APPENDIX C. CALIFORNIA SIMULATION OF EVAPOTRANSPIRATION OF APPLIED WATER (CALSIMETAW)

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C.1 SUMMARY

CalSIMETAW was designed to estimate daily soil water balance to determine potential crop evapotranspiration (ETc) and evapotranspiration of applied water (ETaw) for 132 individual crops, 20 crop categories, and four land-use categories by DAU/county for use in California Water Plan. The model requires weather data, soils, crop coefficients, rooting depths, seepage, etc., that influence crop water balance. The model uses daily weather data, derived from monthly PRISM climate data and daily US National Climate Data Center climate station data to cover California with 4×4 km grid spacing. From the PRISM data, reference evapotranspiration (ETo) is estimated using the Hargreaves-Samani equation that was calibrated to estimate regional Penman-Monteith equation ETo to account for spatial climate differences. In addition to using historical data, CalSIMETAW can use near-real-time data from Spatial CIMIS, which is a model that combines weather station data and remote sensing to provide a statewide grid of ETo information.

CalSIMETAW estimates ETc as the product of ETo and a crop coefficient (Kc) value. Crop coefficients are commonly developed by measuring ETc, calculating ETo, and determining the ratio Kc = ETc / ETo. Most of the crop coefficients used in CalSIMETAW were developed in California. Some were adopted from the literature Doorenbos and Pruitt, (1977) and Allen et al., (1998). Also, Kc values need adjustment for microclimates, which are plentiful and extreme in California. A microclimate Kc correction based on the ETo rate is included in the CalSIMETAW model. CalSIMETAW also accounts for the influence of orchard cover crops on Kc values. With a cover crop, the Kc values for deciduous trees and vine crops are higher. When a cover crop is present, Kc values are increased by up to 0.35 depending on the amount of cover. However, Kc values are not allowed to exceed 1.15. Since ground cover will continue to transpire during the leafless period of deciduous trees and vines, the Kc values are not allowed to fall below 0.90. CalSIMETAW also accounts for immaturity effects on Kc values for tree and vine crops. Immature tree and vine crops use less water than mature crops. When the canopy reaches 70% ground cover, the crop is considered mature. In other words, when the canopy reaches 70% ground cover, the crop coefficient values for tree and vine crops are at peak because of light interception by the crop canopy.

Because the Land IQ datasets provided for the Delta Consumptive Use Study did not specifically delineate the acreages of young orchards in 2015 or 2016, the results of CalSIMETAW that are reported assume that all orchard crops were mature. This may result in overestimating ETc for orchards in the Delta. More specifically, the degree of accuracy of CalSIMETAW on agricultural water use estimates is largely dependent on the accuracy and limitations of the input data.

CalSIMETAW also uses daily rainfall data to estimate bare soil evaporation as a function of mean ETo and wetting frequency in days. A bare soil Kc value is calculated to estimate the off-season evapotranspiration and a baseline for in-season Kc calculations. The Kc values and corresponding growth dates are included by crop in the model. These dates and Kc values are used to estimate daily Kc values during a season.

The model uses SSURGO soil characteristic data and crop information with precipitation and ETc data to generate hypothetical water balance irrigation schedules to determine ETaw, which is an estimate of the seasonal irrigation requirement assuming minimal water stress and 100% application efficiency.

C.2 DETAILED ANALYSIS UNITS/COUNTY (DAU/COUNTY)

The California Department of Water Resources (DWR) has subdivided California into study areas for planning purposes. The largest study areas are the ten hydrologic regions (HR), which are composed of detailed analysis units (DAU). The DAUs are often split by county, which are the smallest study areas used by DWR. The DAU/counties are used for estimating water demand by agricultural crops and other surfaces for water resources planning.

C.3 SOIL CHARACTERISTICS

A database containing the soil water holding capacity and soil depth information for all of California was developed from the USDA-NRCS SSURGO database (SSURGO, 2011). The developed database covers all of California on the same 4×4 km grid for all locations that are included in the PRISM database, which covers most of California.

C.4 DAILY SOIL WATER BALANCE CALCULATIONS

Although CalSIMETAW has soil characteristic information and computes ETo on a 4×4 km grid, crop planting information is limited to the detailed analysis unit (DAU)/county level. Therefore, the DAU/county is the smallest unit for calculation of the water balance and thus ETaw. Using GIS, a weight mean value is determined by DAU/county for the soil water holding characteristic, soil depth, root depth, and ETo. The smaller of the soil and root depth and the weighted mean water holding characteristics are used to determine the plant available water (PAW). A 50% allowable depletion is used to estimate the readily available water (RAW) for the effective rooting zone. A management allowable depletion (MAD) is determined by comparing the RAW with the cumulative ETc during the season. The MAD is always less than or equal to RAW, and it is set so that the soil water content at the end of the season is between RAW and PAW.

Weighted crop coefficient curves for each land use category are used with the daily ETo estimates to calculate daily ETc. The ETc is subtracted from the soil water content on each day until the soil water depletion (SWD) exceeds the MAD. Then an irrigation is applied and the soil water depletion goes back to zero (i.e. back to field capacity). Similarly, rainfall will decrease the soil water depletion to zero but never negative. When rainfall depths are greater than the SWD, the rainfall is only effective up to a depth equal to SWD. There is not correction for runoff or runon to the field. It is assumed that if rainfall is sufficient to have appreciable runoff, then the soil will be filled to field capacity and our assumption that effective rainfall cannot exceed SWD still applies. This method works because the water balance calculations are daily. It might fail for intervals longer than daily.

C.5 STRUCTURE OF CALSIMETAW AND ITS DATABASE

CalSIMETAW was written using Microsoft C# for calculations and Oracle Spatial 11 g for data storage to provide a new tool for obtaining accurate estimates of ETc, ETaw, effective precipitation (Ep), and applied water (AW) for 20 crop categories by DAU/county.

The application uses batch processing to read (1) the daily weather data, (2) the crop coefficient values, (3) growth dates, (4) soil information, (5) crop and irrigation information, and (6) the surface area of each crop category in each of the 482 DAU/counties in California. Then the program computes daily ETo, Kc, ETc, daily soil water balance, Ep, and ETaw for every surface within each DAU/county for the period of record. Using the surface areas, volumes of water corresponding to ETc, Ep, ETaw, and AW are computed for each surface on each DAU/county. The application also accounts for seepage contributions to ETc and it estimates soil evaporation using a 2-stage soil evaporation model based on mean ETo and wetting frequency in days. Figure C-1 illustrates the structure, database, and lists of input and output data files of the CalSIMETAW model. The input data files in the CalSIMETAW model include historical land use records and crop and irrigation information for each crop category within each DAU/county. The model's Oracle database includes:

- Daily and monthly PRISM weather data to cover California on a 4×4 km grid spacing from October 1921 to December 2016.
- Daily Spatial CIMIS weather data on a 4×4 km grid spacing from October 2004 to December 2016.
- Geographic database to help identify the PRSIM grids by five different land use groups (agricultural irrigated land, urban, native vegetation, water surface, and wetland) within each DAU/county.
- Available soil water-holding capacity and maximum soil depth on a 4×4 km grid spacing over California developed using the USDA NRCS SSURGO database.
- Crop information which includes plant dates, harvest dates, effective rooting depth, and crop coefficients for 20 crop categories on each DAU/county.

The output data files generated by CalSIMETAW consist of:

- Climate and calculated ETo data by PRISM grid (latitude and longitude) and DAU/county over the entire state.
- Daily soil water balance output by unit for individual crops and 20 crop categories by DAU/county.

- Monthly total ETo, ETc, Ep, ETaw, and AW by unit for individual crops and 20 crop categories by DAU/county.
- Seasonal and annual ETc, Ep, ETaw, and AW by unit for 20 crop categories by DAU/county within DAUs, counties, planning areas (PAs), hydrologic regions (HR), and region offices (ROs).
- Seasonal ETc, Ep, ETaw, and AW by volume for 20 crop categories by DAU/county, DAU, County, PA, HR, and RO.
- Volume values of seasonal and annual ETc, Ep, ETaw, and AW for 20 crop categories by DAU/county, DAU, County, PA, HR, and RO for a specific water year and calendar year.

After performing a quality control evaluation of the output data files, they are be stored in a logically organized database available to all who need the information. The Oracle database is used to store the water use/demand data by DAU/County, DAU, County, PA, hydrologic region, RO, and the State over the period of record.

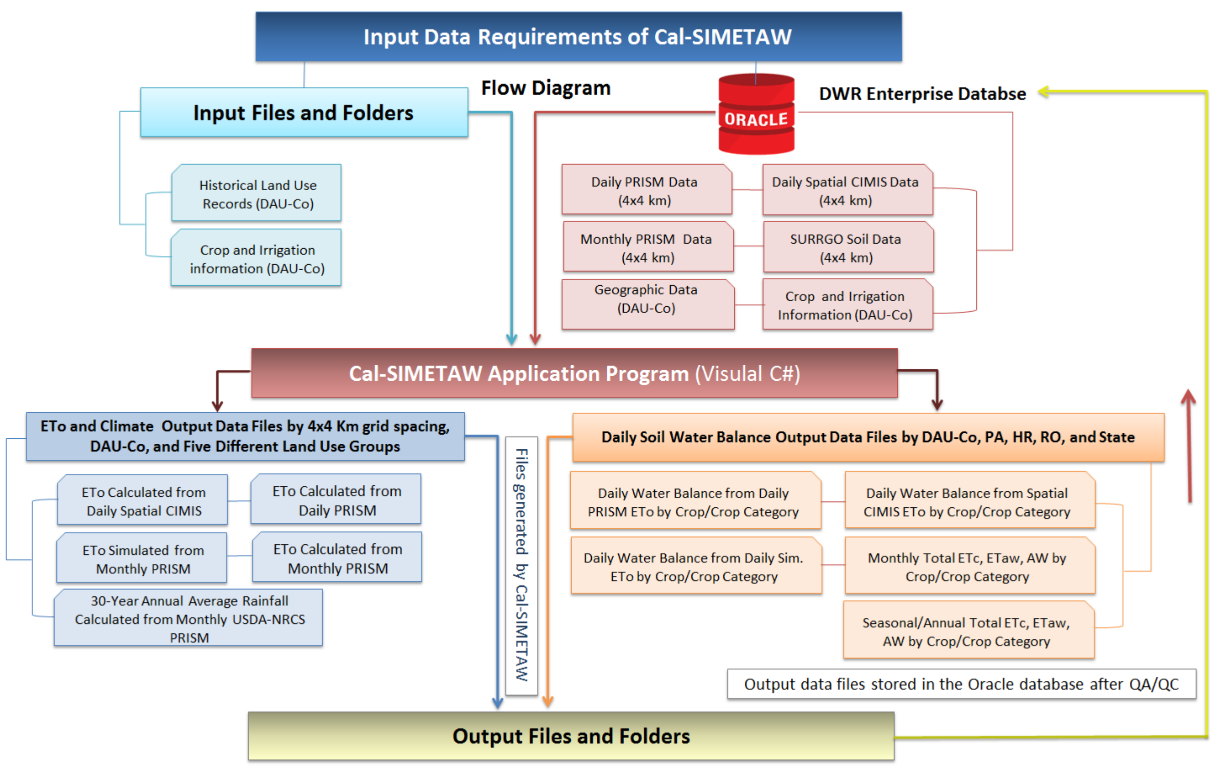

Figure C-1. Schematic of the Oracle database structure and lists of input and output data files of the CalSIMETAW model.

C.6 REFERENCES

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