APPENDIX 2-6 Supporting Documentation for Water Quality Analysis

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Eastern San Joaquin Region
2015 IRWM Implementation Grant Application

Aplication Efficiency: Hydrologic Region 2010

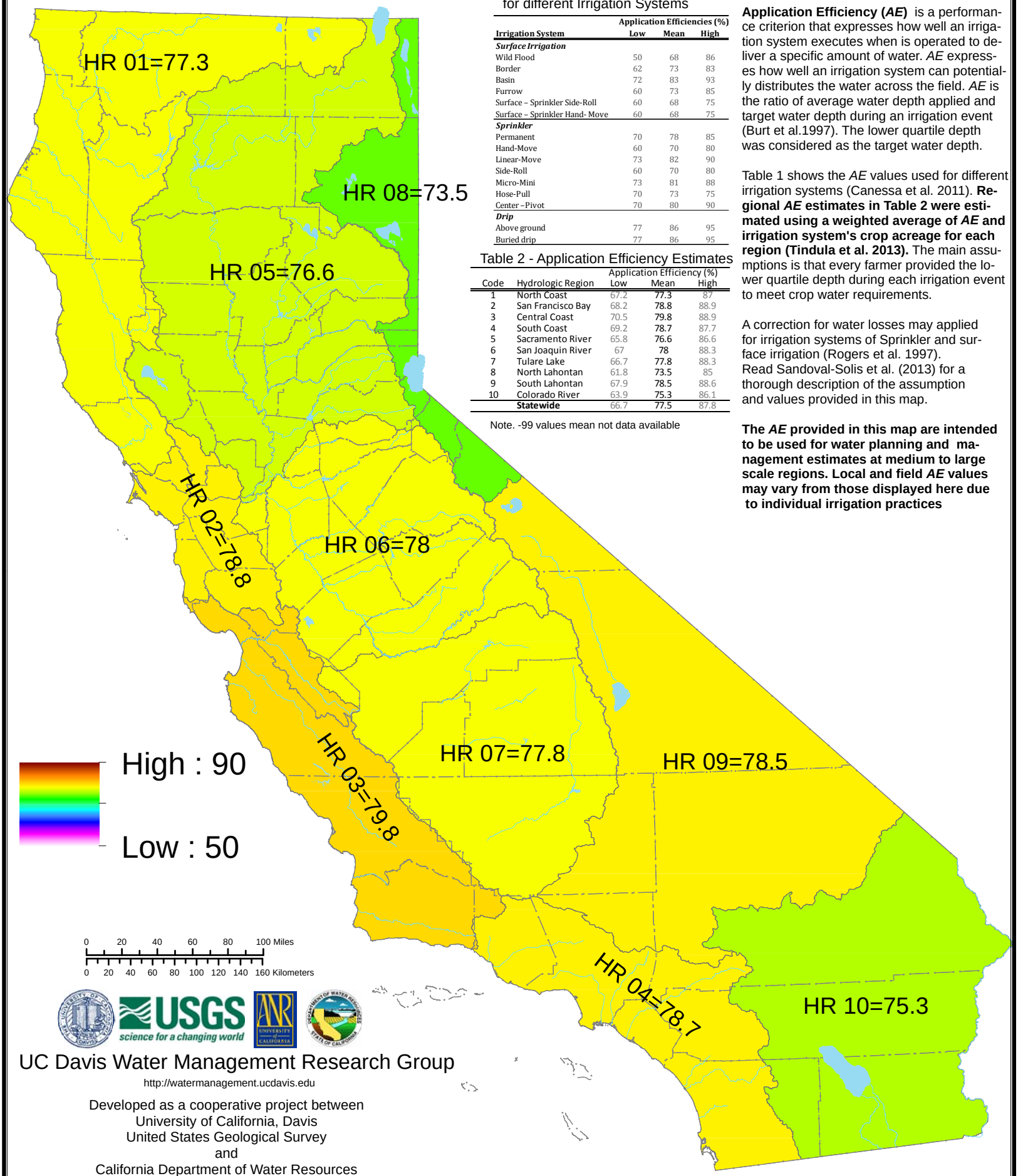

Table 1 - Application Efficiencies for different Irrigation Systems

Irrigation System	Application Efficiencies (%) Low	Mean	High
Surface Irrigation			
Wild Flood	50	68	86
Border	62	73	83
Basin	72	83	93
Furrow	60	73	85
Surface – Sprinkler Side-Roll	60	68	75
Surface – Sprinkler Hand- Move	60	68	75
Sprinkler			
Permanent	70	78	85
Hand-Move	60	70	80
Linear-Move	73	82	90
Side-Roll	60	70	80
Micro-Mini	73	81	88
Hose-Pull	70	73	75
Center –Pivot	70	80	90
Drip			
Above ground	77	86	95
Buried drip	77	86	95

Table 2 - Application Efficiency Estimates

Code	Hydrologic Region	Application Efficiency (%) Low	Mean	High
1	North Coast	67.2	77.3	87
2	San Francisco Bay	68.2	78.8	88.9
3	Central Coast	70.5	79.8	88.9
4	South Coast	69.2	78.7	87.7
5	Sacramento River	65.8	76.6	86.6
6	San Joaquin River	67	78	88.3
7	Tulare Lake	66.7	77.8	88.3
8	North Lahontan	61.8	73.5	85
9	South Lahontan	67.9	78.5	88.6
10	Colorado River	63.9	75.3	86.1
	Statewide	66.7	77.5	87.8

Note. -99 values mean not data available

Application Efficiency (*AE*) is a performance criterion that expresses how well an irrigation system executes when is operated to deliver a specific amount of water. *AE* expresses how well an irrigation system can potentially distributes the water across the field. *AE* is the ratio of average water depth applied and target water depth during an irrigation event (Burt et al.1997). The lower quartile depth was considered as the target water depth.

Table 1 shows the *AE* values used for different irrigation systems (Canessa et al. 2011). **Regional *AE* estimates in Table 2 were estimated using a weighted average of *AE* and irrigation system's crop acreage for each region (Tindula et al. 2013).** The main assumptions is that every farmer provided the lower quartile depth during each irrigation event to meet crop water requirements.

A correction for water losses may applied for irrigation systems of Sprinkler and surface irrigation (Rogers et al. 1997).
Read Sandoval-Solis et al. (2013) for a thorough description of the assumption and values provided in this map.

The *AE* provided in this map are intended to be used for water planning and management estimates at medium to large scale regions. Local and field *AE* values may vary from those displayed here due to individual irrigation practices

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Developed as a cooperative project between
University of California, Davis
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and
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Map prepared by P.I.: Samuel Sandoval Solis, Ph.D. © 2013.

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Almond Board of California

Irrigation Scheduling using Evapotranspiration (ET) and Updated Almond Crop Coefficients (Kc)

A first step toward optimum irrigation scheduling is to understand the changing demand of almond trees based on water use by evapotranspiration, or ET. ET scheduling accounts for the loss of water through soil surface evaporation and transpiration through openings in the leaves. In almonds, ET will change throughout the year according to weather (e.g., heat and humidity impact evaporation) and time of year or crop stage (e.g., lower leaf surface in early season equals lower transpiration).

The amount of almond water demand (ETc) can be calculated using this equation: ETc = ETo x Kc.

ETo represents water use by a reference crop, which is grass pasture. Evapotranspiration rates for reference crops can be found through a number of sources including the free state-operated CIMIS system (http://www.cimis.water.ca.gov) or through various free or fee-based services. Note that ETo is multiplied by a scientifically based crop coefficient (Kc). The Kc is a simplified way of representing the ratio of water use by the crop in question (ETc), almonds in this case, to the reference ETo, which is water use by grass pasture. Almond crop coefficients have been updated by recent research and are shown in the table below.

Estimates of the monthly crop coefficient (Kc) values for mature almond trees for research performed within California. The more recent Kc values (Sanden, Goldhamer) are recommended for use with a grass reference crop (ETo).

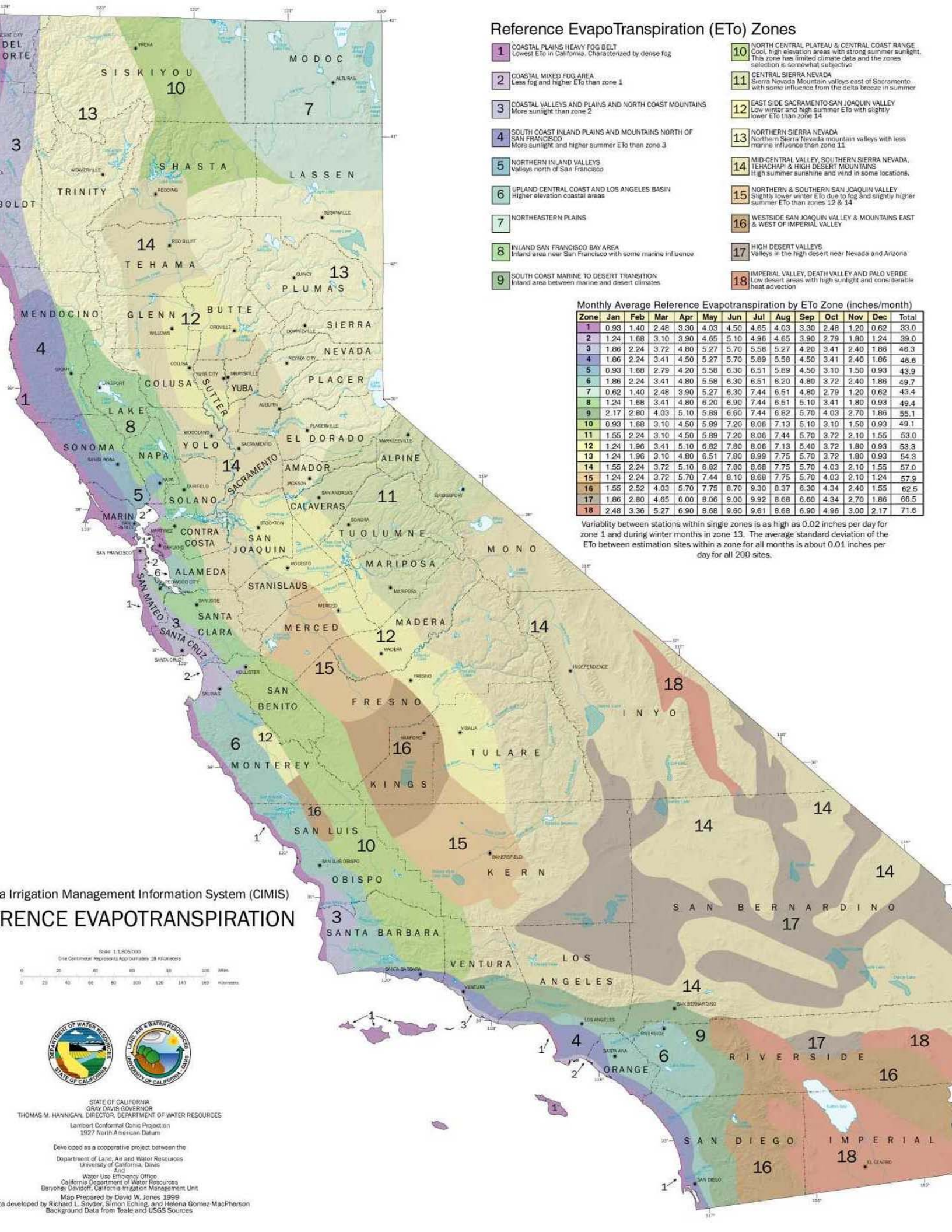
	Almond Production Manual (1996)	Sanden (2007)	Goldhamer (2012)
March	0.54	0.59	0.20
April	0.63	0.78	0.67
May	0.76	0.92	0.95
June	0.85	1.01	1.09
July	0.94	1.08	1.15
August	0.94	1.08	1.17
September	0.93	1.02	1.12
October	0.82	0.89	0.85
November	0.70	0.69	

References

1.) Doll, David. 2010. "Irrigation Scheduling 101" in Irrigation Module of California Almond Sustainability Manual, pages16-25.

2.) Goldhamer, David. 2012. Almond in Grop Yield Response to Water. FAO Irrigation and Drainage Paper No. 66, P. Steduto, T.C. Hsiao, E. Fereres, and D. Raes, eds. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 246:296.

3.) Sanden, Blake. 2007. Fall irrigation management in drought year for almonds, pistachios, and citrus. September Kern Soil and Water Newsletter, Univ. CA Coop. Ext, Kern County. 8 pp.



Reference EvapoTranspiration (ETo) Zones

1. COASTAL PLAINS HEAVY FOG BELT — Lowest ETo in California. Characterized by dense fog
2. COASTAL MIXED FOG AREA — Less fog and higher ETo than zone 1
3. COASTAL VALLEYS AND PLAINS AND NORTH COAST MOUNTAINS — More sunlight than zone 2
4. SOUTH COAST INLAND PLAINS AND MOUNTAINS NORTH OF SAN FRANCISCO — More sunlight and higher summer ETo than zone 3
5. NORTHERN INLAND VALLEYS — Valleys north of San Francisco
6. UPLAND CENTRAL COAST AND LOS ANGELES BASIN — Higher elevation coastal areas
7. NORTHEASTERN PLAINS
8. INLAND SAN FRANCISCO BAY AREA — Inland area near San Francisco with some marine influence
9. SOUTH COAST MARINE TO DESERT TRANSITION — Inland area between marine and desert climates
10. NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE — Cool, high elevation areas with strong summer sunlight. This zone has limited climate data and the zones selection is somewhat subjective
11. CENTRAL SIERRA NEVADA — Sierra Nevada Mountain valleys east of Sacramento with some influence from the delta breeze in summer
12. EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY — Low winter and high summer ETo with slightly lower ETo than zone 14
13. NORTHERN SIERRA NEVADA — Northern Sierra Nevada mountain valleys with less marine influence than zone 11
14. MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA, TEHACHAPI & HIGH DESERT MOUNTAINS — High summer sunshine and wind in some locations.
15. NORTHERN & SOUTHERN SAN JOAQUIN VALLEY — Slightly lower winter ETo due to fog and slightly higher summer ETo than zones 12 & 14
16. WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST & WEST OF IMPERIAL VALLEY
17. HIGH DESERT VALLEYS — Valleys in the high desert near Nevada and Arizona
18. IMPERIAL VALLEY, DEATH VALLEY AND PALO VERDE — Low desert areas with high sunlight and considerable heat advection

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.