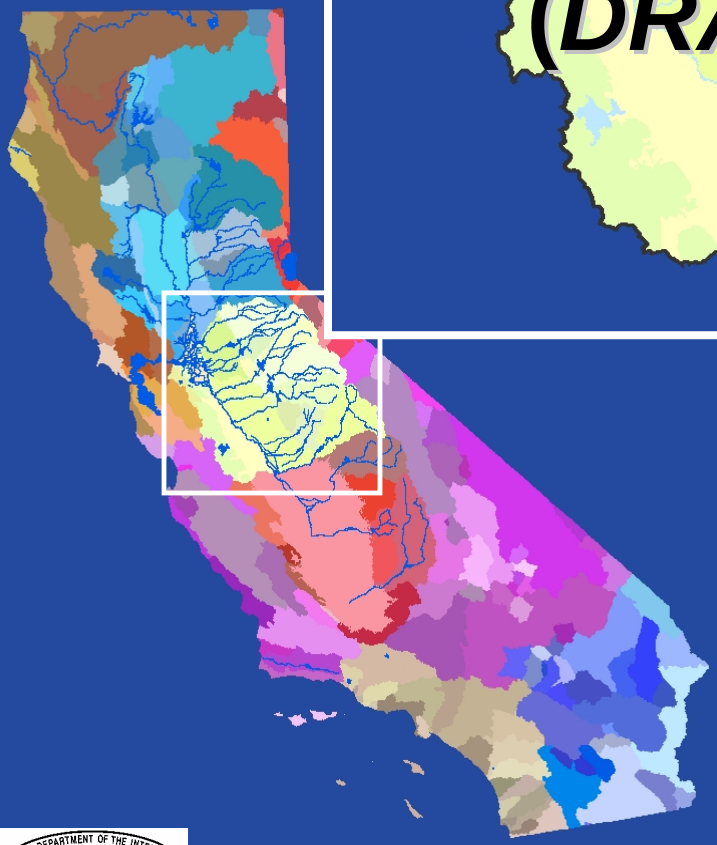
RECLAMATION

Managing Water in the West

CALSIM II San Joaquin River Model (*DRAFT*)



U.S. Department of the Interior
Bureau of Reclamation
Mid Pacific Region
Sacramento, CA

April 2005

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations/Acronyms

AF	Acre-Feet
AF/year	Acre-Feet per Year
AFRP	Anadromous Fish Restoration Program
Agreement	Oakdale ID/South San Joaquin ID Operational Agreement with Reclamation
Benchmark	September 30, 2002 CALSIM II Benchmark Model
Calaveras County WD	Calaveras County Water District
cfs	Cubic Feet per Second
Chowchilla WD	Chowchilla Water District
COE	United States Army Corps of Engineers
CU Model	Consumptive Use Model
CUAW	Consumptive Use of Applied Water
CVGSM	Central Valley Groundwater - Surface Water Simulation Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
D-1422	State Water Resources Control Board Water Rights Decision 1422
D-1641	State Water Resources Control Board Water Rights Decision 1641
DAU	Detailed Analysis Unit
DFG	California Department of Fish and Game
DMC	Delta-Mendota Canal
DPLA	Division of Planning and Local Assistance
DWR	California Department of Water Resources
EC	Electrical Conductivity
El Nido ID	El Nido Irrigation District
ET	Evapotranspiration
ETAW	Evapotranspiration of Applied Water
Exchange Contractors	San Joaquin River Exchange Contractors Water Authority
FERC	Federal Energy Regulatory Commission
FWS	United States Fish and Wildlife Service
GIS	Geographic Information System
gpcd	Gallons per Capita per Day
IE	Irrigation Efficiency
Interior	United States Department of the Interior

IPO	New Melones Interim Plan of Operations
M&I	Municipal and Industrial
Madera ID	Madera Irrigation District
MAF	Million Acre-Feet
Merced ID	Merced Irrigation District
Merced NWR	Merced National Wildlife Refuge
Modesto ID	Modesto Irrigation District
MS Excel	Microsoft Excel
NRL	Non-Recoverable Loss
Oakdale ID	Oakdale Irrigation District
PG&E	Pacific Gas and Electric Company
PWSS	Public Water System Statistics
Reclamation	United States Bureau of Reclamation
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
South San Joaquin ID	South San Joaquin Irrigation District
Stevinson WD	Stevinson Water District
Stockton East WD	Stockton East Water District
SWP	California State Water Project
SWRCB	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
Turlock ID	Turlock Irrigation District
USAN	Upper San Joaquin River Basin Model
VAMP	Vernalis Adaptive Management Plan
WQ Module ver 1.00	San Joaquin River Water Quality Module Version 1.00
WSI	Water Supply Index

1. Purpose of Document

This document has been prepared to support the joint California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) water resources planning model, CALSIM II. The purpose is to record the San Joaquin River Basin implementation of CALSIM II as of April 2005. This document describes model methodology, logic, assumptions, data input and output.

The objective of this document is to provide model development and reference material of water demands, hydrology, and operation protocol in the San Joaquin River Basin. It is anticipated that this document be used by managers and technical specialists within DWR and Reclamation, and external agencies to understand the San Joaquin River Basin CALSIM II simulation.

This document and accompanied results do not reflect a benchmark release of the CALSIM II model. The logic and results presented within this document are preliminary and are subject to change. Questions or comments regarding benchmark status and current modifications to the model should be directed to DWR or Reclamation.

2. Introduction

CALSIM II is a computer model that simulates much of the water resources systems and their operations in California's Central Valley and Sacramento-San Joaquin Delta region. The focus of CALSIM II representation is primarily on the Central Valley Project and State Water Project systems (CVP-SWP). The model was developed jointly by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation). Its purpose is to provide quantitative hydrologic information related to scenario-based CVP-SWP operations and assumptions related to climate, water demands, and regulatory environment. As the official planning model of both agencies, CALSIM II is used extensively to support a variety of studies describing comparative effects of alternative scenarios varying by infrastructure, operational rules, regulations, water demands, and/or climate.

CALSIM II is a significant upgrade relative to its predecessor models, PROSIM and DWRSIM, particularly in the representation of project operations in the Sacramento River Basin, its tributaries, and the Delta, and operations that meet provisions of the Central Valley Improvement Act (CVPIA) and CALFED ROD. Nevertheless, DWR and Reclamation continue to invest in CALSIM II enhancements. Two motivations drive this investment: (a) response to perceived

gaps between CALSIM II capabilities and ongoing planning questions, and (b) anticipation of future planning questions that will need to be served by CALSIM II with functionality beyond the current model. Both of these factors motivated redevelopment of CALSIM II's hydrology representation on the Eastside San Joaquin River Basin.

The original representation of the San Joaquin River Basin within CALSIM II was based on the SANJASM and STANMOD models, using simplifying assumptions that allow the basin a fairly static role in planning studies focused on impacts to other areas of the CVP/SWP system. Correlations were employed to define some hydrologic factors, and demands were implemented as monthly distributions of fixed contract amounts. These assumptions precluded dynamic interaction with new and evolving river system operations decision processes, or of projected land use change effects on San Joaquin Basin operations. In anticipation of studies specifically focused on San Joaquin Basin operations, an updated depiction of the Basin was clearly needed and has now been developed and incorporated into CALSIM II. This effort combined a thorough review of existing model attributes with the development of new information and data to produce a contemporary representation of the hydrology and operations of the San Joaquin Basin.

San Joaquin River hydrology is significantly affected by the operations of several major east side irrigation districts. The model revisions described in this document are underpinned by a new, land-use based, depiction of east side water demands. With this approach, variable acreage and associated land use combine with consumptive use data to define demand for water. Including seasonal and year-to-year variation of weather dependent demands has become critical to the needs of today's planning studies. As acreage and land use assumptions change, the model is able to dynamically portray demand-driven operations in the Basin. It must be noted that throughout this effort, the assistance and cooperation of the irrigation districts was invaluable in defining an appropriate characterization of their operations.

The area of analysis (see Figure 2-1) is the portion of the San Joaquin Basin that is bounded by the Calaveras River to the north, the upper San Joaquin River (Friant) to the south, the Sierra Nevada Mountains to the east, and the Delta-Mendota Canal and San Luis Service area that is hydraulically connected to the San Joaquin River to the west.

The interaction between groundwater and surface water is not included in this version of CALSIM II. The hydrology and operations included in this version represent the surface water component of the San Joaquin River Basin. Groundwater is loosely linked through the inference that demands not met with surface supplies are met with groundwater. Also, the development of water balances for surface water operations includes assumptions for deep percolation of surface supplies to the groundwater aquifer and the interaction of groundwater

within the accretions/depletions of the streams. Additional linkages within CALSIM II between surface water and groundwater are anticipated in future refinements. The demand areas on which the water balances are developed are depicted in Figure 2-1. The schematic representation of the San Joaquin River Basin in CALSIM II is depicted in Figure 1-2.

The refinement of east side operations, hydrology, and demands has been accomplished over several years through multiple efforts. The Bureau of Reclamation Reservoir System Analysis Branch (MP710) initiated the development effort in 2002 through a contract with MBK Engineers. The effort was further enhanced with a subsequent contract, again with MBK Engineers in 2003. The framework for modeling the San Joaquin Basin in CALSIM II was completed and validated after completion of the second contract; however, there were still some remaining tasks to be accomplished prior to being used in planning studies. These tasks included developing projected level land use for both the current (2005) and future (2030) levels of development, integrating the D-1641 stand alone representation of the San Joaquin Basin with a full five-step (D-1485, D-1641, B2, JPOD, EWA) CALSIM II model. Integration of the San Joaquin Model into a full CALSIM II OCAP study was completed in late 2004 through Reclamation's effort in developing the San Joaquin River Eastside Integrated Resources Management Plan (IRMP). Land use projections are approaching completion, also through the IRMP.

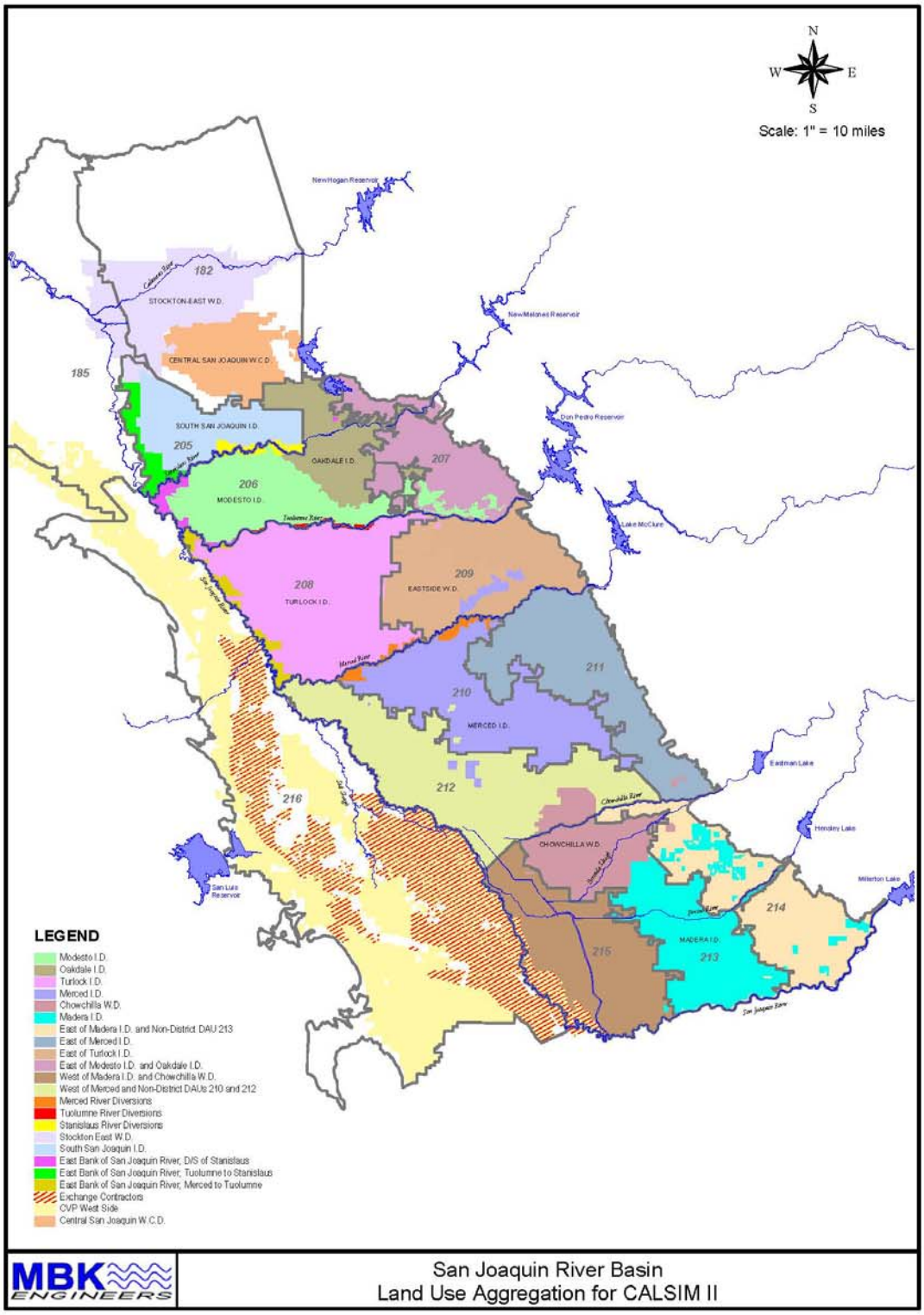


Figure 2-1: CALSIM II Representation of the San Joaquin River Basin and Demand Areas

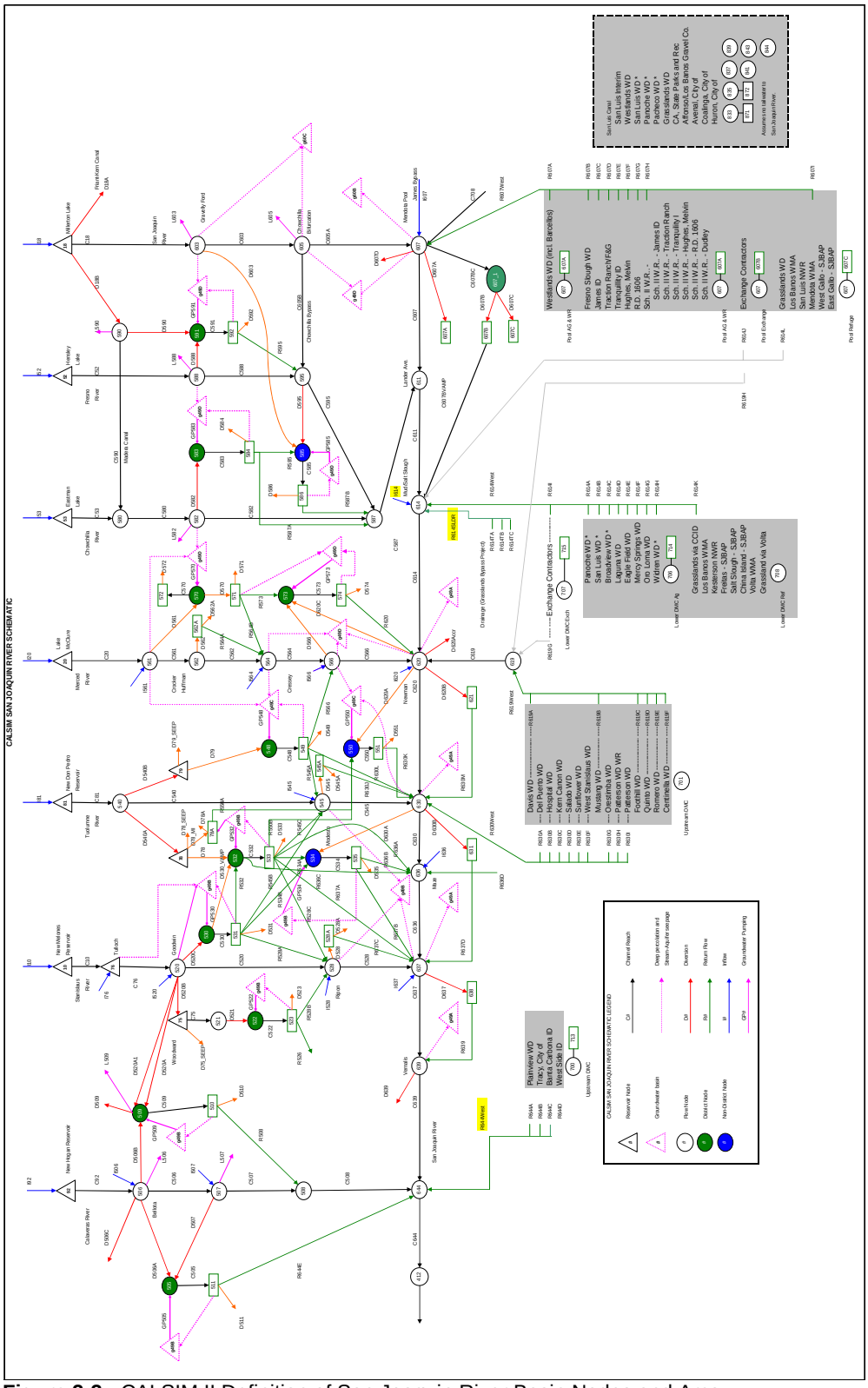


Figure 2-2: CALSIM II Definition of San Joaquin River Basin Nodes and Arcs

3. Water Demands

There are three types of water demands identified in CALSIM II: agricultural, municipal and industrial (M&I), and refuge. Each of these demands has its own characteristics in terms of demand pattern, its sources of supply, and its affect on other aspects of a hydrologic balance.

East Side Demands

Agricultural Demands

Simply put, land-use based agricultural demands are developed by assuming an irrigated acreage and estimating how much water is required to irrigate that land's associated crops.

Land-use based demands are developed by first estimating the consumptive use of applied water (CUAW), often referred to as the evapotranspiration of applied water (ETAW), or the amount of irrigation directly required by crops. The CUAW represents the amount of applied water realized as evapotranspiration (ET); it does not include water that is lost or returned to the water system.

The CUAW is determined based on irrigated acreage using the California Department of Water Resources (DWR) consumptive use model (CU model). Irrigated acreage for all east side demand areas within the area of analysis was developed using the Geographic Information System (GIS) coverage from the 1995 DWR land use survey. Land use is aggregated to 13 crop types, based on crops with similar water use, and input to the CU model to estimate the CUAW.

Demand Areas

As depicted in Figure 2-1, the east side of the San Joaquin Basin was divided into 21 demand areas. Demand areas are the fundamental unit of analysis for the basin. A water budget is performed on each area to determine diversion requirements, water sources, losses, and return flows. With the exception of the demand area representing non-district lands on the east bank of the San Joaquin River north of the Stanislaus River confluence, a representation of each of the east side areas has been implemented in CALSIM II. Currently, the area on the east bank San Joaquin River north of the Stanislaus River has a simplified operation that acts as a surrogate until it is integrated in CALSIM II consistently with the other areas.

Land Use

CALSIM II demands are traditionally based on a projected level land use, such as projecting land use that might occur for the time horizon of year 2005 or 2030.

Projected levels of land use for the San Joaquin River Basin were not available for the CALSIM II improvements. Historical land use data was used in place of projected land use to perform water budgets and develop CALSIM II simulations for model validation. GIS was used to determine land use for each demand area in the San Joaquin Basin. GIS land use coverage was also used to distribute regional land use estimates to CALSIM II demand areas, based on relative land use within CALSIM II demand areas. A map containing CALSIM II demand areas and land use is illustrated in Figure 3-1.

Land use data development (for use as an input into CALSIM II) consisted of five basic steps:

- Assembling data
- Developing new CALSIM II demand areas
- Rectifying overlapping water districts
- Combining GIS data
- Generating a summary table

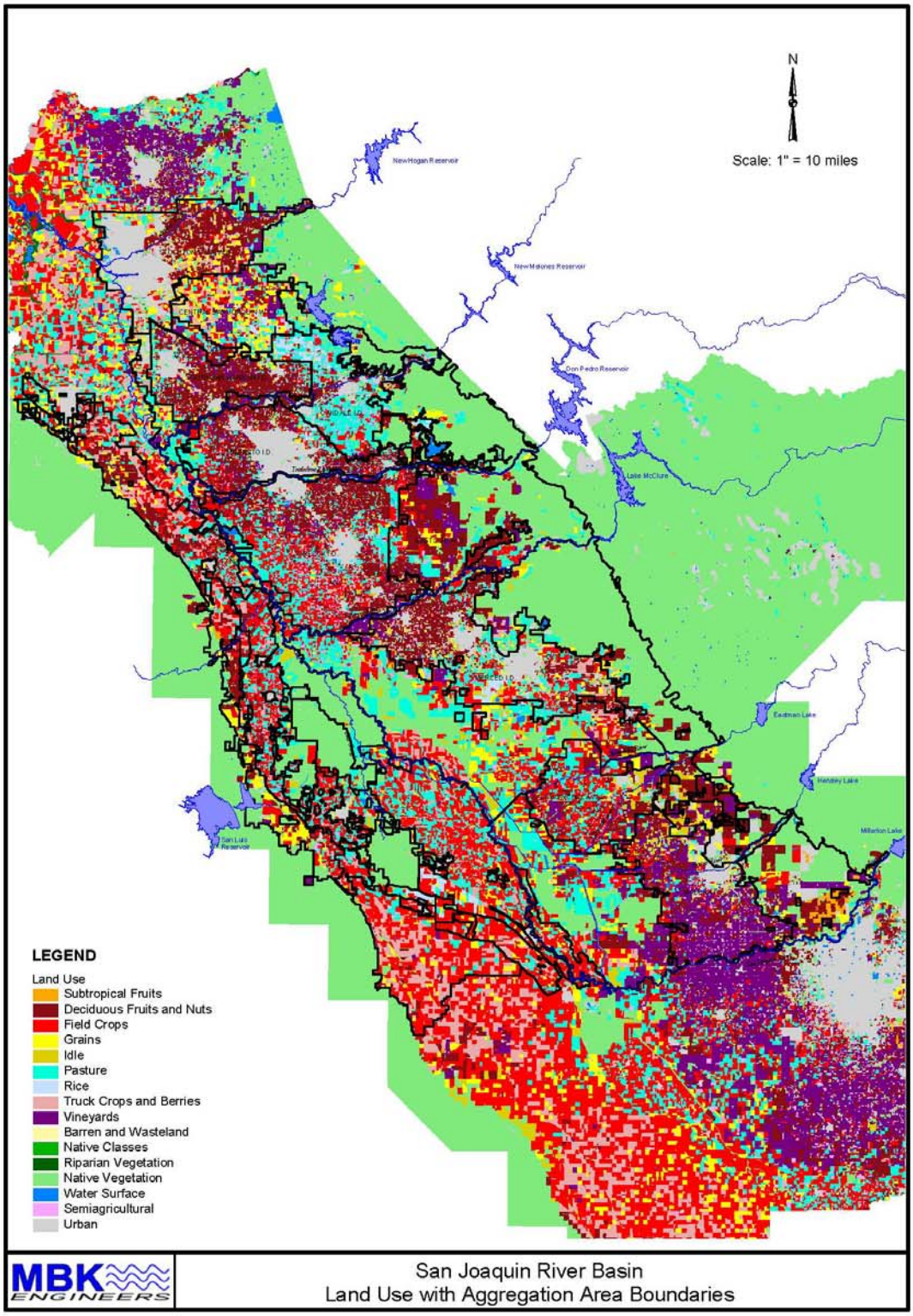


Figure 3-1: CALSIM II Demand Area Land Use

Assembly of Data

DWR provided county delineated GIS land use files. These individual counties were merged into one "shapefile", which represents the following vintage of survey for land use data within each county.

County	Survey Year
Fresno	1994
Madera	1995
Merced	1995
San Joaquin	1988
Stanislaus	1996
Tuolumne	1997
Mariposa	1998

The crop types identified in the DWR land use surveys did not correspond to CU model input requirements and therefore had to be categorized based on similar crop characteristics. For example, the DWR files included total acreage for kiwi crops within a given county. Kiwi fruit is not identified as a CU model input but can be categorized as "citrus/olive" which is a CU model crop type. The categorization of each crop type identified in the DWR land use data is shown in Appendix C.

The DWR land use files also included a water source attribute that describes whether the water source is surface, ground, mixed, or unknown. This attribute was used to identify sources of water on the east side.

Several other GIS shapefiles were merged into the land use shapefile for demand area delineation purposes. These shapefiles defined DWR planning area (e.g., Detailed Analysis Units) and water district boundaries.

Development of CALSIM II Demand Areas

New CALSIM II demand areas were developed on the basis of subdividing areas of unique water demands. Demand area boundaries were defined according to three categories: water districts, non-district lands, and non-district riparian water users. Water district demand areas were delineated based on actual water district boundaries. In many cases, these boundaries coincided with detailed analysis unit (DAU) boundaries. Non-district lands were delineated according to DAU boundaries, except where district boundaries overlapped the DAUs. Non-district riparian water user boundaries were defined as the residual area between water district boundaries and a corresponding river reach.

Rectification of Overlapping Water Districts

After assembling the district boundaries, it became apparent that overlaps existed. To avoid double-counting land use data, the overlapping areas were reconciled in terms of water source. For each overlapping area, based on judgment, the district

that supplies water to the area was chosen to be associated with the area. The overlaps were then eliminated using GIS software tools.

Union of GIS Data

In order to query land use in terms of any combination of the data layers, all the layers needed to be combined in a spatial 'union', described by the following diagram.

The files that were united are: DWR planning areas (e.g., DAUs), water districts, CALSIM II demand areas, and land use. The resulting shapefile was then cropped to the extent of the CALSIM II demand areas.

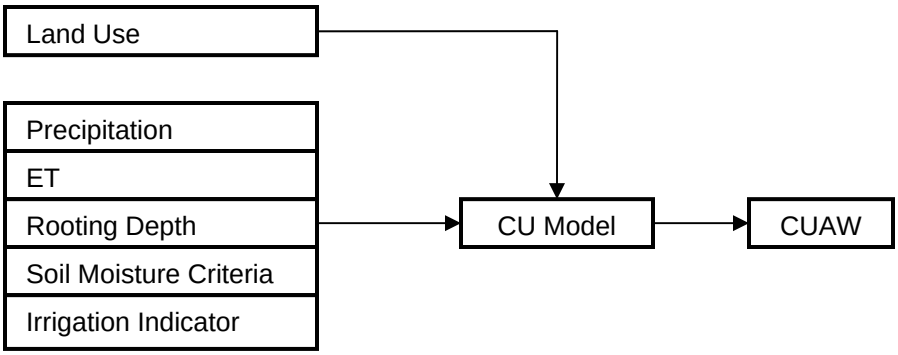
Generation of Summary Table

The final step in creating tabular data (for Microsoft Excel) was to generate a summary table. The table needed to show the total acreage of each unique land use type for each unique combination of data layers. ArcView is only capable of summarizing data based on one attribute; therefore, it was necessary to concatenate all of the desired fields into one field, and then summarize the total acreage based on that attribute.

A table was then generated showing the total acreage for each unique value of this concatenation of attributes. The data in this table can be used to determine land use for combinations of specific regions of any (or all) of the input layers. Land use for each CALSIM II demand area in the San Joaquin River Basin is displayed in Appendix C.

Consumptive Use

The CUAW represents the amount of applied water realized as ET; it does not include water that is lost or returned to the water system. The CUAW for an area is based on irrigated acreage using the DWR CU model. Irrigated acreage for any particular area is developed using the GIS coverage as described previously in this section. Land use is aggregated to 13 crop types based on crops with similar water use. The DWR CU model incorporates monthly precipitation, ET rates, soil moisture criteria, rooting depth, irrigation indicators, and other factors along with land use to estimate the CUAW on a monthly basis. The interaction of the land use and environmental data within the CU model is depicted below.



The CU model does not currently consider temperature or other meteorological data in its determination of CUAW. The ET data in the current CU model is based on 1976 evaporation values. It consists of crop ET during growing months and evaporative demand during non-growing months. Inaccurate ET assumptions could influence results of the water budgets and consequently, water district operations. For example, above normal temperatures would likely cause CUAW values to be higher than those reported by the CU model. A refinement of the CU model and its results could be incorporated into CALSIM II at a later time.

Monthly CUAW values for each demand area, calculated based on historical land use from GIS coverage, are located in Appendix A.

District Area Agricultural Demands

As previously described, each east side demand area can have a unique circumstance that translates demands for CUAW to a diversion requirement. Generically, CUAW is combined with conveyance losses (if any), operational spills and tailwater (return flow), non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The diversion requirement is the volume of water supplied from surface or groundwater, regardless of source. Complicating this conceptual diversion model are district system operations which may include canal regulating storage that seasonally increases or decreases diversion requirements. Each district included in CALSIM II is somewhat unique in the factors leading to the determination of diversion requirements.

Deep Percolation of Applied Water

Applied water returns to the stream network, percolates to groundwater or is used consumptively as ET. In CALSIM II, deep percolation of applied water is specified in a lookup table as a fixed percentage of the applied water less the surface runoff. These percentages are based on average percolation rates that are output from the historical run of the Central Valley Groundwater - Surface Water Simulation Model (CVGSM), water district budgets, and judgment. Within the current water balances of several of the east side areas, deep percolation was not specifically identified but inherently incorporated within a larger factor applied to CUAW. The consistency of deep percolation assumptions will require validation

(at the time of integration) of the San Joaquin Valley groundwater component of CALSIM II.

Conveyance Losses

Conveyance losses are generally associated with district conveyance and distribution facilities. These losses are comprised of canal leakage, seepage and evaporation. Separately determined, when significant, are losses from district regulating storage. CALSIM II identifies the disposition of these losses as either to the atmosphere or the stream network including groundwater.

Non-Recoverable Losses

DWR employs a method to identify a proportion of applied irrigation water that is not used in crop ET, does not return to the surface or groundwater system, but is depleted or lost. This may happen through:

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

Return Flow and Operational Spills

For many districts in the San Joaquin River Basin, return flow (operational spills) should not be simulated as a fraction of CUAW or diversion. Operational spills are more a function of the operation of district canals and laterals, and are dependent upon the state of water availability within a year. During dryer years when water supply is limited, districts are more vigilant in controlling their systems and attempt to minimize operational spill. Several of the modeled districts have operational spills depicted as an assumed constant volume year-to-year, varying by year-type. Return flows typically associated with farmer-level tailwater that escape out of the district boundary are currently accounted for (if accounted for) within the factor used to adjust CUAW to a diversion requirement.

Description of Demands by District

For the major irrigation districts on the east side of the San Joaquin Valley separate protocols were developed to determine water demands and diversion requirements.

Madera Irrigation District

Methodology The factors leading to determining the water demands and diversion requirements of the Madera Irrigation District (Madera ID) were developed by preparing a water budget for the district. Water demands were developed using land use data, estimated CUAW, historical records from Madera ID, estimates of district losses, estimates of deep percolation, and guidance from Madera ID personnel. Madera ID records on stream diversions, Madera Canal deliveries, and flows leaving the district were readily available and useful in developing a water budget.

Water Budget The water budget for Madera ID was performed on a monthly basis from 1980 to 1998. All water entering and leaving Madera ID was accounted for in the water budget. The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The diversion requirement is the volume of water that must be diverted into the district, regardless of source, and is depicted in the following graphic.

CUAW
Deep Percolation of Applied Water
Conveyance Loss (Seepage)
Spills
Non Recoverable Loss

= Diversion Requirement

The district's diversion requirement is satisfied by Fresno River diversions, Madera Canal deliveries, and pumping from private wells located in the district (depicted below).

Fresno River Diversions
Groundwater Pumping
Madera Canal Delivery

= Diversion Requirement

The water budget balanced water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the ground. The balance of water leaving the district with water entering the district is illustrated as follows.

CUAW
Deep Percolation of Applied Water
District Losses (Seepage)
Spills
Non Recoverable Loss

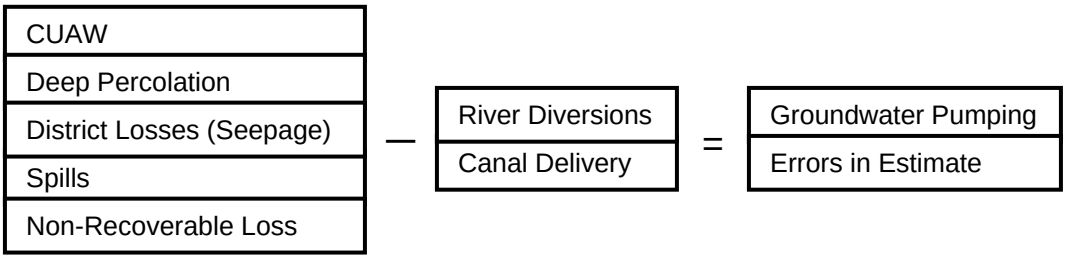
=

River Diversions
Groundwater Pumping
Madera Canal Delivery

Flows leaving the district are very small. These flows are either diverted by downstream users or enter the groundwater aquifer through seepage shortly after it leaves the district boundary. Non-recoverable loss is assumed to be 10 percent of CUAW, a standard used by DWR and the Bureau of Reclamation (Reclamation).

The annual distribution system loss in Madera ID is assumed to be 30 percent of the surface diversion in dry years[1] and 40 percent in normal years[2]. This estimate is based on experience of Madera ID operators and data gathered by the district.

Deep percolation of applied water and groundwater pumping from private wells are two water budget components that are not measured and are difficult to estimate. However, when combined they provide a closure term for balancing the water budget. An assumption was made regarding the amount of applied water that percolates into the groundwater aquifer. Deep percolation of applied water is assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and discussions with district personnel.
By assuming that deep percolation is 25 percent of CUAW and distribution system losses are 30 percent in dry years and 40 percent in normal years, the only component of the water budget that has not been determined is groundwater pumping from privately owned wells. Groundwater pumping from privately owned wells is thus determined by subtracting river diversions and Madera Canal deliveries from the diversion requirement. All errors in the estimation procedure are manifest in the private groundwater pumping estimates. Consequently, the results can provide guidance when developing private pumping estimates, but will not yield exact pumping values. The calculation procedure is illustrated below.



Results of Water Budget and Model Input Based on Madera ID water budget results, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model are directly input into CALSIM II. The non-recoverable loss of 10 percent of CUAW is also a direct data parameter input to the model. District losses are set to 30 percent of surface water diversions in dry years and 40 percent in normal years. Deep percolation of applied water is set at 25 percent of CUAW.

Groundwater pumping from private wells within the district is input as a minimum monthly amount that will be pumped every year regardless of supply, and a maximum monthly volume that can be pumped in dryer years. These groundwater pumping parameters are described in Table 3-1.

[1] Except as noted, within the text of this document a “dry” year refers to both dry and critically dry hydrologic conditions as defined by the San Joaquin River Basin 60-20-20 index.
[2] Except as noted, within the text of this document a “normal” year refers to wet, above normal, and below normal hydrologic conditions as defined by the San Joaquin River Basin 60-20-20 index.

Table 3-1: Groundwater Pumping Parameters (acre-feet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	0	0	0	0	0	0	0	20,000	30,000	30,000	25,000	3,000
Maximum	8,000	1,000	0	0	1,000	20,000	45,000	66,000	55,000	50,000	50,000	30,000

Based on a review of historical flows leaving the district, there is a distinct difference between dry year and normal year operations. During wetter years, much of the return flow is either precipitation runoff or saturated soils drainage. Within CALSIM II, the flows leaving the district are depicted by the values shown in Table 3-2.

Table 3-2: Flow Exiting District (acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Critical[3]	500	180	0	0	0	950	920	1,100	940	840	880	790	7,100
Non-Critical	240	70	0	0	0	0	0	180	190	210	230	40	1,160

Chowchilla Water District

Methodology The water demands and diversions of Chowchilla Water District (Chowchilla WD) were determined by preparing a water budget for the district using available data and judgment. Water demands were developed using land use data, estimated CUAW, historical stream flow records, estimates of district losses, and estimates of deep percolation.

The operation of Eastman Lake is determined by the diversion requirement developed from the water budget and water supplied by the Friant system. Both the pattern and quantity of water supplied from Friant may influence the operation of Eastman Lake. Operational rules for Eastman Lake were developed to best use the water supplies from both water supply sources.

Water Budget The water budget for Chowchilla WD was performed on a monthly basis from 1980 to 1998. All water entering and leaving Chowchilla WD was accounted for in the water budget. The factors included surface diversions, spills, ET, non-recoverable loss, and deep percolation. The same water budget model used for Madera ID applied to Chowchilla WD. The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The district's diversion requirement is satisfied by Chowchilla River diversions (including Ash and Berenda Sloughs), Madera Canal deliveries, and pumping from private wells located in the district.

The process of performing a water budget involves balancing water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the ground. The only information available to

[3] Except as noted, within the text of this document a "critical" year refers to the critically dry hydrologic condition as defined by the San Joaquin River 60-20-20 index.

perform the water budget for Chowchilla WD is CUAW (based on DWR land use data), flow below Buchanan Dam, and Madera Canal deliveries. All other data are estimated.

Flow leaving the district was assumed to be very small and is either diverted by downstream users or enters the groundwater aquifer through seepage shortly after it leaves the district boundary. The non-recoverable loss is assumed to be 10 percent of CUAW. The annual distribution system losses in Chowchilla WD are assumed to be 35 percent of surface diversion. This value is based on judgment and characteristics of water districts in the area.

Deep percolation of applied water is assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and values assumed for districts in the area. By assuming that deep percolation is 25 percent of CUAW and distribution system losses are 35 percent, the remaining component of the water budget that has not been determined is groundwater pumping from privately owned wells. This component is estimated by subtracting river diversions and Madera Canal deliveries from the diversion requirement. Identical to the Madera ID procedure, all errors in the estimation procedure are manifest in the private groundwater pumping estimates. Therefore, the results for this parameter can provide guidance when developing private pumping estimates, but will not yield exact pumping values.

Results of Water Budget and Model Input Based on results of the Chowchilla WD water budget, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model is directly input into CALSIM II. Non-recoverable loss of 10 percent is also directly input into the model. District losses are set to 35 percent of surface diversion, and deep percolation of applied water is 25 percent of CUAW.

Groundwater pumping from private wells within the district is input as a minimum monthly amount that will be pumped every year, regardless of supply, and a maximum monthly volume that can be pumped in dryer years. These values are shown in Table 3-3.

Table 3-3: Groundwater Pumping Parameters (acre-feet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	500	0	0	0	0	0	1,500	12,000	20,000	20,000	20,000	5,000
Maximum	7,000	500	0	0	1,000	35,000	35,000	35,000	45,000	45,000	45,000	20,000

There are no data available regarding flows leaving Chowchilla WD; they are assumed to be very small. For modeling purposes, and without any available data, the flows leaving the district are set equal to Madera ID spills. The actual spill parameters used in CALSIM II can be seen in Table 3-2 above.

Merced Irrigation District

Methodology The Merced Irrigation District (Merced ID) is primarily located south of the Merced River, but does include about 5,000 acres of irrigated land north of the Merced River. For the purposes of modeling the Merced ID system in CALSIM II, lands north of the Merced River are combined with lands south of the river to represent one diversion for the district.

The water demands and operation of Merced ID were determined by preparing a water budget for the district. Water demands are developed using land use data, estimated CUAW, historical records from Merced ID, estimates of district losses, estimates of deep percolation, and guidance from Merced ID personnel. The Merced ID maintains detailed records of district operations. Records of stream diversions, flows leaving the district, district pumping, and district losses were useful in developing a water budget.

Water Budget The water budget for Merced ID was performed on a monthly basis from 1980 to 1998. Water entering and leaving Merced ID was accounted for in the water budget. The factors included surface water diversions, spills, ET, non-recoverable loss, deep percolation, and water deliveries within Merced ID and its sphere-of-influence.

The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The district's diversion requirement is satisfied by Merced River diversions, pumping from district wells, and pumping from private wells located in the district. Water leaves the district to either the atmosphere, surface flow, or into the groundwater aquifer.

Merced ID has more than 750 miles of canals that convey water to the district's customers. The annual canal loss was provided by the district and the non-recoverable loss was assumed to be 10 percent of CUAW. Merced ID maintains records of flows leaving the district.

Deep percolation of applied water and groundwater pumping from private wells are unknown components of the water budget. An assumption was made regarding the amount of applied water that percolates into the groundwater aquifer. Deep percolation of applied water is assumed to be 30 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and the influence the assumptions has upon private pumping estimates.

By assuming that deep percolation is 30 percent of CUAW, groundwater pumping from privately owned wells is the closure term of the water budget and is determined by subtracting historical river diversions and district pumping from the diversion requirement. All errors in the estimation procedure are manifest within the estimation of private groundwater pumping. Therefore, the result can provide guidance when developing private pumping estimates; however, it will not yield exact pumping values.

Results of Water Budget and Model Input Based on results of the Merced ID water budget, inputs for CALSIM II have been developed. CUAW (developed from the DWR CU model) is directly input into CALSIM II. A non-recoverable loss of 10 percent of CUAW is also directly input into the model. District losses are assumed to be 150,000 acre-feet (AF) per year, distributed on the pattern of monthly CUAW. Pumping from district owned wells is set at about 9,000 AF per year and is also distributed on the monthly pattern of CUAW. District pumping was based on annual pumping from 1993 through 1998. Although district pumping has been greater in the past, many changes within the district have occurred and pumping from district owned wells should not be allowed to increase above the assumed value.

Deep percolation of applied water is set at 30 percent of CUAW. Groundwater pumping from private wells is assumed to be a minimum of 45,000 AF per year, distributed on the CUAW monthly pattern, and bounded by a maximum of 250,000 AF per year, also distributed on the CUAW monthly pattern. District delivery to areas outside the district boundary are set as 40,000 AF per year (not including Stevinson Water District or Merced National Wildlife Refuge), subject to reductions based on water availability. Spills or flows leaving the district are a function of requirements for downstream water districts, excess runoff from small tributaries, and normal district operations. Additionally, some spills which are independent of requirements for downstream water districts are returned to the Merced River at Cressey. These returns are determined by water year type and month, and only occur when there is an irrigation demand (see Table 3-4 below).

Table 3-4: Flow Exiting District (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Critical	200	0	0	0	0	100	400	400	350	400	400	400	2,650
Non-Critical	1,500	300	0	100	130	600	1,100	1,200	1,750	1,550	1,900	1,700	11,830

Merced ID spills are discussed in further detail in Section 7, page 97.

Turlock Irrigation District

Methodology The methodology used to determine the diversion requirement for Turlock Irrigation District (Turlock ID) differs from the previously described methodologies. Deep percolation within the district is variable and dependent upon the availability of water from the district. The availability of system operation data and estimates of groundwater pumping allows the development of a monthly varying factor that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-

recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the district. Other parameters (district operational spills and canal losses) are added to this estimate to determine diversions from Turlock Lake. The diversion from La Grange Reservoir for the district is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Turlock Lake. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Turlock Lake, net evaporation and seepage losses for the regulating reservoir and the canal between Turlock Lake and La Grange Dam are estimated.

Table 3-5: Turlock Lake and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	5,265	4,884	4,733	5,438	6,293	7,270	8,352	9,524	9,952	10,505	11,000	9,141

Current operational spills from the district's canals have also been estimated and differentiated by year-type, based on recent historical records. Canal losses are estimated to be 800 AF per month.

Table 3-6: Operational Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	2,000	2,000	2,000	2,000	2,000	2,000	2,500	2,500	3,000	3,000	3,000	2,500
Non-Critical	9,000	2,000	2,000	2,000	2,000	2,500	7,500	8,500	8,500	8,500	8,000	8,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown below. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-7: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	8,000	0	0	0	0	1,500	6,500	8,500	10,000	12,000	11,000	10,000
Maximum	8,000	0	0	0	0	6,000	10,000	15,000	17,000	17,000	15,000	12,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with district personnel and a review of the groundwater management plan for the area.

Table 3-8: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,382	0	0	0	0	4,719	8,090	13,483	16,854	18,876	16,180	7,416

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters, then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-9: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	35	60	65	75	65	60	60

For the month of March, the canal turnout delivery factor varies between 35 and 50 percent, depending upon the level of CUAW during the month.

Modesto Irrigation District

Methodology The methodology used to determine the diversion requirement for Modesto Irrigation District (Modesto ID) is consistent with the methodology used for Turlock ID. Deep percolation within the district is variable and dependent upon the availability of water from the district. The availability of system operation data and estimates of groundwater pumping allows the development of a monthly varying factor that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and then becomes the canal delivery of the district. Other parameters (district operational spills, intercepted flows useable for

supply, and canal losses) are added to this estimate to determine diversions from Modesto Lake. The diversion from La Grange Reservoir for the district is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Modesto Lake. Also considered was the diversion from Modesto Lake for the Modesto Water Treatment Plant. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Modesto Lake, net evaporation and seepage losses for the regulating reservoir and in the canal between Modesto Lake and La Grange Dam are estimated.

Table 3-10: Modesto Lake and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,300	3,500	3,300	3,600	3,700	3,900	4,300	5,100	5,400	6,000	6,000	5,400

Current operational spills from the district's canals have also been estimated and differentiated by year-type, based on recent historical records. Canal losses are estimated to be 100 AF per month.

Table 3-11: Operation Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000
Non-Critical	7,000	2,000	2,000	2,000	2,000	3,000	6,500	8,000	7,000	7,000	7,500	7,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown in Table 3-12. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-12: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	2,000	0	0	0	0	1,000	2,500	2,500	2,500	3,000	3,000	2,000
Maximum	8,000	0	0	0	0	6,000	2,500	6,000	6,000	7,000	7,000	2,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with the district and review of the groundwater management plan for the area.

Table 3-13: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	974	0	0	0	0	1,049	1,798	2,996	3,745	4,195	3,596	1,648

The district currently provides water to the Modesto Water Treatment Plant. The diversion from Modesto Lake is shown in Table 3-14.

Table 3-14: Diversion to Modesto Water Treatment Plant (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	2,916	2,855	2,925	2,767	2,425	2,776	2,742	2,994	3,004	3,124	3,095	3,003

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters, then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-15: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	35	60	75	80	80	70	70

For the month of March, the canal turnout delivery factor varies between 35 and 60 percent, depending upon the level of CUAW during the month.

Oakdale Irrigation District (South of Stanislaus River)

Methodology The methodology used to determine the diversion requirement for Oakdale Irrigation District (Oakdale ID) is consistent with the methodology used for Turlock ID and Modesto ID. The district is physically located both north and south of the Stanislaus River, diverting water to the South Main Canal and jointly with the South San Joaquin Irrigation District (South San Joaquin ID) from the Joint Main Canal. CALSIM II depicts the district separately north and south of the river. A monthly varying factor is developed that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, and diversions as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. This value is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the district.

Other parameters (district operational spills and canal losses) are added to this estimate to determine diversions from Goodwin Dam. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Current operational spills from the district's canals have been estimated and differentiated by year-type. Canal losses are estimated to be 2,000 AF per month.

Table 3-16: Operation Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	2,110	1,400	1,400	1,400	1,400	2,110	2,110	2,800	2,510	2,510	3,200	2,800
Non-Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,510	3,510	4,510	4,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown below. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-17: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	487	0	0	0	0	524	899	1,498	1,873	2,097	1,798	824
Maximum	2,000	0	0	0	0	1,000	2,500	6,000	6,000	7,000	7,000	2,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with district personnel and a review of the groundwater management plan for the area.

Table 3-18: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	747	0	0	0	0	724	1,018	1,471	1,697	1,765	1,493	1,086

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters. These values were then adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-19: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	60	60	35	35	35	60	60	60	75	70	65	60

South San Joaquin Irrigation District and Oakdale Irrigation District (North of Stanislaus River)

Methodology The methodology used to determine the diversion requirement for the South San Joaquin ID and Oakdale ID North demand area is consistent with

the methodology used for the Turlock ID and Modesto ID demand areas. The combined operation of South San Joaquin ID (located entirely north of the Stanislaus River) and Oakdale ID (located both north and south of the river) is depicted by CALSIM II. Although diversions to Oakdale ID physically occur prior to Woodward Reservoir, CALSIM II has the combined diversions of the two districts routed through Woodward Reservoir. This modeling convenience does not violate the depiction of diversions from Goodwin Dam. A monthly varying factor that relates CUAW to canal deliveries and thus, diversions, is developed for the combined demands. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate the combined districts' system operation parameters and to determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the districts. Other parameters (district operational spills, intercepted flows useable for supply, and canal losses) are added to this estimate to determine diversions from Woodward Reservoir and above. The diversion from Woodward Reservoir and above (for the districts) is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Woodward Reservoir. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Woodward Reservoir, net evaporation and seepage losses for the regulating reservoir and in the canal between Woodward Reservoir and Goodwin Dam are estimated.

Table 3-20: Woodward Reservoir and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,052	3,658	3,501	3,437	3,492	4,320	5,587	6,212	7,000	7,000	7,000	6,513

Current operational spills from the combined districts' canals have also been estimated, differentiated by year-type, based on recent historical records. Canal losses are estimated to be 2,000 AF per month.

Table 3-21: Operation Canal Spills – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000
Non-Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000

Groundwater and drainage pumping used by the districts as a supply within their canal systems (at a minimum) are shown in Table 3-22.

Table 3-22: District Groundwater Parameters – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	487	0	0	0	0	524	899	1,498	1,873	2,097	1,798	824

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with each district's personnel.

Table 3-23: Non-District Groundwater Parameters – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	3,136	0	0	0	0	3,041	4,276	6,176	7,127	7,412	6,271	4,561

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters and then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-24: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	40	70	75	80	80	70	70

Central San Joaquin Water Conservation District

Methodology The Central San Joaquin WCD methodology of determining agricultural demands varies from the methodologies used for the other districts on the east side. Central San Joaquin WCD has a relatively small effect on reservoir operations and the surface water network, and therefore a more simplified approach of developing the district's demands was used.

Demands Development and Model Input The Central San Joaquin WCD diversion requirement was developed based on crop consumptive use. Estimates of the district's CUAW were determined using the CU model and loss factors were added to the estimates to account for deep percolation and non-recoverable losses. Per DWR guidelines, non-recoverable losses were assumed to be 10 percent of CUAW while deep percolation was assumed to be 30 percent of CUAW. Flows that leave district boundaries and become available for reuse are assumed to be negligible.

Stockton East Water District

Methodology A water budget for Stockton East Water District (Stockton East WD) was performed on a monthly basis for the period when data was available. Water entering and leaving Stockton East WD was accounted for in the water budget. The parameters included surface diversions, spills, ET, non-recoverable loss, deep percolation, and urban diversions.

Water Budget The water budget was developed by first estimating CUAW. The CUAW was combined with district losses, district spills, non-recoverable loss, deep percolation of applied water, and urban demands to estimate the diversion requirement of the district, regardless of source. The district diversion requirement is satisfied by Calaveras River diversions, pumping from private wells located in the district, urban groundwater pumping, and diversions (imports) from the Stanislaus River at Goodwin Dam (depicted below).

Calaveras River Diversions
Stanislaus River Diversions
Agriculture Groundwater Pumping
Urban Groundwater Pumping

=

Diversion Requirement

The process of performing the water budget involved balancing water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the groundwater aquifer. Mathematically balancing the water leaving and entering the district is illustrated below.

CUAW
Deep Percolation of Applied Water
District Losses (Seepage)
Spills
Non-Recoverable Loss
Urban Demands

=

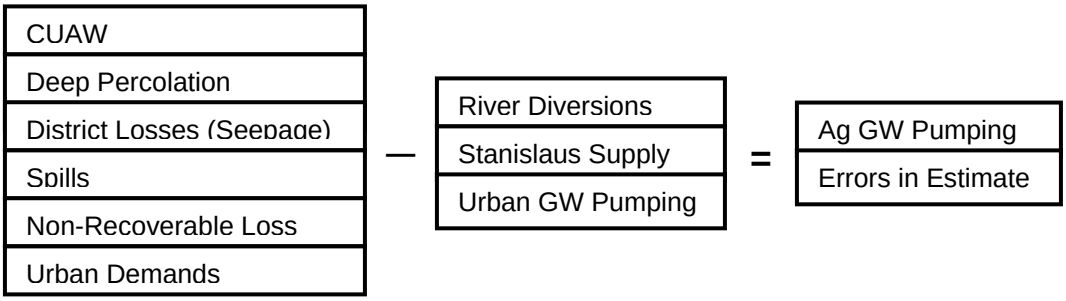
Calaveras River Diversions
Stanislaus River Diversions
Agriculture Groundwater Pumping
Urban Groundwater Pumping

Non-recoverable loss was assumed to be 10 percent of CUAW. District spills are very minor and are estimated to be approximately 10 cubic feet per second (cfs) during the irrigation season (based on conversations with district personnel). District losses occur throughout the distribution system.

The deep percolation of applied water and groundwater pumping from wells are unknown components of the water budget. One factor was selected as an assumption and the other was solved as the closure term. An assumption was made regarding the amount of applied water that percolates into the groundwater

aquifer. Deep percolation of applied water was assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and the resulting calculated pumping estimates.

By assuming that deep percolation was 25 percent of CUAW, the remaining component of the water budget was groundwater pumping from wells and use of other minor unaccounted stream flow. Pumping was estimated by subtracting historical river diversions from the other diversion requirement factors. All errors in the estimations are manifest within the groundwater pumping estimates; therefore, the result can provide guidance when developing private pumping estimates but will not yield exact pumping values. The estimation procedure is illustrated below.



Results of Water Budget and Model Input Based on operating rules provided by the Stockton East WD and results of the water budget, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model are directly input into CALSIM II. A non-recoverable loss of 10 percent of CUAW is also a direct input to the model.

Agricultural demands within the Stockton East WD boundaries are greater than surface water supply in every year; therefore, the amount of groundwater pumping is calculated as the total diversion requirement, minus available surface water. The average annual groundwater pumping is about 75,000 AF and ranges from about 60,000 AF in wetter years to about 110,000 AF in dry years.

Urban demands are treated as a constant 40,000 AF diversion volume each year, based on input from Stockton East WD. Urban groundwater pumping is used to satisfy urban demands of 40,000 AF and varies depending on availability of surface water defined by CALSIM II.

Non-District Demand Area Agricultural Demands

Those water demand areas not identified as districted areas are referred to as “non-district” areas. These areas do not normally cause or affect direct changes to the major water supply facilities located in the San Joaquin Valley. Their sources of supply may be incidental runoff from district areas, groundwater pumping, or pumping from a stream. All non-district demands are defined in CALSIM II using the following parameters:

- CUAW (time series from the DWR CU model)
- Non-recoverable loss (10 percent)
- Deep percolation of applied water (30 percent of CUAW)
- Irrigation efficiency (75 percent for surface deliveries, no assumption for groundwater)

For non-district areas, irrigation efficiency is used to calculate return flows. Irrigation efficiency is assumed to be 75 percent for surface water delivery, but there is no assumption for groundwater delivery (i.e., there are no return flows associated with groundwater pumping). These assumptions are consistent for all non-district areas.

There are 12 non-district agricultural demand areas within the east side area. A description of each non-district area and the accompanying operations for meeting the areas' demands are found in Section 7.

Municipal Demands

Historically, urban demands have only made up a small percentage of the total water demand in the east side of the San Joaquin Basin, and much of that demand has been met through groundwater pumping. Urban demands have, therefore, had a relatively small surface water diversion requirement in comparison to agriculture.

With the exception of the Stockton East WD, the CALSIM II Benchmark essentially ignored east side urban water demands because of their insignificance on surface water diversions. However, the DWR Division of Planning and Local Assistance (DPLA) land use projections show large urban growth within the San Joaquin Valley during the next 20 years. Some predictions show that most of this urban development will take place on agricultural lands and will thus change the land's use. Land use conversion will have a considerable impact on both groundwater and surface water demands. The anticipation of land use changes requires a more refined assessment and depiction of urban water use in CALSIM II.

Development Methodology

Typically, urban water use values are analyzed and published in units of gallons per capita per day (gpcd). To estimate municipal water demands, one simply applies these factors to an estimate of population for a geographic area and multiplies that value by the number of days in the analysis period. This method was selected for calculating San Joaquin Valley urban demands due to the availability of data. The DPLA collects and analyzes water use information from water purveyors for updating Bulletins 160 (California Water Plan) and 166 (Urban Water Use in California). The data is then stored in the Public Water System Statistics (PWSS) database. From these surveys, DPLA has determined

daily per capita water use for much of California. Additionally, DPLA has completed population forecasts that extend more than 20 years.

It is difficult to estimate what the average water consumption will be decades from now. Some predictions indicate that new technology and conservation techniques will considerably reduce future urban water demand. The 1998 update of Bulletin 160 assumes that if water conservation activities take place, urban demands in the San Joaquin Valley will be reduced up to 12 percent by the year 2020, with respect to 1995 demands. Table 3-25 contains population and per capita water use information provided by DPLA. The table also includes the resulting annual water use in AF for each DAU on the east side of the Basin.

Table 3-25: DPLA Population and Water Demand Information

DAU	Population		Annual Water Use (gpcd)		Annual Water Use (AF)	
	Existing	2030	Existing	2030	Existing	2030
205	99,075	176,100	225	198	24,972	39,060
206	280,955	517,300	278	245	87,495	141,766
206	2,065	2,500	280	246	648	690
208	174,900	320,075	304	268	59,562	95,920
209	1,945	2,350	326	287	710	755
210	141,750	243,600	348	306	55,259	83,568
211	1,530	1,800	317	279	543	562
212	4,275	5,020	303	267	1,451	1,499
213	63,325	139,400	295	260	20,927	40,539
214	37,875	81,100	320	282	13,577	25,853
215	1,245	1,450	261	230	364	373

Note: 2030 values assume a 12% reduction from existing demand, based on the 1995 to 2020 reduction in demand.

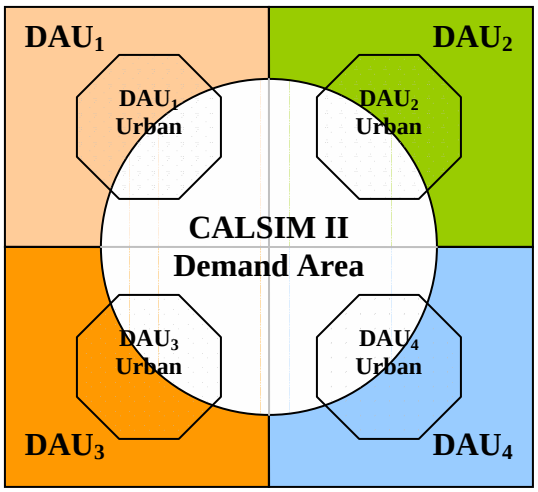
Data Limitations and Solutions

There are at least two significant limitations of the DPLA data with regard to implementation and use in CALSIM II. The biggest limitation is that per capita water use values and population projections are published according to DAU, whereas the new CALSIM II east side representation incorporates new planning areas (introduced in Sections 1 and 3 as CALSIM II demand areas) which are inconsistent with DAU boundaries. A second limitation to the DPLA data is that the daily per capita water use is based on annual averages rather than monthly or daily averages. For example, a California city with an average annual water use of 300 gpcd may actually use 400 gpcd during the summer months and 200 gpcd during the winter months. Since CALSIM II is a monthly model, the DPLA annual data must be disaggregated to a monthly time step.

Because DAU boundaries do not coincide with the new demand areas, a method was developed to estimate total annual water use in each demand area using the DAU per capita water use values. This method relies on GIS technology and land use surveys to determine the percentage of the total DAU urban land use that is

located within the overlapping portion of a corresponding demand area. Multiplying this percentage by the total DAU population gives an estimation of the number of residents in that section of the DAU. This assumes that the number of people per acre of urban-classified land is consistent throughout the entire DAU.

The DPLA per capita water use value for the given DAU can then be multiplied by the population estimate, returning an annual water requirement for a section of the corresponding demand area. Because each demand area may coincide with multiple DAUs, this procedure must be applied to all sections overlapping a different DAU. The total urban water demand for the demand area is the sum of each section's water requirement. Figure 3-2 illustrates the methodology for determining annual urban water requirements for the new demand areas.



DAU_1
Area = 1000 acres
Residents = 500
Urban Per Capita Water Use (Average Annual) = 250 gpcd
Area Overlapping the Demand Area = 200 acres
DAU_1 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area = 60 acres

DAU_2
Area = 1000 acres
Residents = 1000
Urban Per Capita Water Use (Average Annual) = 300 gpcd
Area Overlapping the Demand Area = 200 acres
DAU_2 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping Sub-Basin = 60 acres

DAU_3
Area = 1000 acres
Residents = 300
Urban Per Capita Water Use (Average Annual) = 275 gpcd
Area Overlapping the Demand Area = 200 acres
DAU_3 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area = 60 acres

DAU_4
Area = 1000 acres
Residents = 700
Urban Per Capita Water Use (Average Annual) = 290 gpcd
Area Overlapping the Demand Area = 200 acres
DAU_4 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area = 60 acres

Demand Area
Area = 1000 acres
Urban Area = (60 + 60 + 60 + 60) = 240 acres
Average Annual Urban Water Use =
{[(60 ac / 150 ac) * 500 * 250 gpcd] +
[(60 ac / 150 ac) * 1000 * 300 gpcd] +
[(60 ac / 150 ac) * 300 * 275 gpcd] +
[(60 ac / 150 ac) * 700 * 290 gpcd]} *
Conversion Factor

= 318 acre-feet annually

Figure 3-2: Defining Urban Water Requirements in CALSIM II Demand Areas

The resulting annual urban water demand for each CALSIM II demand area is shown in Table 3-26.

Table 3-26: Annual Urban Water Demand (AF)

CALSIM II Demand Area	Urban Water Demand
Chowchilla Water District	4,792
East bank of San Joaquin River, Downstream of Stanislaus	5,221
East bank of San Joaquin River, Merced to Tuolumne	345

CALSIM II Demand Area	Urban Water Demand
East bank of San Joaquin River, Tuolumne to Stanislaus	5
East of Madera Irrigation District and Non-District DAU 213	13,473
East of Merced Irrigation District	540
East of Modesto Irrigation District and Oakdale Irrigation District	887
East of Turlock Irrigation District	663
Madera Irrigation District	16,254
Merced Irrigation District	54,734
Merced River Diversions	1,056
Modesto Irrigation District	64,823
Oakdale Irrigation District North	3,743
Oakdale Irrigation District South	15,841
South San Joaquin Irrigation District	17,338
Stanislaus River Diversions	2,053
Tuolumne River Diversions	2,212
Turlock Irrigation District	57,834
West of Madera Irrigation District and Chowchilla Water District	262
West of Merced Irrigation District and Non-District Areas in DAU 210 and 212	1,450

Since CALSIM II is a monthly model, annual municipal water requirements are disaggregated to a monthly time step before inclusion in the model. The PWSS database provided by DPLA includes population estimates and monthly municipal and industrial delivery volumes for water purveyor service areas. With this information, it was possible to determine the annual delivery volume for a given purveyor (and corresponding service area) and the monthly percent of total annual delivery. The resulting monthly delivery pattern is used for distributing the demand areas' derived annual urban demands over each month of the year.

The monthly delivery patterns derived from PWSS data are representative of a single service area and not an entire demand area or DAU. However, since data is not available at an aggregate level, distribution patterns associated with individual service areas were used as surrogates for the entire demand areas. The representative service area was selected based on proximity, population served, and reasonableness of the data (i.e., follows basic trends of increased water use during the drier months and vise versa). Table 3-27 shows the monthly distribution of annual deliveries applied to each area.

Table 3-27: Monthly Distribution of Annual M&I Deliveries Based on Representative Purveyor

Demand Area	Service Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chowchilla WD	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%

Demand Area	Service Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
East bank of SJR, Downstream of Stanislaus	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
East bank of SJR, Merced to Tuolumne	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
East bank of SJR, Tuolumne to Stanislaus	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
East of Madera ID, Non-District	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
East of Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
East of Modesto ID and Oakdale ID	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
East of Turlock ID	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
Madera ID	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Merced River Riparian Diversions	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Modesto ID	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Oakdale ID (North)	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Oakdale ID (South)	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
South San Joaquin ID	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
Stanislaus River Riparian Diversions	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
Tuolumne River Riparian Diversions	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Turlock ID	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
West of Madera ID and Chowchilla WD	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
West of Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Stockton East WD	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%

It is not necessary to ensure that each monthly pattern is exactly representative of the demand area. First, almost all urban water diversion requirements in CALSIM II (at the current level of development) are met through groundwater pumping, and CALSIM II assumes that none of the urban uses are returned as surface flows. Second, urban water use (also at the current level of development) is a small percentage of total water use in the Basin. Therefore, the CALSIM II results will not be sensitive to small changes in the monthly percentages.

As San Joaquin Valley municipal water use becomes a greater percentage of the total water use, errors associated with the derived monthly delivery patterns will

have a more significant effect on surface water operations. With future land use and population projections showing significant urbanization, it would seem less reasonable to apply one service area's monthly delivery pattern to an entire demand area at a future level of demand. However, the errors associated with this procedure will likely be less than the errors associated with projecting per capita water use 20 years into the future. Without better data available, it was assumed that a single service area's current monthly delivery pattern is representative of a corresponding demand area's future monthly water delivery pattern.

Implementation in CALSIM II

Under the current demand level for the San Joaquin Basin CALSIM II modeling, most of the urban water demands are met through groundwater pumping. For urban uses satisfied through groundwater sources, it is assumed that 100 percent of the demand will be met each year and that there are no return flows to the system. Only the major surface water M&I diversions are represented in CALSIM II and consist of Stockton East WD's delivery to City of Stockton (up to 40 TAF[4] annually, see also Section 3, page 40 and Section 7, page 117), Modesto ID's delivery to City of Modesto (up to 34.6 TAF[5] annually, see also Section 3, page 34 and Section 7, page 104), and South San Joaquin ID's South County Project delivery (up to 25 TAF[6] annually, see also Section 7, page 111). As the revised CALSIM II San Joaquin representation is developed for a future level of development, new assumptions will have to be made as to which urban water users will be served by surface water and how return flows will be accounted.

Refuge Demands

With the exception of the Merced National Wildlife Refuge (Merced NWR), all San Joaquin Valley wildlife management areas and refuges are modeled as part of the west side operations. The Merced NWR has a 15,000 AF[7] demand for Merced River water via Merced ID, which is distributed monthly as shown in Table 3-28. This demand was not determined as part of a water budget approach, but was determined based on information provided by both Merced ID and Merced NWR.

Table 3-28: Merced NWR Monthly Demands (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	600	800	1,100	600	600	1,900	400	200	1,100	3,800	2,800	1,100

[4] The City of Stockton water treatment facility has an annual capacity of 40 TAF. The City's actual M&I demand exceeds 40 TAF, but this additional demand is satisfied through groundwater pumping, which is not represented in CALSIM II.

[5] The City of Modesto water treatment facility has an annual capacity of 34.6 TAF. The annual M&I demand within the Modesto ID demand area as shown in Table 2 27 approaches 65 TAF. Demands above the treatment plant's capacity represent demand for groundwater.

[6] The South County Project delivery of 25 TAF is in excess of the total M&I demand within the South San Joaquin ID demand area. This apparent discrepancy in information can be reconciled through the knowledge that the South County Project services municipalities outside South San Joaquin ID (including City of Tracy).

[7] This demand does not represent the consumptive demand for water, but is representative of Merced NWR's use of Merced River water.

West Side Demands

The water demand assumptions on the San Joaquin Valley west side are fundamentally different than the east side demand assumptions. Where the east side utilizes an approach to determine the land use within spatially defined demand areas and then estimates the volume and origin of water necessary to meet that land's requirements, the west side representation (with two exceptions[8]) relies only on surface water contract (or water rights) amounts to define demand. A land use-based approach to modeling the San Joaquin Basin west side could be a significant enhancement to CALSIM II in the future.

As mentioned previously in this document, there are three types of water demands represented in CALSIM II: agricultural, M&I, and wildlife refuge demands. The large majority of west side water users that are hydraulically connected to the San Joaquin River are Central Valley Project (CVP) contractors. CVP commitments on the west side include agricultural, M&I, refuge, and exchange contracts; non-CVP west side demands include Schedule II water rights, Patterson Water District water rights, and San Joaquin River main stem riparian diversions.
Table 3-29 through Table 3-32 below identify the west side water contracts and water rights included in CALSIM II that have some hydraulic connectivity (return flows) to the San Joaquin River[9].

Table 3-29: West Side Demands (Mendota Pool)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Westlands WD (incl. Barcellos)	CVP Ag	50,000
Fresno Slough WD	CVP Ag	4,000
James ID	CVP Ag	35,300
Traction Ranch/F&G	CVP Ag	2,080
Tranquility ID	CVP Ag	13,800
Melvin Hughes	CVP Ag	70
R.D. 1606	CVP Ag	228
Exchange Contractors	CVP Ex	700,000
Grasslands WD	CVP Ref	19,118
Los Banos WMA	CVP Ref	7,952
San Luis NWR	CVP Ref	25,333
Mendota WMA	CVP Ref	27,594
West Gallo	CVP Ref	14,413
East Gallo	CVP Ref	0

[8] Mainstem diversions between the Merced and Tuolumne Rivers and between the Tuolumne and Stanislaus Rivers do not use contract/water rights amounts to define water demand.
[9] Table 3-29 should not be misinterpreted as a comprehensive table of all CALSIM II south-of-delta demands. The intent of this document is to detail water operations in the San Joaquin Basin that have an effect on the flow and water quality of the San Joaquin River. Those contracts in the San Joaquin Valley west side that do not have the potential of returning flow (or otherwise affecting flow/quality) to the San Joaquin River are not included in Table 2 30 (e.g., CVP San Felipe Division demands, State Water Project demands, Cross Valley Canal demands, etc.).

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Schedule II Water Rights	WR	34,813
Project Losses	Loss	101,500
CVP Ag		105,478
CVP M&I		0
CVP Exchange		700,000
CVP Refuge		94,410
Water Right		34,813
CVP Losses		101,500
CVP Total		**1,001,388**
TOTAL		**1,036,201**

Table 3-30: West Side Demands (Lower Delta-Mendota Canal)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Panoche WD	CVP Ag	6,580
San Luis WD	CVP Ag	65,000
Broadview WD	CVP Ag	27,000
Laguna WD	CVP Ag	800
Eagle Field WD	CVP Ag	4,550
Mercy Springs WD	CVP Ag	13,300
Oro Loma WD	CVP Ag	4,600
Widren WD	CVP Ag	2,990
Exchange Contractors	CVP Ex	140,000
Grasslands via CCID	CVP Ref	83,824
Los Banos WMA	CVP Ref	7,501
Kesterson NWR	CVP Ref	11,147
Freitas – SJBAP	CVP Ref	7,053
Salt Slough – SJBAP	CVP Ref	7,859
China Island – SJBAP	CVP Ref	8,196
Volta WMA	CVP Ref	13,000
Grasslands via Volta Wasteway	CVP Ref	44,118
CVP Ag		124,820
CVP M&I		0
CVP Exchange		140,000
CVP Refuge		182,698
Water Right		0
CVP Losses		0
CVP Total		**447,518**
TOTAL		**447,518**

Table 3-31: West Side Demands (Upper Delta-Mendota Canal)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Plainview WD	CVP Ag	20,600
Banta Carbona ID	CVP Ag	25,000