Understanding Your Orchard's Water Requirements

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INTRODUCTION

The California State Water Code requires anyone discharging waste that could affect the waters of the state to obtain a permit or coverage under a waiver. Agricultural runoff, whether from irrigation or rainfall, that leaves a property has been determined to likely contain waste (sediment, nutrients, chemicals, etc.).

Compliance under the Irrigated Lands Conditional Waiver is available to agricultural landowners who have runoff from their property caused by irrigation practices or winter rainfall. The California Water Code does not impact the property owner if no runoff from any source leaves a property.

One potential cause of irrigation water runoff from an orchard is overirrigation, or irrigation in excess of the amount required to refill the trees' root zone. A simple way to determine the proper irrigation amount is to estimate the amount of water the trees have used, which is known as the evapotranspiration (ET), since the last irrigation.

HISTORICAL EVAPOTRANSPIRATION

A good initial step in estimating water use in your orchard is to use historical evapotranspiration estimates. These estimates are long-term averages developed by measuring the water use of a reference crop (well-watered pasture grass), and then converting the data for the reference crop to estimates for the orchard crop. Tables 1 through 9 show historical average evapotranspiration estimates for selected California locations during approximate 2-week periods for

- mature almonds (table 1)
- walnuts (table 2)
- pistachios (table 3)
- stone fruit (table 4)
- prunes (table 5)
- olives (table 6)
- citrus (table 7)
- apples (table 8)
- pears (table 9)

To determine the daily average orchard crop evapotranspiration (ET_c) (inches per day), divide the historical evapotranspiration during the period from table 1 through 9 by the number of days in the period.

The evapotranspiration estimates in Tables 1 through 9 are for orchards without a cover crop. Orchards with a cover crop may use up to 30 percent more water than the estimates presented. (Note: for metric conversion, 1 inch of water = 2.54 cm.)

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Figure 1. CIMIS station. *Photo:* Lawrence J. Schwankl.

REAL-TIME EVAPOTRANSPIRATION

It is possible to estimate orchard crop evapotranspiration more accurately using real-time evapotranspiration data provided by systems such as CIMIS (California Irrigation Management Information System), operated by the California Department of Water Resources. This system uses an extensive network of weather stations (fig. 1) to collect weather data and to estimate the daily reference crop evapotranspiration (ET_o) from well-watered pasture grass.

Since the evapotranspiration of an orchard crop is not the same as that of pasture grass, a crop coefficient (k_c) must be used to convert reference crop evapotranspiration (ET_o) to orchard crop evapotranspiration (ET_c). Table 10 lists the crop coefficients for almonds, walnuts, pistachios, stone fruit, prunes, olives, citrus, apples, and pears.

Orchard crop evapotranspiration is determined by multiplying the reference crop evapotranspiration by the crop coefficient:

$$ET_c = ET_o \times k_c$$

As an example, table 11 gives CIMIS real-time weather data for Modesto, Stanislaus County, from July 1 to July 15, 2005, including reference crop evapotranspiration. To determine the real-time almond crop evapotranspiration (ET_c) for Modesto on July 11, multiply the reference crop evapotranspiration (ET_o) for July 11 from table 11 (0.25 inch) by the almond crop coefficient (k_c) for July 1–15 from table 10 (0.93) to get an almond evapotranspiration of 0.23 inch.

CIMIS real-time evapotranspiration information can be accessed at the CIMIS Web site, http://wwwcimis.water.ca.gov/cimis/welcome.jsp. CIMIS stations do not cover all irrigated lands in California. More information on CIMIS, as well as other local and regional weather networks, can be accessed at

- University of California Integrated Pest Management (UC IPM) Web site, http://www.ipm.ucdavis.edu/ (click on "Weather data and products")
- University of California Fruit and Nut Research and Information Center Web site, http://fruitsandnuts.ucdavis.edu (click on "Weather")

You may also contact your local University of California Cooperative Extension office for local weather data and evapotranspiration information.

IRRIGATING YOUNG TREES

The smaller canopy of young trees results in less evapotranspiration than in mature trees. The evapotranspiration of young trees can be estimated from figure 2 by adjusting mature tree evapotranspiration based on the percent ground shading of the young trees, which can be estimated by examining the extent of the orchard floor shaded at midday. Note that evapotranspiration increases at a rate approximately twice that of the percent ground shading. Maximum evapotranspiration occurs at about 60 to 70 percent ground shading.

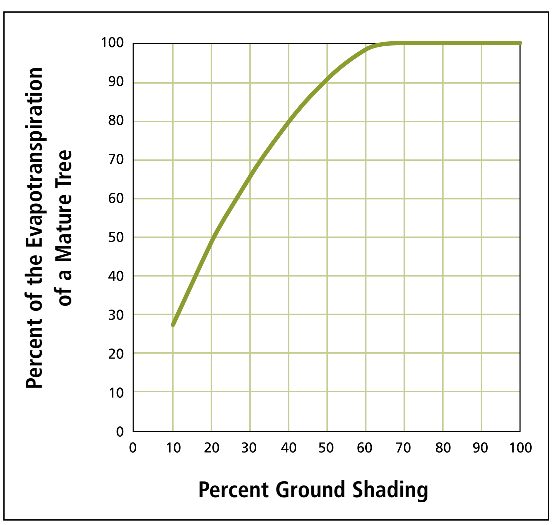

Figure 2. Evapotranspiration of young trees expressed as the percentage of the evapotranspiration of a mature tree versus the percent ground shading by a young tree.

DETERMINING THE IRRIGATION AMOUNT REQUIRED

To determine irrigation amount to be applied, calculate the total amount of orchard water used since the last irrigation. Using historical crop evapotranspiration information (see “Historical Evapotranspiration,” above) or real-time crop evapotranspiration (see “Real-Time Evapotranspiration,” above), sum the daily crop evapotranspiration since the last irrigation. This is the amount of soil water that must be replaced by irrigation. It is often necessary to apply additional water due to irrigation inefficiencies.

Irrigation System Application Rates

Evapotranspiration information is most frequently provided as inches of water use per unit of time. To operate an irrigation system efficiently, the irrigation system application rate must be known in compatible units. The following sections explain how to determine your system application rate.

Figure 3. Orchard border irrigation. *Photo:* Lawrence J. Schwankl.

Border Irrigation Systems

Border irrigation systems flood the area between tree rows (fig. 3). The amount of irrigation water applied may be determined by the following formula.

inches applied = [1.6 × flow to border (gpm) × irrigation set time (min)] ÷ [tree row length (ft) × tree row spacing (ft)]

For more information on determining the flow rate of border irrigation systems, see *Measuring Irrigation Flows in a Pipeline* (Publication 8213) and *Measuring Applied Water in Surface Irrigation* (Publication 8226).

Figure 4. Orchard furrow irrigation. *Photo:* Lawrence J. Schwankl.

Furrow Irrigation Systems

Furrow irrigation systems (fig. 4) carry water in furrows rather than flooding the entire area between tree rows. Most often, two or more furrows per tree row are used. The amount of irrigation water applied may be determined by the following formula.

inches applied = [1.6 × furrow inflow rate (gpm) × number of furrows per tree row × irrigation set time (min)] ÷ [tree row length (ft) × tree row spacing (ft)]

For more information on determining the flow rate of furrow irrigation systems, see the companion water management publications *Measuring Irrigation Flows in a Pipeline* (Publication 8213) and *Measuring Applied Water in Surface Irrigation* (Publication 8226).

Sprinkler Irrigation Systems

The application rates of sprinkler irrigation systems are most often provided in inches per hour, which is compatible with evapotranspiration data. If you do not know the sprinkler application rate in an orchard, see the companion water management publication *Soil Intake Rates and Application Rates in Sprinkler-Irrigated Orchards* (Publication 8216).

Microirrigation Systems

The application rate of microirrigation system emitters (drip emitters and microsprinklers) is usually measured in gallons per hour (gph). To convert an application rate in gallons per hour to inches per hour, use the following formula.

application rate (in/hr) = [1.6 × discharge from emission devices per tree (gph)] ÷ [tree row spacing (ft) × tree spacing within row (ft)]

FOR FURTHER INFORMATION

Storing Runoff from Winter Rains (ANR Publication 8211), 2007.

Measuring Irrigation Flows in a Pipeline (ANR Publication 8213), 2007.

Causes and Management of Runoff from Surface Irrigation in Orchards (ANR Publication 8214), 2007.

Managing Existing Sprinkler Irrigation Systems (ANR Publication 8215), 2007.

Soil Intake Rates and Application Rates in Sprinkler-Irrigated Orchards (ANR Publication 8216), 2007.

Tailwater Return Systems (ANR Publication 8225), 2007.

Measuring Applied Water in Surface Irrigation (ANR Publication 8226) [in process].

Scheduling Irrigations: When and How Much Water to Apply (ANR Publication 3396), 1999.

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Table 1. Almond historical evapotranspiration estimates (inches during period)

Date	Red Bluff	Williams	Modesto	Madera	Parlier	Visalia	Bakersfield
Mar 16–31	0.96	0.95	1.04	1.04	1.12	1.12	1.21
Apr 1–15	1.80	1.26	1.26	1.26	1.53	1.44	1.53
Apr 16–30	2.40	1.68	1.78	1.78	1.88	1.98	1.98
May 1–15	2.70	2.08	2.08	2.19	2.41	2.30	2.63
May 16–31	2.80	2.65	2.91	2.78	3.03	2.91	3.29
June 1–15	2.85	2.90	3.28	3.15	3.28	3.28	3.40
June 16–30	3.00	3.35	3.35	3.48	3.48	3.48	3.61
July 1–15	3.30	3.91	3.63	3.91	3.77	3.77	3.91
July 16–31	3.68	4.21	3.91	4.21	3.76	4.06	4.36
Aug 1–15	3.45	3.53	3.38	3.67	3.38	3.53	3.95
Aug 16–31	3.52	3.31	3.01	3.31	3.31	3.31	3.76
Sept 1–15	2.85	2.68	2.68	2.82	2.68	2.96	2.96
Sept 16–30	2.25	2.18	2.05	2.18	2.05	2.32	2.46
Oct 1–15	1.80	1.66	1.66	1.66	1.66	1.79	1.91
Oct 16–31	1.28	1.14	1.14	1.14	1.14	1.26	1.64
Nov 1–15	0.75	0.63	0.74	0.74	0.74	0.84	0.84

Table 2. Walnut historical evapotranspiration estimates (inches during period)

Date	Red Bluff	Chico	Stockton	Modesto	Parlier	Visalia
Mar 16–31	—	0.23	0.23	0.23	0.25	0.25
Apr 1–15	—	1.27	1.25	1.11	1.35	1.27
Apr 16–30	1.35	1.73	1.87	1.84	1.94	2.04
May 1–15	1.50	2.49	2.45	2.25	2.61	2.49
May 16–31	2.40	3.03	2.97	3.16	3.30	3.16
June 1–15	2.55	3.49	3.39	3.63	3.63	3.63
June 16–30	3.00	3.90	3.85	3.90	4.05	4.05
July 1–15	3.45	4.62	4.50	4.45	4.62	4.62
July 16–31	4.32	4.56	4.39	4.74	4.56	4.92
Aug 1–15	4.20	4.10	4.05	4.10	4.10	4.28
Aug 16–31	4.48	3.83	3.65	3.65	4.01	4.01
Sept 1–15	3.60	2.62	2.97	3.08	3.08	3.40
Sept 16–30	2.85	2.33	2.18	2.18	2.18	2.47
Oct 1–15	2.25	1.72	1.63	1.72	1.72	1.85
Oct 16–31	0.96	0.57	0.71	0.73	0.73	0.82
Nov 1–15	0.30	0.25	0.27	0.29	0.29	0.34

Table 3. Pistachio historical evapotranspiration estimates (inches during period)

Date	Parlier	Visalia	Kern County
Apr 1–15	0.18	0.17	0.18
Apr 16–30	1.23	1.29	1.29
May 1–15	2.24	2.14	2.45
May 16–31	3.57	3.42	3.87
June 1–15	4.25	4.25	4.41
June 16–30	4.74	4.74	4.91
July 1–15	4.82	4.82	5.00
July 16–31	4.76	5.14	5.52
Aug 1–15	4.28	4.46	5.00
Aug 16–31	3.94	3.94	4.48
Sept 1–15	2.82	3.12	3.12
Sept 16–30	1.96	2.22	2.35
Oct 1–15	1.31	1.41	1.51
Oct 16–31	0.72	0.80	1.04
Nov 1–15	0.37	0.42	0.42

Table 4. Stone fruit historical evapotranspiration estimates (inches during period)

Date	Madera	Merced	Stockton	Modesto	Parlier	Visalia	Yuba City
Mar 1–15	0.66	0.66	0.66	0.66	0.83	0.74	0.99
Mar 16–31	1.19	1.19	0.10	1.19	1.29	1.29	1.39
Apr 1–15	1.41	1.41	1.41	1.41	1.71	1.61	1.71
Apr 16–30	1.97	1.97	1.97	1.97	2.08	2.19	1.97
May 1–15	2.34	2.22	2.22	2.22	2.57	2.46	2.11
May 16–31	2.99	3.13	2.86	3.13	3.26	3.13	2.58
June 1–15	3.26	3.26	3.13	3.39	3.39	3.39	2.74
June 16–30	3.52	3.52	3.39	3.39	3.52	3.52	2.87
July 1–15	3.65	3.65	3.39	3.39	3.52	3.52	3.00
July 16–31	3.90	3.90	3.62	3.62	3.48	3.76	3.34
Aug 1–15	3.39	3.26	3.13	3.13	3.13	3.26	3.26
Aug 16–31	3.06	2.92	2.92	2.78	3.06	3.06	3.20
Sept 1–15	2.61	2.61	1.31	2.48	2.48	2.74	2.74
Sept 16–30	1.97	1.97	1.97	1.85	1.85	2.09	2.21
Oct 1–15	1.46	1.46	1.46	1.46	1.46	1.58	1.80
Oct 16–31	0.98	0.98	0.76	0.98	0.98	1.09	1.52

Table 5. Prune historical evapotranspiration estimates (inches during period)

Date	Red Bluff	Yuba City
Apr 1–15	1.45	1.68
Apr 16–30	2.20	2.25
May 1–15	2.63	2.71
May 16–31	2.87	2.93
June 1–15	2.85	2.85
June 16–30	3.07	3.07
July 1–15	3.26	3.45
July 16–31	3.65	3.71
Aug 1–15	3.51	3.43
Aug 16–31	3.56	3.46
Sept 1–15	2.81	2.40
Sept 16–30	2.30	2.19
Oct 1–15	1.74	1.49
Oct 16–31	1.34	1.30

Table 6. Olive historical evapotranspiration estimates (inches during period)

Date	Lakeport	Ukiah	Orland	Parlier	Santa Rosa	Atascadero
Mar 16–31		0.36	0.98	1.66	1.56	1.92
Apr 1–15	1.32	1.26	1.40	2.04	1.80	2.12
Apr 16–30	1.58	1.50	1.63	2.28	2.00	2.24
May 1–15	1.90	1.83	1.97	2.64	2.16	2.32
May 16–31	2.14	2.08	2.23	3.07	2.40	2.44
June 1–15	2.32	2.24	2.66	3.12	2.52	2.52
June 16–30	2.54	2.41	2.74	3.24	2.56	2.60
July 1–15	2.80	2.68	3.05	3.24	2.52	2.60
July 16–31	2.89	2.64	3.32	3.20	2.36	2.48
Aug 1–15	2.57	2.43	3.53	2.88	2.16	2.32
Aug 16–31	2.32	2.21	3.02	2.82	1.88	2.04
Sept 1–15	2.02	1.94	2.82	2.28	1.56	1.88
Sept 16–30	1.71	1.63	2.30	1.80	1.32	1.68
Oct 1–15	1.36	1.30	1.94	1.56	1.04	1.52
Oct 16–31	1.01	0.98	1.53	1.15	0.68	1.24

Table 7. Citrus historical evapotranspiration estimates (inches during period)

Date	Orange Cove	Lindcove	Kern County	Santa Paula
Mar 16–31	1.04	0.83	1.07	0.98
Apr 1–15	1.17	1.14	1.37	1.40
Apr 16–30	1.46	1.56	1.66	1.63
May 1–15	1.66	1.77	1.98	1.97
May 16–31	2.29	2.18	2.28	2.23
June 1–15	2.34	2.39	2.50	2.66
June 16–30	2.44	2.50	2.60	2.74
July 1–15	2.63	2.60	2.67	3.05
July 16–31	2.91	2.81	2.80	3.32
Aug 1–15	2.83	2.81	2.80	3.53
Aug 16–31	2.71	2.70	2.70	3.02
Sept 1–15	2.44	2.39	2.37	2.82
Sept 16–30	2.05	1.98	2.05	2.30
Oct 1–15	1.66	1.66	1.69	1.94
Oct 16–31	1.46	1.35	1.46	1.53
Nov 1–15	1.07	0.94	1.14	1.30
Nov 16–30	0.68	0.62	0.81	0.90

Table 8. Apple historical evapotranspiration estimates (inches during period)

Date	Lakeport	Ukiah	Stockton	Bakersfield	Orland
Mar 16–31	—	—	—	—	—
Apr 1–15	—	—	—	—	—
Apr 16–30	1.16	1.10	1.62	1.80	1.59
May 1–15	1.59	1.53	2.08	2.58	2.00
May 16–31	2.04	1.98	2.62	3.04	2.68
June 1–15	2.44	2.35	3.07	3.44	3.03
June 16–30	2.92	2.77	3.54	3.91	3.67
July 1–15	3.50	3.35	3.95	4.25	3.87
July 16–31	3.61	3.30	3.85	4.00	4.13
Aug 1–15	3.21	3.04	3.55	3.65	3.52
Aug 16–31	2.90	2.76	3.20	3.15	3.25
Sept 1–15	2.53	2.42	2.75	2.60	2.83
Sept 16–30	2.14	2.04	2.25	2.25	2.46
Oct 1–15	1.55	1.47	1.68	1.59	1.92
Oct 16–31	0.74	0.72	0.83	0.74	0.75
Nov 1–15	—	—	—	—	—
Nov 16–30	—	—	—	—	—

Table 9. Pear historical evapotranspiration estimates (inches during period)

Date	Lakeport	Ukiah	Courtland
Mar 16–31	—	0.25	0.83
Apr 1–15	1.65	0.86	1.28
Apr 16–30	1.44	1.46	1.77
May 1–15	1.90	1.83	2.22
May 16–31	2.28	2.21	2.68
June 1–15	2.52	2.44	2.90
June 16–30	3.14	2.87	3.31
July 1–15	3.05	2.91	3.33
July 16–31	3.14	2.87	3.31
Aug 1–15	2.79	2.64	3.05
Aug 16–31	2.52	2.40	2.77
Sept 1–15	2.20	2.11	2.46
Sept 16–30	1.61	1.53	1.79
Oct 1–15	1.16	1.13	1.26
Oct 16–31	0.82	0.79	0.88

Table 10. Crop coefficients (k_c) for almonds, walnuts, apples, olives, pears, and citrus

Date	Almonds	Walnuts	Pistachios	Stone fruit	Prunes	Olives	Citrus	Apples	Pears
Jan 1–15	—	—	—	—	—	0.8	0.65	—	—
Jan 16–31	—	—	—	—	—	0.8	0.65	—	—
Feb 1–15	—	—	—	—	—	0.8	0.65	—	—
Feb 16–28	—	—	—	—	—	0.8	0.65	—	—
Mar 1–15	—	—	—	0.55	—	0.8	0.65	—	—
Mar 16–31	0.54	0.12	—	0.62	—	0.8	0.65	—	—
Apr 1–15	0.60	0.53	0.07	0.67	0.62	0.8	0.65	—	—
Apr 16–30	0.66	0.68	0.43	0.73	0.84	0.8	0.65	—	—
May 1–15	0.73	0.79	0.68	0.78	0.96	0.8	0.65	0.59	—
May 16 –31	0.79	0.86	0.93	0.85	0.96	0.8	0.65	0.67	0.55
June 1–15	0.84	0.93	1.09	0.87	0.96	0.8	0.65	0.76	0.55
June 16–30	0.86	1.00	1.17	0.87	0.96	0.8	0.65	0.84	0.78
July 1–15	0.93	1.14	1.19	0.87	0.96	0.8	0.65	0.92	0.80
July 16–31	0.94	1.14	1.19	0.87	0.96	0.8	0.65	1.00	0.85
Aug 1–15	0.94	1.14	1.19	0.87	0.95	0.8	0.65	1.00	0.87
Aug 16–31	0.94	1.14	1.12	0.87	0.92	0.8	0.65	1.00	0.87
Sept 1–15	0.94	1.08	0.99	0.87	0.84	0.8	0.65	1.00	0.87
Sept 16–30	0.91	0.97	0.87	0.82	0.78	0.8	0.65	1.00	0.87
Oct 1–15	0.85	0.88	0.67	0.75	0.69	0.8	0.65	1.00	0.87
Oct 16–31	0.79	0.51	0.5	0.68	0.57	0.8	0.65	0.91	0.87
Nov 1–15	0.70	0.28	0.35	—	—	0.8	0.65	0.59	0.87
Nov 16–30	—	—	—	—	—	0.8	0.65	—	0.75
Dec 1–15	—	—	—	—	—	0.8	0.65	—	0.70
Dec 16–31	—	—	—	—	—	0.8	0.65	—	0.65

Table 11. Sample CIMIS data for Modesto, CA, July 1–15, 2005

Date	Precipitation (in)	Air temperature		Wind		ET_o (in)	Solar radiation (LY)	Soil temperature		Relative humidity	
		max (°F)	min (°F)	Direction	Speed (mph)			(°F)	(°F)		
7-01	0.00	95	59	NW	4	0.26	638	81	77	93.2	33.4
7-02	0.00	92	58	NW	5	0.27	656	80	76	91.0	30.0
7-03	0.00	91	52	NW	4	0.25	629	78	74	93.0	31.3
7-04	0.08	92	53	NW	5	0.25	627	78	73	92.9	35.5
7-05	0.00	88	54	N	5	0.25	627	77	73	90.0	37.0
7-06	0.00	91	54	NW	6	0.25	606	77	73	91.2	37.9
7-07	0.00	88	54	N	6	0.27	620	76	73	90.4	29.9
7-08	0.00	84	52	N	8	0.27	633	75	72	87.9	40.0
7-09	0.00	81	52	NW	8	0.23	537	74	71	97.3	45.0
7-10	0.00	85	51	NW	8	0.26	604	74	70	94.8	45.7
7-11	0.00	91	58	NW	5	0.25	621	76	72	94.5	40.0
7-12	0.00	96	60	NW	3	0.23	586	77	72	91.1	33.5
7-13	0.00	97	65	NW	3	0.24	610	78	74	87.6	32.7
7-14	0.00	98	63	NW	4	0.24	601	78	75	89.1	32.0
7-15	0.00	97	63	NW	4	0.23	536	78	75	81.2	35.2

Note: Metric conversions: 1 in = 2.54 cm; °C = (°F – 32) × 0.55; 1 mph = 1.6 km/hr.