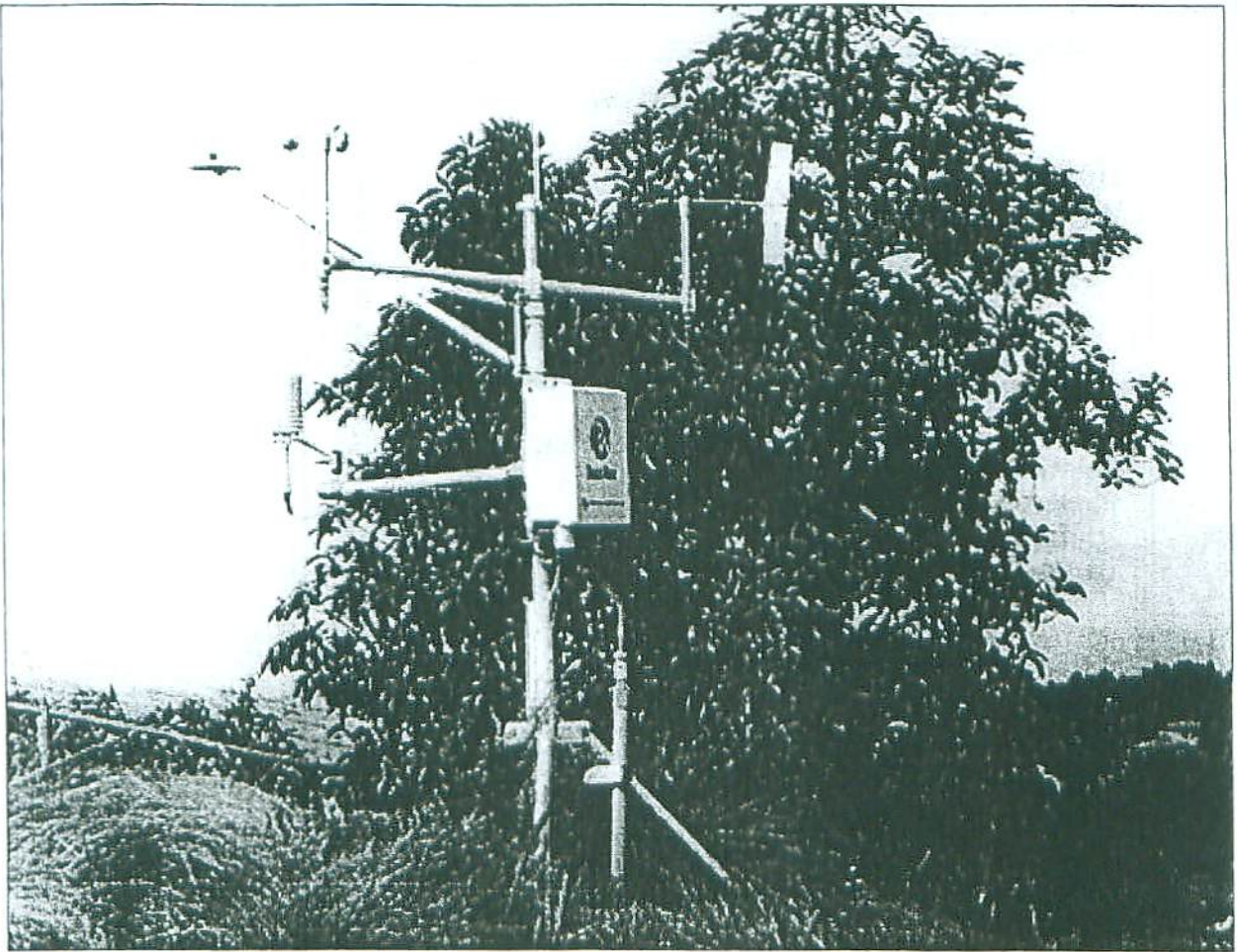


Estimating Orchard Water Use With **CIMIS**



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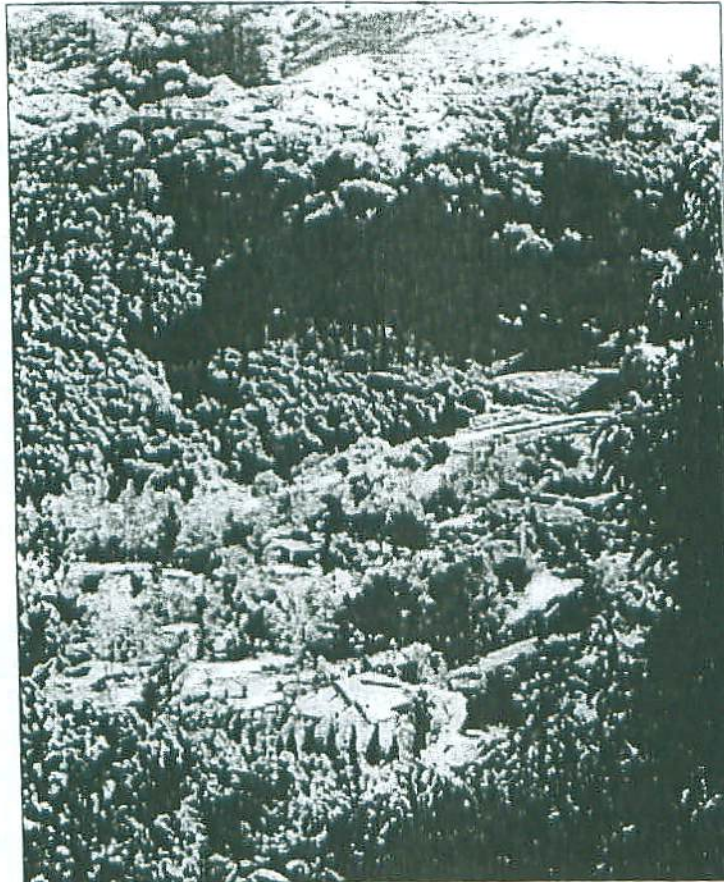
Water is a precious natural resource in San Diego County that presents farmers with unique problems. Purchased water has always been expensive because much of the supply is imported from Northern California or the Colorado River. Ground water, when it can be found, is often very poor quality.

Another factor to consider is San Diego County's undulating and often very steep terrain. While pumping water up hillsides is not impossible, it can be very difficult and expensive. Despite this adversity, San Diego County was eighth in total agricultural production in the state for 1998. Gross farm income was calculated to be 1.18 billion dollars. Plant agriculture accounted for 1.08 billion dollars or 92 percent of all gross farm income in the county.

It is obvious from the above figures that San Diego County is an excellent location for crop production. However, it is also well known that people find San Diego County pleasant as well. New houses and developments are springing up at a rapid pace. As the population of the county swells, more demand will be placed upon an already overburdened water supply system. Even if California receives adequate precipitation in the future, permanent water conservation measures are here to stay. The key to agriculture's survival will be making exist-

ing water supplies stretch as far as possible. CIMIS can be a useful tool for stretching this shared water supply.

CIMIS is an acronym for the California Irrigation Management Information System. Development of the system began in 1981 as a cooperative effort among the California Department of Water Resources, the



University of California, the Soil Conservation Service (now the Natural Resource Conservation Service), local water districts and local Resource Conservation Districts. The purpose of the CIMIS network is to provide daily, real time evapotranspiration data for use in irrigation scheduling. While CIMIS can be an effective and simple irrigation scheduling tool, you need to understand it and use it correctly for it to be effective.

Another consideration is the condition of your irrigation system. If your irrigation system has poor emission uniformity or other problems, CIMIS data will be of little use. By following the steps outlined in this booklet, you will be able to determine basic characteristics about your crop, soil and irrigation system. With this information in hand, you can begin scheduling irrigations with CIMIS.

Where to Start

Before CIMIS data can be used in irrigation scheduling, you should know the following information:

- The potential rooting depth of your crop.
- The available water holding capacity of your soil.
- The size of the area wetted by your emitters.
- The flow rate of your emitters.
- Your irrigation system's emission uniformity percentage.
- The management allowable depletion level preferred by your crop.

These six points will allow you to determine the size of the soil reservoir and the irrigation run times needed to fill the reservoir to various levels.

Potential Rooting Depth

Different crops have different depths at which most of their feeder roots reside. Try to avoid placing water below this depth except for leaching salts from the root zone. If irrigation water is constantly pushed beyond your crop's effective rooting depth, nitrogen, other soil nutrients and pesticides can be lost in the water. Through deep percolation, they eventually end up in the ground water. A large amount of ground water pollution has been caused this way. Expensive and scarce irrigation water will be wasted as well!

Table 1. contains the potential rooting depths of common San Diego County tree crops. While most crops will have some roots below the indicated ranges, the roots that do most of the work are fairly shallow. Actual rooting depths under field conditions could be less than indicated on Table 1. if clay pans, shallow soil depth or other restrictive soil characteristics are present.

Crop Potential Rooting Depth

Avocados	24 Inches
Citrus	36 Inches
Deciduous	36 Inches

Table 1. Potential Rooting Depths of Common San Diego Tree Crops.

Available Water Holding Capacity (AWC)

A soil's ability to hold water depends on its depth to bedrock, other parent materials or restrictive layers such as hard pans and its combination of sand, silt and clay. In San Diego County, soil depths range from 10 inches to more than 60 inches. Soil depth is easy to determine using a soil probe or soil auger. To determine soil depth, sample several locations within each block or field. As a general rule, deeper soils tend to be found on north and east facing slopes and near the bottom of all slopes. Shallow soils tend to be found on south and west facing slopes and near the top of all slopes.

Soil textures range county-wide from sands (low water holding capacities, high infiltration rates) to clay loams and clays (high water holding capacities, low infiltration rates). Table 2. illustrates the available water holding capacities (AWC) of various soil types. The two columns read in inches of water per inch of soil (In./In.), and inches of water per foot of soil (In./Ft.).

Most of the soils in the county fall into four categories: Coarse sandy loams, sandy loams, fine sandy loams and loams. Soil texture is harder to determine than soil depth. However, with a little practice, you can make a good estimation by rubbing a moistened sample of soil between your thumb and forefinger. Sand particles are gritty. Silt is very smooth and feels like flour or talcum powder. Silt is only moderately plastic and sticky when moist. Clay feels very coherent

when moist and will be very plastic and very sticky as well. (Plasticity is the ability of soil to be molded or shaped by moderate pressure.)

Most soils are a combination of sand, silt and clay. A soil that does not exhibit the dominant properties of these three components is termed a loam.

Sands, Loamy Sands — Dry samples are loose, single grained and gritty. Individual grains can be easily felt. Squeezed when dry, the sample will fall apart when pressure is released. Loose sand grains remain on fingers. Squeezed when moist, the sample will form a cast that will fall apart when touched. Moist samples will not be sticky and will therefore, not ribbon. Loose and aggregated sand grains will remain on fingers. Light, uneven staining of the fingers will be evident after handling moist samples.

Sandy Loams — Individual sand grains can be seen and felt. Squeezed when dry, the sample will form a cast that will readily fall apart. Aggregated soil grains will break away from the cast. Squeezed when moist, the sample will form a cast with defined finger marks that can be handled carefully without breaking. Sandy loams will form a short, fragile ribbon. Light soil/water staining will remain on fingers after handling moist samples.

Loams — Aggregates of dry samples are hard to break. Moist samples will feel somewhat gritty, yet fairly smooth and will be slightly sticky and slightly plastic. Loams will form a weak ribbon. When squeezed moist, a moist sample will form a cast that can be handled without breaking. Moist samples will cause light water/soil staining of the hands.

Silt Loams — Aggregates in dry samples will break with some difficulty. Moist samples will form a firm ball and will ribbon fairly well. Both dry and moist samples will form a cast that can be handled without breaking.

Dominant Texture	In./In. ¹	In./Ft. ²
Sand, Fine Sand	.05 - .08	0.6 - 1.0
Loamy Coarse Sand	.05 - .07	0.6 - .08
Loamy Sand	.06 - .08	0.7 - 1.0
Loamy Fine Sand	.08 - .11	1.0 - 1.3
Coarse Sandy Loam	.09 - .12	1.1 - 1.4
Sandy Loam	.10 - .13	1.2 - 1.6
Fine Sandy Loam	.13 - .15	1.6 - 1.8
Very Fine Sandy Loam	.14 - .17	1.7 - 2.0
Loam	.14 - .18	1.7 - 2.2
Silt Loam	.15 - .20	1.8 - 2.4
Clay Loam	.17 - .21	2.0 - 2.5
Clay	.14 - .16	1.7 - 2.0

Table 2. Water Holding Capacities of San Diego County Soils. ¹ Inches of water per inch of soil depth. ² Inches of water per foot of soil depth.

Clay Loams — Aggregates separate easily, but are hard to very hard to break. Moist samples will be firm, but will ribbon well and will show a good finger-print. Clay loams will be both sticky and plastic and will form a cast with defined finger marks that will bear a great deal of handling. Light soil/water staining will be apparent on fingers.

Clays — Clays are fine textured soils. When dry, clay soils form very hard to extremely hard blocks or prisms. Moist samples are very plastic and very sticky. A moist sample will ribbon very well and will form a very good fingerprint. Some clays are very firm to extremely firm when moist. Light soil/water staining will be evident on fingers.

Wetted Area

The size of the wetted area (along with the potential rooting depth of the crop and the AWC of the soil) will determine the size of the soil reservoir. It is the size of this reservoir that will help you to determine irrigation frequency.

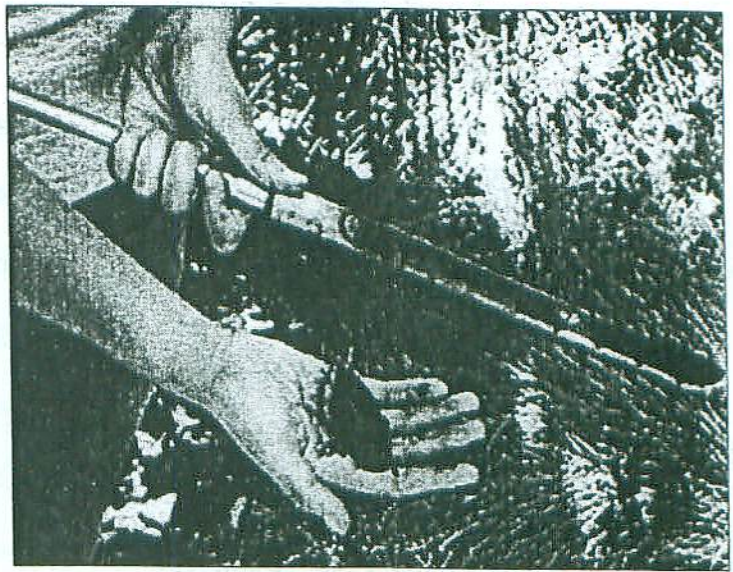
If your wetted area is small, the size of your soil water reservoir will be reduced as well. Thus, the tree's root system has only a small area from which to draw moisture. During warm weather, the reservoir can be depleted quickly. Frequent irrigations will be required to prevent the crop from going into stress.

On the other hand, if your wetted area is large, the trees will spread their roots out over a larger portion of the available soil area. This expanded root zone provides better mechanical stability and helps to make better use of available soil nutrients and moisture. Irrigations that cover a large wetted area are usually longer and less frequent due to a larger soil reservoir.

To estimate the size of your wetted area, you must judge how far laterally water moves away from the emitter. This lateral movement is a combination of: 1. How far the emitters throw water. 2. How far laterally water moves once it enters the soil profile. The throw of emitters varies widely from large nozzle brass spinners to small nozzle micro sprinklers. Drip emitters or drip lines have virtually no throw; they depend on the soil for lateral water movement.

The size of the wetted area is best estimated after a full irrigation during the summer or early fall. By this time, residual moisture caused by rainfall should be depleted. This will provide a more accurate determination of the area wetted by the emitters during each irrigation.

Soon after the irrigation set is complete, observe how much of the soil/ leaf litter surface is wet. Using a soil probe, sample



the soil to a depth of about one foot starting at the edge of the wet surface area. Sample at six inch intervals away from the emitter until the soil samples are unacceptably dry at the one foot level. The distance from the emitter to the point where the samples start to dry up will give you the radius of the wetted area. To find the square footage of a circular wetted area, use the formula: Wetted Area = πr^2 . $\pi = 3.14$

Flow Rate

Once the AWC and the wetted area have been calculated, determine the flow rate of your emitters. Flow rate information will determine the amount of time needed to fill the soil reservoir to various levels.

A good place to start is with the emitter's factory specification sheets. (They can be obtained from emitter manufacturer or local irrigation supply stores.) Factory specification sheet provide flow rates and other characteristics of the emitters under controlled, laboratory conditions. However, conditions such as these rarely exist in the field. Factors that affect emitter flow include water pressure differences, mixed emitters or nozzles, poor water quality, nozzle orifice erosion and clogged nozzles. Rather than assuming your emitters have a particular flow rate, it is better to know the flow rate through simple testing.

Flow Rate/Wetted Area/Precipitation Rate Calculations

1. The catch from a single micro sprinkler is 32 ounces in 30 seconds. Determine the sprinkler's flow rate.

a. Multiply 32 ounces times 2 to get ounces per minute. ($32 \times 2 = 64$)

b. Multiply 64 ounces per minute times 60 (minutes in an hour), to get ounces per hour. ($64 \times 60 = 3840$)

c. Divide 3840 by 128 (ounces in a gallon), to get gallons per hour. ($3840/128 = 30$ gph)

2. The same micro sprinkler is found to have a wetted area radius of 7.5 feet. What is the square footage of the wetted area?

$$\text{Wetted Area} = \pi r^2$$

$$\text{Wetted Area} = 3.14 \times 7.5^2 = 3.14 \times 56.25 = 177 \text{ Square Feet}$$

3. What is the precipitation rate of the micro sprinkler in examples #1 and #2?

$$\text{Precipitation Rate} = \frac{\text{Average Nozzle gpm} \times 96.3}{\text{Wetted Area}} = \frac{0.5 \text{ gpm} \times 96.3}{177} = 0.27 \text{ Inches/Hour}$$

To determine your emitter's flow rate, collect the output from a single emitter for a set amount of time. This provides a flow/time relationship such as gallons per minute (gpm), gallons per hour (gph) or liters per hour (lph). The more flow samples you take, the more accurate your data will be. Collect at least ten flow samples per acre. Older irrigation systems and those on steep terrain will require more samples to obtain accurate results. Flow samples should be taken at the inlet, middle and end of several lateral lines. The average of all flows will give a good representation of how the system is operating. Precipitation rate (PR) is the rate at which an emitter applies water over a given area in a given amount of time. Precipitation rates are often reported in inches per hour.

Emission Uniformity (EU)

Emission uniformity (EU) is a measure of an irrigation system's ability to deliver the same amount of water during each irrigation to each tree. A high EU percentage indicates

that water is being evenly applied throughout a given area. A high EU is essential to ensure that all plants receive the same amount when fertilizer or other chemicals are being injected into the water. A poor EU makes management difficult because there can be gross over-irrigation and gross under-irrigation occurring in the same field simultaneously.

Determining your irrigation system's EU is relatively easy. Use the same data that was used to find the system's flow rate. Take an average of all the flows collected. Then, find the lowest 25 percent of all the flows collected. Take an average of these flows. Divide the average of the lowest 25 percent of flows by the average of all flows. Multiply this number by 100 to get the emission uniformity percentage.

Management Allowable Depletion (MAD)

Management allowable depletion, or MAD, is the amount of water that the trees

are allowed to use between each irrigation. MAD is usually expressed as a percentage of adjusted soil AWC. For example, avocados do well at a 30 percent MAD level. This indicates when 30 percent of the adjusted soil AWC has been used, it is time to irrigate again. If the adjusted AWC in this example is 1.10 inches, then the MAD level would be .33 inches. (30% of 1.10 = .33) The trees would be allowed to use .33 inches of water before the next irrigation. The MAD is set about 30 percent because avocados have a shallow potential rooting depth and are often planted on shallow soils with low water holding capacities. Citrus and deciduous trees have deeper potential rooting depths and are often planted on deeper soils with moderate to high water holding capacities. MAD levels for citrus and deciduous start about 50% and can be pushed higher if soil conditions permit.

System Basics

The CIMIS system is a network of 80 active weather stations located throughout the state. (The system also includes another 24 inactive or closed stations. Historical data has been kept for these stations for the time they were open.) The majority of these stations are located in agricultural areas. CIMIS weather stations range in location from the town of Tulelake in Siskiyou County near the Oregon border, to the town of Seeley in Imperial County. Locally, there are six CIMIS stations in Coastal Riverside and all through San Diego. These include #49, Oceanside; #62, Temecula; #66, San Diego; #147 Otay Lake; #150, Miramar; and #153, Escondido/San Pasqual Valley.

CIMIS automated weather stations have instruments that gather data on air temperature, solar radiation, vapor pressure, wind speed and wind direction. All stations in the network are connected via telephone lines to the Department of Water Resource's central computer in Sacramento. This computer gathers data from each station in the network every 24 hours and summarizes it into hourly and daily formats. The data collected is used

to compute a mathematical model that simulates evapotranspiration. (A mathematical model is a lengthy mathematical formula or calculation that requires many steps and several sources of data.) The model used by CIMIS is a form of Penman's equation modified by Pruitt and Doorenbos. This model also uses a wind function developed at U.C. Davis. The result is reference evapotranspiration or ETo. ETo is a measure of how much moisture an actively growing, six to eight inch tall cool season pasture would pull from the soil during a given amount of time.

Terms and Definitions

Although using CIMIS information is relatively simple, some terms can be confusing. The following are definitions of the most commonly used CIMIS terms.

Evapotranspiration — This is the amount of water used by a particular crop plus the amount of water that has evaporated from the surface of the soil.

ETo — ETo stands for reference evapotranspiration. ETo estimates the evapotranspiration of a cool season grass that is not water stressed. All CIMIS stations use ETo as a standard reporting unit. Remember, ETo is "raw" data. Without proper conversion, ETo data is not an accurate account of your crop's water use.

Kc — Kc represents crop coefficients. These coefficients or conversion factors, account for the difference in the evapotranspiration represented by ETo and the crop you are growing. Crop coefficients are mainly a function of crop growth, stage of development and location (weather conditions) of the crop. Crop coefficients are very low when a crop is young or the weather is mild. An example would be a Kc of .09 for grain sorghum planted in June in the Imperial Valley. This first Kc indicates that while the crop is small, it would use only 9 percent of the daily ETo value. As the crop matures and the weather heats up, the Kc increases to a peak of 1.19. This would indicate that the crop is using 119 percent of the reported ETo value.

For perennial crops, such as trees and vines there are usually 12 different Kc values. Each of these values will correspond to a month of the year. Crop coefficients are highly variable from area to area and need to be tailored for each individual situation.

ETc— ETc represents estimate crop evapotranspiration. ETo is determined by performing the following calculation:

$$ETo \times Kc = ETc$$

ETc is a good estimate of how much water a crop uses daily. Once ETo has been converted into ETc, it is ready for use in irrigation scheduling.

Scheduling Irrigations

Once the EU of the irrigation system has been established and the characteristics of the crop and soil are understood, irrigation scheduling can begin. The fundamental idea of irrigation scheduling is to replace soil moisture that has been used by the crop or has evaporated from the soil surface. There are many methods by which to do this. Two common methods of irrigation scheduling are guessing and using the calendar. These two methods can be arbitrary and are often necessary because of the demands placed on the irrigator. Better methods include the use of tensiometers and judging soil moisture content by its feel and consistency. However, daily weather conditions (along with the stage of crop development) ultimately drive daily evapotranspiration. Using CIMIS data will allow you to correlate daily crop evapotranspiration to daily weather conditions.

Water Budget Method

The method of irrigation scheduling most suited for use with CIMIS data is known as the water budget method. The water budget method is similar to balancing a check book. Deposits (irrigations or rain) are placed

into the account (soil reservoir). Withdrawals (evapotranspiration) can be made until the account reaches a zero balance (MAD). At this time, another deposit should be made or an overdraft (crop stress), will occur. As noted earlier, critical data about the performance of the irrigation system and characteristics of the crop and soil must be known so that proper irrigation scheduling can begin. The more accurate this data, the more precise your irrigation scheduling can be. The first water budget example is based on a hypothetical avocado orchard in Fallbrook:

Crop: Hass avocados, Block #1.

Spacing: 20' x 20' (400 sq. ft.).

Crop Location: Fallbrook.

CIMIS Station: #62, Temecula. The Temecula CIMIS station was chosen due to its proximity to Fallbrook.

Date: July 1991.

Monthly kc: .55. This number indicates that an average, healthy and mature avocado tree will evapotranspire 55 percent of the daily ETo value during July.

Potential Rooting Depth: 2 feet. Over 80 percent of an avocado tree's root system resides within the top 24 inches of the soil profile.

Soil Depth: The soil in Block #1 ranged from 20 to 30 inches deep. Irrigations were scheduled around the 20 inch soil depth areas. Irrigations must always be based on the most limiting soil condition(s) present. Here, the most limiting condition is shallow soil depth which has less water holding capacity than other areas in the block.

Soil AWC: 2.2 inches. This analysis was made at the same time the soil depth was determined. Using the feel method, the grower categorized the soil as a sandy loam with .11 inches of water holding capacity per inch of soil depth. When .11 is multiplied by the most

limiting soil depth of 20 inches, the AWC figure of 2.2 inches of water per 20 inches of soil depth is found (.11 inches x 20 inches = 2.2 inches).

Wetted Area: 201 square feet. By watching the throw of the emitters and using a soil probe to check soil moisture, the grower found that an average emitter was spreading water in a full circle with a radius of 8 feet from the riser ($\pi \times 8^2 = 201 \text{ sq. ft.}$). This is roughly 50 percent of the area occupied by a single tree (201 sq. ft. / 400 sq. ft. = 50%).

Adjusted Soil AWC: 1.10 inches. The AWC of the soil needs to be adjusted because in this example, the wetted area (201 sq. ft.), is less than the area occupied by a single tree (400 sq. ft.). To figure the adjusted soil AWC, multiply the wetted area percent by the soil AWC (50% of 2.20 inches = 1.10 inches). Adjusted soil AWC in gallons can be calculated as follows: Adjusted Soil AWC Inches x .623 x Spacing Sq. Ft. (1.10 inches x .623 x 400 sq. ft. = 274 Gallons).

Emitter Flow Rate: 25 gph. The flows of 20 micro sprinklers in Block #1 were taken and then averaged to find the 25 gph figure.

MAD: 30 percent. When 30% is multiplied by the adjusted AWC, MAD gallons are obtained (30% of 274 gallons = 82 gallons).

EU Percentage: 81 percent. The lowest 25 percent of the flows collected when determining the emitter's flow rate were divided by the average of all flow rates taken to determine this figure.

Normal Irrigation Time: 4.0 Hours. With an emitter flow rate of 25 gph, it took 4 hours of emitter run time to fill the MAD level of 30 percent (82 gallons) with the irrigation system operating at 81 percent emission uniformity.

Normal irrigation time is figured in the following way: Divide MAD gallons by the emitter's flow (82 gallons / 25 gph = 3.3 hours). Then, account for the irrigation

system's emission uniformity. Divide the hours figure by the EU percentage (3.3 hours / .81 = 4.0 hours).

Here are a couple of points to remember concerning normal irrigation run time:

1. Thick layers of leaf litter or mulch can slow water penetration into the soil profile. This problem can be compounded when using low volume sprinklers and/or short irrigation run times. Always check the soil profile after an irrigation to see if water penetration is adequate. If it is not, you may have to adjust the irrigation run time or possibly change emitters.

2. Repeated short irrigation sets can lead to a build up of salts close to the root zone. Because of this, it is best not to alter your irrigation run time. Instead, it is better to alter the days between irrigations and keep the irrigation run time constant. This way, water and salts penetrate to the same depth in the soil during each irrigation and helps to keep the concentrated salt zone at a constant depth. Keep in mind however, that periodic leaching of accumulated salts from the root zone will be required for satisfactory crop development.

Keeping Track

Now comes the day-to-day task of recording daily evapotranspiration. The following example is set up to deal in gallons rather than inches. This is the preference of most North County grove operators. ETo is entered daily. ETc is figured by multiplying ETo by the monthly Kc. ETc in gallons is figured as follows: ETc Gallons = ETc Inches x .623 x Tree Spacing Sq. Ft.

Give It a Try!

The following two pages contain blank water budget forms. These blanks can be photocopied or you can set up your own form that suits your needs. The first blank is set up to record water loss and gain in inches (like the citrus example). The second blank is set up to record water loss and gain in gallons (like the avocado example).



Crop: Avocados Location: Fallbrook CIMIS Station: Temecula #66
 Date: July 1991 Monthly Kc: 0.55 Soil AWC: 2.2" in 20" of soil depth
 Wetted Area: 201ft² (50%) Adjust AWC: 274 gallons MAD (30% Ad.AWC): 83 gal

Date	ETo	Kc	ETc	ETc Gallons	Net Irrigation Gallons	Effective Rainfall Gallons	Remaining Moisture Gallons
7/7	.20	.55	.11	27	83	0	56
7/8	.21	.55	.12	29	0	0	27
7/9	.18	.55	.10	25	0	0	2
7/10	.18	.55	.11	26	83	0	59
7/11	.17	.55	.09	23	0	0	36
7/12	.21	.55	.12	29	0	0	7
7/13	.21	.55	.12	29	83	0	61

Where do these numbers come from?

- The heading information came from the previous page.
- ETo is obtained by contacting a CIMIS Source (see Appendix C).
- Kc is obtained from Appendix A.
- $ETc = ETo \times Kc$
- $ETc \text{ Gallons} = ETc \times 0.623 \times \text{Tree Spacing}[400 \text{ ft}^2]$
- $\text{Net Irrigation Gallons} = \text{MAD}$
- $\text{Effective Rainfall Gallons} = \text{rain inches (local weather page)} \times 0.623 \times \text{Tree Spacing}$
- $\text{Remaining Moisture Gallons} = 83 - 27 = 56$

Think of it this way. The water in the soil profile is your Bank. The ETc Gallons are the Withdrawals. The Net Irrigation Gallons and Effective Rainfall Gallons are Deposits. The Remaining Moisture Gallons are Balances. When the Balance is lower than the Withdrawals, you must Deposit more!

Crop: Valencias Location: Valley Center CIMIS Station: #153 Escondido
 Date: July 1990 Monthly Kc: 0.53 Soil AWC: 5" in 36" of soil depth
 Wetted Area: 254ft² (85%) Adjust AWC: 4.25" MAD (30% Ad.AWC): 2.1"

Date	ET _o	Kc	ET _c	Net Irrigation Inches	Effective Rainfall Inches	Remaining Moisture Inches
7/22	.25	.53	.13	2.1	0	1.97
7/23	.25	.53	.13	0	0	1.84
7/24	.26	.53	.14	0	0	1.70
7/25	.26	.53	.14	0	0	1.56
7/26	.26	.53	.14	0	0	1.42
7/27	.27	.53	.14	0	0	1.28
7/28	.27	.53	.14	0	0	1.14

Citrus in Valley Center

This water budget example is set up around a typical North County citrus operation. Evapotranspiration and irrigations are dealt with in inches rather than gallons.

Crop: Valencia oranges, Block #7.

Spacing: 15' x 20' (300 sq. ft.).

Crop Location: Valley Center.

CIMIS Station: #74, Escondido.

Date: July 1990.

Monthly Kc: .53. This number indicates that an average, healthy and mature Valencia orange tree will evapotranspire 53 percent of the daily ET_o value during July.

Potential Rooting Depth: 3 feet.

Soil Depth: The irrigator found soil depths in Block #7 to be uniform at 50 inches to decomposed granite.

Soil AWC: 5.0 inches. The soil in Block #7 from 0 inches to 12 inches is a sandy loam having .12 inches of water holding capacity per inch of soil depth. From 12 inches to 24

inches, the soil is a loam with .15 inches of water holding capacity per inch of soil depth. Because the effective rooting depth of the crop is 36 inches, soil AWC is not computed beyond this level.

Wetted Area: 254 square feet. By watching the throw of the emitters and using a soil probe to check soil moisture, the irrigator found that an average emitter was spreading water in a circle with a radius of 9 feet from the riser ($\pi \times 81 = 254$ sq.ft.). This is roughly 85 percent of the area occupied by a single tree (254 sq.ft. / 300 sq. ft. = 85%).

Adjusted Soil AWC: 4.25 inches. To figure the adjusted soil AWC, multiply the wetted area percent by the soil AWC. (85% of 5.0 inches = 4.25 inches)

Emitter Flow Rate: 30 gph - The flows of 30 micro sprinklers in Block #7 were taken and then averaged to find the 30 gph figure.

MAD: 50 percent. When 50% is multiplied by the adjusted AWC, MAD inches are obtained (50% of 4.25 inches = 2.1 inches).

EU Percentage: 75 percent. The lowest 25 percent of the flows collected when determining the emitter's flow rate were divided

by the average of all flow rates taken to determine this figure.

Normal Irrigation Time: 17.5 Hours. With an emitter flow rate of 30 gph, it took 17.5 hours of emitter run time to fill the MAD level of 50 percent (2.1 inches) with the irrigation system operating at 75 percent emission uniformity.

Normal irrigation time is figured in the following way: Multiply the tree spacing area square feet by .623. Then, multiply this product by MAD inches (300 sq. ft. x .623 x 2.1 inches = 393 Gallons). Divide 393 gallons by 75 percent to account for the irrigation system's emission uniformity (393 gallons / .75 = 524 gallons). Then divide 524 gallons by the emitter's flow rate of 30 gph to obtain normal irrigation time (524 gallons / 30 gph = 17.5 hours).

Points to Remember

Here are a few points to remember when figuring your soil water balance:

1. **NEVER** draw your soil water balance into a negative (-) state! This is the equivalent of bouncing a check. Extended periods of time at a negative soil water balance can cause severe yield reductions or possible crop failure. (While moisture stress can be used as a yield enhancing technique in some crops, it is normally very undesirable.) The key here is to never draw more water out of the soil than you have put into it.
2. Before starting water budget irrigation scheduling, be sure that your orchard's root zone is fully moist (field capacity), down to the potential rooting depth.
3. Always remember to account for the emission uniformity of your irrigation system when calculating the amount of gross irrigation water to be applied to your crop. Trees require irrigation amounts in terms of net water. However, since no irrigation system operates at 100 percent uniformity, water must be over applied to be sure all trees are re-

ceiving the minimum amount. The lower the EU percentage, the greater the irrigation application must be. Gross water is figured by dividing the net water required by the emission uniformity of your irrigation system: 1.50 inches net water / .75 (75% emission uniformity) = 2.0 inches gross water applied.

4. CIMIS is only one of many tools that can aid irrigation scheduling. It is not fool proof. CIMIS should not replace constant visual observations of orchard and soil conditions. Continue monitoring soil moisture conditions with a soil probe, shovel or tensiometers while CIMIS data is being employed.

5. Account for your tree's daily ET_c when figuring your soil water balance after an irrigation or rainfall. Evapotranspiration continues during periods of irrigation and rainfall. Daily ET_c must be subtracted from the net amount of water applied (irrigation or rainfall) before it is added to the remaining moisture column.

6. Rainfall must be adjusted for effectiveness. A good rule of thumb is to include only 50 percent of total rainfall collected in the effective rainfall column: 1.0 inch total rainfall x .50 (50% effectiveness) = .50 inch net rainfall. If the effective rainfall total is greater than the adjusted soil AWC, use the smaller of the two figures. In other words, you cannot draw more water out of a reservoir than its total capacity.

In Conclusion

Why take the time to use CIMIS? The answer is simple. The utilization of CIMIS data in irrigation scheduling can help you to use water more effectively. By helping to eliminate water wasted by deep percolation, surface runoff, subsurface runoff and surface evaporation, you can lower your water bill. Proper irrigation scheduling can also provide other dividends such as cutting energy use (to run pumps, etc.), optimizing fertilizer use and in some cases, increase crop yields. This means more profit and a better bottom line.

Date	ET _o	K _c	ET _c Inches	Net Irrigation Inches	Effective Rainfall Inches	Remaining Moisture Inches
Date	ET _o	K _c	ET _c	Net Irrig.	Effective Rain	Remain. Moisture

Date	ET _o	K _c	ET _c Inches	ET _c Gallons	Net Irrigation Gallons	Effective Rainfall Gallons	Remaining Moisture Gallons
Date	ET _o	K _c	ET _c	ET _c Gallons	Net Irrig. Gallons	Effect. Rain	Rem. Moisture

Appendix A: Crop Coefficients (Kc)

Crop coefficients are the "keys" that allow daily ETo information to be converted into a useful form. While these crop coefficients will get you into the ball park, they should not be considered accurate for every circumstance. Factors such as crop condition, slope aspect and varying micro climates may mean that given crop coefficients need to be adjusted up or down to function correctly.

The first set of coefficients comes from a Soil Conservation Service publication entitled "Irrigation Water Requirements." These coefficients cover avocados, citrus and deciduous tree crops (with and without cover crops).

The second set of avocado coefficients comes from UC Cooperative Extension specialist Jewell Meyer. These avocado coefficients are unpublished and are based on data taken at the University's avocado irrigation plot in Corona. These coefficients reflect a 20% increase over the current UC Cooperative Extension avocado coefficients. The higher coefficients are recommended because of higher yields and earlier sizing of fruit.

	Avocados ¹	Citrus ²	Grazed Pasture ²	Ungrazed Pasture ²	Open Water Surfaces ²
January	.27	.63	.90	1.0	1.1
February	.42	.66	.90	1.0	1.1
March	.58	.68	.90	1.0	1.1
April	.70	.70	.90	1.0	1.1
May	.78	.71	.90	1.0	1.1
June	.81	.71	.90	1.0	1.1
July	.77	.71	.90	1.0	1.1
August	.71	.71	.90	1.0	1.1
September	.63	.70	.90	1.0	1.1
October	.54	.68	.90	1.0	1.1
November	.43	.67	.90	1.0	1.1
December	.30	.64	.90	1.0	1.1

	Deciduous (No Cover Crop) ³	Deciduous(With Cover Crop) ³
January	.17	.63
February	.25	.73
March	.40	.86
April	.63	.98
May	.88	1.09
June	.96	1.13
July	.95	1.11
August	.82	1.06
September	.54	.99
October	.30	.90
November	.19	.78
December	.15	.66

	Avocados ⁴
January	.40
February	.50
March	.55
April	.55
May	.60
June	.65
July	.65
August	.50
September	.55
October	.55
November	.55
December	.55

Avocados
(2007 Update)

January	.85
February	.85
March	.85
April	.85
May	.85
June	.85
July	.85
August	.85
September	.85
October	.85
November	.85
December	.85

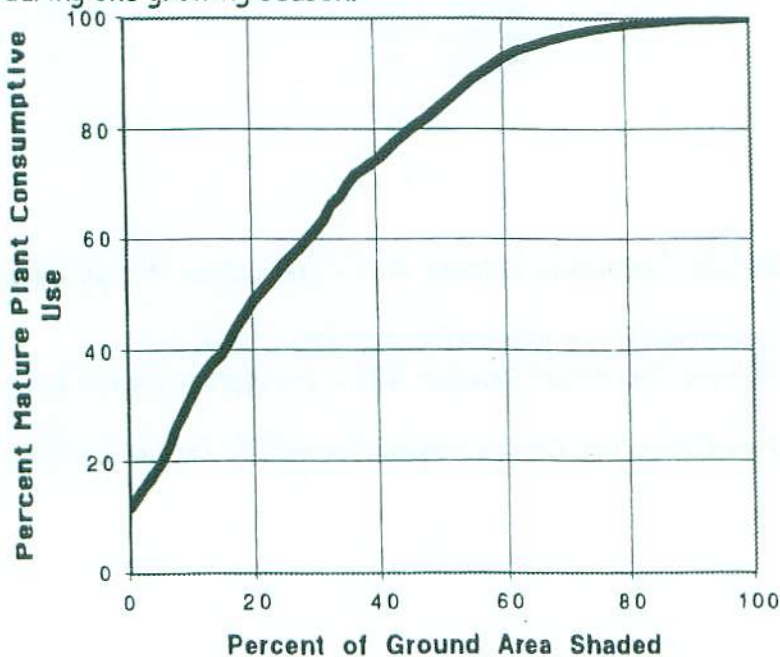
1. USDA/Soil Conservation Service. Technical Release #21 - Irrigation Water Requirements. September 1970
2. University of California Cooperative Extension leaflet #21427 , 1987.
3. USDA/Soil Conservation Service. Technical Release #21 - Irrigation Water Requirements. September 1970
4. Jewell Meyer, UC Cooperative Extension. Corona Foothills Avocado Irrigation Trial, 1993.

Normal crop coefficients assume mature trees and full ground shading conditions. Since juvenile, stumped or newly grafted trees are initially growing under less than fully shaded conditions, adjustment of their ET_c is required.

Example: Two year old avocado trees are planted on 15' x 20' centers. The average radius of the tree's canopies are 3 feet. The Temecula CIMIS station reported the ET_o for July 19 as 0.26. The July crop coefficient for avocados is 0.55. What is the adjusted ET_c for these juvenile trees?

1. Calculate the shaded area of a single tree. (Shaded Area = πr^2) In this case, $3.14 \times 3^2 = 28$ square feet of shaded area.
2. Calculate the area occupied by a single tree. This is simply the tree spacing measurement multiplied together: 15 feet x 20 feet = 300 square feet.
3. Percentage of the area occupied by a single tree that is shaded: $28 \text{ ft}^2 / 300 \text{ ft}^2 = 9 \%$.
4. Calculate the ET_c for mature avocado trees: $.26 (ET_o) \times .55 (K_c) = .14 (ET_c)$.
5. Refer to the following chart. Draw a line straight up from the Percent of Ground Area Shaded range (9 percent), to the point where it intersects with the consumptive use curve. This intersection point corresponds to 31 percent on the Percent Mature Plant Consumptive Use range. This signifies that the juvenile avocado trees in this example are using 31 percent of mature tree ET_c . The adjusted July 19 ET_c for these juvenile trees would be calculated as follows:
 $.14 (\text{Mature Tree } ET_c) \times .31 (\text{Percent Mature Plant Consumptive Use}) = .04 (\text{Adjusted Juvenile Tree } ET_c)$.

Note - Juvenile/stumped trees can grow very quickly during warm weather. This growth means more leaves, which in turn means a larger shaded area. You may need adjust crop coefficients several times during one growing season.



Appendix C: CIMIS Sources

California Department of Water Resources

Division of Planning and Local Assistance

1020 Ninth Street, 3rd Floor

Sacramento, CA 95814

(800) 922-4647

<http://www.dla.water.ca.gov/cimis.html>

DWR can provide growers with passwords and login identifications that allow access to the CIMIS central computer. With a personal computer and a modem, you can obtain daily ETo data, CIMIS weather station information, CIMIS news and other valuable information.

Mission Resource Conservation District

P. O. Box 1777

990 East Mission Road

Fallbrook, California 92088-1777

(760) 728-1332

www.missionrcd.org

The Avocado Commission

<http://www.avocado.org>

The Avocado Commission operates a website that calculates gallons per day requirements, customized to your input data.

North County Times

232 South Main Street

Fallbrook, California 92028-2850

(760) 728-6116

The North County Times newspaper reports CIMIS data from the previous week every Thursday in the Local section. Evapotranspiration data information from station #153, Escondido/San Pasqual Valley is reported in the form of ETo. ETC data is also reported for avocados, citrus, deciduous and pasture/turf. Questions regarding this information should be directed to Mission Resource Conservation District at (760) 728-1332.

Appendix D: CIMIS Help

While the aim of this booklet was to be as comprehensive as possible, every situation cannot be accounted for. Thus, you may need assistance with such things as soil type determination, irrigation system performance, etc. The following agencies can provide help to growers with the various aspects CIMIS use.

Mission Resource Conservation District

P.O. Box 1777
990 East Mission Road
Fallbrook, California 92088
(760) 728-1332

Assistance Offered: Help with all aspects of CIMIS irrigation scheduling, irrigation system evaluations, soil and water conservation education.

USDA/Natural Resource Conservation Service

Escondido Office
332 South Juniper St., Suite 110
Escondido, California 92025
(760) 745-2061

Assistance Offered: Soil type determinations, land use capability determinations, soil erosion control and prevention measures.

California Department of Water Resources

P.O. Box 942836		P.O. Box 29068
Sacramento, California 94236-0001	OR	Glendale, California 91209-9068
(916) 322-6820		(818) 543-4600

Assistance Offered: General CIMIS network information.

U.C. Cooperative Extension

Assistance Offered: The University of California Cooperative Extension offers for sale publications that can aid growers in using CIMIS evapotranspiration data. Useful publications include:

#21454 - Irrigation Scheduling: A Guide for Efficient On-Farm Water Management.

#21426 - Determining Daily Reference Evapotranspiration (ET_o).

#21427 - Using Reference Evapotranspiration (ET_o) and Crop Coefficients to Estimate Crop Evapotranspiration (ET_c) for Agronomic Crops, Grasses and Vegetable Crops.

#21428 - Using Reference Evapotranspiration (ET_o) and Crop Coefficients to Estimate Crop Evapotranspiration (ET_c) for Trees and Vines.

Information regarding publications can be obtained by contacting:

ANR Publications
University of California
6701 San Pablo Avenue
Oakland, California 94608-1239

OR

U.C. Cooperative Extension
5555 Overland Avenue, Building 4
San Diego, California 92123
(858) 694-2849

This printing is made possible by funding from
San Diego County Water Authority



The information presented in this publication can also be found at
www.missionrccd.org

Location is Everything

Deciding which CIMIS station to use is important. Try to use the station nearest to your crop. If your crop is being grown between two stations, take an average of both stations and use accordingly.

Station # 49	Station Name Oceanside	MRCDC Classification Coastal	Nearby City/Town Oceanside
County San Diego	Latitude 33 deg 15' 22"N	Longitude 117 deg 19' 11"W	Elevation 50 ft
Owner San Diego Gas and Electric		Start Date 03-11-1986	Maintenance DWR: Southern District Oceanside Golf Course
Station # 62	Station Name Temecula	MRCDC Classification Inland	Nearby City/Town Temecula
County Riverside	Latitude 33 deg 29' 25"N	Longitude 117 deg 13' 20"W	Elevation 1420 ft
Owner DWR		Start Date 11-25-1986	Maintenance DWR: Southern District
Station # 66	Station Name San Diego	MRCDC Classification Coastal	Nearby City/Town San Diego
County San Diego	Latitude 32 deg 43' 29"N	Longitude 117 deg 08' 05"W	Elevation 370 ft
Owner DWR		Start Date 04-27-1989	Maintenance DWR: Southern District
Station # 147	Station Name Otay Lake	MRCDC Classification Intermediate	Nearby City/Town Otay
County San Diego	Latitude 32 deg 37' 48"N	Longitude 116 deg 56' 18"W	Elevation 580 ft
Owner Metropolitan Water District		Start Date 04-15-1999	Maintenance Otay Water District
Station # 150	Station Name Miramar	MRCDC Classification Intermediate	Nearby City/Town Miramar
County San Diego	Latitude 32 deg 53' 09"N	Longitude 117 deg 08' 31"W	Elevation 445 ft
Owner DWR		Start Date 04-23-1999	Maintenance City of San Diego
Station # 153	Station Name Escondido/SPV	MRCDC Classification Inland	Nearby City/Town San Pasqual Valley
County San Diego	Latitude 33 deg 04' 52"N	Longitude 116 deg 58' 33"W	Elevation 390 ft
Owner Metropolitan Water District		Start Date 04-26-1988	Maintenance City of San Diego

NOTES

Useful Conversions

1 Acre = 43,560 Square Feet

1 Cubic Foot of Water = 7.48 Gallons

1 Gallon of Water = 231 Cubic Inches

1 Acre Foot of Water = 325,829 Gallons

1 Acre Inch = 27,152 Gallons

1 Gallon = 3785 Milliliters

1 gallon of water will cover 1 square foot of open surface to a depth of 1.60 inches.

1 inch of water covering 1 square foot of open surface contains .623 gallons.

Conversion from inches of water used per day (ETc) to gallons of water used per tree per day is as follows:

1. **Measure:** The distance between trees and multiply to calculate the area per tree.

Example: If your trees are 20 feet apart, $20' \times 20' = 400$ square feet.

2. **Multiply:** $.623 \times \text{Daily ETc} \times \text{area (in square feet)}$.

Example: $.623 \times .15 \times 400 = 37$ gallons\tree\day.

3. **Account:** For the emission uniformity of your irrigation system. Divide the gallons\tree\day figure by the emission uniformity percentage of your system. Most well maintained systems operate at or near 75 percent emission uniformity.

Example: $37 / .75 = 49.3$ gallons\tree\day adjusted for 75% emission uniformity.

The above method can also be used to calculate the amount of effective rainfall in gallons:

20' x 20' Tree Spacing (400 Square Feet Per Tree)

.50" of Effective Rainfall

.623 = Inches to Gallons Conversion Factor

$400 \times .50 \times .623 = 125$ Gallons of Effective Rainfall Per Tree



**Micro-Irrigation
Tips for San Diego
County Orchards**



Micro-Irrigation Tips for San Diego County Orchards

A COSTLY ISSUE

As you well know, irrigation water is very expensive in San Diego County compared to other farming areas in California. That's the price we pay for living at the end of the water supply pipeline. The results of a 1996 survey indicated that the average price of water in North San Diego County has risen to \$611 an acre foot - pumping costs not included. For the foreseeable future, wildlife and urban interests will continue to compete with agriculture throughout the County and the State for bigger pieces of California's developed water supply. Due to this competition, two things are bound to happen:

You will receive less irrigation water in the future.

You will pay more for what you do get.

Because of this, sound irrigation water management now becomes crucial to your farming operation's continued survival.

EU - IQ

A given amount of irrigation water will go farther and benefit your trees more when it's evenly applied. It makes no sense to randomly under-irrigate and at the same time, over-irrigate various parts of a single irrigation set. Yet, by not monitoring and maintaining their irrigation systems, many growers are doing just this.

Emission Uniformity, or EU, is a measure of how evenly an irrigation system can apply water to a given area. Poor emission uniformity indicates that while some trees in a block are being under-irrigated, others are possibly being over-irrigated. For example, part of a single block could be swimming in water (opening the door for root rot), while elsewhere in the same block, the soil could be dry enough to cause wilt (and yield loss). While no irrigation system can operate at 100% emission uniformity, well designed and maintained micro-irrigation systems can easily achieve 85% or better.

GET READY...

What can you do to improve your micro-irrigation system's performance? Plenty! Here are a few suggestions to help you start on the right foot.

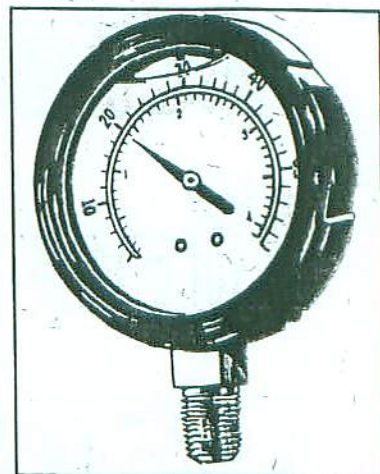
Water Pressure - Water pressure problems can wreak havoc on an irrigation system's emission uniformity. Inadequate pressure can be just as troublesome as too much pressure. While very common in hillside orchards, pressure problems can afflict flat orchards as well.

First Things First - If you don't already own one, spend about twenty-five dollars and buy a good liquid-filled pressure gauge. An accurate gauge is an essential piece of equipment needed to monitor pressures throughout your orchard.

Pressure Uniformity - Most micro-sprinklers operate ideally near 20 psi. To check system pressures, turn on a normal irrigation set and take along your new pressure gauge. Walk through the set and randomly test the pressures of ten or more sprinklers. If you find pressures above 20 psi and/or not consistent between lateral lines, you need to reduce or regulate pressures. There are three main areas that require attention.

Head Unit - Pressure regulation at the head unit may be required if you have high system inlet pressures (over 80 psi). **Block Inlets** - Pressure regulation may be needed here if there is a large elevation loss between the head unit and block inlets. As you lose elevation, water pressure will increase by 0.433 psi for every foot of elevation loss. Conversely, water will lose 0.433 psi for every foot of elevation gain. **Lateral Lines** - Lateral line pressure regulation is essential to insure even pressure distribution throughout an entire irrigation block. Good emission uniformity is difficult to achieve without lateral line regulation.

Pressures can be regulated at any of these locations by using pressure regulators and/or valves. Pressure regulators are advantageous because they automatically reduce



An accurate pressure gauge is one of most important tools that you need to manage a micro-irrigation system.

higher inlet pressures to steady lower output pressures. Valves, while generally cheaper to purchase, need to be monitored and adjusted regularly. They can easily fall out of adjustment between irrigations. Valves are a good choice in places where few are needed, such as the head unit or at block inlets. Pressure regulators are a good choice at lateral line inlets, where the sheer number needed would make constant valve adjustment extremely time consuming.

If you find pressures below 20 psi, there are several methods to increase them. **Lateral Lines** - First and foremost is lateral line pressure regulation. If you have a block that has no lateral line pressure regulation, a great deal of pressure can accumulate at the bottom of the slope. This can result in the bottom lines being over pressured and the top lines being under pressured. By regulating lateral line pressures, you can take excess pressure at the bottom of the slope and "push" it up the hill. **Friction Loss** - As water passes through pipe it produces friction. If you try to push too much water through a piece of pipe, excess friction loss can cause a drop in pressure. To lower friction loss, irrigate fewer trees during each set, switch to a lower flow micro-sprinkler or install larger size pipe. **Booster Pump** - A booster pump may be required if your meter or water source is much lower in elevation than your grove. Because of the cost of purchasing, installing and operating a booster pump, it is usually used as a last resort.

Micro-Sprinklers - Another major problem that detracts from a system's emission uniformity is a lack of micro-sprinkler performance. Two of the most common sprinkler problems are:

Mixed Sprinklers - Emission uniformity can suffer dramatically when sprinklers are mixed within an irrigation block. Mixing sprinklers lowers emission uniformity by applying different amounts of water to different trees within a single block. To make things uniform, standardize all sprinklers in an irrigation block to a single model and orifice size. If you regulate pressures on top of this, your emission uniformity will increase dramatically.

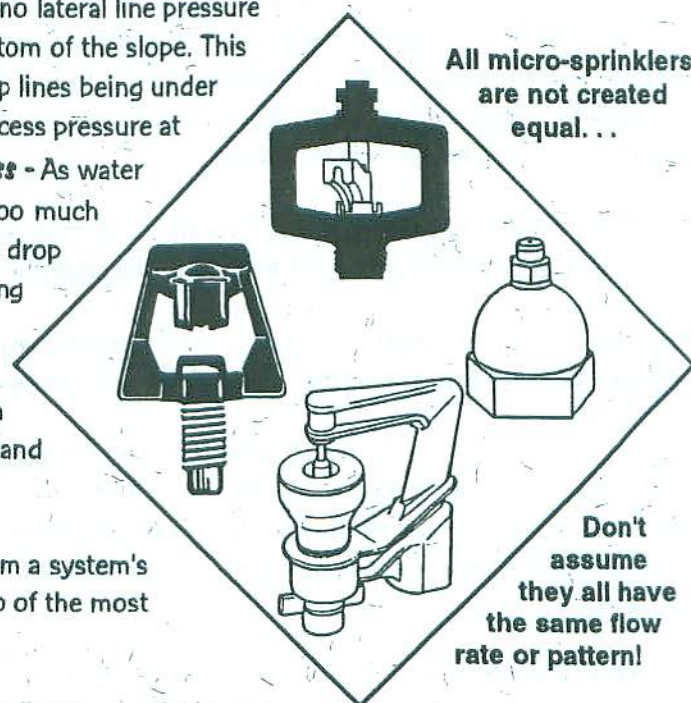
Not Knowing Your Sprinkler's Flow Rate - While this may seem like common knowledge, it's better to *know* your sprinkler's flow than to *assume*. A good place to start is with the specification sheet that is provided by the sprinkler's manufacturer. If you did not receive a spec sheet when you purchased your sprinklers, ask your dealer to provide you with a copy. The spec sheet will provide baseline flow rate data at several different pressures. To verify their performance however, you must test your sprinklers under normal operating conditions. Turn on a normal irrigation set and randomly test the flow of ten or more sprinklers. Capture a sprinkler's flow for a set amount of time (15 seconds, 1 minute, etc.). Then, measure the amount of water you collected (10 ounces, 500 milliliters, etc.). You now have a flow/time relationship that can be increased into more usable forms such as gallons per minute or gallons per hour.

System Maintenance - Like all things mechanical, irrigation systems can and do breakdown. While regular system maintenance will not eliminate problems, it can reduce their occurrence and severity.

Head Unit - Verify the operation of all equipment at the head unit. This includes water meters, backflow devices, valves, injectors, etc. Check that gate and globe valves open and close completely. Observe other control valves (such as Bermad, Cla-Val, etc.) while the system is running. If they are leaking, they need maintenance.

Pay extra attention to the filter. For screen filters: Is the sock clean and free from holes? Is the sock's mesh the right size for the sprinklers you are using? For sand filters: Is the sand still sharp and angular? Round sand has reduced filtering capabilities and should be replaced. Are the insides of the tanks free from excessive amounts of rust?

All of these devices, if not functioning properly, can cause excessive pressure loss and poor system performance. Replace or repair these items as needed.



*For information on how to build a simple device that captures sprinkler flow, see the Mission RCD brochure entitled "How to Build A Mad Bee."

Lateral Lines - Lateral lines should be flushed at least once a month during periods of frequent irrigation. This practice helps to clean out accumulated foreign material (sand, silt, clay, insects, plastic parts, etc.), that has slipped past the filter and tends to settle at the ends of lines. If this foreign material is allowed to accumulate, sprinkler plugging can occur. To flush your lines, remove the last sprinkler from each line with the system running and allow clear water to flow from the riser for at least one minute.

Walk Your Orchard - Walk your lateral lines (while the system is running), as often as possible. Sprinklers can become clogged, broken or stuck between irrigations due to leaf litter interference, foreign material in the water, plastic deterioration, animal damage, etc. Walking lateral lines often also gives you a chance to look for other problems such as soil erosion, poor tree vigor, pipe leaks, etc.

Wetted Area - While not directly tied to emission uniformity, wetted area is important nonetheless. Wetted area is simply the amount of soil that gets wet during each irrigation. The larger the wetted area, the more "on demand" water the trees have.

Maximize Sprinkler Water Delivery - Operate your irrigation system as close to the sprinkler manufacturer's recommended pressure as possible. This will produce the best sprinkler pattern.

Sprinkler Pattern - Trees are often established with sprinklers that throw less than 360 degree patterns. This is fine when trees are young and have small root systems. Why wet soil that has no tree roots? As trees mature however, their root systems spread and their demand for water grows. A sprinkler that is adequate for two year-old tree is often not adequate for a ten year-old tree. Be sure that your sprinklers have a pattern that is large enough for the age and size of the trees.

Sprinkler Interference - Remove all obstructions that interfere with the wetting pattern of the sprinklers. Typical obstructions include pruning debris, weeds and low tree branches. To correct low branch problems, skirt your trees a foot or so above the orchard floor. By removing low branches, you not only improve your sprinkler's patterns but you also take away a path that non-beneficial insects use to invade your trees.

Riser Height - Extend sprinkler risers so that the tops of the sprinklers are between 6 to 10 inches above the orchard floor. Taller risers will increase the radius of the sprinkler's throw, thus increasing the size of the wetted area. Taller risers also make the sprinklers less susceptible to blockage problems associated with leaf litter.

Tilted Risers - Adjust and maintain sprinkler risers so they are perpendicular to the orchard floor. Tilted sprinklers throw very poor patterns.

Need Some Help?

Assistance with irrigation problems is available from Mission Resource Conservation District's Agricultural Water Management Program. Program funding is made available by the San Diego County Water Authority and the United States Department of the Interior, Bureau of Reclamation.

The program's mission is to provide impartial, on-farm irrigation system evaluations. An irrigation evaluation will provide you with a comprehensive report that outlines the condition and performance of your system and also furnishes recommendations to aid in correcting problems. If you own or manage 2 or more irrigated acres of irrigated crop land in San Diego County, just give us a call and we'll be happy to schedule an irrigation system evaluation at your convenience.



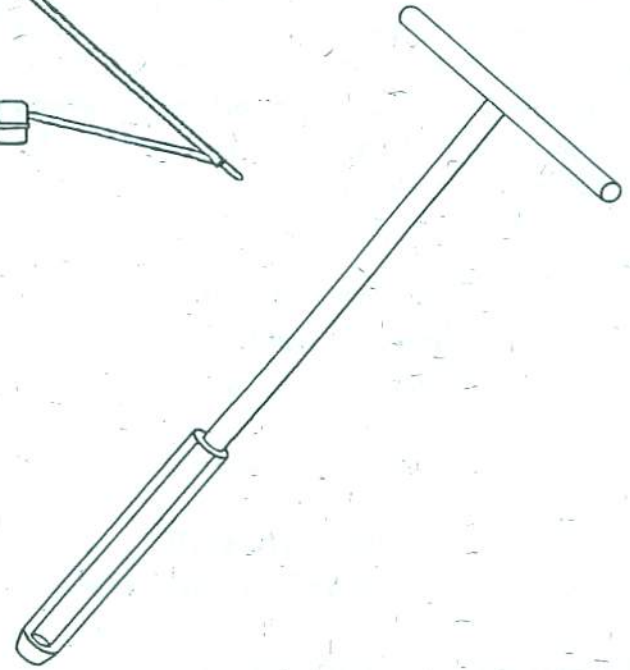
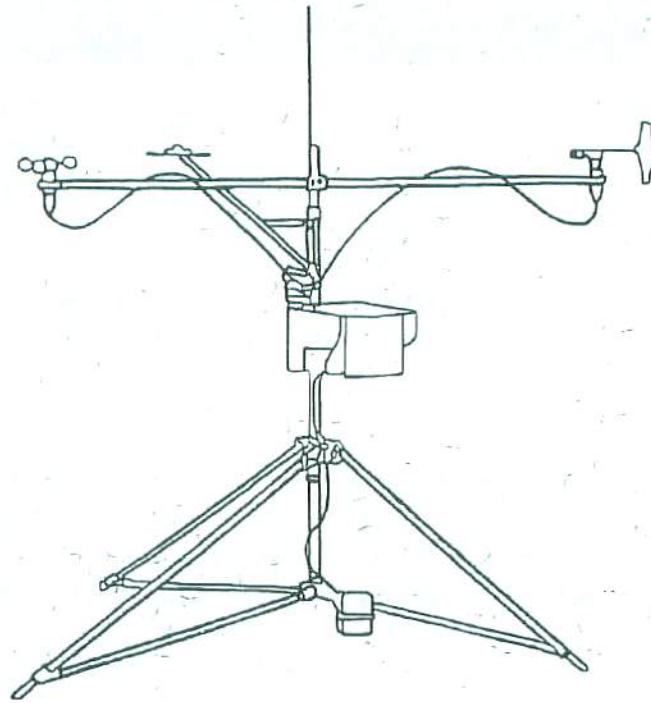
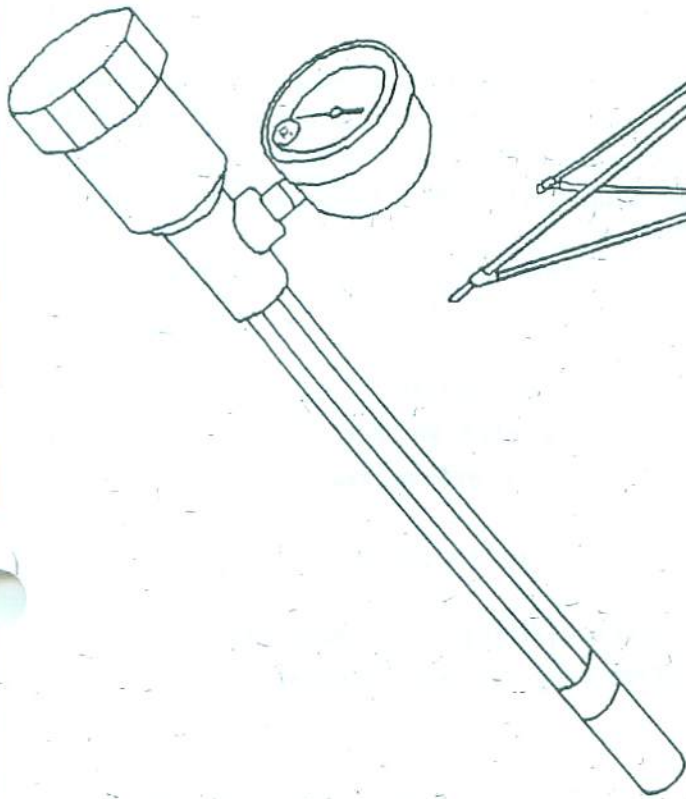
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P.O. Box 1777
Fallbrook, CA 92088-1777 (760) 728-1332

www.missionrcd.org



Recycled and
Recyclable!



Practical Irrigation Scheduling



Practical Irrigation Scheduling

Whether you know it or not, your irrigation system consists of two distinct components. The first is your system's *hardware*; the pipes, valves, pumps and sprinklers that move and apply water. If your system is well designed and maintained, it will allow you to apply water evenly and at a rate that is compatible with your soil type and crop. Poorly designed and maintained systems apply water unevenly and can restrict your crop's growth and yield potential.

The second component is the system's *software*. Better known as irrigation scheduling, this software is the method or methods you use to determine how much water to apply to your crop and how often it should be applied. Without sound irrigation scheduling, even the most technologically advanced irrigation hardware available will yield poor results.

Water Use

The principle of irrigation scheduling is to replenish soil moisture that has been used by the crop you are growing. Water use can be broken down into *beneficial use* and *non-beneficial use*. Beneficial use of irrigation water includes water incorporated in the plant's structure, transpiration losses, water held in the soil, water used for leaching salts, etc. Non-beneficial use of irrigation water is any water you have purchased that does not directly benefit your crop. This includes water lost to surface runoff, sub-surface runoff, deep percolation and on farm conveyance losses (pipe leaks, etc.).

Why bother with irrigation scheduling? Effective irrigation scheduling will allow you to maximize your beneficial water use. This can provide for:

- ✓ *Reduction in water usage*
- ✓ *Better crop quality*
- ✓ *Pest mitigation*

- ✓ *Better yields*
- ✓ *Lower per unit cost*
- ✓ *Better nutrient use*

Effective irrigation scheduling can also help reduce non-beneficial water usage by providing for:

- ✓ *Less water loss to runoff*
- ✓ *Less water loss to deep percolation*
- ✓ *Reduced leaching of nutrients and pesticides into groundwater supplies*

On Farm Irrigation Scheduling

All farms and fields are different. So, what works well for your neighbor down the road might not necessarily work well for you. Irrigation scheduling is most effective when it is tailored to specific crop/field situations. To start, you need to find out the following:

What is your crop's average annual water requirement?

How mature is your crop and what is its stage of growth?

Is your crop salt sensitive? If so, how good is your irrigation water?

How much soil area gets wet during each irrigation set?

How uniform is your irrigation system and at what rate does it apply water?

What are your climatic conditions?

What are your soil characteristics?

How deep is your soil and how much water can it hold?

Are there pan layers that could restrict root growth or drainage?

Does your soil have problems with its chemistry such as excess sodium, abnormal pH, etc.?

If you don't have a good handle on this information, you should. Enlist the help of your farm advisor, the Natural Resource Conservation Service, professional crop consultant or mobile irrigation laboratory. Without this information, irrigation scheduling is guess work at best.

Since no one has yet figured out a way of asking plants directly if they need water or not, you must rely on various methods of *estimating* your crop's need for water. Experiment. Find out which methods work for you and which do not. Above all else, keep in mind there is no single fool proof irrigation scheduling method. All irrigation scheduling methods have their strong points and their weak points. Thus, the best strategy is to use a combination of methods. Common irrigation scheduling methods include:

The Calendar Method is by far the crudest irrigation scheduling technique of all. Using the calendar to schedule irrigation events is always arbitrary and seldom successful. The calendar method considers the needs of the farm manager, irrigator or water district rather than the needs of the crop. It is a known fact that plants continue to transpire and need moisture after five o'clock, on weekends and on holidays.

Soil Moisture Measurement monitors the reservoir that holds moisture for crop use. If this reservoir is allowed to fall below an acceptable level, crop stress and possible yield reduction can occur. By monitoring how fast soil moisture is depleted, you can determine how often to irrigate. By monitoring different areas and different depths, you can determine how long to irrigate.

The Feel Method is the simplest method of soil moisture measurement. It requires nothing more than a soil probe or shovel and a little leg work. Soil samples are taken at various depths within the crop's root zone and the moisture content judged by how the soil feels and looks.

While being the simplest method of soil moisture measurement, the feel method is also the most subjective. Some subjectivity can be eliminated by using standard descriptions of how different soils feel and appear at different moisture levels available from UC Cooperative Extension or the Natural Resources Conservation Service. Competency in judging soil moisture by feel will allow you to spot check the accuracy of other irrigation scheduling methods being used or specific areas that are troublesome. If you don't already know how to judge soil moisture by feel, **LEARN!**

Tensiometers are essentially mechanical roots. A tensiometer consists of a tube fitted with a porous ceramic tip at one end and a vacuum gauge at the other. The tube is filled with water, sealed and placed into the soil. If the adjacent soil is drier than the saturated ceramic tip, the soil extracts water from the tip. Since the tube is sealed, this suction or tension will cause the gauge to move. The drier the soil is, the harder it tries to pull water out of the tip leading to higher gauge readings. If the soil has more moisture than the tip, there will be little or no suction and the gauge will give low readings. Tensiometer gauges read in centibars (cb).

Placement of your tensiometers in respect to the crop's root zone is critical if you want accurate information. Since a tensiometer reads soil moisture conditions only at the tip, the tip needs to be placed in an area of active root growth or other area that you want to monitor moisture.

Limitations of tensiometers include the need for periodic maintenance, poor readings in rocky or very heavy soils and a loss of suction in the 80 to 100 cb range. However, for moisture monitoring in the 10 to 50 cb range (preferred by shallow rooted trees such as avocados), tensiometers are the instruments of choice.

Gypsum Blocks have been around since the 1930s - about as long as tensiometers. They detect soil moisture by measuring low voltage electrical resistance between two electrodes embedded in a block of gypsum. Gypsum blocks are placed into the soil at the desired depth and wires connected to the electrodes are run to the soil surface. The block's resistance levels are then read with a portable meter. As the gypsum housing the electrodes absorbs moisture from the surrounding soil, the block gives low readings. As the soil and the gypsum dry, higher readings are given. Data from gypsum blocks is usually read in or converted to centibars. Gypsum blocks give their best data at readings of over 50 cb and when they are used in medium to heavy textured soils.

Gypsum blocks have certain limitations that can make them less useful in certain situations. The main drawback of gypsum blocks is that they need to be individually calibrated due to variations from sensor to sensor. Gypsum (calcium sulfate), is soluble in water. Because of this, gypsum blocks dissolve and change calibration over time and need to be replaced. Average life is one to three years. Also, gypsum blocks may give inaccurate readings in very saline soils where a high salt load can affect electrical resistance.

Improved Gypsum Blocks do not dissolve over time like conventional gypsum blocks and have overcome the major limitations previously described. Unlike conventional gypsum blocks, improved gypsum blocks have their electrodes embedded in a non-dissolving material. While the blocks can give readings from 10 to nearly 200 cb, the first 15 to 20 cb of resolution is not as good as a tensiometer. Season to season consistency is quite high, thus individual calibration is not needed.

Although not as accurate as tensiometers, improved gypsum blocks closely correlate to tensiometers on a consistent basis. They also do not require the periodic maintenance of a tensiometer and can be left in the soil over the winter in freezing climates.

Neutron Probes are out of the scope of most farmers due to their high cost. They produce information on soil moisture conditions by emitting fast neutrons into the soil profile. When fast neutrons strike hydrogen atoms (which make up 2/3 of a water molecule), they lose speed and become slow neutrons. The higher a soil's moisture content, the more slow neutrons it will produce. A counter on the probe tallies the number of slow neutrons detected over a given period of time. The subsequent reading produced is meaningless however, unless the probe is calibrated to the particular soil type it is being used in. Once calibrated, neutron probes provide a quick and accurate picture of soil moisture conditions.

Evapotranspiration Estimates gauge crop water use by daily weather conditions. Factors such as temperature, day length, humidity, wind intensity, etc., have a significant impact on crop water use.

Evaporation Pans go back a long way - the State has evaporation records that date to the 1880s. At one time, there were nearly 500 evaporation pans being monitored throughout California.

You can make a good estimate of evaporation and evapotranspiration rates specific to your farm by reading the daily water level changes in a pan or other open, straight sided container filled with water. If you farm in an area that has numerous micro climates, evaporation pans will allow you to look at subtle climatic differences from area to area. However, to obtain good data, evaporation pans should be read and refilled daily (a lot of work!). Off readings can be caused by birds, dogs, squirrels etc., drinking or taking baths in your pan(s).

CIMIS is an acronym for the California Irrigation Management System. CIMIS consists of a series of weather stations located throughout the State that are linked to a central computer in Sacramento. Using a mathematical model, CIMIS reports data in the form of ET_0 or reference evapotranspiration. ET_0 is an estimate of the amount of moisture an uncut, non-moisture stressed, cool season pasture uses in a given amount of time. Unless you happen to be growing cool season irrigated pasture, ET_0 is of little use. To convert ET_0 into useful data, it must be factored by a crop coefficient or K_c . Crop coefficients account for the difference in water use between your crop and area and CIMIS reported ET_0 .

To be effective, the use of CIMIS and evaporation pans need to be verified by using the feel method, tensiometers, etc. It is not enough to rely on evapotranspiration data alone. Used as a supplement to other methods however, both CIMIS and evaporation pans provide excellent real time information on constantly changing weather and seasonal conditions.

In these days of ever tightening water supplies, we often hear about irrigation scheduling as a "water conservation" method. However, irrigation scheduling is not about conserving water - it's about using water correctly. It's about making the irrigation water you purchase do as much for your crop as possible. It's about providing your crop with an environment that will allow it to yield to its fullest potential. And, it's about being a responsible steward of our State's water resources, by using water for a beneficial end use for which you can be proud. Anything less is truly a waste of water.



MISSION

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