

Complying with the GWPA Requirements

Estimating Crop Water Use

Introduction

DPR regulations for use of selected pesticides in Leaching GWPA require that for each irrigation for 6 months following the pesticide application, the net irrigation application be no more than 133% of the net irrigation requirement. Determining the net irrigation requirement can be most easily determined by calculating the crop water use since the last irrigation. Crop water use is frequently referred to as *Evapotranspiration (ET)*. To simplify the determination of crop water use, this section contains tables which give historical ET estimates for many of the crops grown in the Leaching GWPA's.

Evapotranspiration (ET)

Evapotranspiration (ET) consists of two components: transpiration and evaporation. *Transpiration* is water evaporated from plant leaves. *Evaporation* is water evaporated from the soil surface. The two terms are combined into one term evapotranspiration because it is difficult to measure the two components separately.

Transpiration is the water evaporated from plant leaves and occurs mainly inside pores in the leaf called stomata. The rate of transpiration depends on the solar energy available for evaporating the leaf water, the movement of the air around the plant, and the relative dryness of the air. At least 95% of the water taken up by plants is transpired. The purpose of transpiration is to cool the plants so that growth processes can occur, and to stimulate water flow from the roots to the leaf.

Solar radiation is the primary source of energy for evapotranspiration. Increased solar radiation increases the potential evapotranspiration. The amount of solar radiation depends on the time of day, time of year, latitude and cloud cover. Maximum radiation occurs in June in California. Daily solar radiation increases with time of day to a maximum at about noon during the summer. On cloudless days, about 70 to 80 percent of the sun's radiation (direct radiation) reaches the earth's surface directly. On cloudy days, most solar radiation is diffuse radiation, which is direct radiation scattered by the atmosphere.

Although solar radiation provides the energy needed for evapotranspiration, the evaporated water or water vapor must also flow away from the leaf and soil surface for evapotranspiration to occur. The rate at which water vapor flows away depends on the water vapor content of the surrounding air, and the air turbulence. Water vapor content of the surrounding air depends on temperature and humidity. High temperatures mean increased potential for transpiration. High humidity means the potential is less for transpiration. The rate at which water vapor flows from a leaf is also affected by turbulence caused by eddies and wind. This turbulent air transports water away from the leaves into the atmosphere. Wind affects evapotranspiration considerably. Air blowing over a hot surface picks up heat. The heated air blowing over an irrigated field heats the leaves, causing increased transpiration. The effect of heated air on crop growth is more

noticeable at the edge of the field than inside the field. Plants at the edge of the field can be stressed while plants elsewhere are not.

During crop germination and establishment, most evapotranspiration is evaporated from the soil surface. The higher the frequency of soil wetting, whether from irrigation or rainfall, the higher the evaporation rate from the soil. An exception is subsurface drip irrigation, in which case soil evaporation depends on the depth of the drip tape or tubing system.

As leaves grow, evaporation from the soil surface decreases and transpiration from leaf surfaces increases. Canopy coverage of about 60 to 70 percent for tree crops and about 70 to 80 percent of field and row crops result in maximum evaporation. Maximum evapotranspiration rates are somewhat similar for many field and row crops under the same conditions but significant differences can occur for tree crops. For example, evapotranspiration rates for citrus and olive crops are much lower than many other tree crops in the Sacramento and San Joaquin Valleys.

For many crops, plant growth is most sensitive to water stress during reproductive stages (development of seeds and fruit). Water stress occurring during these stages will depress yields more than in other growth stages.

Estimating crop water use from climate data

Climate data such as net solar radiation, temperature, humidity and wind speed are commonly used to calculate a reference crop evapotranspiration. The reference crop evapotranspiration is that of an adequately-irrigated grass or alfalfa crop where soil moisture is not a limiting factor. The reference crop provides a standard measure of evapotranspiration that can be determined easily at various locations using climate data.

The evapotranspiration for a particular crop is then calculated from:

$$ET_c = K_c \times ET_o$$

where

ET_c = crop evapotranspiration

K_c = crop coefficient

ET_o = evapotranspiration of the reference crop

Crop coefficients relate crop evapotranspiration to the reference crop evapotranspiration. The value of the crop coefficient depends on crop type, stage of growth, and type of reference crop used (alfalfa or grass).

Availability of ET Information

Evapotranspiration information is often available in two forms: historical ET information and real-time information. Historical ET information is the crop water use, estimated from long-term averages. For any particular day, the actual ET may vary from the historical average, but it has

been found that the actual ET for longer time periods (e.g. a week) agree very closely with historical average ET for the same time period.

Real-time ET estimates are also available to most growers in California. Real-time ET is determined by collecting weather data and estimating ET. California uses the CIMIS (California Irrigation management Information System) network of weather stations to collect the data and then estimate the ET of pasture grass. This information is readily available from a number of sources. Two good sources are web-based and are www.ipm.ucdavis.edu/ and www.cimis.water.ca.gov/. The pasture grass ET must then be converted to the ET of your crop by using a crop coefficient. While seemingly complicated at first, this process of calculating real-time ET can be readily mastered. For more information on real-time ET, see the University of California ANR Publication 3396 “Scheduling Irrigations: When and How Much Water to Apply” (<http://anrcatalog.ucdavis.edu>).

Using historical crop ET to estimate crop water use

Using Historical ET information is an excellent method of determining crop water use for quantifying irrigation efficiency. Historical ET is simply long-term average values of ET. Because of the consistency of the climate in the Central Valley, where most of the GWPA's are located. Variability in reference crop evapotranspiration from year to year is small, and thus differences between historical ET values based on many years of data and actual values for any given year are small.

Tables of crop water use information for the predominant crops in the main counties with GWPA's in California's Central Valley are provide in Tables CWU-1 to CWU-11. It should be noted that the information in the Tables combines the historic reference crop ET with crop coefficients to give the crop water use. The main advantages of using historic evapotranspiration are convenience and the ability to predict irrigations throughout the growing season.

Historical crop water use for the following crops are listed in the following tables:

<u>Table Number</u>	<u>Crop</u>
CWU-1	Almonds
CWU-2	Walnuts
CWU-3	Stone Fruit
CWU-4	Grapes
CWU-5	Corn (Planted March 1)
CWU-6	Corn (Planted March 15)
CWU-7	Corn (Planted April 1)
CWU-8	Corn (Planted May 1)
CWU-9	Corn (Planted June 1)
CWU-10	Olives
CWU-11	Prunes

Since California has so many crops, it is possible that a particular crop is missing from the list above. If this is the case, contact the authors, your local UC Cooperative Extension Advisor or a private consultant to get assistance in quantifying crop water use. There is also additional crop ET information contained in the University of California ANR Publication 3396 “Scheduling Irrigations: When and How Much Water to Apply” (<http://anrcatalog.ucdavis.edu>).

To estimate the crop water use during a specific period and at a specific location, reference should be made to the appropriate table for the crop being grown.

The crop water use in the tables is provided in the form of inches/day during various two-week time periods throughout the year. For example, referring to a crop water use table for walnuts in Merced county (Table CWU-2) shows that crop ET is 0.26 in/day during July 1-15. This means that during each day of the period July 1-15, the historical averaged ET would be 0.26 in/day. If you wanted to know the total crop water use during the July 1-15 period, it would be 0.26 in/day \times 15 days = 3.90 inches. For a 10-day interval during the July 1-15 period, the total crop water use would be 0.26 in/day \times 10 days = 2.6 inches, and so on.

Also if the period between irrigations covers two of the periods listed, the ET for each period should be used proportionally. For example, if an almond crop in Stockton was irrigated on June 24 and July 7, the crop water use during the period was (6days \times 0.22 inches/day) plus (7 days \times 0.24 inches/day) making a total crop water use during the 13 day-period of 3.00 inches.

A worksheet for estimating crop water use from historic ET Values is given below.

Worksheet for estimating crop water use from historic ET Values

A	B	C	D	E	F	G	
Irrigation Number	Date of previous irrigation	Date of Irrigation	Crop Water Use since last irrigation (from CWU Tables)			Total crop water use during period since last irrigation	
			Period from CWU Table	Number of days	Daily crop water use from CWU Table	Crop water use (CWU) (Column D \times Column E)	(Sum of CWU listed in Column F since last irrigation)
3		June 24					
4	June 24	July 7	June16-30	6	0.22	1.32	
			July 1-15	7	0.24	1.68	3.00

Table CWU-1. Almond ET (in/day)

	Location						
	Red Bluff	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15							
Jan 16-31							
Feb 1-15							
Feb 16-28							
Mar 1-15							
Mar 16-31	0.06	0.06	0.06	0.01	0.06	0.07	0.07
Apr 1-15	0.12	0.08	0.08	0.08	0.08	0.10	0.10
Apr 16-30	0.16	0.12	0.12	0.12	0.12	0.13	0.13
May 1-15	0.18	0.15	0.14	0.14	0.14	0.16	0.15
May 16-31	0.18	0.17	0.18	0.17	0.18	0.19	0.18
Jun 1-15	0.19	0.21	0.21	0.20	0.22	0.22	0.22
Jun 16-30	0.20	0.23	0.23	0.22	0.22	0.23	0.23
July 1-15	0.22	0.26	0.26	0.24	0.24	0.25	0.25
July 16-31	0.23	0.26	0.26	0.24	0.24	0.24	0.25
Aug 1-15	0.23	0.24	0.24	0.23	0.23	0.23	0.24
Aug 16-31	0.22	0.21	0.20	0.20	0.19	0.21	0.21
Sept 1-15	0.19	0.19	0.19	0.09	0.18	0.18	0.20
Sept 16-30	0.15	0.15	0.15	0.15	0.14	0.14	0.15
Oct 1-15	0.12	0.11	0.11	0.11	0.11	0.11	0.12
Oct 16-31	0.08	0.07	0.07	0.06	0.07	0.07	0.08
Nov 1-15	0.05	0.05	0.05	0.04	0.05	0.05	0.06
Nov 16-30							
Dec 1-15							
Dec 16-31							
Total	37.84	38.53	38.26	34.42	37.13	38.44	39.55

Table CWU-2. Walnut ET (in/day)

	Location						
	Red Bluff	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15							
Jan 16-31							
Feb 1-15							
Feb 16-28							
Mar 1-15							
Mar 16-31		0.01	0.01	0.00	0.01	0.02	0.02
Apr 1-15		0.07	0.07	0.07	0.07	0.09	0.08
Apr 16-30	0.09	0.12	0.12	0.12	0.12	0.13	0.14
May 1-15	0.10	0.16	0.15	0.15	0.15	0.17	0.17
May 16-31	0.15	0.19	0.20	0.18	0.20	0.21	0.20
Jun 1-15	0.17	0.23	0.23	0.22	0.24	0.24	0.24
Jun 16-30	0.20	0.27	0.27	0.26	0.26	0.27	0.27
July 1-15	0.23	0.32	0.32	0.30	0.30	0.31	0.31
July 16-31	0.27	0.32	0.32	0.30	0.30	0.29	0.31
Aug 1-15	0.28	0.30	0.29	0.27	0.27	0.27	0.29
Aug 16-31	0.28	0.25	0.24	0.24	0.23	0.25	0.25
Sept 1-15	0.24	0.22	0.22	0.11	0.21	0.21	0.23
Sept 16-30	0.19	0.16	0.16	0.16	0.15	0.15	0.16
Oct 1-15	0.15	0.11	0.11	0.11	0.11	0.11	0.12
Oct 16-31	0.06	0.05	0.05	0.04	0.05	0.05	0.05
Nov 1-15	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Nov 16-30							
Dec 1-15							
Dec 16-31							
Total	37.04	41.96	41.63	38.21	40.29	41.62	42.77

Table CWU-3. Stone Fruit ET (in/day)

	Location						
	Yuba City	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15							
Jan 16-31							
Feb 1-15							
Feb 16-28							
Mar 1-15	0.07	0.04	0.04	0.04	0.04	0.06	0.05
Mar 16-31	0.09	0.07	0.07	0.01	0.07	0.08	0.08
Apr 1-15	0.11	0.09	0.09	0.09	0.09	0.11	0.11
Apr 16-30	0.13	0.13	0.13	0.13	0.13	0.14	0.15
May 1-15	0.14	0.16	0.15	0.15	0.15	0.17	0.16
May 16-31	0.16	0.19	0.20	0.18	0.20	0.20	0.20
Jun 1-15	0.18	0.22	0.22	0.21	0.23	0.23	0.23
Jun 16-30	0.19	0.23	0.23	0.23	0.23	0.23	0.23
July 1-15	0.20	0.24	0.24	0.23	0.23	0.23	0.23
July 16-31	0.21	0.24	0.24	0.23	0.23	0.22	0.23
Aug 1-15	0.22	0.23	0.22	0.21	0.21	0.21	0.22
Aug 16-31	0.20	0.19	0.18	0.18	0.17	0.19	0.19
Sept 1-15	0.18	0.17	0.17	0.09	0.17	0.17	0.18
Sept 16-30	0.15	0.13	0.13	0.13	0.12	0.12	0.14
Oct 1-15	0.12	0.10	0.10	0.10	0.10	0.10	0.11
Oct 16-31	0.10	0.06	0.06	0.05	0.06	0.06	0.07
Nov 1-15							
Nov 16-30							
Dec 1-15							
Dec 16-31							
Total	36.70	37.62	37.37	33.66	36.33	37.87	38.66

Table CWU-4. Table Grapes or fully-irrigated winegrapes ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15						
Mar 16-31	0.04	0.04	0.00	0.04	0.04	0.04
Apr 1-15	0.06	0.06	0.06	0.06	0.07	0.07
Apr 16-30	0.09	0.09	0.09	0.09	0.10	0.10
May 1-15	0.12	0.11	0.11	0.11	0.13	0.12
May 16-31	0.15	0.16	0.14	0.16	0.17	0.16
Jun 1-15	0.20	0.20	0.19	0.20	0.20	0.20
Jun 16-30	0.22	0.22	0.21	0.21	0.22	0.22
July 1-15	0.23	0.23	0.21	0.21	0.22	0.22
July 16-31	0.23	0.23	0.21	0.21	0.21	0.22
Aug 1-15	0.21	0.21	0.20	0.20	0.20	0.21
Aug 16-31	0.17	0.16	0.16	0.15	0.17	0.17
Sept 1-15	0.13	0.13	0.07	0.13	0.13	0.14
Sept 16-30	0.09	0.09	0.09	0.08	0.08	0.09
Oct 1-15	0.06	0.06	0.06	0.06	0.06	0.06
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	29.87	29.64	27.06	28.72	29.75	30.37

Table CWU-5. Corn (Planted March 1) ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15	0.02	0.02	0.02	0.02	0.02	0.02
Mar 16-31	0.02	0.02	0.00	0.02	0.02	0.02
Apr 1-15	0.06	0.06	0.06	0.06	0.07	0.07
Apr 16-30	0.14	0.14	0.14	0.14	0.14	0.15
May 1-15	0.22	0.21	0.21	0.21	0.24	0.23
May 16-31	0.26	0.27	0.25	0.27	0.28	0.27
Jun 1-15	0.29	0.29	0.28	0.30	0.30	0.30
Jun 16-30	0.29	0.29	0.28	0.28	0.29	0.29
July 1-15	0.22	0.22	0.21	0.21	0.21	0.21
July 16-31	0.15	0.15	0.14	0.14	0.13	0.14
Aug 1-15						
Aug 16-31						
Sept 1-15						
Sept 16-30						
Oct 1-15						
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	24.99	25.00	23.60	24.62	25.88	25.72

Table CWU-6. Corn (Planted March 15) ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15						
Mar 16-31	0.02	0.02	0.00	0.02	0.02	0.02
Apr 1-15	0.03	0.03	0.03	0.03	0.03	0.03
Apr 16-30	0.08	0.08	0.08	0.08	0.08	0.09
May 1-15	0.15	0.14	0.14	0.14	0.17	0.16
May 16-31	0.23	0.24	0.22	0.24	0.25	0.24
Jun 1-15	0.29	0.29	0.28	0.30	0.30	0.30
Jun 16-30	0.32	0.32	0.30	0.30	0.32	0.32
July 1-15	0.28	0.28	0.26	0.26	0.27	0.27
July 16-31	0.21	0.21	0.20	0.20	0.19	0.21
Aug 1-15	0.13	0.13	0.12	0.12	0.12	0.13
Aug 16-31						
Sept 1-15						
Sept 16-30						
Oct 1-15						
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	26.18	26.15	24.56	25.54	26.43	26.51

Table CWU-7. Corn (Planted April 1) ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15						
Mar 16-31						
Apr 1-15	0.03	0.03	0.03	0.03	0.03	0.03
Apr 16-30	0.04	0.04	0.04	0.04	0.04	0.04
May 1-15	0.10	0.09	0.09	0.09	0.11	0.10
May 16-31	0.17	0.17	0.16	0.17	0.18	0.17
Jun 1-15	0.25	0.25	0.24	0.26	0.26	0.26
Jun 16-30	0.30	0.30	0.29	0.29	0.30	0.30
July 1-15	0.31	0.31	0.29	0.29	0.30	0.30
July 16-31	0.30	0.30	0.28	0.28	0.27	0.29
Aug 1-15	0.21	0.20	0.19	0.19	0.19	0.20
Aug 16-31	0.12	0.12	0.12	0.11	0.12	0.12
Sept 1-15						
Sept 16-30						
Oct 1-15						
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	27.20	27.03	25.72	26.16	26.94	27.20

Table CWU-8. Corn (Planted May 1) ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15						
Mar 16-31						
Apr 1-15						
Apr 16-30						
May 1-15	0.04	0.04	0.04	0.04	0.04	0.04
May 16-31	0.05	0.05	0.04	0.05	0.05	0.05
Jun 1-15	0.14	0.14	0.13	0.14	0.14	0.14
Jun 16-30	0.24	0.24	0.23	0.23	0.24	0.24
July 1-15	0.30	0.30	0.28	0.28	0.29	0.29
July 16-31	0.30	0.30	0.28	0.28	0.27	0.29
Aug 1-15	0.28	0.27	0.25	0.25	0.25	0.27
Aug 16-31	0.20	0.19	0.19	0.18	0.20	0.20
Sept 1-15	0.13	0.13	0.07	0.13	0.13	0.14
Sept 16-30						
Oct 1-15						
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	24.88	24.59	22.52	23.51	24.03	24.64

Table CWU-9. Corn (Planted June 1) ET (in/day)

	Location					
	Madera	Merced	Stockton	Modesto	Parlier	Visalia
Jan 1-15						
Jan 16-31						
Feb 1-15						
Feb 16-28						
Mar 1-15						
Mar 16-31						
Apr 1-15						
Apr 16-30						
May 1-15						
May 16-31						
Jun 1-15	0.08	0.08	0.07	0.08	0.08	0.08
Jun 16-30	0.18	0.18	0.17	0.17	0.18	0.18
July 1-15	0.29	0.29	0.27	0.27	0.28	0.28
July 16-31	0.30	0.30	0.28	0.28	0.27	0.29
Aug 1-15	0.28	0.27	0.26	0.26	0.26	0.27
Aug 16-31	0.23	0.22	0.22	0.21	0.23	0.23
Sept 1-15	0.15	0.15	0.08	0.14	0.14	0.16
Sept 16-30	0.07	0.07	0.07	0.07	0.07	0.07
Oct 1-15						
Oct 16-31						
Nov 1-15						
Nov 16-30						
Dec 1-15						
Dec 16-31						
Total	23.72	23.41	21.34	22.22	22.63	23.47

Table CWU-10. Olive ET (in/day)

	Location	
	Red Bluff	Visalia
Jan 1-15		
Jan 16-31		
Feb 1-15		
Feb 16-28		
Mar 1-15	0.10	0.10
Mar 16-31	0.12	0.12
Apr 1-15	0.14	0.15
Apr 16-30	0.16	0.18
May 1-15	0.17	0.19
May 16-31	0.17	0.21
Jun 1-15	0.18	0.24
Jun 16-30	0.19	0.25
July 1-15	0.21	0.25
July 16-31	0.22	0.25
Aug 1-15	0.22	0.23
Aug 16-31	0.22	0.20
Sept 1-15	0.20	0.19
Sept 16-30	0.18	0.15
Oct 1-15	0.15	0.13
Oct 16-31	0.13	0.09
Nov 1-15		0.07
Nov 16-30		
Dec 1-15		
Dec 16-31		
Total	38.92	43.30

Table CWU-11. Prune ET (in/day)

	Location	
	Red Bluff	Yuba City
Jan 1-15		
Jan 16-31		
Feb 1-15		
Feb 16-28		
Mar 1-15		
Mar 16-31		
Apr 1-15	0.10	0.10
Apr 16-30	0.15	0.15
May 1-15	0.18	0.18
May 16-31	0.18	0.18
Jun 1-15	0.19	0.19
Jun 16-30	0.20	0.20
July 1-15	0.22	0.23
July 16-31	0.23	0.23
Aug 1-15	0.23	0.23
Aug 16-31	0.22	0.22
Sept 1-15	0.19	0.16
Sept 16-30	0.15	0.15
Oct 1-15	0.12	0.10
Oct 16-31	0.08	0.08
Nov 1-15		
Nov 16-30		
Dec 1-15		
Dec 16-31		
Total	37.25	36.91