IRRIGATION

RESOURCES FOR GROWERS

california almonds
Almond Board of California

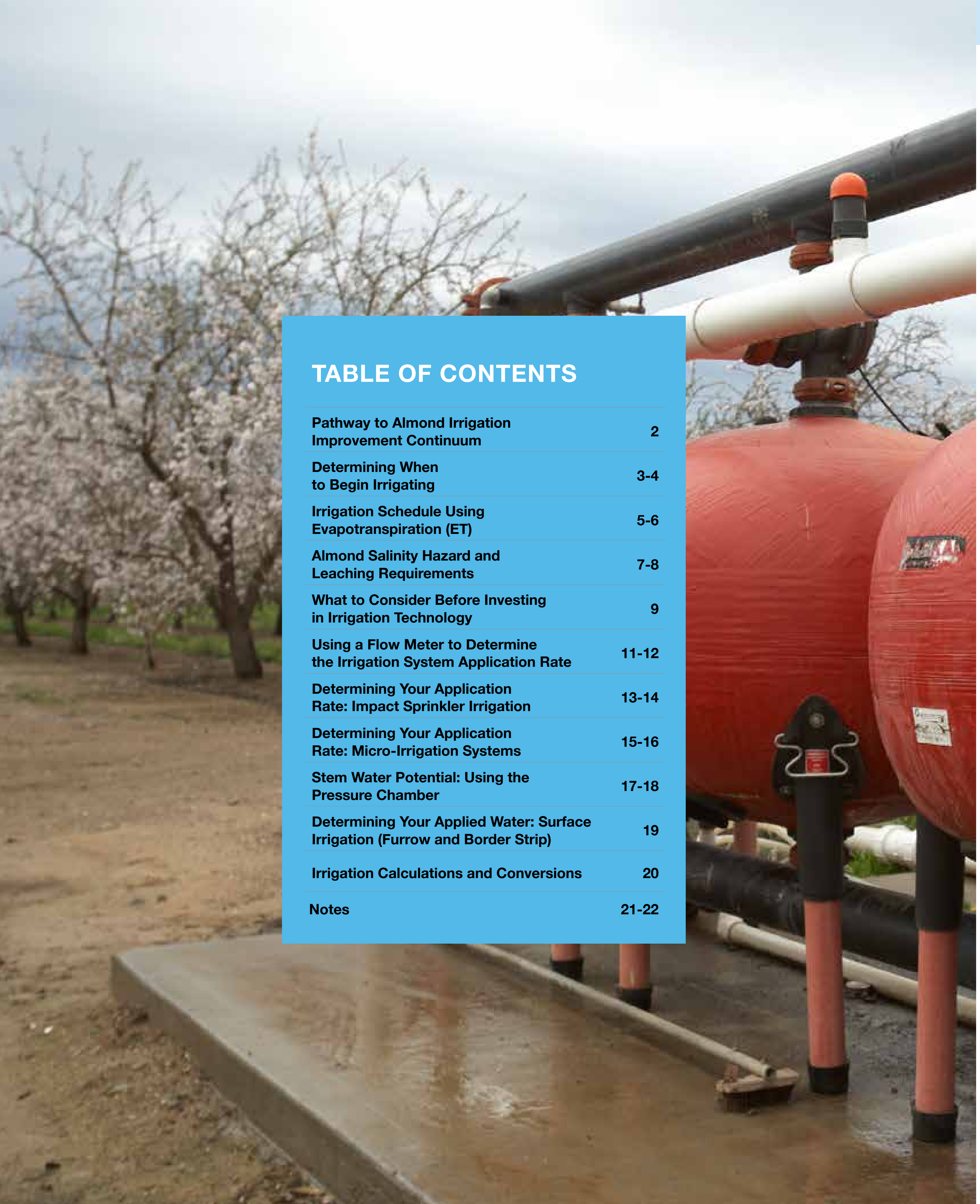


TABLE OF CONTENTS

PATHWAY TO ALMOND IRRIGATION IMPROVEMENT CONTINUUM

Use the management levels and guidance below to adopt good irrigation management practices for almonds. Each level of the Almond Board's Irrigation Improvement Continuum provides the tools necessary to obtain measurements needed to best schedule and manage almond irrigation.

LEVEL 1.0 FUNDAMENTAL — Practices **within reach** of all California almond growers

LEVEL 2.0 INTERMEDIATE — More **sophisticated** practices to attain more crop per drop

LEVEL 3.0 ADVANCED — Advanced practices to **maximize** crop per drop

Irrigation System

Evaluate Irrigation System Performance

Correct and diagnose system performance problems

- **1.0** Record **pressure variation** and calculate **average application rate**
- **2.0** Measure **distribution uniformity** and **average application rate** by measuring water volume
- **3.0** Measure **distribution uniformity** and **average application rate** by measuring water volume

EVERY THREE YEARS — EVERY TWO YEARS

Water Use

Determine Orchard Water Requirement

- **1.0** Use **"normal year" regional ETc** to estimate irrigation demand
- **2.0** Adjust for **current weather** and cover crop use
- **3.0** Use **real-time ETc data** to correct the schedule

MONTHLY — BI-WEEKLY

Determine Applied Water and Irrigation Efficiency

- **1.0** Calculate by **mutliplying application rate** by **duration of irrigation**
- **2.0** Measure with a **flow meter**
- **3.0** Compare against crop water use (ETc) to **determine irrigation efficiency**

Monitor Soil & Plant

Monitor Soil Moisture Status

Ensure calculated water applications are not over/under irrigating trees

- **1.0** **Auger 3'-5' deep** to evaluate soil moisture based on feel and appearance
- **2.0** Use **manually operated** soil moisture sensors to 3'-5' depth
- **3.0** Use **automated** soil moisture sensors that store data over time

Monitor Plant Water Status

Ensure calculated water applications are not over/under irrigating trees

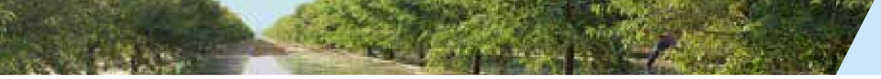
- **1.0** Use **visual plant clues**
- **2.0** Use a **pressure chamber** to measure midday stem water potential
- **3.0** Compare readings **to baseline** and use to decide **when to start irrigating**

Management

Integrating Irrigation Management Practices

- **1.0** **Adjust schedule by:**
  - Checking soil moisture with an auger
  - Visually monitoring plant water status
- **2.0** **Adjust schedule by:**
  - Current weather data
  - Manually operated soil moisture sensors
  - Pressure chambers for plant water status
- **3.0** **Adjust schedule by:**
  - Using real-time ETc data
  - Automated soil moisture sensors
  - Pressure chamber data in comparison to baseline values to start irrigating

Use irrigation system performance data with regional estimates of "normal year" ETc to determine orchard-specific water requirements and to schedule irrigations



DETERMINING WHEN TO BEGIN IRRIGATING ALMONDS USING ET, SOIL WATER HOLDING CAPACITY, AND EFFECTIVE RAINFALL

Knowing when to begin almond irrigation and how much to apply requires knowledge of crop water use, the level of moisture stored in the root zone, and the effectiveness of spring rainfall.

Factors that determine the root zone available-water reservoir are:

- Root zone depth
- Soil water holding capacity (largely determined by soil texture)
- Estimate of the effective rainfall

Plant-available water holding capacities of various textured soils

Soil Texture	Plant-Available Water Holding Capacity (in. of water per ft. of soil)
Very coarse sands	0.40 – 0.75
Coarse sands, fine sands, loamy sands	0.75 – 1.25
Sandy loams, fine sandy loams	1.25 – 1.75
Very fine sandy loams, loams, silt loams	1.50 – 2.30
Clay loams, silty clay loams, sandy clay loams	1.75 – 2.50
Sandy clays, silty clays, clays	1.60 – 2.50

Source: Adapted from: Schwankl, L.J. and T. L. Prichard. 2009. University of California Drought Management website. http://UCManageDrought.ucdavis.edu

Example: A sandy loam with a 4-foot root zone:
1.5 inches per foot x 4 feet = 6 inches available water capacity

Estimating the effective rainfall to fill the root zone

A study by the California Department of Water Resources conducted over a four-year period developed relationships for determining effective rainfall in California. Monthly rainfall is factored by the evaporative effect using bare soil. The table below indicates the effective rainfall by month for each inch of rainfall.

Rainfall (inches)	Effective Rainfall (inches)		
	Oct	Nov-Feb	Mar-April
1	0.6	0.4	-0.2
2	1.2	1.3	0.6
3	1.8	2.3	1.4
4	2.5	3.2	2.3
5	3.1	4.2	3.1
6	3.8	5.1	4.0

Below is an example using Merced average rainfall to estimate effective rainfall showing rainfall in inches totaling 9.2 and effective rainfall calculated as 6.2 inches.

	Rainfall (inches)	Effective Rainfall (inches)
Oct	0.8	0.5
Nov	1.3	0.7
Dec	2.1	1.4
Jan	2.6	1.9
Feb	2.4	1.7
Total	9.2	6.2

In this example, the estimated effective rainfall would fill the root zone reservoir capacity. If the effective rainfall exceeds the root zone capacity, it is lost; so the reservoir would be 6 inches.

When to irrigate?

The difference between estimated crop water use and the sum of the in-season effective rainfall and available soil storage is a good method to estimate when to begin and how much to apply.

Zone 12 (inches)	Merced OWR*	2016		
		Effective Rainfall	Stored Moisture	Irrigation Application
March	2.1	2.5	0.0	0.0
April	4.1	1.5	1.0	1.6
May	6.4	0.0	1.0	5.4
June	8.2	0.0	1.0	7.2
July	8.9	0.0	0.0	8.9

*Orchard Water Requirement

It is generally recommended to only use 50% of the available water in the root zone to prevent water stress. That would be 50% of 6 inches or 3 inches. In this example, one third (1 inch) was used in the months of April, May, and June.

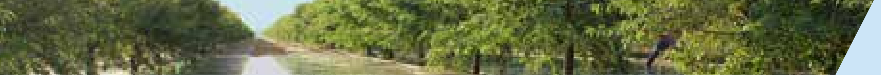
March. Effective rainfall exceeded OWR. No soil water reservoir use or irrigation.

April. Effective rainfall provided 1/3 of the OWR. The remainder is made up from soil storage (1.0 inch) and irrigation (1.6 inches).

May. No effective rainfall. Soil storage 1.0 inch and 5.4 inches from irrigation.

June. No effective rainfall. Soil storage 1.0 inch and 7.2 inches from irrigation.

July. No effective rainfall or soil storage. 8.9 inches from irrigation.



IRRIGATION SCHEDULING USING EVAPOTRANSPIRATION (ET)

Understanding the changing demand of almond trees based on water use by evapotranspiration, or ET, is a first step toward optimum irrigation scheduling. 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).

Crop Water Use (ETc) = Reference Evaporation (ETo) x Crop Coefficient (Kc)

ETc (almond water use) in inches of water can be time-framed to the day, week, month, or season in order to assess the orchard's water requirements for irrigation scheduling purposes.

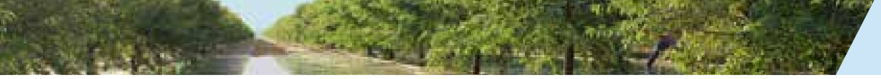
ETo (reference ET) information is available from a variety of sources, but most well-known is the California Department of Water Resources' CIMIS network of nearly 100 California weather stations that provide daily reference evapotranspiration values (www.cimis.water.ca.gov).

Thirty-year average evapotranspiration reference rates (ETo)[1] and almond (ETc)[2] for several CIMIS zones within almond-producing areas of California (adapted from UC ANR Pub. 8515)

		Zone 12[4]		Zone 14[5]		Zone 15[6]		Zone 16[7]	
	Kc[3]	ETo	ETc	ETo	ETc	ETo	ETc	ETo	ETc
Jan	0.4	1.24	0.5	1.55	0.62	1.24	0.5	1.55	0.62
Feb	0.41	1.96	0.81	2.24	0.92	2.24	0.92	2.52	1.04
Mar	0.62	3.41	2.11	3.72	2.3	3.72	2.3	4.03	2.49
Apr	0.8	5.1	4.09	5.1	4.09	5.7	4.57	5.7	4.57
May	0.94	6.82	6.44	6.82	6.44	7.44	7.02	7.75	7.31
Jun	1.05	7.8	8.2	7.8	8.2	8.1	8.51	8.7	9.14
Jul	1.11	8.06	8.93	8.68	9.61	8.68	9.61	9.3	10.3
Aug	1.11	7.13	7.9	7.75	8.59	7.75	8.59	8.37	9.28
Sep	1.06	5.4	5.73	5.7	6.05	5.7	6.05	6.3	6.68
Oct	0.92	3.72	3.41	4.03	3.69	4.03	3.69	4.34	3.97
Nov	0.69	1.8	1.23	2.1	1.44	2.1	1.44	2.4	1.64
Dec	0.43	0.93	0.4	1.55	0.66	1.24	0.53	1.55	0.66
Totals (in)									
Yearly			49.75		52.61		53.73		57.70
Crop Season[8]			47.43		49.69		51.06		54.56
Non-crop Season[9]			2.32		2.92		2.67		3.14

[1]Normal year evapotranspiration of unstressed grass (reference crop, ETo) 30-year CIMIS average for the respective zone.
[2]Evapotranspiration rates for almonds were calculated by multiplying ETo by the crop coefficient (Kc).
[3]Almond crop coefficient (UC ANR Pub. 8515).
[4]Zone 12 ETo rates from Chico, Fresno, Madera, Merced, Modesto, and Visalia.
[5]Zone 14 ETo rates from Newman, Red Bluff, and Woodland.
[6]Zone 15 ETo rates from Bakersfield, Los Banos and westside San Joaquin Valley.
[7]Zone 16 ETo rates from Coalinga and Hanford.
[8]Crop season ETc rates March-Nov 15.
[9]Non-crop season ETc rates Jan, Feb, Nov 16-30, and Dec.
[10]1 Inch equals 27,154 gallons/acre.

Reference Evapotranspiration Zones



ALMOND SALINITY HAZARD AND LEACHING REQUIREMENTS

All irrigation water contains dissolved mineral salts, but the concentration and composition of the salts vary, depending on the specific water source. Over time, salts can build up in the root zone and without removal by leaching, can reduce orchard production.

Salt accumulation poses distinct hazards to almond orchards:

- Excess total salinity creates an osmotic stress, which reduces crop production.
- An accumulation of sodium, chloride and boron can have a toxic effect.
- Increased sodium salts can decrease water infiltration rates.

Measuring total salts

Total salt content of the water used for irrigation and the salinity of the saturated soil extract is reported as electrical conductivity (EC) in units of decisiemens per meter (dS/m, which is the same as the older unit mmho/cm).

How much leaching is needed?

- An estimate of how much leaching is required for almonds can be determined by knowing the average salt content of the applied water.
- The table values below indicate the percent of seasonal applied water that needs to pass through the root zone and the additional water in inches required for water use in Zone 15 (Bakersfield to Los Banos), assuming steady state conditions and the average soil salinity at the beginning of the season is below the tolerance level for almonds of 1.5 dS/m. No leaching rainfall is assumed.

Irrigation water electrical conductivity (dS/m)	Leaching requirement % to maintain root zone salinity at 1.5 dS/m (%)	Water required in addition to crop water use in Zone 15 (inches)
0.25	3	1.8
0.50	7	3.9
0.75	11	6.4
1.00	15	9.3
1.20	19	12.0
1.50	30	21.9

Measuring salts in the root zone to determine when to leach

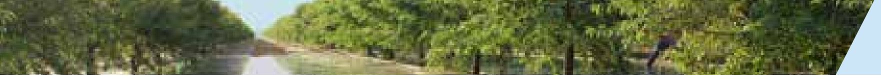
- Measure soil salinity at points in the root zone to get an average. An example would be a sample of each foot of depth of a 4-foot root zone. If the average soil salinity is near the tolerance level of 1.5 dS/m, leaching should be considered.
- If samples are taken at the end of the season, leaching can be accomplished in some part or in total by effective rainfall in amounts needed to fill the root zone.
- If samples are taken at the beginning of the season and salts are significantly lower than the 1.5 dS/m level, leaching can wait until after the season.
- However if salts are near 1.5 dS/m, in-season leaching using irrigation water is needed.

Toxic salt effects

In addition to the salinity or total salt effect on the orchard, certain elements such as sodium, chloride, and boron can build up in the root zone and be taken up by the tree to a toxic level, burning the leaves and reducing photosynthesis. It is important to note that there are differences in tolerances between rootstocks and varieties. Tissue analysis is the best indicator of the toxic element hazard. These specific salts can be leached — just as total salts. However, boron and sodium are more difficult to remove, especially when compared to chloride.

Salt leaching considerations

- Salinity leaching may not be needed every season. Soil and irrigation water testing will help determine when leaching is necessary or how much is needed.
- Rainfall may be adequate in reducing salts when it fills the root zone to field capacity and then provides the leaching water requirement. In areas of lower rainfall, early fall dormant irrigation can recharge the root zone and leverage the rainfall amount.
- To the extent possible, time the irrigations to leach salinity during fallow or dormant periods. This will avoid critical periods of crop growth and development when nitrogen uptake and fertilization should not be occurring.
- If salinity in the root zone is at the threshold at the start of the season, in-season leaching will be necessary to prevent yield loss.
- The use of partial coverage irrigation systems — drip and microirrigation — result in non-traditional salt buildup patterns. Typically, the salts build up on the edge of the wetted zone. Leaching with the irrigation system is not as effective as with traditional surface-applied full coverage systems.
- Irrigation to fill the root zone near the end of season to leverage any effective rainfall is a good practice. This practice tends to keep accumulated salts moving away from, rather than into the root zone.

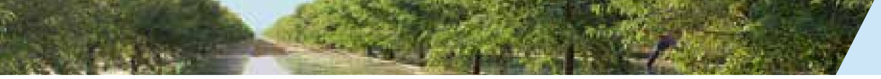


WHAT TO CONSIDER BEFORE INVESTING IN IRRIGATION TECHNOLOGY

In-field monitoring systems that monitor such variables as weather, soil moisture and plant stress can be highly advanced and have multiple "moving parts." Some examples are wind sensors, rain gauges, temperature sensors and pest traps. These technologies have a certain life expectancy, just like any other piece of equipment on your operation. A monitoring system is simply a computer in a weather-resistant case — it is exposed to constant heat, rain, sprays and dust. Equipment does not last forever and requires maintenance.

Consider asking these questions:

- Does the provider only offer one solution or multiple solutions for growers? For example, what type(s) of irrigation monitoring sensors are available?
- Is this company investor-backed?
- Under what conditions does this type of technology or sensor work best? For example, what is the best sensor for your growing environment?
- What is the life expectancy of the sensors?
- What is included in the warranty?
- Does the company review your data for reliability, or are you responsible for this?
- What is included in the grower support network?
- Does the company have a service team, and if so, what kind of training or certifications do they have?
- What kind of documentation does the company provide when service is done in the field?



USING A FLOW METER TO DETERMINE THE IRRIGATION SYSTEM APPLICATION RATE

Understanding your systems water application rate allows you to compare your estimated application to actual applied water, a key component of irrigation scheduling.

A flow meter readout usually has a totalizing register recording the total flow (gallons, cubic feet, ac – in, etc.) passing through the meter. Many meters also have an instantaneous flow rate indicator (gpm, cfs, etc.) on the readout. The most reliable flow rate value comes from noting the change in the totalized flow across a known time interval rather than using the instantaneous readings. For example, if a flow meter measured 30,000 gallons passing through it in one hour, the flow rate would be 500 gpm.

Frequently, it is very useful to determine the application rate (in/hr) from the flow meter information.

Formulas for Calculating Irrigation System Application Rate
____ gpm ÷ area irrigated (acres) x 0.0022 = ____ in/hr
____ cfs ÷ area irrigated (acres) x 0.992 = ____ in/hr
____ gallons ÷ time period over which measured (min) ÷ acres irrigated x 0.0022 = ____ in/hr
____ cubic feet ÷ time period over which measured (min) ÷ acres irrigated x 0.0165 =____ in/hr
____ ac – ft ÷ time period over which measured (min) ÷ acres irrigated x 720 = ____ in/hr

Flow Meter with Instantaneous Rate Readout

This handy formula is used to determine the inches of water applied during an irrigation:

$$\text{Inches Applied} = \frac{\text{Flow Rate (gpm)} \times \text{Irrigation Time (hrs)}}{449 \times \text{Acres Irrigated}}$$

Flow Meter Readout in Total Gallons

The totalizing register of many flow meters displays in gallons. If reading the totalized flow at the beginning and end of an irrigation to determine the total gallons of water applied, the total gallons applied can be converted to inches of applied water using this formula:

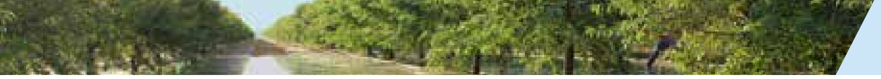
$$\text{Total Gallons Applied} \div \text{Acres Irrigated} \div 27{,}152 = \text{Inches of Water Applied}$$

Flow Meter Readout in Acre-Inches

In some cases, the totalizing register of the flow meter will record in acre-inches. Those readings can be easily converted to inches of applied water using this formula:

$$\text{Total ac – in Applied} \div \text{Irrigated Acres} = \text{Inches of Water Applied}$$

Useful Unit Conversions:
1 cubic foot = 7.48 gallons
1 gallon = 3.785 liters
1 cubic meter = 264 gallons
1 ac-ft = 325,851 gallons = 43,560 cubic feet
1 acre = 0.4 hectare = 43,560 square feet
1 cubic foot per second (cfs) = 449 gallons per minute (gpm)
450 gpm for 1 hour = 1 ac – in per hour



DETERMINING YOUR APPLICATION RATE
IMPACT SPRINKLER IRRIGATION

An important part of irrigation water management is replacing the soil water used by the almond tree since the last irrigation. The amount of almond tree water use, often called the almond tree evapotranspiration (ET), is available to you and is provided in inches of water use.

To determine how many hours you should run your sprinkler system during an irrigation, you can compare the tree ET in inches (in) since the last irrigation event with the sprinkler system application rate (in/hr).

$$\text{Irrigation Set Time (hrs)} = \frac{\text{Irrigation Amt. to be Applied (in)}}{\text{Sprinkler Application Rate (in/hr)}}$$

Determining the Sprinkler Application Rate

Determining your sprinkler application rate requires that you know:

1. The spacing between sprinklers in a tree row and the spacing of sprinklers across the tree row.
2. The average discharge rate (gal/min) of the sprinkler nozzles in the orchard.

$$\text{Average Sprinkler Application Rate (in/hr)} = \frac{96.3 \text{ x (Sprinkler Nozzle Discharge Rate — gpm)}}{\text{Sprinkler Spacing in the Tree Row (ft)} \text{ x } \text{Sprinkler Spacing in the Tree Row (ft)}}$$

In the above formula, the sprinkler nozzle discharge rate must be determined if you do not already know it. Measuring the sprinkler nozzle discharge rate directly is easy. Measure the discharge from 10 to 20 (or more) sprinklers throughout the orchard using the guidance below. Measure some sprinklers at the head of the system, some at the end of the system, some at the head of the lateral lines, and some at the end of the lateral lines. System pressure differences will cause the sprinkler discharges to be different, so gather the measurements and average them.

Using Direct Measurement of Sprinkler Discharge Rate

Using a short (3–5-foot) section of hose (such as a garden hose), place one end of the hose over the sprinkler nozzle, and direct the discharge into a container of known volume. (A 5-gallon bucket, marked in 1-gallon increments, works well). Keep track of the time it takes to collect a known volume of water. Then, calculate the sprinkler discharge rate (gallons per minute).

Example: If it takes 100 seconds to collect 2 gallons of water from a sprinkler head, the discharge rate is 1.2 gpms.

$$\text{100 seconds} \text{ x } \frac{\text{min}}{\text{60 secs}} = \text{1.67 minutes}$$

$$\frac{\text{2 gallons}}{\text{1.67 min}} = \text{1.2 gpms} \quad \textbf{Sprinkler Discharge Rate}$$

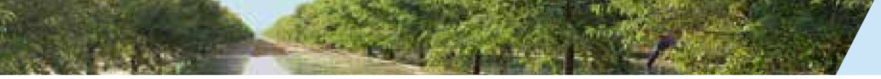
After calculating your sprinkler discharge rate, use that number to calculate your average sprinkler application rate:

$$\text{Average Sprinkler Application Rate (in/hr)} = \frac{96.3 \text{ x (Sprinkler Nozzle Discharge Rate — gpm)}}{\text{Sprinkler Spacing in the Tree Row (ft)} \text{ x } \text{Sprinkler Spacing in the Tree Row (ft)}}$$

You now have the average sprinkler application rate for the orchard. As long as the pressure does not change in the orchard, this application rate value will remain constant.

Example:
If the average sprinkler nozzle discharge rate is 1.6 gpm, and the sprinkler spacing is 35' x 44", the average sprinkler application rate is 0.1 in/hr.

$$\text{Average Sprinkler Application Rate (in/hr)} = \frac{96.3 \text{ x (1.6 gpm)}}{\text{(36 ft) x (44 ft)}} = \text{0.1 Average Sprinkler Application Rate in/hr}$$



DETERMINING YOUR APPLICATION RATE
MICRO-IRRIGATION SYSTEMS

An important part of irrigation water management is replacing the soil water used by the almond tree since the last irrigation. The amount of almond tree water use, often called the almond tree evapotranspiration (ET), is available to you and is provided in inches of water used.

To determine how many hours you should run your micro-irrigation system during an irrigation, you can compare the tree ET in inches (in) since the last irrigation event with the micro-irrigation system application rate (in/hr):

$$\text{Irrigation Set Time (hrs)} = \frac{\text{Irrigation Amt. to be Applied (in)}}{\text{Microirrigation Application Rate (in/hr)}}$$

Measuring Emission Device Discharge

It is relatively easy to collect the discharge from either drip emitters or microsprinklers.

- Measure 10 to 20 (or more) drippers or microsprinklers throughout the orchard.
- Measure emission devices at the head of the system, end of the system, head of the lateral lines, and end of the lateral lines.
- Collect water for 30 seconds and then remove the container from below the emitter.

DRIP EMITTERS:

- Measure the collected water using a 100-ml graduated cylinder.
- Collecting the discharge is as simple as sliding a low-profile container under the emitter.
- Make sure that the inflow into the container is only from the single dripper being measured, as sometimes water will run along the hose due to surface tension.

MICROSPRINKLERS:

- Pull the microsprinkler/stake assembly out of the ground and place the microsprinkler head into a graduated cylinder.
- A 500-ml or 1000-ml graduated cylinder usually works well.

The emission device discharge can be determined in gallons per hour (gph) using the formula below:

____ mL of water collected in 30 seconds x 0.032 = ____ gph

Determining the Average Application Rate

Follow these steps to estimate the average application rate:

1. Determine the average of all the individual, field-collected emission device discharge rates.
2. Using the average emitter rate (gph) and the number of emitters per tree, determine the average tree discharge rate (gph).

Drip emitter example:
The average emitter discharge rate for a drip emitter system, was 1.1 gph, and there were 5 drip emitters per tree; therefore, the average tree discharge rate (gph) would be 5.50 gph (5 drippers/tree x 1.1 gph/dripper = 5.50 gph).

Microsprinkler example:
The average emitter discharge rate for a microsprinkler system was 8.0 gph, and there was a single microsprinkler per tree; therefore, the average tree discharge rate would be 8.0 gph (1 microsprinkler/tree x 8.0 gph/microsprinkler = 8.0 gph).

3. Calculate the micro-irrigation system average application rate (in/hr) using the following formula:

$$\text{Micro-irrigation System Average Application Rate (in/hr)} = \frac{\text{Average Tree Discharge Rate (gph)}}{\text{Tree Spacing (ft}^2\text{)}} \times 1.6$$

Drip emitter example:
For an almond orchard with a tree spacing of 16 feet x 22 feet and a drip system with an average tree discharge rate of 5.50 gph (from above), the average application rate would be:

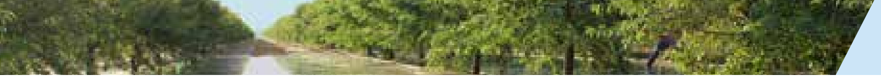
Tree spacing = 16 feet x 22 feet = 352 ft²

$$\text{Micro-irrigation System Average Application Rate (in/hr)} = \frac{5.50\text{ (gph)}}{352\text{ ft}^2} \times 1.6 = 0.025\text{ in/hr}$$

Microsprinkler example:
For an almond orchard with a tree spacing of 16 feet x 22 feet and a microsprinkler system with an average tree discharge rate of 8.0 gph, the average application rate would be:

Tree spacing = 16 feet x 22 feet = 352 ft²

$$\text{Micro-irrigation System Average Application Rate (in/hr)} = \frac{8.0\text{ (gph)}}{352\text{ ft}^2} \times 1.6 = 0.04\text{ in/hr}$$



STEM WATER POTENTIAL USING THE PRESSURE CHAMBER

Growers often use visual cues to determine the plant water status of their trees. However, in most instances, by the time you can visually detect issues with your trees the crop has already undergone irreversible damage. To be one step ahead and stop damage before it occurs, growers are advised to use a more quantitative method known as the pressure chamber to determine their trees' water status.

A pressure chamber measures plant water tension by applying pressure to a severed leaf and stem enclosed in an airtight chamber. The pressure required to force water out of the petiole of a severed leaf equals the water potential and is measured by an external pressure gauge.

How To Use A Pressure Chamber

Tools needed: Magnifying glass (10x Jeweler's loop), pressure chamber, razor blade, foil bags for leaves, and flagging tape

Process

1. Take measurements between 12-4 p.m. on a sunny day, as overcast days may affect your reading.

2. Choose 5-10 trees to test that are good representations of the orchard, taking into account variety, rootstock, tree age, degree of pruning and canopy size.

3. Once you have chosen your trees, select a leaf toward the center of the canopy that's around shoulder height. You should look for a healthy leaf with a long stem and no holes.

4. Place the foil bag on the leaf. Be sure to not crush the stem as a damaged stem can cause an inaccurate reading. Bag all the leaves in your sample at the same time.

5. Keep the bag on each leaf for at least 10 minutes. This time allows the leaf to get back to equilibrium of the tree.

6. Once 10 minutes is up, you can take your razor blade and make a clean cut at the stem. Make sure you do not cut the stem too short. Leave the bag on the leaf until after the reading is completed. Note: You have about 1 minute from the time you cut the leaf off the tree to take the reading in the pressure chamber.

7. Insert the stem of the bagged leaf upward through the top of the pressure chamber. After the leaf has been inserted securely tighten the pressure chamber cap around the stem. Make sure you do not over tighten the gasket. Once leaf is in the chamber make sure to lock the chamber lid into place.

8. Open the valve to start inserting the gas into the chamber. Make sure the bars are moving at the rate of half a bar each second. If they are moving faster than that rate, adjust the rate valve but do not tighten it too much. If you hear gas leaking from the chamber, tighten the chamber lid. If that doesn't work, stop the chamber reading and release the gas. From there, you may try to gain a reading once more, but this time make sure the chamber lid is greased and well lubricated (a stick of Chapstick works well).

9. Take the reading (shut off gas) as soon as you see water coming out of the stem. Once you see air bubbles coming from the stem you have gone too far.

10. Document the reading, release the pressure and continue until all samples are complete.

11. Choose the method you want use to interpret your data: the Guideline Method or the Baseline Method.

STEM WATER POTENTIAL USING THE PRESSURE CHAMBER

Interpreting Data

Guideline Method: For the guideline method take the average of all of your stem water potential readings for your orchard and see what reading level your average aligns with. Once you have determined the stress level, use that data to inform your next irrigation.

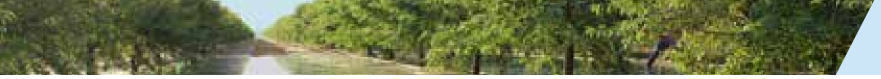
Pressure Chamber reading or SWP (bars)	Stress level	Extent of crop and types of crop responses associated with different SWP levels in almond
0 to - 6	None	No stress. Not commonly observed in almond. Only observed in early spring.
- 6 to - 12	Minimal	Fully irrigated conditions. Stimulates shoot growth, especially in developing orchards. Higher yield potential may be possible if these levels of crop stress are sustained over a season, barring other limitations related to frost, pollination, diseases, or nutrition. Sustaining these levels may result in higher incidence of disease and reduced life span. Typical of mature trees from leaf-out through mid-June.
- 12 to - 14	Mild	Reduced growth in young trees and shoot extension in mature trees. Suitable from mid-June until the onset of hullsplit (July). Still able to produce competitively. Recommended crop stress level after harvest. May reduce energy costs or help cope with drought conditions.
- 14 to - 18	Moderate	Stops shoot growth in young orchards. Mature almonds can tolerate this level of crop stress during hullsplit (July/August) and still yield competitively. May help control diseases such as hull rot and alternaria, if present. May expedite hullsplit and lead to more uniform nut maturity. Also may help reduce energy costs and cope with drought conditions.
- 18 to - 22	Very High	Wilting observed. Widespread defoliation. Stomatal conductance of CO2 and photosynthesis declines as much as 50% and impacts yield potential due to reduced leaf activity. Some limb dieback.
- 30 to - 60	Severe	Extensive or complete defoliation is common. Trees may survive despite severe defoliation and may be rejuvenated. Some limb dieback. Much less or no bloom and very low yield potential can be expected the following season until trees are rejuvenated.
less than - 60	Extreme	Complete defoliation, no flowering in the subsequent year. Dieback likely.

Guidelines for interpreting SWP measurements in almonds.

Baseline Method: Estimating the baseline will require access to public or private weather databases (e.g., CIMIS) that provide hourly temperature and relative humidity data. Growers may also use an inexpensive handheld psychrometer that can measure temperature and relative humidity in the orchard at the same time that stem water potential measurements are taken. The baseline is based on CIMIS, which should be equivalent to the temperature and relative humidity above the orchard, rather than in the orchard (presumably under the canopy). This difference in temperature and humidity has been reported to impact pressure chamber readings by about one bar.

	Air relative humidity (RH,%)						
Temp. (˚F)	10	20	30	40	50	60	70
75	- 7.3	- 7.0	- 6.6	- 6.2	- 5.9	- 5.5	- 5.2
80	- 7.9	- 7.5	- 7.0	- 6.6	- 6.2	- 5.8	- 5.4
85	- 8.5	- 8.1	- 7.6	- 7.1	- 6.6	- 6.1	- 5.6
90	- 9.3	- 8.7	- 8.2	- 7.6	- 7.0	- 6.4	- 5.8
95	- 10.2	- 9.5	- 8.8	- 8.2	- 7.5	- 6.8	- 6.1
100	- 11.2	- 10.4	- 9.6	- 8.8	- 8.0	- 7.2	- 6.5
105	- 12.3	- 11.4	- 10.5	- 9.6	- 8.7	- 7.8	- 6.8
110	- 13.6	- 12.6	- 11.5	- 10.4	- 9.4	- 8.3	- 7.3
115	- 15.1	- 13.9	- 12.6	- 11.4	- 10.2	- 9.0	- 7.8

Baseline SWP (bars) to expect for fully irrigated almond trees under different conditions of air temperature and relative humidity.



DETERMINING YOUR APPLIED WATER
SURFACE IRRIGATION (FURROW AND BORDER STRIP)

Almond tree water use estimates (evapotranspiration, or ET) are provided to you in inches of water use. Because one of the objectives of good irrigation water management is to replace the soil water used by the trees (estimated from tree ET) since the last irrigation, measuring the applied water also in inches makes the comparison between the amount you want to apply and the actual applied water easier.

Here's how to calculate applied water:

Information Needed

1. The flow rate or the total water applied during the irrigation.
2. The orchard area irrigated during the irrigation set.
3. The irrigation set time.

Determining the Water Applied

With the above information, use one of the following formulas to determine the applied water measured in inches (in) during the irrigation set:

$$\frac{\text{Flow Rate to Orchard (gpm)} \times \text{Irrigation Set Time (min)} \times 1.6}{\text{Orchard Area Irrigated (ft}^2\text{)}} = \text{Applied Water (in)}$$

$$\frac{\text{Flow Rate to Orchard (gpm)} \times \text{Irrigation Set Time (min)} \times 27{,}152}{\text{Orchard Area Irrigated (acres)}} = \text{Applied Water (in)}$$

If the water applied to the orchard is measured in acre-inches (ac – in), to determine the inches of water applied, use the following formula:

$$\frac{\text{Water Applied (ac – in)}}{\text{Orchard Area Irrigated (ac)}} = \text{Applied Water (in)}$$

Note that the following conversions may be helpful in working through the formulas above:

Useful Unit Conversions:
1 acre = 43,560 ft^2
1 cubic foot per second (cfs) = 449 gallons per minute (gpm)

IRRIGATION CALCULATIONS AND CONVERSIONS

Water Calculations

1 US Gallon	= 231 Cubic Inches = .1337 Cubic Feet = 8.35 Pounds = 3.75 Liters
1 Cubic Foot	= 7.48 Gallons/62.35 LBS
1 Cubic Foot per Second	= 448.8 Gallons per minute = 646,320 Gallons per Day = 40 Miners Inches
For 24 Hours	= 1.983 Acre Feet
For 30 Days	= 59.5 Acre Feet
For 1 Year	= 724 Acre Feet
1 Miners Inch	= 11.2 Gallons per Minute
1 Acre Inch	= 27,154 Gallons
1 Acre Foot	= 325,850 Gallons
1000 GPM	= 4.42 Acre Feet per Day

Area and Distance Conversions	
1 Acre	= 43560 Square Feet
1 Square Mile	= 640 Acres
1 Mile	= 5280 Feet
1 Mile	= 1760 Yards
1 Square Mile	= 259 Hectares
1 Hectare	= 2.47 Acres

Calculating Application Rate - Inches per Hour

Sprinkler Application Rate	Application Rate = $\frac{\text{Flow Rate} \times 96.3}{\text{Row Spacing} \times \text{Tree Spacing}}$
Drip/Micro Application Rate	Application Rate = $\frac{\text{Flow Rate per Tree (GPH)}}{\text{Row Spacing} \times \text{Tree Spacing}} \times 1.6$ Avg. Flow = Number of Emitters per tree x emitter flow rate

Pump Calculations

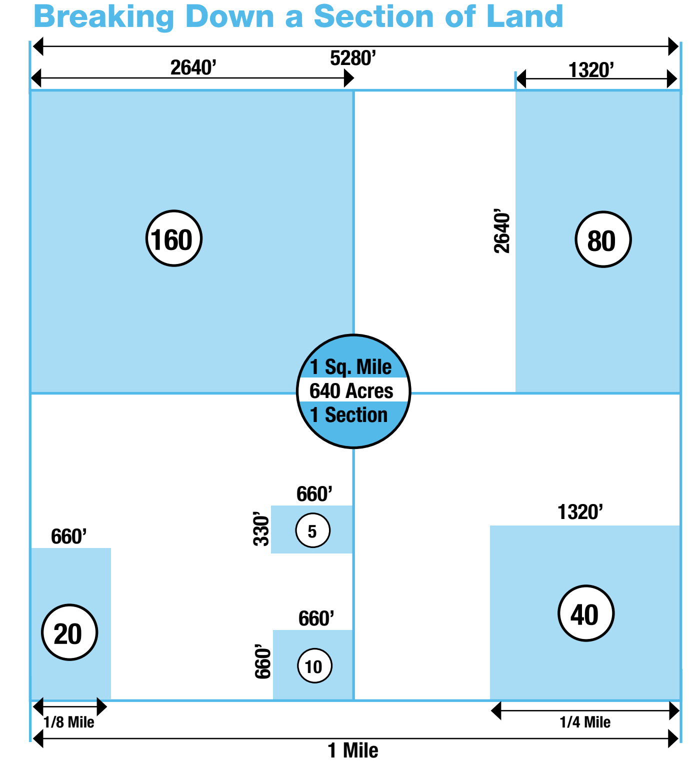
Brake Horsepower	Brake Horsepower = $\frac{\text{Gallons per Minute} \times \text{Total Head}}{3960 \times \text{Pump Efficiency}}$
Pressure	PSI = $\frac{\text{Total Head}}{2.31}$
Feet of Head	Head = 2.31 x PSI
Pump Efficiency	Pump Efficiency = $\frac{\text{Gallons per Minute} \times \text{Total Head}}{3960 \times \text{Input Horsepower}}$
Kilowatt Hour	KWh = 0.746 x Motor Horsepower

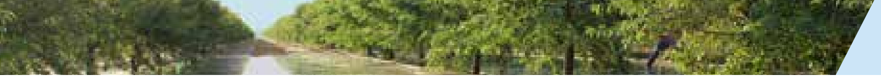
Pumping Cost

Electric	\$ per hour = $\frac{\text{Gallons per Minute} \times \text{Total Head} \times 0.746 \times \text{Rate per KWh}}{3960 \times \text{Pump Efficiency}}$
Diesel or Gas	\$ per hour = $\frac{\text{Gallons per Minute} \times \text{Total Head} \times K \times \text{\$ per Gallon}}{3960 \times \text{Pump Efficiency}}$

70% Pump Efficiency is a good average
K factor for diesel and gas the K = 0.110 for gasoline or 0.065 diesel

Breaking Down a Section of Land





NOTES

NOTES

Vision

California almonds make life better by what we grow and how we grow.

Mission

Expand global consumption of California almonds through leadership in strategic market development, innovative research and accelerated adoption of industry best practices.

california almonds
Almond Board of California

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