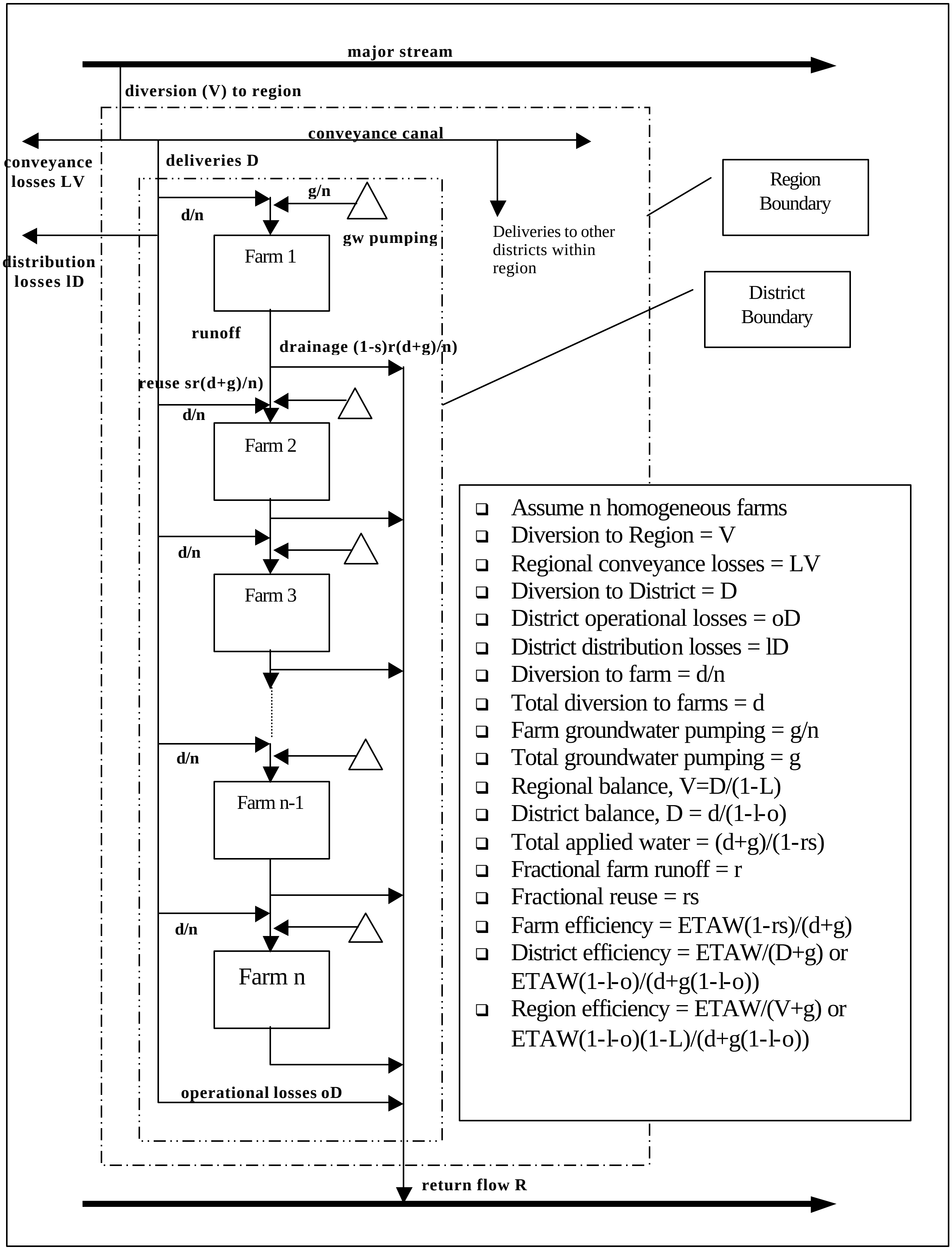
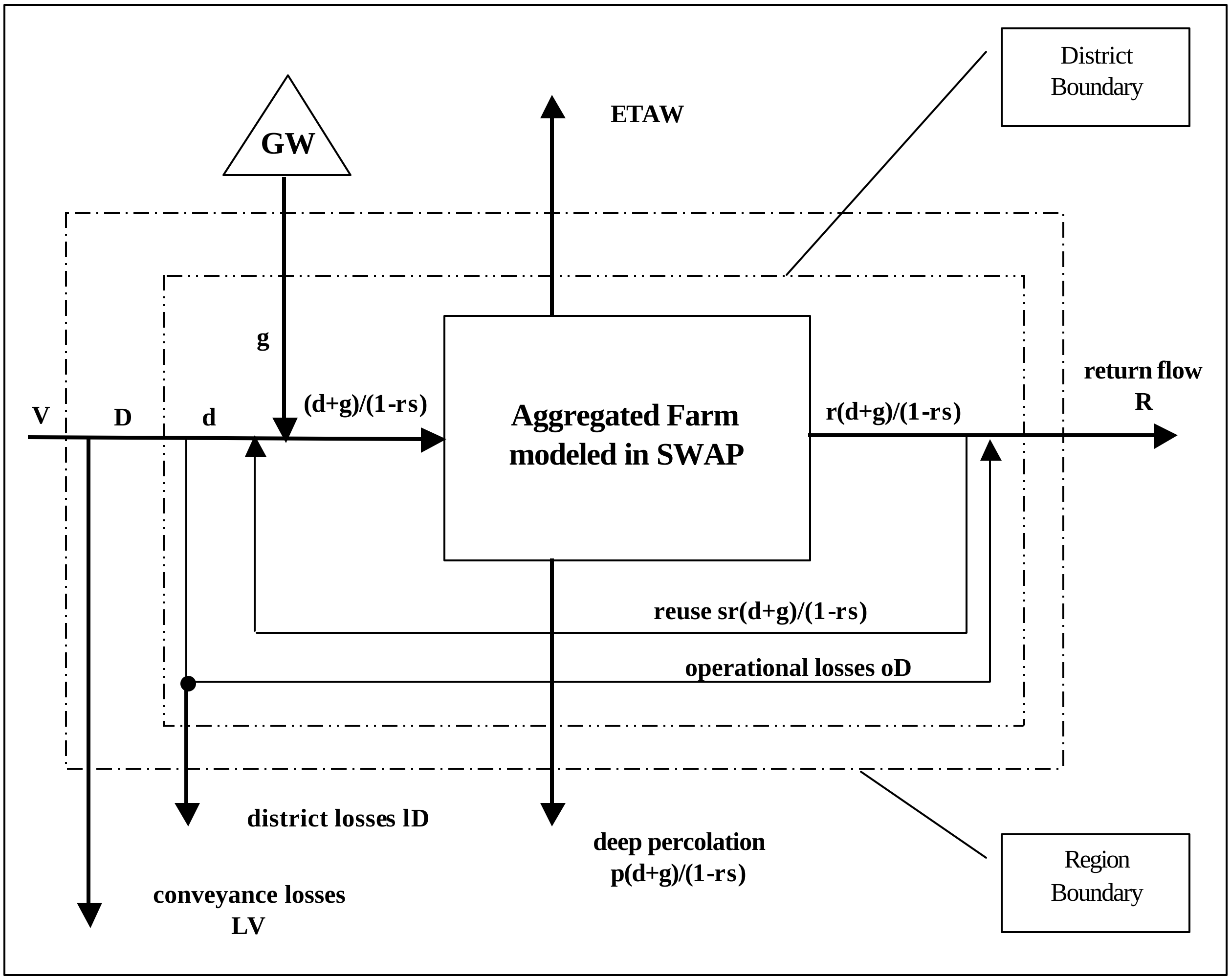


Figure K-3. Conceptual Water Balance



Non-Recoverable Losses

It is important to distinguish between recoverable and non-recoverable losses. Recoverable losses include runoff, deep percolation and seepage where they may be reapplied. Reuse of recovered water may involve additional cost through pumping and the recovered water may be of significantly lower water quality. Non-recoverable losses cannot be recovered (other than by the hydrologic cycle) and represent a depletion of the water resource. Accurate estimates of non-recoverable losses are as important as estimates of other model inflows and outflows. Depletion of the water resource occurs predominantly through crop evapotranspiration but with additional depletion occurring due to:

- Evaporation from canals, laterals and farm reservoirs,
- Percolation to a saline aquifer,
- Disposal of sub-surface drainage using evaporation ponds, and
- Surface runoff to a saline sink or the ocean.

Central Valley

In 1984 the Central Valley Water Use Study Committee (CVWUSC) was formed to explore possible water savings through increases in irrigation efficiency and improved management in the Central Valley. The Committee, composed of UC faculty and staff from federal, state and local water agencies, focused on possible reductions in non-recoverable losses. Losses associated with riparian vegetation and evaporation from water surfaces were estimated from 1:24,000 scale mapping and aerial photographs. Losses from canal distribution systems to small to be identified at 1:24,000 scale mapping (< 60 ft) were estimated from hydrologic balance accounting by DWR. These additional losses totaled 157 taf/yr for a region with an estimated ETAW of 15,290 taf/yr, i.e. approximately 2% of ETAW.

CVGSM contains parameters for losses from the larger conveyance channels. Associated with each surface water diversion in the model are recoverable loss fractions (FRACRL) and non-recoverable loss fractions (FRACNL). These are constant values that do not vary with time and are given in Unit 9 input file 'cnjdvsp2.nda and in Table K-31. Non-recoverable losses are only applied to surface water deliveries. As a fraction of ETAW they account for an additional 2% (not including losses from project canals). CVGSM does not account explicitly for any in-district or on-farm non-recoverable loss.

In contrast to the relatively low figures estimated by CVWUSC and used in CVGSM, for the depletion analysis DWR assumes that non-recoverable losses in the mountain basins of the Central Valley are 15% of ETAW and 10% of ETAW within the Central Valley floor (DWR 1991).

On the West Side of the San Joaquin, high concentrations of salt and selenium in tile drainage make reuse of this water hazardous. Currently drainage water discharges into the San Joaquin River, or is evaporated in salt ponds. In Westlands WD, the tile drains have been sealed so that irrigation is adding saline drainage water to the shallow aquifer. Table K-29 lists the area of tile drainage on the West Side. In these areas, all deep percolation should be regarded as a non-recoverable loss.

Table K-29. Sub-Surface Drainage within the Central Valley

Region	Tile Drained Dist	Area (ac)	Drains to
CVPM 10	Broadview WD	6,500	Salt & Mud Sloughs to San Joaquin River
	Pacheco WD	3,500	Camp 13 drain to San Joaquin River
	Panoche WD inside district	22,000	Salt slough to San Joaquin River
	Panoche WD outside district	3,300	
	San Luis WD inside district	3,600	Mud Slough to San Joaquin River
	San Luis WD outside district	800	
	Central California ID, Firebaugh CC, Widren WD	13,760	Salt slough to San Joaquin River
	Charleston DD	1,100	Salt slough to San Joaquin River (not included)
	Newman DD	3,100	San Joaquin River
	Spanish Grant, Moran RD, Marshall RD, Combined Drain	1,550	San Joaquin River
	Romona Lake Drain	1,360	San Joaquin River
	Patterson WD	1,650	San Joaquin River
	Richie Slough	350	San Joaquin River
	Hospital Creek, El Solyo WD	1,600	San Joaquin River
	Mc Cracken RD	400	San Joaquin River
	Sub-Total	64,570	
CVPM 14	Westlands WD	42,000	Kesterson Res. via San Luis Drain Operated 1978-1986 108 miles of drain
	Sub-Total	42,000	
	Total	106,570	

Source: San Joaquin Valley Drainage Program 1990. "Documentation of the Use of Data, Analysis, and Evaluation Processes that Resulted in the SJVDP recommended Plan." Technical Information Record, September 1990.

<u>Southern California</u>

The non-recoverable loss fraction varies between the three agricultural regions modeled in Southern California. IID, located in Imperial Valley is supplied entirely from the All American Canal. Groundwater within the District is of low quality and is not used for irrigation. Soils within the District are predominantly heavy clays with very restricted infiltration capacities. Sub-surface drainage is used to control the water table and facilitate leaching. All sub-surface drainage and any surface runoff are discharged via an open drainage system and the New and Alamo rivers into the Salton Sea. All water delivered to the District, which is not consumptively used by the crop, can be considered as a non-recoverable loss.

The Coachella Valley ID is similar to IID except that some of the District is located on lighter alluvial soils and groundwater is of a suitable quality for irrigation. Like IID, all surface return flows drain to the Salton Sea. Non-recoverable losses for agriculture located adjacent to the Colorado River are relatively small.

RETURN FLOWS

Non-consumptive use of agricultural water supplies returns to either the groundwater as deep percolation or the surface water system as tailwater. For CALVIN, these two components need to be separated as indicated in Figure K-1. It is assumed that there are no operational spills so that all recoverable losses associated with the conveyance and distribution system return to the groundwater system[9].

In CALVIN, many of the groundwater flow components are preprocessed and aggregated into a single net inflow. These components include natural recharge from rainfall, accretions from streamflow, lateral inter-basin groundwater movement and seepage losses from conveyance and distribution channels. These flow components are based on results from the CVGSM No-Action Alternative model run. Only groundwater pumping and deep percolation of irrigation water is modeled dynamically in CALVIN

Central Valley

Basin efficiency factors have been determined by DWR for use in the depletion analysis. These factors are the ratio of evapotranspiration of applied water (ETAW) to the "prime" diversion supply required for a given basin or service area (Roos 1976). After consumptive use the remainder of the prime supply after allowing for non-recoverable losses leaves the area as surface return flow. The prime diversion supply is the sum of diverted surface water entering the service area and net groundwater pumping. The latter is the total pumping less recharge from irrigation. The prime ground water supply is water not derived from percolation of previously applied irrigation water and canal seepage. Basin efficiency factors were originally estimated from 1966-71 data. These estimates are updated by DWR's district offices as part of the Bulletin 160 supporting data. Basin efficiencies are calculated from: (a) measured surface water diversions, (b) estimated net groundwater pumping, and (c) measured surface water return flows. Irrigation return flow rates as a percentage of supply varies throughout the season. Typically mid-summer percentage return flows are lower than early and late season return flows. Either efficiencies tend to be high in the mid-summer in many service areas or the return flow is relatively constant, independent of diversions. In the Central Sacramento Valley, return flow rates will be affected by drainage of rice fields. In DWRSIM, any errors in basin efficiency factors do not have a large impact as water is simply routed through the service area and returns to the stream network.

CVGSM provides estimates of both surface and groundwater return flows from irrigation. The sum of diverted water, less conveyance losses, plus groundwater pumping is applied to the finite elements within an agricultural modeling unit (water is pro-rated between finite elements according to the agricultural area of each element). Surface runoff from the region is initially calculated as a fixed percentage of deliveries to the region. Crop evapotranspiration is deducted from the remaining volume to obtain the volume of deep percolation. If this volume expressed as an average monthly depth exceeds the infiltration capacity of the soil, the amount of surface runoff is increased until the deep percolation equals the infiltration capacity. The CVGSM soil water budget should not be regarded as representing the process of irrigation, runoff and infiltration at field level, but rather a method of forcing water into the soil profile. Surface runoff is the volume of water that returns to the stream network and does *not* represent runoff from farms that may be subsequently reused within the CVPM region (Montgomery Watson 1993). As groundwater deep percolation is calculated by subtraction, it represents all groundwater recharge, whether directly from irrigation or from seepage from canals.

[9] Water that is diverted but remains in the main conveyance system and returns to the surface stream network is not modeled in CALVIN. Diversions should not include this through water.

Surface return flows to the stream network as a fixed percentage of the agricultural water supply are input as part of the parameter data file cnjparm.dat in input Unit 7 (AGRTN factors). The return flow factors are given in Table K-31. It is unclear how these factors have been derived. Actual runoff calculated dynamically in CVGSM is very sensitive to the assumed soil infiltration rates and the assumed uniformity of distribution.

Table K-30 gives monthly basin efficiency factors that are used in DWR's depletion analysis. The low observed efficiencies in the Central Sacramento Valley in September may reflect drainage of rice fields. In the CU model, basin efficiencies are applied to diversions for both agricultural and urban landscape demands[10]. The basin efficiency factors cannot be used directly in CALVIN as they exclude the fraction of applied water that percolates to the groundwater. However, based on an assumed non-recoverable loss of 10%, the surface return flow can be expressed in terms of ETAW:

$$\text{Surface Return Flow} = ETAW * \left(\frac{1}{\text{Basin Efficiency Factor}} - 1.1 \right)$$

Table K-30. DWR's Basin Efficiency Factors (%)

DA	CVPM		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
58	1	Median	65	65	65	65	65	65	65	65	65	65	65	65
		Max												
10	2	Median	70	70	70	70	70	70	70	70	70	70	70	70
		Max	80	80	80	80	80	80	80	80	80	80	80	80
12	3	Median	70	70	70	70	70	70	79	65	75	78	65	35
		Max						90	79	65		78	70	50
15	4	Median	70	70	70	70	70	70	79	65	75	78	65	35
		Max												
69	5	Median	40	70	70	70	70	70	70	65	75	80	75	30
		Max	85	85	85	85	85	85	85	85	85	85	85	85
65	6	Median	78	80	80	80	80	80	84	87	88	89	88	85
		Max												
70	7	Median	65	65	65	65	65	65	65	65	65	65	65	65
		Max												
59	8	Median	75	80	80	80	80	80	77	80	81	82	81	76
		Max												
55[1]	9													
49	10-13	Median	60	80	80	80	80	65	77	81	84	85	84	76

Notes
1. Basin efficiency factors are not calculated for the Delta (DA55)
2. Basin efficency factors for DA49 are taken from Roos (1976)
3. Blank max values indicate they are the same as median i.e. no inter-annual variation

Source: Consumptive Use Model, DWR.

Table K-31 compares return flows between CVGSM and the depletion analysis. The differences between the two models are significant.

[10] For domestic water supply, DWR assumes 100% return flow

Table K-31. Central Valley Surface Return Flows

		CVGSM			DWR's Depletion Analysis			
DA	CVPM	Surface return factor	DP/ETAW	RF/ETAW	Efficiency (%)	Basin efficiency factor	Non-recoverable losses (%)	RF/ETAW
58	1	0.080	0.29	0.35	0.61	0.65	15	0.32
10	2	0.080	0.29	0.12	0.71	0.70	10	0.25
12	3	0.080	0.33	0.22	0.64	0.71	10	0.39
15	4	0.080	0.07	0.48	0.64	0.71	10	0.39
69	5	0.080	0.35	0.24	0.63	0.69	10	0.42
65	6	0.080	0.15	0.25	0.72	0.87	10	0.37
70	7	0.080	0.34	0.47	0.55	0.65	10	0.49
59	8	0.080	0.07	0.42	0.67	0.80	10	0.37
55	9	0.030	0.20	0.07	0.79	-	-	-
49A	10	0.200	0.14	0.54	0.59	0.80	10	0.51
49B	11	0.150	0.50	0.26	0.57	0.80	10	0.35
49C	12	0.200	0.11	0.41	0.66	0.80	10	0.27
49D	13	0.005	0.09	0.28	0.73	0.80	10	0.27
60A	14	0.005	0.35	0.01	0.74	-	-	-
60B	15	0.005	0.12	0.27	0.72	-	-	-
60C	16	0.100	0.12	0.70	0.55	-	-	-
60D	17	0.005	0.16	0.22	0.73	-	-	-
60E	18	0.005	0.45	0.01	0.68	-	-	-
60F	19	0.005	0.41	0.01	0.70	-	-	-
60G	20	0.015	0.26	0.18	0.69	-	-	-
60H	21	0.005	0.45	0.03	0.67	-	-	-

Notes: DP= deep percolation, RF=surface return flow

Southern California

For Southern California it is assumed that there is no reuse other than groundwater pumping of previously percolated applied water within CVID. For IID and CVID, surface runoff and tile water is of low quality and drains into the Salton Sea. There is no groundwater pumping within IID.

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ATTACHMENT A: SWAP INPUT (CENTRAL VALLEY ONLY)

From File: CAPDAT21.GMS

TABLE ETAW(G,J) evapotranspiration (acre-feet per acre)

	COTT	DRCE	FDDR	GRPS	MFLD	MGRN	ORCH	PAST	SBTS	STRP	TOMT	TRCK
V01	0.00	0.00	3.09	2.00	2.00	0.64	2.71	2.93	0.00	2.00	0.00	1.19
V02	0.00	3.31	3.19	2.00	1.95	0.50	2.70	3.22	2.70	1.92	2.00	1.32
V03	2.89	3.30	3.13	1.99	1.83	0.52	2.63	3.05	2.66	2.01	2.10	1.33
V04	2.88	3.35	3.13	0.00	1.39	0.55	2.68	3.26	2.63	0.00	2.10	1.29
V05	2.80	3.34	3.12	1.75	1.50	0.55	2.56	3.08	2.46	2.00	2.09	1.20
V06	0.00	3.42	2.99	1.89	1.42	0.60	2.24	3.32	2.31	0.00	2.10	1.19
V07	0.00	3.42	2.99	1.89	1.50	0.60	2.51	2.96	2.31	0.00	2.10	1.19
V08	0.00	3.58	2.99	1.89	1.54	0.69	2.52	3.20	2.33	0.00	2.10	1.12
V09	0.00	3.30	2.72	1.79	1.37	0.60	2.42	2.99	2.31	0.00	1.89	1.70
V10	2.50	3.60	3.10	2.10	1.59	0.99	2.59	3.30	2.50	2.00	2.20	1.10
V11	0.00	3.46	3.01	1.89	1.77	0.62	2.04	3.10	0.00	0.00	2.10	1.18
V12	0.00	0.00	2.88	1.93	1.92	0.68	2.21	3.08	0.00	1.80	0.00	1.29
V13	2.45	3.40	3.00	2.07	1.87	0.74	2.32	3.12	2.41	1.82	2.10	1.30
V14	2.31	0.00	3.40	1.90	2.10	1.00	2.59	3.40	2.60	2.00	2.00	1.30
V15	2.50	3.60	2.84	2.20	2.05	1.00	2.66	3.41	2.60	2.00	2.30	1.38
V16	2.40	0.00	2.90	2.00	1.96	0.67	2.32	3.08	0.00	1.77	0.00	1.40
V17	2.33	0.00	2.83	2.06	1.79	0.62	2.51	3.08	2.40	1.76	0.00	1.33
V18	2.50	0.00	3.10	2.10	1.97	0.90	2.69	3.30	2.50	1.90	2.00	1.30
V19	2.50	0.00	3.30	2.20	1.73	1.20	2.54	3.50	2.70	2.20	2.30	1.35
V20	2.50	0.00	3.20	2.20	1.82	1.00	2.46	3.40	0.00	2.00	2.30	1.40
V21	2.50	0.00	3.29	2.20	1.88	1.13	2.59	3.46	2.70	2.00	2.30	1.38

TABLE AW(G,J) base applied water (acre-feet per acre)

	COTT	DRCE	FDDR	GRPS	MFLD	MGRN	ORCH	PAST	SBTS	STRP	TOMT	TRCK
V01	0.00	0.00	4.34	2.99	2.99	0.84	3.80	4.35	0.00	2.78	0.00	1.66
V02	0.00	5.11	4.35	2.50	2.74	0.65	3.56	4.73	3.82	2.39	2.86	1.72
V03	4.08	5.25	4.47	2.61	2.62	0.69	3.53	4.51	3.80	2.57	2.99	1.83
V04	4.01	5.41	4.48	0.00	1.93	0.78	3.66	4.72	3.62	0.00	2.98	1.78
V05	4.00	5.35	4.43	2.39	2.13	0.76	3.54	4.66	3.45	2.76	3.00	1.73
V06	0.00	5.70	4.40	2.56	2.01	0.90	3.16	5.04	3.30	0.00	3.00	1.70
V07	0.00	5.70	4.40	2.70	2.14	0.90	3.55	4.55	3.30	0.00	3.00	1.71
V08	0.00	5.97	4.39	2.69	2.25	0.99	3.61	4.90	3.32	0.00	3.00	1.60
V09	0.00	5.50	4.00	2.60	1.90	0.90	3.45	4.60	3.30	0.00	2.70	2.30
V10	2.94	6.10	4.60	2.80	2.45	1.39	3.40	4.70	3.30	2.50	3.14	1.70
V11	0.00	5.86	4.35	2.61	2.66	0.91	2.95	4.44	0.00	0.00	3.00	1.79
V12	0.00	0.00	4.30	2.50	2.77	1.05	2.83	4.34	0.00	2.50	0.00	1.89
V13	3.21	6.10	4.28	2.93	2.77	1.06	3.06	4.35	3.11	2.42	2.80	1.85
V14	2.72	0.00	4.72	2.50	2.60	1.36	3.39	4.52	3.30	2.70	2.60	2.00
V15	3.22	6.10	4.13	2.90	2.97	1.50	3.43	4.58	3.40	2.74	3.18	2.07
V16	3.10	0.00	4.40	2.70	2.97	1.07	2.89	4.39	0.00	2.37	0.00	2.18
V17	3.13	0.00	4.47	2.74	2.80	1.03	3.27	4.62	3.20	2.37	0.00	1.98
V18	3.10	0.00	4.30	2.80	2.97	1.40	3.42	4.50	3.30	2.50	3.10	1.78
V19	3.00	0.00	4.47	2.90	2.42	1.73	3.29	4.79	3.60	2.79	3.30	1.90
V20	3.00	0.00	4.50	2.90	2.64	1.47	3.19	4.70	0.00	2.70	3.30	1.90
V21	3.23	0.00	4.59	2.90	2.76	1.67	3.22	4.74	3.60	2.70	3.21	1.88

TABLE XACRE(G,J) base acres aggregated over crops & regions

	COTT	DRCE	FDDR	GRPS	MFLD	MGRN	ORCH	PAST	SBTS	STRP	TOMT	TRCK
V01	0	0	1,100	100	500	1,300	4,000	24,700	0	400	0	1,600
V02	0	4,500	9,500	200	18,700	15,500	88,900	34,500	3,300	24,500	200	5,300
V03	11,300	153,700	29,100	5,700	32,800	48,300	44,600	14,500	9,900	3,500	33,200	21,300
V04	3,100	88,600	6,900	0	58,600	44,700	32,100	1,200	7,100	0	35,300	18,500
V05	800	170,500	4,700	400	21,200	23,200	128,300	26,100	1,900	4,000	1,500	7,000
V06	0	10,400	33,900	3,300	46,300	60,000	34,700	14,600	14,500	0	51,300	11,900
V07	0	48,600	3,100	200	4,800	7,000	10,700	30,600	2,500	0	500	500
V08	0	4,500	11,900	60,800	53,100	31,100	48,900	46,700	1,400	0	12,900	17,100
V09	0	900	43,900	9,500	159,000	69,500	22,700	26,000	11,400	0	43,700	48,200
V10	100,000	5,000	45,000	3,000	51,800	13,300	39,100	15,000	13,000	500	43,400	110,000
V11	0	3,100	8,400	9,400	26,700	5,900	83,000	41,800	0	0	800	6,100
V12	0	0	26,400	12,800	48,400	24,300	96,800	17,600	0	200	0	5,900
V13	71,000	2,800	56,500	93,200	44,900	41,900	137,500	38,200	4,000	9,800	12,000	16,300
V14	210,400	0	4,000	7,000	22,500	30,000	37,000	1,000	4,900	500	113,000	116,000
V15	265,200	200	75,200	68,900	63,500	57,100	36,200	15,100	8,200	800	11,200	10,000
V16	3,000	0	4,100	48,300	2,500	2,900	13,000	5,300	0	9,500	0	9,300
V17	4,500	0	4,700	86,100	5,300	5,300	82,000	7,700	100	35,700	0	7,500
V18	151,000	0	85,800	55,200	87,200	70,000	81,000	7,500	2,800	112,500	800	19,700
V19	118,000	0	32,700	7,700	5,800	21,900	52,800	500	4,400	3,000	1,400	12,000
V20	31,800	0	15,200	43,400	1,700	8,800	58,400	300	0	28,000	500	20,000
V21	115,100	0	29,300	36,400	12,500	18,200	20,800	800	1,000	19,000	2,700	82,800

From File: CUDAT4.GMS

TABLE MET(G,J,M) MONTHLY ET

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
V01.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V01.DRCE	0.000	0.000	0.000	0.190	0.180	0.250	0.230	0.160	0.000	0.000	0.000	0.000
V01.FDDR	0.000	0.000	0.010	0.080	0.170	0.170	0.220	0.190	0.120	0.040	0.000	0.000
V01.GRPS	0.000	0.000	0.000	0.040	0.190	0.210	0.260	0.200	0.100	0.010	0.000	0.000
V01.MFLD	0.000	0.000	0.010	0.050	0.050	0.250	0.370	0.210	0.060	0.000	0.000	0.000
V01.MGRN	0.000	0.000	0.110	0.890	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V01.ORCH	0.000	0.000	0.010	0.080	0.170	0.170	0.220	0.190	0.120	0.040	0.000	0.000
V01.TOMT	0.000	0.000	0.000	0.000	0.170	0.290	0.340	0.190	0.000	0.000	0.000	0.000
V01.PAST	0.000	0.000	0.010	0.080	0.170	0.170	0.220	0.190	0.120	0.040	0.000	0.000
V01.SBTS	0.000	0.000	0.000	0.010	0.130	0.210	0.280	0.250	0.110	0.010	0.000	0.000
V01.STRP	0.000	0.000	0.000	0.050	0.230	0.210	0.260	0.160	0.080	0.000	0.000	0.000
V01.TRCK	0.000	0.000	0.000	0.080	0.070	0.120	0.200	0.410	0.130	0.000	0.000	0.000
V02.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V02.DRCE	0.000	0.000	0.000	0.200	0.180	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V02.FDDR	0.000	0.000	0.010	0.100	0.180	0.170	0.210	0.170	0.120	0.040	0.000	0.000
V02.GRPS	0.000	0.000	0.000	0.030	0.200	0.220	0.260	0.190	0.090	0.000	0.000	0.000
V02.MFLD	0.000	0.000	0.030	0.030	0.060	0.270	0.360	0.200	0.050	0.000	0.000	0.000
V02.MGRN	0.000	0.020	0.130	0.850	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V02.ORCH	0.000	0.000	0.010	0.100	0.180	0.170	0.210	0.170	0.120	0.040	0.000	0.000
V02.TOMT	0.000	0.000	0.000	0.010	0.210	0.280	0.320	0.180	0.000	0.000	0.000	0.000
V02.PAST	0.000	0.000	0.010	0.100	0.180	0.170	0.210	0.170	0.120	0.040	0.000	0.000
V02.SBTS	0.000	0.000	0.010	0.010	0.150	0.220	0.270	0.240	0.100	0.010	0.000	0.000
V02.STRP	0.000	0.000	0.010	0.050	0.250	0.220	0.250	0.150	0.070	0.000	0.000	0.000
V02.TRCK	0.000	0.000	0.000	0.060	0.070	0.140	0.200	0.410	0.120	0.000	0.000	0.000
V03.COTT	0.000	0.000	0.000	0.000	0.000	0.280	0.370	0.350	0.000	0.000	0.000	0.000
V03.DRCE	0.000	0.000	0.000	0.220	0.180	0.240	0.220	0.140	0.000	0.000	0.000	0.000
V03.FDDR	0.000	0.000	0.030	0.130	0.180	0.160	0.190	0.160	0.110	0.040	0.000	0.000
V03.GRPS	0.000	0.000	0.000	0.050	0.230	0.220	0.240	0.180	0.080	0.000	0.000	0.000
V03.MFLD	0.000	0.000	0.060	0.040	0.080	0.260	0.340	0.180	0.040	0.000	0.000	0.000
V03.MGRN	0.000	0.050	0.200	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V03.ORCH	0.000	0.000	0.030	0.130	0.180	0.160	0.190	0.160	0.110	0.040	0.000	0.000
V03.TOMT	0.000	0.000	0.000	0.020	0.240	0.280	0.300	0.160	0.000	0.000	0.000	0.000
V03.PAST	0.000	0.000	0.030	0.130	0.180	0.160	0.190	0.160	0.110	0.040	0.000	0.000
V03.SBTS	0.000	0.000	0.020	0.020	0.180	0.210	0.250	0.220	0.090	0.010	0.000	0.000
V03.STRP	0.000	0.000	0.030	0.090	0.260	0.210	0.230	0.130	0.060	0.000	0.000	0.000
V03.TRCK	0.000	0.000	0.000	0.090	0.090	0.140	0.180	0.380	0.110	0.000	0.000	0.000
V04.COTT	0.000	0.000	0.000	0.000	0.000	0.270	0.380	0.360	0.000	0.000	0.000	0.000
V04.DRCE	0.000	0.000	0.000	0.200	0.180	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V04.FDDR	0.000	0.000	0.010	0.100	0.180	0.170	0.200	0.170	0.120	0.050	0.000	0.000
V04.GRPS	0.000	0.000	0.000	0.030	0.200	0.220	0.250	0.200	0.110	0.000	0.000	0.000
V04.MFLD	0.000	0.000	0.020	0.020	0.050	0.270	0.360	0.210	0.070	0.000	0.000	0.000
V04.MGRN	0.000	0.040	0.130	0.830	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V04.ORCH	0.000	0.000	0.010	0.100	0.180	0.170	0.200	0.170	0.120	0.050	0.000	0.000
V04.TOMT	0.000	0.000	0.000	0.010	0.190	0.290	0.320	0.190	0.000	0.000	0.000	0.000
V04.PAST	0.000	0.000	0.010	0.100	0.180	0.170	0.200	0.170	0.120	0.050	0.000	0.000
V04.SBTS	0.000	0.000	0.010	0.000	0.130	0.220	0.260	0.240	0.110	0.020	0.000	0.000
V04.STRP	0.000	0.000	0.010	0.060	0.240	0.210	0.240	0.150	0.090	0.000	0.000	0.000
V04.TRCK	0.000	0.000	0.000	0.040	0.070	0.140	0.200	0.410	0.150	0.000	0.000	0.000
V05.COTT	0.000	0.000	0.000	0.000	0.000	0.260	0.380	0.360	0.000	0.000	0.000	0.000
V05.DRCE	0.000	0.000	0.000	0.200	0.180	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V05.FDDR	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.130	0.040	0.000	0.000
V05.GRPS	0.000	0.000	0.000	0.030	0.200	0.220	0.250	0.200	0.110	0.000	0.000	0.000
V05.MFLD	0.000	0.000	0.030	0.030	0.060	0.260	0.350	0.210	0.070	0.000	0.000	0.000
V05.MGRN	0.000	0.030	0.120	0.850	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V05.ORCH	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.130	0.040	0.000	0.000
V05.TOMT	0.000	0.000	0.000	0.010	0.200	0.280	0.320	0.180	0.000	0.000	0.000	0.000
V05.PAST	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.130	0.040	0.000	0.000
V05.SBTS	0.000	0.000	0.010	0.010	0.150	0.210	0.260	0.240	0.110	0.010	0.000	0.000
V05.STRP	0.000	0.000	0.010	0.050	0.240	0.220	0.250	0.160	0.090	0.000	0.000	0.000
V05.TRCK	0.000	0.000	0.000	0.060	0.070	0.140	0.200	0.400	0.140	0.000	0.000	0.000

TABLE MET(G,J,M) MONTHLY ET (cont.)

V06.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V06.DRCE	0.000	0.000	0.000	0.230	0.190	0.240	0.210	0.130	0.000	0.000	0.000	0.000
V06.FDDR	0.000	0.000	0.060	0.150	0.180	0.160	0.190	0.140	0.090	0.030	0.000	0.000
V06.GRPS	0.000	0.000	0.000	0.130	0.280	0.200	0.210	0.120	0.060	0.010	0.000	0.000
V06.MFLD	0.000	0.000	0.100	0.060	0.090	0.250	0.310	0.150	0.040	0.000	0.000	0.000
V06.MGRN	0.000	0.070	0.230	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V06.ORCH	0.000	0.000	0.060	0.150	0.180	0.160	0.190	0.140	0.090	0.030	0.000	0.000
V06.TOMT	0.000	0.000	0.000	0.040	0.270	0.270	0.280	0.140	0.000	0.000	0.000	0.000
V06.PAST	0.000	0.000	0.060	0.150	0.180	0.160	0.190	0.140	0.090	0.030	0.000	0.000
V06.SBTS	0.000	0.000	0.050	0.040	0.190	0.190	0.220	0.200	0.090	0.020	0.000	0.000
V06.STRP	0.000	0.000	0.040	0.120	0.260	0.210	0.220	0.110	0.050	0.000	0.000	0.000
V06.TRCK	0.000	0.000	0.000	0.150	0.100	0.140	0.170	0.340	0.090	0.000	0.000	0.000
V07.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V07.DRCE	0.000	0.000	0.000	0.200	0.180	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V07.FDDR	0.000	0.000	0.020	0.110	0.170	0.160	0.190	0.170	0.120	0.050	0.000	0.000
V07.GRPS	0.000	0.000	0.000	0.060	0.210	0.210	0.240	0.190	0.100	0.000	0.000	0.000
V07.MFLD	0.000	0.000	0.050	0.050	0.070	0.250	0.330	0.190	0.070	0.000	0.000	0.000
V07.MGRN	0.000	0.060	0.170	0.770	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V07.ORCH	0.000	0.000	0.020	0.110	0.170	0.160	0.190	0.170	0.120	0.050	0.000	0.000
V07.TOMT	0.000	0.000	0.000	0.030	0.230	0.270	0.300	0.170	0.000	0.000	0.000	0.000
V07.PAST	0.000	0.000	0.020	0.110	0.170	0.160	0.190	0.170	0.120	0.050	0.000	0.000
V07.SBTS	0.000	0.000	0.020	0.020	0.160	0.200	0.240	0.230	0.110	0.020	0.000	0.000
V07.STRP	0.000	0.000	0.020	0.070	0.240	0.210	0.230	0.150	0.090	0.000	0.000	0.000
V07.TRCK	0.000	0.000	0.000	0.090	0.080	0.130	0.180	0.380	0.140	0.000	0.000	0.000
V08.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V08.DRCE	0.000	0.000	0.000	0.220	0.170	0.230	0.220	0.150	0.000	0.000	0.000	0.000
V08.FDDR	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.120	0.040	0.000	0.000
V08.GRPS	0.000	0.000	0.000	0.020	0.200	0.220	0.260	0.200	0.100	0.000	0.000	0.000
V08.MFLD	0.000	0.000	0.020	0.020	0.040	0.320	0.400	0.170	0.030	0.000	0.000	0.000
V08.MGRN	0.000	0.030	0.140	0.820	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V08.ORCH	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.120	0.040	0.000	0.000
V08.TOMT	0.000	0.000	0.000	0.010	0.190	0.290	0.320	0.190	0.000	0.000	0.000	0.000
V08.PAST	0.000	0.000	0.010	0.090	0.180	0.170	0.200	0.180	0.120	0.040	0.000	0.000
V08.SBTS	0.000	0.000	0.000	0.010	0.160	0.200	0.220	0.220	0.140	0.040	0.000	0.000
V08.STRP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V08.TRCK	0.000	0.000	0.000	0.030	0.080	0.190	0.400	0.300	0.000	0.000	0.000	0.000
V09.COTT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V09.DRCE	0.000	0.000	0.000	0.180	0.190	0.240	0.230	0.150	0.000	0.000	0.000	0.000
V09.FDDR	0.000	0.000	0.010	0.120	0.200	0.180	0.210	0.160	0.100	0.020	0.000	0.000
V09.GRPS	0.000	0.000	0.000	0.020	0.230	0.220	0.260	0.180	0.090	0.000	0.000	0.000
V09.MFLD	0.000	0.000	0.010	0.010	0.080	0.360	0.350	0.150	0.030	0.000	0.000	0.000
V09.MGRN	0.000	0.020	0.060	0.920	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V09.ORCH	0.000	0.000	0.010	0.120	0.200	0.180	0.210	0.160	0.100	0.020	0.000	0.000
V09.TOMT	0.000	0.000	0.000	0.000	0.190	0.300	0.330	0.180	0.000	0.000	0.000	0.000
V09.PAST	0.000	0.000	0.010	0.120	0.200	0.180	0.210	0.160	0.100	0.020	0.000	0.000
V09.SBTS	0.000	0.000	0.010	0.020	0.280	0.210	0.190	0.180	0.100	0.030	0.000	0.000
V09.STRP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V09.TRCK	0.000	0.000	0.000	0.020	0.080	0.210	0.340	0.290	0.060	0.000	0.000	0.000
V10.COTT	0.000	0.000	0.190	0.000	0.000	0.250	0.270	0.290	0.000	0.000	0.000	0.000
V10.DRCE	0.000	0.000	0.000	0.190	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V10.FDDR	0.000	0.000	0.090	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V10.GRPS	0.000	0.000	0.000	0.060	0.220	0.210	0.230	0.180	0.090	0.000	0.000	0.000
V10.MFLD	0.000	0.000	0.080	0.040	0.110	0.290	0.300	0.140	0.040	0.000	0.000	0.000
V10.MGRN	0.000	0.130	0.330	0.540	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V10.ORCH	0.000	0.000	0.090	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V10.TOMT	0.000	0.000	0.000	0.030	0.240	0.260	0.270	0.190	0.000	0.000	0.000	0.000
V10.PAST	0.000	0.000	0.090	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V10.SBTS	0.000	0.000	0.040	0.020	0.220	0.230	0.230	0.180	0.070	0.010	0.000	0.000
V10.STRP	0.000	0.000	0.040	0.100	0.250	0.200	0.210	0.130	0.070	0.000	0.000	0.000
V10.TRCK	0.000	0.000	0.000	0.100	0.190	0.300	0.220	0.190	0.000	0.000	0.000	0.000

TABLE MET(G,J,M) MONTHLY ET (cont.)

V11.COTT	0.000	0.000	0.140	0.000	0.000	0.270	0.290	0.310	0.000	0.000	0.000	0.000
V11.DRCE	0.000	0.000	0.000	0.180	0.190	0.250	0.220	0.160	0.000	0.000	0.000	0.000
V11.FDDR	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.100	0.050	0.000	0.000
V11.GRPS	0.000	0.000	0.000	0.030	0.210	0.220	0.240	0.190	0.100	0.000	0.000	0.000
V11.MFLD	0.000	0.000	0.040	0.030	0.100	0.310	0.320	0.150	0.040	0.000	0.000	0.000
V11.MGRN	0.000	0.060	0.270	0.670	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V11.ORCH	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.100	0.050	0.000	0.000
V11.TOMT	0.000	0.000	0.000	0.010	0.210	0.280	0.290	0.200	0.000	0.000	0.000	0.000
V11.PAST	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.100	0.050	0.000	0.000
V11.SBTS	0.000	0.000	0.010	0.010	0.210	0.250	0.240	0.190	0.070	0.010	0.000	0.000
V11.STRP	0.000	0.000	0.010	0.070	0.260	0.220	0.230	0.140	0.070	0.000	0.000	0.000
V11.TRCK	0.000	0.000	0.000	0.050	0.180	0.320	0.240	0.200	0.000	0.000	0.000	0.000
V12.COTT	0.000	0.000	0.140	0.000	0.000	0.260	0.290	0.310	0.000	0.000	0.000	0.000
V12.DRCE	0.000	0.000	0.000	0.180	0.190	0.250	0.220	0.160	0.000	0.000	0.000	0.000
V12.FDDR	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V12.GRPS	0.000	0.000	0.000	0.030	0.210	0.220	0.240	0.190	0.100	0.000	0.000	0.000
V12.MFLD	0.000	0.000	0.040	0.030	0.100	0.310	0.320	0.150	0.040	0.000	0.000	0.000
V12.MGRN	0.000	0.060	0.270	0.670	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V12.ORCH	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V12.TOMT	0.000	0.000	0.000	0.010	0.210	0.280	0.290	0.200	0.000	0.000	0.000	0.000
V12.PAST	0.000	0.000	0.040	0.120	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V12.SBTS	0.000	0.000	0.010	0.010	0.200	0.250	0.240	0.190	0.070	0.010	0.000	0.000
V12.STRP	0.000	0.000	0.010	0.070	0.260	0.220	0.230	0.150	0.070	0.000	0.000	0.000
V12.TRCK	0.000	0.000	0.000	0.050	0.180	0.330	0.240	0.200	0.000	0.000	0.000	0.000
V13.COTT	0.000	0.000	0.170	0.000	0.000	0.260	0.280	0.300	0.000	0.000	0.000	0.000
V13.DRCE	0.000	0.000	0.000	0.180	0.190	0.250	0.220	0.160	0.000	0.000	0.000	0.000
V13.FDDR	0.000	0.000	0.060	0.120	0.170	0.160	0.170	0.150	0.100	0.050	0.000	0.000
V13.GRPS	0.000	0.000	0.000	0.040	0.210	0.220	0.230	0.190	0.100	0.000	0.000	0.000
V13.MFLD	0.000	0.000	0.060	0.030	0.100	0.300	0.310	0.150	0.040	0.000	0.000	0.000
V13.MGRN	0.000	0.100	0.310	0.590	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V13.ORCH	0.000	0.000	0.060	0.120	0.170	0.160	0.170	0.150	0.100	0.050	0.000	0.000
V13.TOMT	0.000	0.000	0.000	0.020	0.230	0.270	0.280	0.200	0.000	0.000	0.000	0.000
V13.PAST	0.000	0.000	0.060	0.120	0.170	0.160	0.170	0.150	0.100	0.050	0.000	0.000
V13.SBTS	0.000	0.000	0.020	0.010	0.210	0.240	0.240	0.190	0.070	0.010	0.000	0.000
V13.STRP	0.000	0.000	0.020	0.080	0.250	0.210	0.220	0.140	0.070	0.000	0.000	0.000
V13.TRCK	0.000	0.000	0.000	0.070	0.190	0.320	0.230	0.200	0.000	0.000	0.000	0.000
V14.COTT	0.000	0.000	0.210	0.000	0.000	0.230	0.280	0.280	0.000	0.000	0.000	0.000
V14.DRCE	0.000	0.000	0.000	0.200	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V14.FDDR	0.000	0.000	0.130	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V14.GRPS	0.000	0.000	0.000	0.100	0.220	0.200	0.210	0.170	0.090	0.010	0.000	0.000
V14.MFLD	0.000	0.000	0.120	0.070	0.180	0.290	0.220	0.090	0.030	0.000	0.000	0.000
V14.MGRN	0.000	0.340	0.330	0.330	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V14.ORCH	0.000	0.000	0.130	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V14.TOMT	0.000	0.000	0.000	0.120	0.410	0.280	0.160	0.020	0.000	0.000	0.000	0.000
V14.PAST	0.000	0.000	0.130	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V14.SBTS	0.000	0.000	0.100	0.120	0.320	0.230	0.120	0.080	0.030	0.000	0.000	0.000
V14.STRP	0.000	0.000	0.090	0.120	0.230	0.180	0.190	0.120	0.070	0.000	0.000	0.000
V14.TRCK	0.000	0.000	0.000	0.230	0.240	0.240	0.180	0.110	0.000	0.000	0.000	0.000
V15.COTT	0.000	0.000	0.190	0.000	0.000	0.230	0.290	0.290	0.000	0.000	0.000	0.000
V15.DRCE	0.000	0.000	0.000	0.190	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V15.FDDR	0.000	0.000	0.110	0.130	0.160	0.150	0.160	0.140	0.100	0.050	0.000	0.000
V15.GRPS	0.000	0.000	0.000	0.080	0.220	0.210	0.220	0.180	0.090	0.000	0.000	0.000
V15.MFLD	0.000	0.000	0.100	0.060	0.180	0.300	0.230	0.090	0.030	0.000	0.000	0.000
V15.MGRN	0.000	0.310	0.340	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V15.ORCH	0.000	0.000	0.110	0.130	0.160	0.150	0.160	0.140	0.100	0.050	0.000	0.000
V15.TOMT	0.000	0.000	0.000	0.090	0.420	0.300	0.170	0.020	0.000	0.000	0.000	0.000
V15.PAST	0.000	0.000	0.110	0.130	0.160	0.150	0.160	0.140	0.100	0.050	0.000	0.000
V15.SBTS	0.000	0.000	0.070	0.120	0.330	0.230	0.130	0.090	0.030	0.000	0.000	0.000
V15.STRP	0.000	0.000	0.060	0.110	0.240	0.190	0.200	0.130	0.070	0.000	0.000	0.000
V15.TRCK	0.000	0.000	0.000	0.200	0.240	0.250	0.190	0.120	0.000	0.000	0.000	0.000

TABLE MET(G,J,M) MONTHLY ET (cont.)

V16.COTT	0.000	0.000	0.180	0.000	0.000	0.230	0.300	0.290	0.000	0.000	0.000	0.000
V16.DRCE	0.000	0.000	0.000	0.190	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V16.FDDR	0.000	0.000	0.070	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V16.GRPS	0.000	0.000	0.000	0.060	0.220	0.210	0.230	0.180	0.100	0.000	0.000	0.000
V16.MFLD	0.000	0.000	0.080	0.050	0.180	0.320	0.240	0.100	0.030	0.000	0.000	0.000
V16.MGRN	0.000	0.250	0.340	0.410	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V16.ORCH	0.000	0.000	0.070	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V16.TOMT	0.000	0.000	0.000	0.060	0.430	0.310	0.180	0.020	0.000	0.000	0.000	0.000
V16.PAST	0.000	0.000	0.070	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V16.SBTS	0.000	0.000	0.040	0.100	0.350	0.250	0.140	0.090	0.030	0.000	0.000	0.000
V16.STRP	0.000	0.000	0.030	0.090	0.250	0.200	0.220	0.140	0.070	0.000	0.000	0.000
V16.TRCK	0.000	0.000	0.000	0.160	0.250	0.260	0.210	0.130	0.000	0.000	0.000	0.000
V17.COTT	0.000	0.000	0.120	0.000	0.000	0.230	0.320	0.320	0.000	0.000	0.000	0.000
V17.DRCE	0.000	0.000	0.000	0.180	0.190	0.250	0.230	0.160	0.000	0.000	0.000	0.000
V17.FDDR	0.000	0.000	0.040	0.110	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V17.GRPS	0.000	0.000	0.000	0.020	0.200	0.230	0.240	0.200	0.100	0.000	0.000	0.000
V17.MFLD	0.000	0.000	0.030	0.030	0.180	0.350	0.260	0.110	0.030	0.000	0.000	0.000
V17.MGRN	0.000	0.130	0.370	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V17.ORCH	0.000	0.000	0.040	0.110	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V17.TOMT	0.000	0.000	0.000	0.020	0.430	0.330	0.190	0.030	0.000	0.000	0.000	0.000
V17.PAST	0.000	0.000	0.040	0.110	0.180	0.160	0.180	0.160	0.110	0.050	0.000	0.000
V17.SBTS	0.000	0.000	0.010	0.070	0.370	0.270	0.150	0.100	0.030	0.000	0.000	0.000
V17.STRP	0.000	0.000	0.010	0.060	0.260	0.220	0.230	0.150	0.080	0.000	0.000	0.000
V17.TRCK	0.000	0.000	0.000	0.090	0.260	0.290	0.230	0.140	0.000	0.000	0.000	0.000
V18.COTT	0.000	0.000	0.140	0.000	0.000	0.260	0.310	0.300	0.000	0.000	0.000	0.000
V18.DRCE	0.000	0.000	0.000	0.200	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V18.FDDR	0.000	0.000	0.060	0.140	0.180	0.160	0.180	0.150	0.090	0.040	0.000	0.000
V18.GRPS	0.000	0.000	0.000	0.040	0.240	0.220	0.230	0.180	0.080	0.000	0.000	0.000
V18.MFLD	0.000	0.000	0.040	0.070	0.200	0.330	0.240	0.090	0.020	0.000	0.000	0.000
V18.MGRN	0.000	0.120	0.340	0.530	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V18.ORCH	0.000	0.000	0.060	0.140	0.180	0.160	0.180	0.150	0.090	0.040	0.000	0.000
V18.TOMT	0.000	0.000	0.000	0.030	0.450	0.310	0.180	0.020	0.000	0.000	0.000	0.000
V18.PAST	0.000	0.000	0.060	0.140	0.180	0.160	0.180	0.150	0.090	0.040	0.000	0.000
V18.SBTS	0.000	0.000	0.020	0.110	0.370	0.260	0.140	0.090	0.020	0.000	0.000	0.000
V18.STRP	0.000	0.000	0.020	0.100	0.270	0.210	0.220	0.130	0.060	0.000	0.000	0.000
V18.TRCK	0.000	0.000	0.000	0.160	0.260	0.260	0.200	0.110	0.000	0.000	0.000	0.000
V19.COTT	0.000	0.000	0.210	0.000	0.000	0.230	0.280	0.280	0.000	0.000	0.000	0.000
V19.DRCE	0.000	0.000	0.000	0.200	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V19.FDDR	0.000	0.000	0.120	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V19.GRPS	0.000	0.000	0.000	0.090	0.220	0.200	0.220	0.170	0.090	0.010	0.000	0.000
V19.MFLD	0.000	0.000	0.110	0.070	0.180	0.300	0.220	0.090	0.030	0.000	0.000	0.000
V19.MGRN	0.000	0.350	0.330	0.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V19.ORCH	0.000	0.000	0.120	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V19.TOMT	0.000	0.000	0.000	0.110	0.410	0.290	0.170	0.020	0.000	0.000	0.000	0.000
V19.PAST	0.000	0.000	0.120	0.130	0.160	0.140	0.160	0.140	0.090	0.050	0.000	0.000
V19.SBTS	0.000	0.000	0.090	0.120	0.330	0.230	0.130	0.090	0.030	0.000	0.000	0.000
V19.STRP	0.000	0.000	0.080	0.110	0.240	0.190	0.200	0.130	0.070	0.000	0.000	0.000
V19.TRCK	0.000	0.000	0.000	0.210	0.240	0.240	0.190	0.120	0.000	0.000	0.000	0.000
V20.COTT	0.000	0.000	0.190	0.000	0.000	0.220	0.290	0.290	0.000	0.000	0.000	0.000
V20.DRCE	0.000	0.000	0.000	0.190	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V20.FDDR	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V20.GRPS	0.000	0.000	0.000	0.070	0.220	0.210	0.220	0.180	0.090	0.010	0.000	0.000
V20.MFLD	0.000	0.000	0.100	0.060	0.180	0.310	0.230	0.100	0.030	0.000	0.000	0.000
V20.MGRN	0.000	0.310	0.330	0.360	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V20.ORCH	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V20.TOMT	0.000	0.000	0.000	0.080	0.420	0.300	0.180	0.020	0.000	0.000	0.000	0.000
V20.PAST	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.150	0.100	0.050	0.000	0.000
V20.SBTS	0.000	0.000	0.070	0.100	0.340	0.240	0.130	0.090	0.030	0.000	0.000	0.000
V20.STRP	0.000	0.000	0.060	0.100	0.240	0.200	0.210	0.130	0.070	0.000	0.000	0.000
V20.TRCK	0.000	0.000	0.000	0.180	0.240	0.250	0.200	0.120	0.000	0.000	0.000	0.000

TABLE MET(G,J,M) MONTHLY ET (cont.)

V21.COTT	0.000	0.000	0.200	0.000	0.000	0.220	0.290	0.290	0.000	0.000	0.000	0.000
V21.DRCE	0.000	0.000	0.000	0.190	0.190	0.240	0.220	0.150	0.000	0.000	0.000	0.000
V21.FDDR	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.140	0.100	0.050	0.000	0.000
V21.GRPS	0.000	0.000	0.000	0.070	0.220	0.210	0.220	0.180	0.090	0.010	0.000	0.000
V21.MFLD	0.000	0.000	0.100	0.060	0.180	0.310	0.230	0.100	0.030	0.000	0.000	0.000
V21.MGRN	0.000	0.320	0.330	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V21.ORCH	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.140	0.100	0.050	0.000	0.000
V21.TOMT	0.000	0.000	0.000	0.080	0.420	0.300	0.180	0.020	0.000	0.000	0.000	0.000
V21.PAST	0.000	0.000	0.100	0.130	0.170	0.150	0.170	0.140	0.100	0.050	0.000	0.000
V21.SBTS	0.000	0.000	0.070	0.110	0.340	0.240	0.130	0.090	0.030	0.000	0.000	0.000
V21.STRP	0.000	0.000	0.060	0.100	0.240	0.200	0.210	0.130	0.070	0.000	0.000	0.000
V21.TRCK	0.000	0.000	0.000	0.180	0.240	0.250	0.200	0.120	0.000	0.000	0.000	0.000

ATTACHMENT B: FILE LIST

All data files are contained in a series of sub-directories:

(A) Land Use

(B) Crop Evapotranspiration

(C) Precipitation

(D) Evapotranspiration of Applied Water

(E) Applied Water

(F) CU Model

(G) Losses

(H) Return Flows

(I) SWAP Input Files

(J) SWAP Output Files