# Irrigation Scheduling

## Determining Run Times

Loren Oki
Dept. of Plant Sciences and
Dept. Human Ecology
UC Davis

Doing More With Less
Stockton, CA
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University *of* California
Agriculture and Natural Resources

UC DAVIS
UNIVERSITY OF CALIFORNIA

# Learning Objectives

- How to calculate a schedule
  - Irrigation system factors
  - Why is soil important in scheduling?
  - Climate
  - Landscape factors

# Irrigation Objectives

- Provide water to plants
  - only when it is needed
  - only the amount that will be used
  - only where it can be used

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients
  - Climate (Water Use Rates)

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
    - How fast water is applied

# Precipitation Rate

- Calculating PR
  - Average of all ($Avg_T$), mL
  - Catch can throat area (C), sq.in
    - This is 16.6 sq. in. for the ones used
  - Valve on duration (T), minutes
    - Let's set this at 4 minutes

| | mL |
|---|---|
| | 36 |
| | 29 |
| | 18 |
| | 19 |
| | 26 |
| | 33 |
| | 16 |
| | 22 |
| | 38 |
| | 22 |
| | 14 |
| | 21 |
| $Avg_T$ = | 24.5 |

$$PR = \frac{Avg_T}{C \, x \, T} \text{ x } 3.66 = \frac{24.5}{16.6 \, x \, 4} \text{ x } 3.66 = 1.35 \text{ in/hr}$$

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
    - Plant available water

SoilWeb app

http://casoilresource.lawr.ucdavis.edu/gmap/

# Soil Texture

| Soil Texture | | Infiltration Rate (in/hr) | Plant Avail Water (cm/cm)* | Irrig to Wet to Depth (in)** |
| --- | --- | --- | --- | --- |
| Coarse | sand / fine sand | 1.5 | 0.05 | 0.3 |
| | loamy sand | 1 | 0.07 | 0.42 |
| Moderately Coarse | sandy loam | 0.8 | 0.11 | 0.66 |
| Medium | loam | 0.4 | 0.16 | 0.96 |
| | silty loam | 0.25 | 0.2 | 1.2 |
| | silt | 0.3 | 0.2 | 1.2 |
| Moderately Fine | sandy clay loam | 0.1 | 0.15 | 0.9 |
| | clay loam | 0.07 | 0.16 | 0.96 |
| | silty clay loam | 0.05 | 0.18 | 1.08 |
| Fine | sandy clay | 0.08 | 0.12 | 0.72 |
| | silty clay | 0.05 | 0.14 | 0.84 |
| | clay | 0.05 | 0.15 | 0.9 |

*Irrigation Association Landscape Irrigation Auditor Manual page 177

**assume 50% dry down (managed allowable depletion) and 12 inch wetted depth

# Soil Texture

| Soil Texture | | Infiltration Rate (in/hr) | Plant Avail Water (cm/cm)* | Irrig to Wet to Depth (in)** |
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| Medium | loam | 0.4 | 0.16 | 0.96 |
| | silty loam | 0.25 | 0.2 | 1.2 |
| | silt | 0.3 | 0.2 | 1.2 |

Irrig to wet to depth

Desired depth to wet = 12”

Plant avail water = 0.2

Assume 50% dry down

= 12” x 0.2 x 50% = 1.2”

*Irrigation Association Landscape Irrigation Auditor Manual page 177

**assume 50% dry down (managed allowable depletion) and 12 inch wetted depth

# Run-time, Part 1

| | Soil Texture | Infiltration Rate (in/hr) | Plant Avail Water (cm/cm)* | Irrig to Wet to Depth (in)** |
|---|---|---|---|---|
| Medium | silty loam | 0.25 | 0.2 | 1.2 |

- Calculating Run-time
  - **Lower Boundary (LB)**
    - PR = 1.35 in/hr
    - Irrigation to wet to depth = 1.2”

$$LB = \frac{Irrig\ to\ Wet\ to\ Depth}{PR} \times 60 = \frac{1.2}{1.35} \times 60 = 53\ min$$

# Run-time, Part 2

- Calculating Run-time with DU
  - **Upper Boundary (UB)**
    - Scheduling multiplier (SM)
      - DU = 0.65
    - Lower boundary (LB) = 53 min.

$$SM = \frac{1}{0.4+(0.6 \times DU)} = \frac{1}{0.4+(0.6 \times 0.65)} = 1.26$$

UB = LB x SM = 53 x 1.26 = 67 min

# Developing An Irrigation Schedule

- Things you know
  - Distribution uniformity = 0.65
  - Precipitation rate = 1.35 in/hr
  - Soil texture
    - Lower boundary = 53 min
    - Upper boundary = 67 min
- This is **how much** to water
- Now we need to know **when** to irrigate

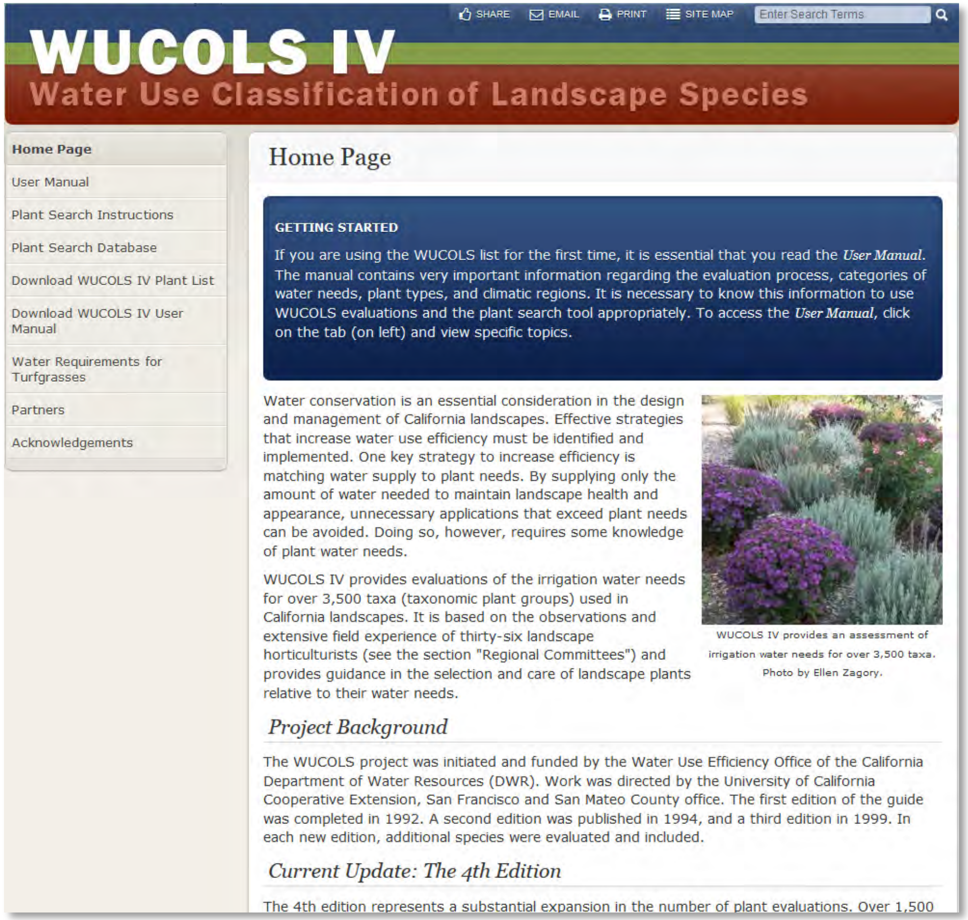
# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ($K_L$)

# Landscape Coefficients

- Information on plant water use
  - WUCOLS

www.ucanr.sites/WUCOLS



# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ($K_L$)
  - Climate ($ET_0$)

# CIMIS

**C** alifornia
**I** rrigation
**M** anagement
**I** nformation
**S** ystem

- Collects weather info
- Estimates plant water use
- More than 120 stations

Water use reports are used with a crop or landscape coefficient to estimate site water use

http://wwwcimis.water.ca.gov/cimis/

# Climate

- Water use models
  - Based on weather data
  - Requires previous research
  - Crop specific
  - Easy to use

# Climate

- Water use models

Reference ET ($ET_0$) is reported (CIMIS)

Crop coefficient ($K_c$) is necessary

Determine $ET_{crop}$ ($ET_c$) to estimate crop water use

so, $ET_c = ET_0 \times K_c$

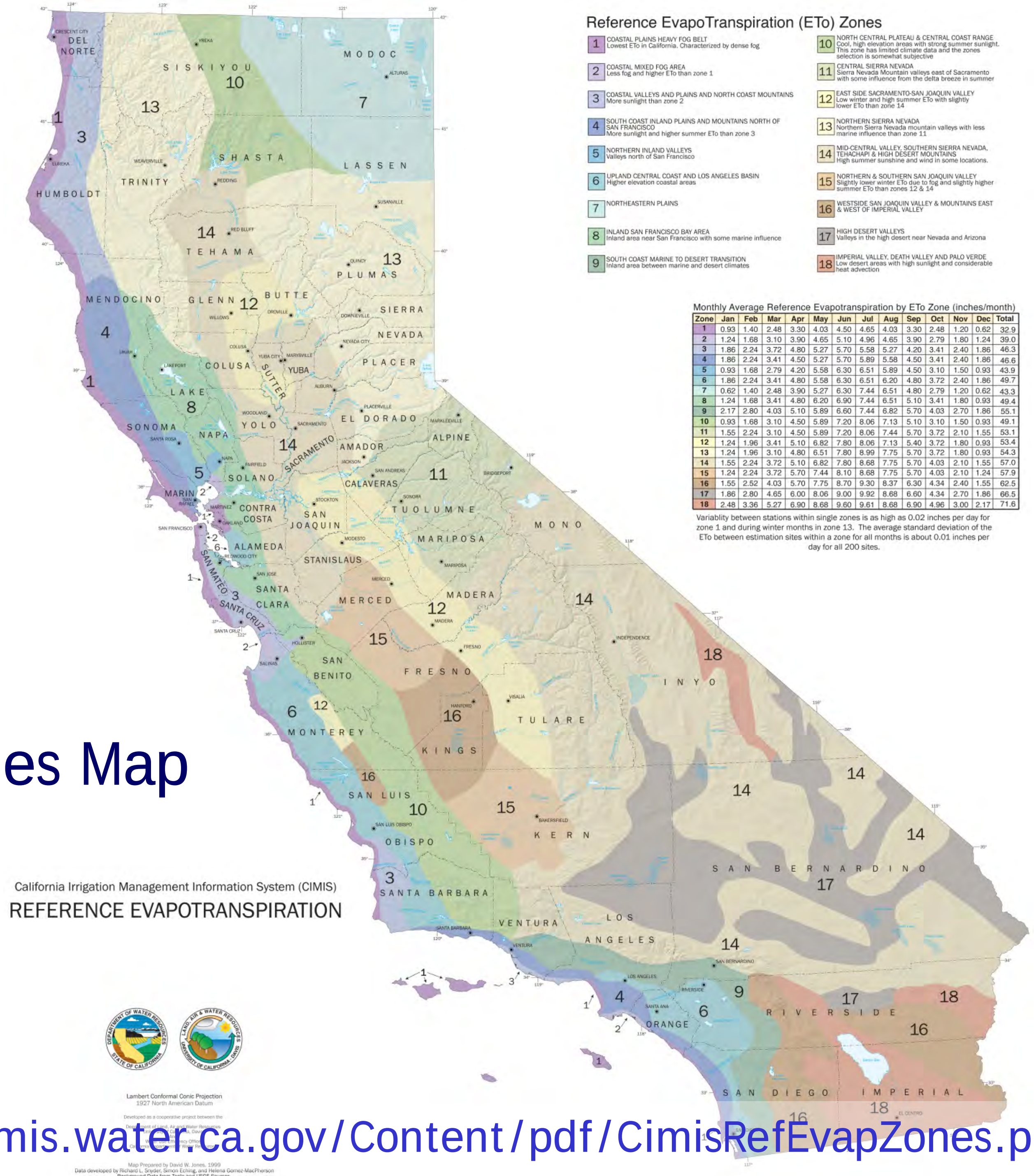
Example: citrus orchard

$K_c = 0.65$

If $ET_0 = 0.5$", then

crop water use is 0.325" (0.325=0.5 x 0.65)

# ETo Zones Map



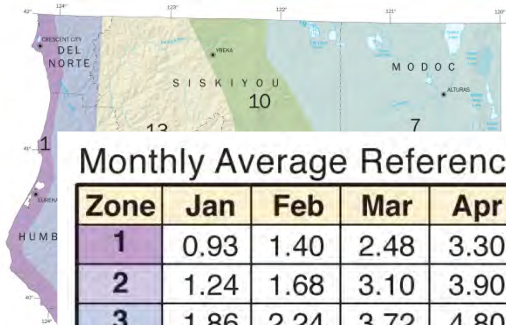

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

| Zone | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.93 | 1.40 | 2.48 | 3.30 | 4.03 | 4.50 | 4.65 | 4.03 | 3.30 | 2.48 | 1.20 | 0.62 | 32.9 |
| 2 | 1.24 | 1.68 | 3.10 | 3.90 | 4.65 | 5.10 | 4.96 | 4.65 | 3.90 | 2.79 | 1.80 | 1.24 | 39.0 |
| 3 | 1.86 | 2.24 | 3.72 | 4.80 | 5.27 | 5.70 | 5.58 | 5.27 | 4.20 | 3.41 | 2.40 | 1.86 | 46.3 |
| 4 | 1.86 | 2.24 | 3.41 | 4.50 | 5.27 | 5.70 | 5.89 | 5.58 | 4.50 | 3.41 | 2.40 | 1.86 | 46.6 |
| 5 | 0.93 | 1.68 | 2.79 | 4.20 | 5.58 | 6.30 | 6.51 | 5.89 | 4.50 | 3.10 | 1.50 | 0.93 | 43.9 |
| 6 | 1.86 | 2.24 | 3.41 | 4.80 | 5.58 | 6.30 | 6.51 | 6.20 | 4.80 | 3.72 | 2.40 | 1.86 | 49.7 |
| 7 | 0.62 | 1.40 | 2.48 | 3.90 | 5.27 | 6.30 | 7.44 | 6.51 | 4.80 | 2.79 | 1.20 | 0.62 | 43.3 |
| 8 | 1.24 | 1.68 | 3.41 | 4.80 | 6.20 | 6.90 | 7.44 | 6.51 | 5.10 | 3.41 | 1.80 | 0.93 | 49.4 |
| 9 | 2.17 | 2.80 | 4.03 | 5.10 | 5.89 | 6.60 | 7.44 | 6.82 | 5.70 | 4.03 | 2.70 | 1.86 | 55.1 |
| 10 | 0.93 | 1.68 | 3.10 | 4.50 | 5.89 | 7.20 | 8.06 | 7.13 | 5.10 | 3.10 | 1.50 | 0.93 | 49.1 |
| 11 | 1.55 | 2.24 | 3.10 | 4.50 | 5.89 | 7.20 | 8.06 | 7.44 | 5.70 | 3.72 | 2.10 | 1.55 | 53.1 |
| 12 | 1.24 | 1.96 | 3.41 | 5.10 | 6.82 | 7.80 | 8.06 | 7.13 | 5.40 | 3.72 | 1.80 | 0.93 | 53.4 |
| 13 | 1.24 | 1.96 | 3.10 | 4.80 | 6.51 | 7.80 | 8.99 | 7.75 | 5.70 | 3.72 | 1.80 | 0.93 | 54.3 |
| 14 | 1.55 | 2.24 | 3.72 | 5.10 | 6.82 | 7.80 | 8.68 | 7.75 | 5.70 | 4.03 | 2.10 | 1.55 | 57.0 |
| 15 | 1.24 | 2.24 | 3.72 | 5.70 | 7.44 | 8.10 | 8.68 | 7.75 | 5.70 | 4.03 | 2.10 | 1.24 | 57.9 |
| 16 | 1.55 | 2.52 | 4.03 | 5.70 | 7.75 | 8.70 | 9.30 | 8.37 | 6.30 | 4.34 | 2.40 | 1.55 | 62.5 |
| 17 | 1.86 | 2.80 | 4.65 | 6.00 | 8.06 | 9.00 | 9.92 | 8.68 | 6.60 | 4.34 | 2.70 | 1.86 | 66.5 |
| 18 | 2.48 | 3.36 | 5.27 | 6.90 | 8.68 | 9.60 | 9.61 | 8.68 | 6.90 | 4.96 | 3.00 | 2.17 | 71.6 |

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

http://wwwcimis.water.ca.gov/Content/pdf/CimisRefEvapZones.pdf

# ETo Zones




Reference EvapoTranspiration (ETo) Zones

1 COASTAL PLAINS HEAVY FOG BELT
Lowest ETo in California. Characterized by dense fog

2 COASTAL MIXED FOG AREA
Less fog and higher ETo than zone 1

3 COASTAL VALLEYS AND PLAINS AND NORTH COAST MOUNTAINS
More sunlight than zone 2

10 NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE
Cool, high elevation areas with strong summer sunlight. This zone has limited climate data and the zones selection is somewhat subjective

11 CENTRAL SIERRA NEVADA
Sierra Nevada Mountain valleys east of Sacramento with some influence from the delta breeze in summer

12 EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY
Low winter and high summer ETo with slightly lower ETo than zone 14

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

| Zone | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
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| 3 | 1.86 | 2.24 | 3.72 | 4.80 | 5.27 | 5.70 | 5.58 | 5.27 | 4.20 | 3.41 | 2.40 | 1.86 | 46.3 |
| 4 | 1.86 | 2.24 | 3.41 | 4.50 | 5.27 | 5.70 | 5.89 | 5.58 | 4.50 | 3.41 | 2.40 | 1.86 | 46.6 |
| 5 | 0.93 | 1.68 | 2.79 | 4.20 | 5.58 | 6.30 | 6.51 | 5.89 | 4.50 | 3.10 | 1.50 | 0.93 | 43.9 |
| 6 | 1.86 | 2.24 | 3.41 | 4.80 | 5.58 | 6.30 | 6.51 | 6.20 | 4.80 | 3.72 | 2.40 | 1.86 | 49.7 |
| 7 | 0.62 | 1.40 | 2.48 | 3.90 | 5.27 | 6.30 | 7.44 | 6.51 | 4.80 | 2.79 | 1.20 | 0.62 | 43.3 |
| 8 | 1.24 | 1.68 | 3.41 | 4.80 | 6.20 | 6.90 | 7.44 | 6.51 | 5.10 | 3.41 | 1.80 | 0.93 | 49.4 |
| 9 | 2.17 | 2.80 | 4.03 | 5.10 | 5.89 | 6.60 | 7.44 | 6.82 | 5.70 | 4.03 | 2.70 | 1.86 | 55.1 |
| 10 | 0.93 | 1.68 | 3.10 | 4.50 | 5.89 | 7.20 | 8.06 | 7.13 | 5.10 | 3.10 | 1.50 | 0.93 | 49.1 |
| 11 | 1.55 | 2.24 | 3.10 | 4.50 | 5.89 | 7.20 | 8.06 | 7.44 | 5.70 | 3.72 | 2.10 | 1.55 | 53.1 |
| 12 | 1.24 | 1.96 | 3.41 | 5.10 | 6.82 | 7.80 | 8.06 | 7.13 | 5.40 | 3.72 | 1.80 | 0.93 | 53.4 |
| 13 | 1.24 | 1.96 | 3.10 | 4.80 | 6.51 | 7.80 | 8.99 | 7.75 | 5.70 | 3.72 | 1.80 | 0.93 | 54.3 |
| 14 | 1.55 | 2.24 | 3.72 | 5.10 | 6.82 | 7.80 | 8.68 | 7.75 | 5.70 | 4.03 | 2.10 | 1.55 | 57.0 |
| 15 | 1.24 | 2.24 | 3.72 | 5.70 | 7.44 | 8.10 | 8.68 | 7.75 | 5.70 | 4.03 | 2.10 | 1.24 | 57.9 |
| 16 | 1.55 | 2.52 | 4.03 | 5.70 | 7.75 | 8.70 | 9.30 | 8.37 | 6.30 | 4.34 | 2.40 | 1.55 | 62.5 |
| 17 | 1.86 | 2.80 | 4.65 | 6.00 | 8.06 | 9.00 | 9.92 | 8.68 | 6.60 | 4.34 | 2.70 | 1.86 | 66.5 |
| 18 | 2.48 | 3.36 | 5.27 | 6.90 | 8.68 | 9.60 | 9.61 | 8.68 | 6.90 | 4.96 | 3.00 | 2.17 | 71.6 |

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

California
REFER...


Lambert Conformal Conic Projection
1927 North American Datum

http://wwwcimis.water.ca.gov/Content/pdf/CimisRefEvapZones.pdf

# Developing An Irrigation Schedule

- So,
  - We know how much to apply (1.2 in)
  - Replaces ½ of field capacity
- Then,
  - We need to estimate when that amount of water is used
  - We know our plants
  - We have info about the climate

# Developing An Irrigation Schedule

- Landscape and plant coefficients ($K_L$)
  - For this example, 0.4
- Climate (Water Use Rates)

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

| Zone | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 1.55 | 2.24 | 3.72 | 5.10 | 6.82 | 7.80 | 8.68 | 7.75 | 5.70 | 4.03 | 2.10 | 1.55 | 57.0 |

  - For this example, we'll use October = 4.03 in/month
  - $ET_{day}$ = 4.03 in ÷ 31 days = 0.13 in/day

# Developing An Irrigation Schedule

- How fast is our landscape using water?
  - $ET_L = ET_{day} \times K_L$
  - $ET_{day} = 0.13$ in/day
  - $K_L = 0.4$

$ET_L = 0.13 \times 0.4 = 0.07$ in/day

# Developing An Irrigation Schedule

- Determine when to irrigate
  - Irrigation application = 1.2 in
  - $ET_L$ = 0.07 in/day
- Accumulate $ET_L$ daily
- When accumulated total reaches 1.2 in
- Irrigate!

# Developing An Irrigation Schedule

$ET_{day}$ = 0.13
$K_L$ = 0.4
**$ET_L$ = 0.07**
Irrig = 1.2

October

| Day | Total $ET_L$ | Day | Total $ET_L$ |
|---|---|---|---|
| 1 | 0.07 | 11 | 0.77 |
| 2 | 0.14 | 12 | 0.84 |
| 3 | 0.21 | 13 | 0.91 |
| 4 | 0.28 | 14 | 0.98 |
| 5 | 0.35 | 15 | 1.05 |
| 6 | 0.42 | 16 | 1.12 |
| 7 | 0.49 | 17 | 1.19 |
| 8 | 0.56 | 18 | 0.06 |
| 9 | 0.63 | 19 | 0.13 |
| 10 | 0.70 | 20 | 0.20 |

1.19
+ 0.07 ($ET_L$)
= 1.26
- 1.20 (Irrig)
= 0.06

# Developing An Irrigation Schedule

$ET_{day}$ = 0.13
$K_L$ = 0.4
**$ET_L$ = 0.07**
Irrig = 1.2

October

| Day | Total $ET_L$ | Day | Total $ET_L$ | Day | Total $ET_L$ |
|---|---|---|---|---|---|
| 1 | 0.07 | 11 | 0.77 | 21 | 0.27 |
| 2 | 0.14 | 12 | 0.84 | 22 | 0.34 |
| 3 | 0.21 | 13 | 0.91 | 23 | 0.41 |
| 4 | 0.28 | 14 | 0.98 | 24 | 0.48 |
| 5 | 0.35 | 15 | 1.05 | 25 | 0.55 |
| 6 | 0.42 | 16 | 1.12 | 26 | 0.62 |
| 7 | 0.49 | 17 | 1.19 | 27 | 0.69 |
| 8 | 0.56 | 18 | 0.06 | 28 | 0.76 |
| 9 | 0.63 | 19 | 0.13 | 29 | 0.83 |
| 10 | 0.70 | 20 | 0.20 | 30 | 0.90 |

# Developing An Irrigation Schedule

$ET_{day}$ = 0.13
$K_L$ = 0.4
**$ET_L$ = 0.07**
Irrig = 1.2

October

| Day | Total $ET_L$ |
|---|---|
| 1 | 0.07 |
| 2 | 0.14 |
| 3 | 0.21 |
| 4 | 0.28 |
| 5 | 0.35 |
| 6 | 0.42 |
| 7 | 0.49 |
| 8 | 0.56 |
| 9 | 0.63 |
| 10 | 0.70 |

- For more accuracy
  - Use actual daily ET
  - Obtain from CIMIS
  - Calculate & accumulate actual rather than historical $ET_L$

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ($K_L$)
  - Climate ($ET_0$)

# More Things to Consider

- Adjust controllers monthly
  - Program for monthly changes in $ET_{day}$
- Interval vs. duration
  - Increase interval between irrigations
  - DO NOT reduce run times
  - Affects wetting depth

# Precipitation Rates

- Precipitation rate
  - How fast water is applied
- Infiltration rates
  - How fast water enters soil


Precipitation > Infiltration = RUNOFF

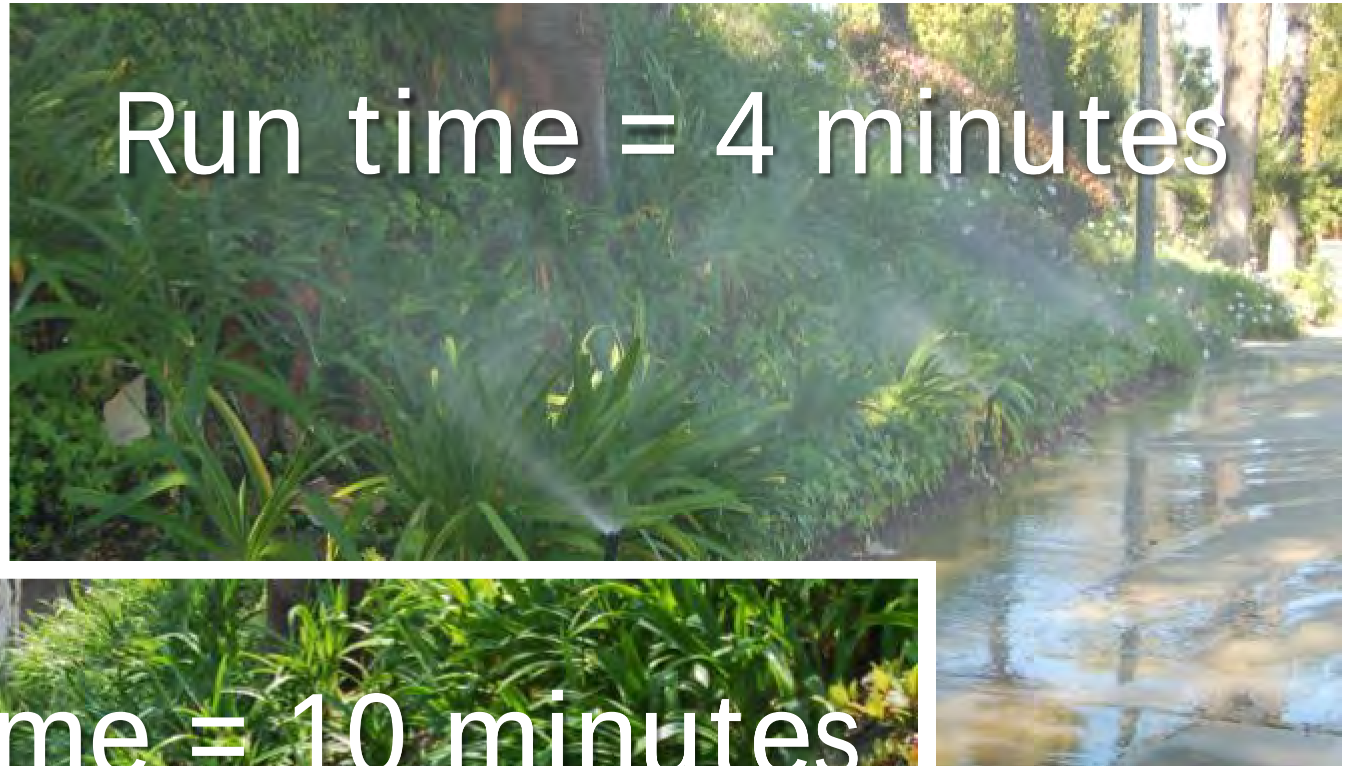
# Precipitation Rates

- Note interval when runoff occurs
- Example:
  - Duration to runoff is 6 minutes
  - Upper boundary is 30 minutes
  - 6 minute duration, 5 times
  - "Cycle-Soak" or "Pulsing"

Precipitation > Infiltration = RUNOFF

# Delivery Method

- Upgrade sprinklers if possible
- At three study sites upgrades resulted in DU increases of 21%, 24%, and 18%





Photos: D. Franklin, Hunter

# Time of Day

- Why early in the day?
  - Lower temperatures
  - Less wind

Photo: L. Oki

# Deep irrigation

- Deep irrigation

  Fills a larger volume of soil to provide water to plants

- Use a soil probe to check wetting depth

# Drip Irrigation

- Can it save water?
- Does it save water?

| GENERAL GUIDELINES | TURF | | | | | | | | | | | | SHRUB & GROUNDCOVER | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY SOIL | | | LOAM SOIL | | | SANDY SOIL | | | COARSE SOIL | | | CLAY SOIL | | | LOAM SOIL | | | SANDY SOIL | | | COARSE SOIL | | |
| EMITTER FLOW | 0.26 GPH | | | 0.4 GPH | | | 0.6 GPH | | | 0.9 GPH | | | 0.26 GPH | | | 0.4 GPH | | | 0.6 GPH | | | 0.9 GPH | | |
| EMITTER SPACING | 18" | | | 18" | | | 12" | | | 12" | | | 18" | | | 18" | | | 12" | | | 12" | | |
| LATERAL (ROW) SPACING | 18" | 20" | 22" | 18" | 20" | 22" | 12" | 14" | 16" | 12" | 14" | 16" | 18" | 21" | 24" | 18" | 21" | 24" | 16" | 18" | 20" | 16" | 18" | 20" |
| BURIAL DEPTH | Bury evenly throughout the zone from 4" to 6" | | | | | | | | | | | | On-surface or bury evenly throughout the zone to a maximum of 6" | | | | | | | | | | | |
| APPLICATION RATE (INCHES/HOUR) | 0.19 | 0.17 | 0.15 | 0.30 | 0.27 | 0.25 | 0.98 | 0.84 | 0.73 | 1.48 | 1.27 | 1.11 | 0.19 | 0.16 | 0.14 | 0.30 | 0.26 | 0.23 | 0.73 | 0.65 | 0.59 | 1.11 | 0.99 | 0.89 |
| TIME TO APPLY ¼" OF WATER (MINUTES) | 80 | 89 | 97 | 50 | 55 | 61 | 15 | 18 | 20 | 10 | 12 | 13 | 80 | 93 | 106 | 50 | 58 | 66 | 20 | 23 | 26 | 13 | 15 | 17 |
| Following these maximum spacing guidelines, emitter flow selection can be increased if desired by the designer. 0.9 GPH flow rate available for areas requiring higher infiltration rates, such as coarse sandy soils. | | | | | | | | | | | | | | | | | | | | | | | | |

Note: 0.4, 0.6 and 0.9 GPH are nominal flow rates. Actual flow rates used in the calculations are 0.42, 0.61 and 0.92 GPH.

# Drip Irrigation

- Precipitation rates approach those of overhead
- Proper management is key

| GENERAL GUIDELINES | TURF | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY SOIL | | | LOAM SOIL | | | SANDY SOIL | | | COARSE SOIL | | |
| EMITTER FLOW | 0.26 GPH | | | 0.4 GPH | | | 0.6 GPH | | | 0.9 GPH | | |
| EMITTER SPACING | 18" | | | 18" | | | 12" | | | 12" | | |
| LATERAL (ROW) SPACING | 18" | 20" | 22" | 18" | 20" | 22" | 12" | 14" | 16" | 12" | 14" | 16" |
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| TIME TO APPLY ¼" OF WATER (MINUTES) | 80 | 89 | 97 | 50 | 55 | 61 | 15 | 18 | 20 | 10 | 12 | 13 |

# Drip Irrigation

- Precipitation rates approach those of overhead
- Proper management is key

# Drip Irrigation

- F
  c
- F

# Even More Things To Consider

- Prioritize plants that receive water
- Know water stress symptoms
- Precondition to enhance survival
- Manage salinity

# Managing Irrigation

- It's a "piece of cake"
  - There are a lot of ingredients needed to make the cake
  - There are several, distinct steps to put the ingredients together properly
  - Each has to be managed as part of a program
  - Changing one affects another
- The short version: "It's complex"

# Managing Irrigation

- Anyone can do a mediocre (or less) job
- Doing it well requires diligence
- We've gotten away with "good enough" because water supply wasn't an issue. Now it is.

- The question that will be asked:
  - Are the rewards worth the effort?

# Thank you

lroki@ucdavis.edu

Photo: L.Oki