SMART Irrigation Controllers

How smart are they?

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Get A Grip On Drip
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Agriculture and Natural Resources

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Topics

- Irrigation objectives
- What are SMART controllers?
- Types of SMART controllers
- How do they work?

What I won’t cover:

- Which are the “good” ones?
- Which ones are recommended by the University of California?

Manufacturers

(of controllers with 20 stations or fewer)

- Brilliant Technologies
- Cyber-Rain
- Desert Irrigation
- H20
- Hunter
- HydroPoint
- Hydro-Rain
- Irritrol
- Nxeco
- OnPoint
- Orbit
- Rachio
- Rain Bird
- Raindrip
- RainMachine
- RainMaster
- RainPal
- Signature
- SkyDrop
- Toro
- Weathermatic

https://www.epa.gov/sites/production/files/2017-02/watersenses-labeled-products.xlsx

Learning Objectives

Education how SMART controllers work

- Show you the different types of controllers
- Provide you with knowledge to understand how they are designed
- What's good and what's not so good

Irrigation Objectives

Maximize water use efficiency

- Apply the amount the plants need
- Apply when the plants need it

Irrigation Objectives

Information needed

- To determine valve run time:
  - PAW- plant available water)
  - Depth to wet
  - DU- Distribution Uniformity
  - PR- Precipitation (application) Rate
- To determine when to irrigate:
  - K_L- Landscape Coefficient
  - ET_0- Reference ET

What are SMART controllers?

"Smart sensors and controllers monitor weather and other site conditions and adjust the irrigation system to apply just the right amount of water at just the right time."

Irrigation Association

What are SMART controllers?

"Smart sensors and controllers monitor weather and other site conditions and adjust the irrigation system to apply just the right amount of water at just the right time."

Irrigation Association

Types of SMART controllers

- Weather-based
- Soil moisture-based

Types of SMART controllers

- Weather-based
  - Manages irrigation based on weather conditions
    - Signal
      - Weather data from central source
    - Historical
      - Preprogrammed with local climate data
    - On-site measurement
      - Weather station on location

Weather-Based Irrigation Controllers

Weather-based irrigation controllers "adjust the irrigation system's station run times based on plants' watering needs rather than on a preset, fixed schedule."

from: EPA's WeatherSense Labeled Weather-Based Irrigation Controllers.

What's wrong with this statement?

Weather-Based Irrigation Controllers

Weather-based irrigation controllers "adjust the irrigation system's station schedule based on an estimation of plants' watering needs rather than ` a preset, fixed schedule."

This is more correct.

- Run times should not be modified.
- The ET method is an estimation of plant water needs.

Weather-Based Irrigation Controllers

- How they work
- How to determine
  - How much to apply
  - When to apply

Weather-Based Irrigation Controllers

- How they work
- How to determine how much to apply
  - Need to know:
    - Soil type
      - Plant Available Water
    - Depth to wet

Soil Information

Depth to wet (in.): 12

Soil Texture		Infiltration- mid rate* (in./hr)	Plant Avail Water- mid**	Irrig to wet to depth (in)†
Coarse	sand / fine sand	2.25	0.05	0.3
	loamy sand	1.5	0.07	0.42
Moderately Coarse	sandy loam	1	0.11	0.66
Medium	loam	0.5	0.16	0.96
	silty loam	0.33	0.20	1.2
	silt	0.4	0.20	1.2
Moderately Fine	sandy clay loam	0.2	0.15	0.9
	clay loam	0.16	0.16	0.96
	silty clay loam	0.09	0.18	1.08
Fine	sandy clay	0.14	0.12	0.72
	silty clay	0.1	0.15	0.9
	clay	0.08	0.14	0.84

*Also known as intake rate. Mid values in the range.

**IA Landscape Irrigation Auditor Manual page 177. Mid value in the range.

†assume 50% dry down (managed allowable depletion)

Weather-Based Irrigation Controllers

- How they work
- Determine how much to apply

Amount to apply= PAW × Depth to wet × MAD

PAW=Plant Available Water

MAD=Management Allowable Depletion

(how much water to be used)

Amount to apply= 0.2 × 12” × 0.5 = **1.2”**

Weather-Based Irrigation Controllers

- How they work
- Determine how much to apply (1.2”)
- Determine runtime
  - From catch can assessment
    - DU (ex: 0.75)
    - Precipitation Rate (ex: 0.4 in/hr, rotors)

$$\text{Run time} = \frac{\text{Amt to apply}}{\text{PR}\times(0.4+(0.6*\text{DU}))}$$

$$= \frac{1.2}{0.4\times(0.4+(0.6*0.75))} = 3.5 \text{ hrs}$$

Weather-Based Irrigation Controllers

- How they work
- Determine how much to apply (1.2”)
- Determine runtime (3.5 hrs)
- **How to determine when to apply**

Weather-Based Irrigation Controllers

- How to determine when to apply
- Require weather or ET_0 data
- What is ET_0?
  - Reference Evapotranspiration
    - The amount of water used by the reference crop (**transpiration**) and losses directly from the soil surface (**evapo**ration)
    - Needs to be modified to landscape conditions
    - http://www.cimis.water.ca.gov/

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://www.cimis.water.ca.gov

Weather-Based Irrigation Controllers

- How it works for crops
  - Reference ET (ET_0) is reported by CIMIS
  - Crop coefficient (K_C) is necessary
  - Determine crop ET (ET_C) to estimate water use
    - so, $ET_C = ET_0 \times K_C$
  - Example: citrus orchard
    - $K_C = 0.65$
    - If ET_0 for the past 5 days= 1.75”, then
    - Citrus crop water use was 1.75” x 0.65 = 1.14”

Weather-Based Irrigation Controllers

- How it works for landscapes
  - Reference ET (ET_0) is reported by CIMIS
  - Landscape coefficient (K_L) is necessary
  - Determine landscape ET (ET_L) to estimate water use
    - so, $ET_L = ET_0 \times K_L$
  - Example: moderate water use landscape zone
    - $K_L = 0.4$
    - If ET_0 for the past 5 days= 1.75", then
    - Landscape water use was 1.75" x 0.4 = 0.7"

Weather-Based Irrigation Controllers

- How they work
  - The amount of water to apply is **1.2”**
  - Landscape water use for the past 5 days was **0.7”** (from: 1.75” x 0.4 = 0.7”)
  - The controller retrieves or calculates ET_0 and determines ET_L each day
  - ET_L is accumulated
  - When the accumulated ET_L reaches 1.2”, Irrigation is initiated

Weather-Based Irrigation Controllers

- So, how do they REALLY work?
- Information the controller needs
- Weather to determine ET_0
  - Historical (see CIMIS)
  - From on-site weather station
  - From central source (web, tel, etc.)

Weather-Based Irrigation Controllers

- Information the controller needs
- Weather to determine ET_0 or ET_0
- Landscape zone to determine K_L
  - Turf, shrubs, trees, etc.
  - Water use

Weather-Based Irrigation Controllers

- Information the controller needs
- Weather to determine ET_0
- Landscape zone to determine K_L
- Irrigation system to determine PR and DU
  - Spray, rotor, drip

From: Netafim

Weather-Based Irrigation Controllers

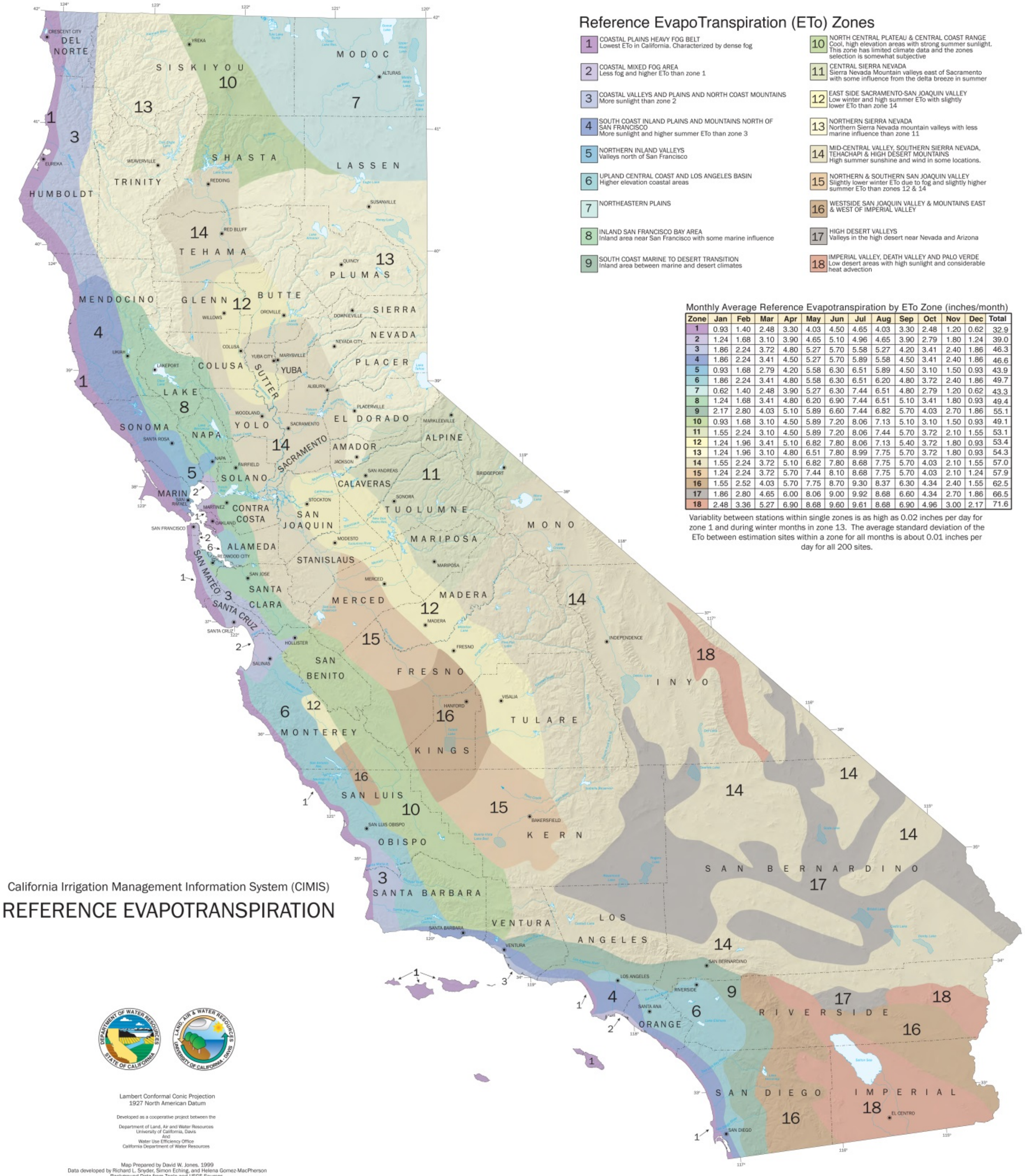
- Information the controller needs
- Weather to determine ET_0
- Landscape zone to determine K_L
- Irrigation system to determine PR and DU
- Soil type to determine PAW
- Slope to prevent runoff

From this, the program estimates the specific information it needs to do the calculations presented earlier.

Water Budget Adjustment
(percent adjustment)

- To reduce irrigation as a fraction of that applied in the driest period
- July has the greatest ET rates
- See CIMIS Reference ET Zones map

http://www.cimis.water.ca.gov/Content/pdf/CimisRefEvapZones.pdf



Reference EvapoTranspiration (ETo) Zones

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

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

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

4 SOUTH COAST INLAND PLAINS AND MOUNTAINS NORTH OF SAN FRANCISCO
More sunlight and higher summer ETo than zone 3

5 NORTHERN INLAND VALLEYS
Valleys north of San Francisco

6 UPLAND CENTRAL COAST AND LOS ANGELES BASIN
Higher elevation coastal areas

7 NORTHEASTERN PLAINS

8 INLAND SAN FRANCISCO BAY AREA
Inland area near San Francisco with some marine influence

9 SOUTH COAST MARINE TO DESERT TRANSITION
Inland area between marine and desert climates

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

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

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

13 NORTHERN SIERRA NEVADA
Northern Sierra Nevada mountain valleys with less marine influence than zone 11

14 MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA, TEHACHAPI & HIGH DESERT MOUNTAINS
High summer sunshine and wind in some locations.

15 NORTHERN & SOUTHERN SAN JOAQUIN VALLEY
Slightly lower winter ETo due to fog and slightly higher summer ETo than zones 12 & 14

16 WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST & WEST OF IMPERIAL VALLEY

17 HIGH DESERT VALLEYS
Valleys in the high desert near Nevada and Arizona

18 IMPERIAL VALLEY, DEATH VALLEY AND PALO VERDE
Low desert areas with high sunlight and considerable heat advection

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

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	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.

California Irrigation Management Information System (CIMIS)

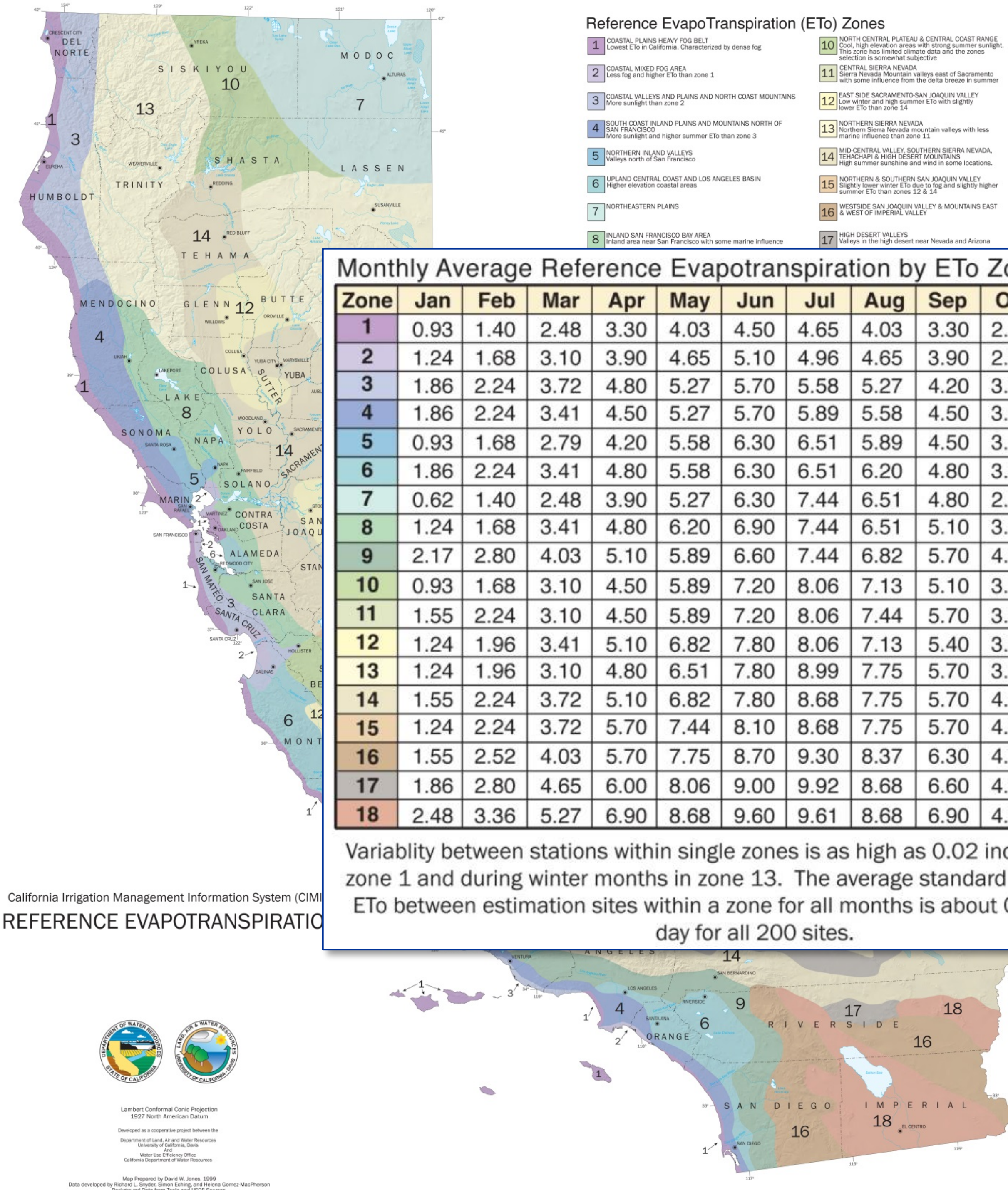
REFERENCE EVAPOTRANSPIRATION

Lambert Conformal Conic Projection
1927 North American Datum

Developed as a cooperative project between the

Department of Land, Air and Water Resources
University of California, Davis
And
Water Use Efficiency Office
California Department of Water Resources

Map Prepared by David W. Jones. 1999
Data developed by Richard L. Snyder, Simon Eching, and Helena Gomez-MacPherson
Background Data from Teale and USGS Sources



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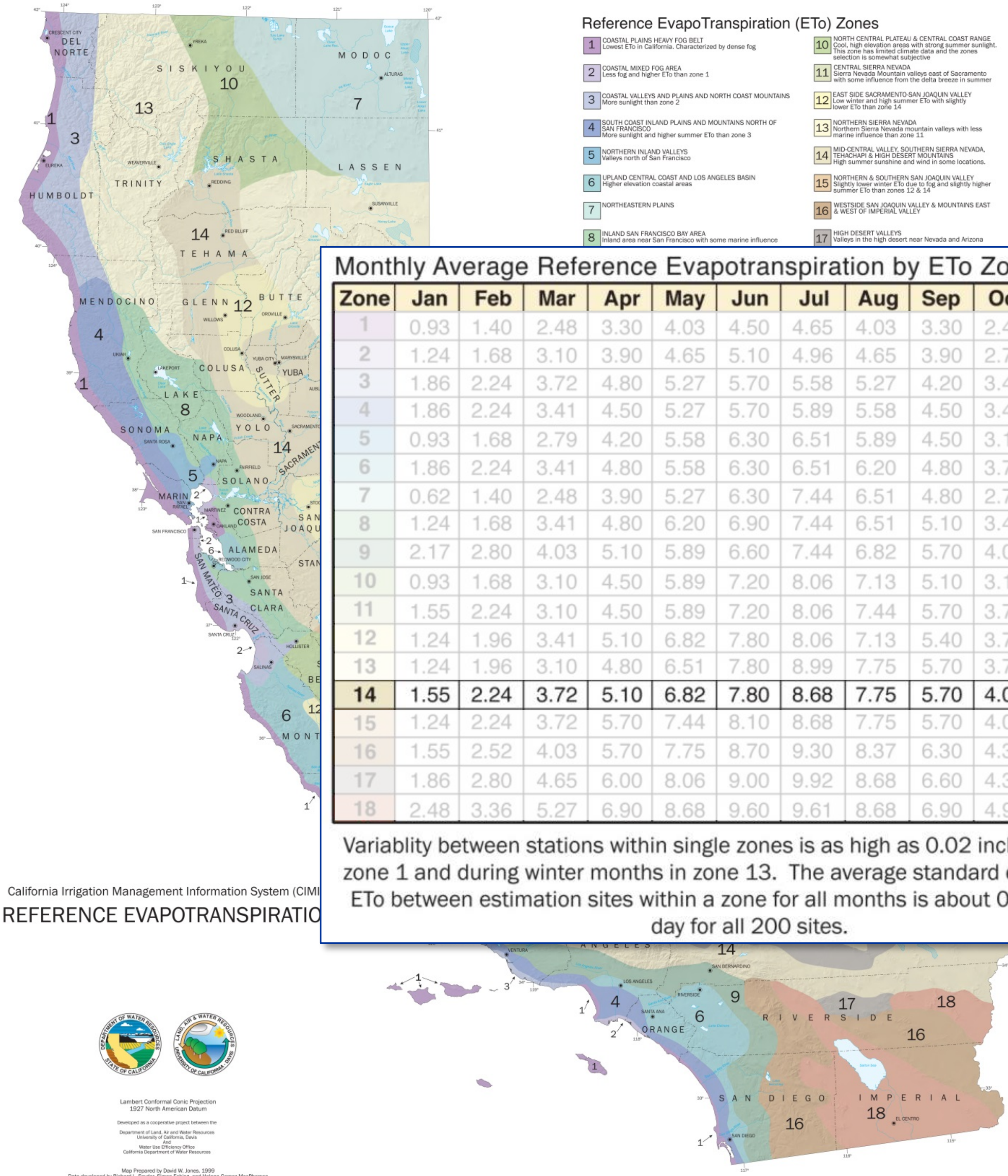

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Water Budget Adjustment
(percent adjustment)

Monthly Average ET (inches/mo)

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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
	15%	24%	42%	63%	85%	97%	100%	88%	67%	46%	22%	12%	

So how does a controller make the adjustment?

- Use the percentage to reduce
  - Valve run time
  - Irrigation schedule

YES! RIGHT WAY!

Types of SMART controllers

- Weather-based
- Soil moisture-based
  - Manages irrigation based on soil moisture condition
    - Requires sensors in the soil

Soil Moisture-Based Irrigation Controllers

- Applies water based on the amount of water in the soil
  - When dry, apply water
  - If not dry, don’t irrigate
  - Can also shut off valve as soil is rewetted

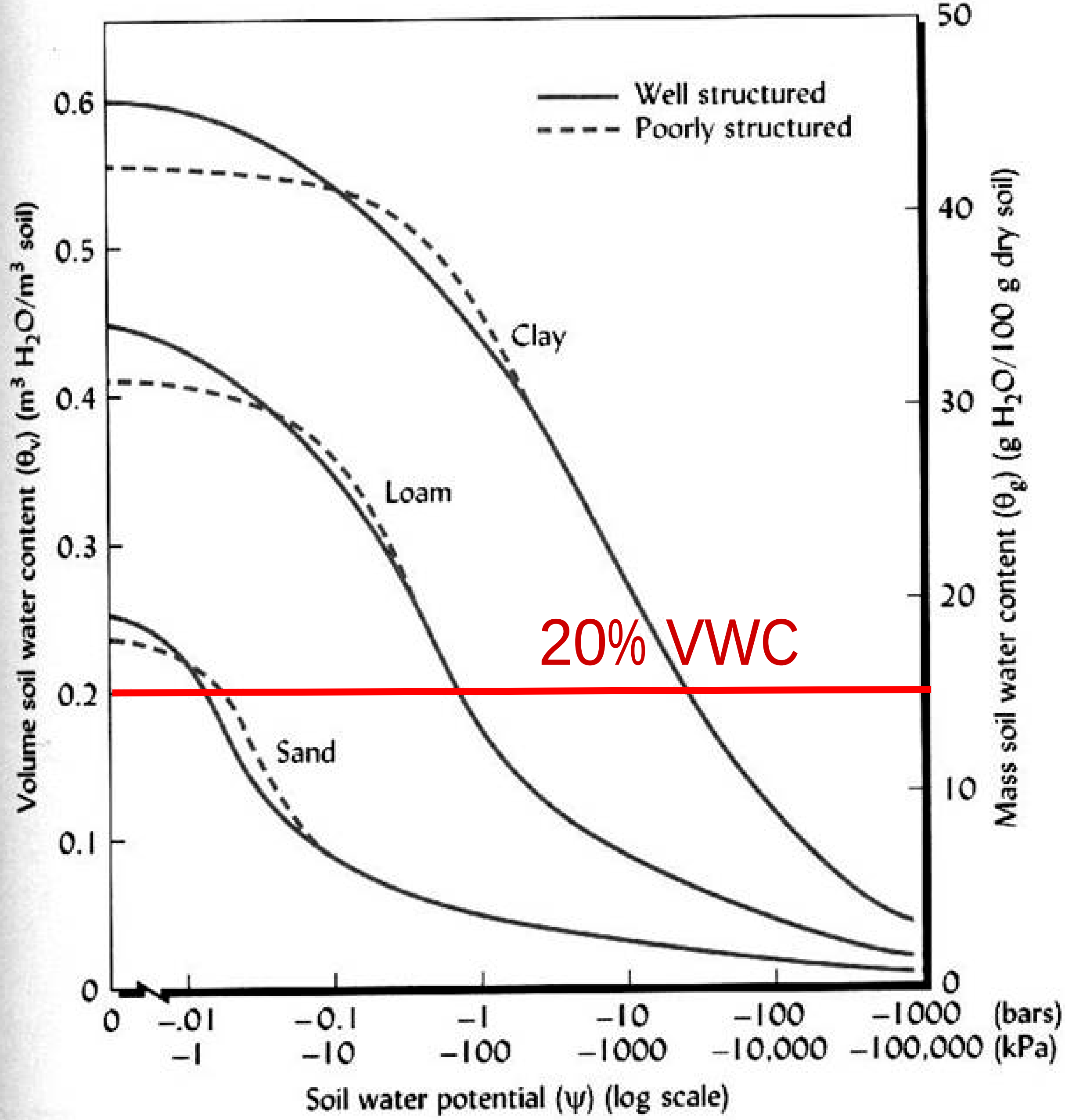
Soil Moisture-Based Irrigation Controllers

Types

- Bypass/interruption
  - Does not allow irrigation if soil is wet
- Initiate/terminate
  - Starts irrigation when dry
  - Ends irrigation when soil is rewetted

Soil Moisture-Based Irrigation Controllers

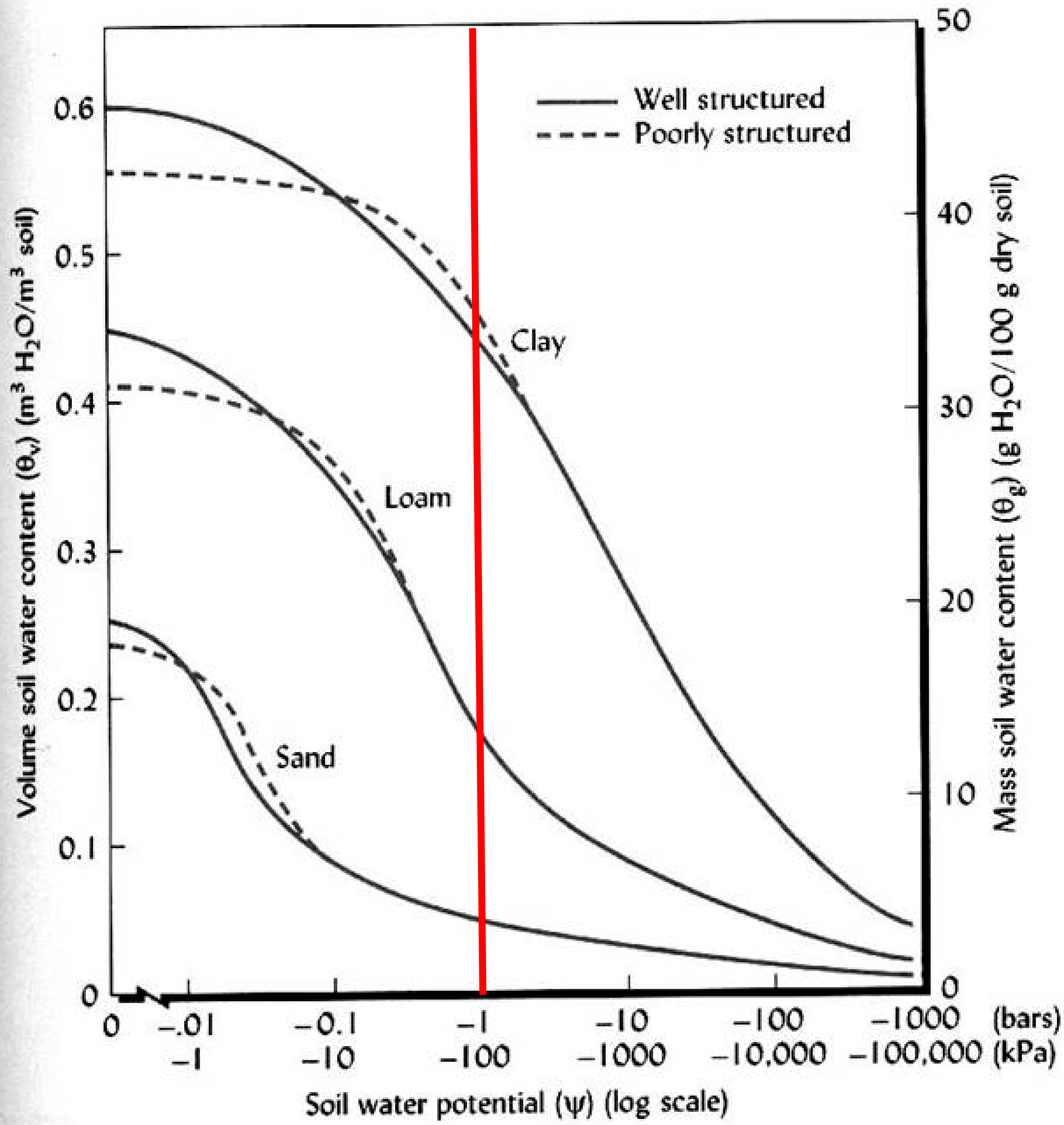
- Sensor types
  - Volumetric Water Content
    - The amount of water
  - Matric potential
    - How tightly the water is held in the soil
- It's important to know the difference



Graphic: Brady & Weil, The Nature and Properties of Soils, 2002

Moisture Retention Curve

All soils have a characteristic curve



Graphic: Brady & Weil, The Nature and Properties of Soils, 2002

Moisture Retention Curve

All soils have a characteristic curve

Permanent Wilting Point at 100 kPa

Soil Moisture-Based Irrigation Controllers

- Sensor types
  - Volumetric Water Content
    - The amount of water
    - Depends on soil texture
  - Matric potential
    - How tightly the water is held in the soil
    - More important in plant-water relations

Soil Moisture-Based Irrigation Controllers

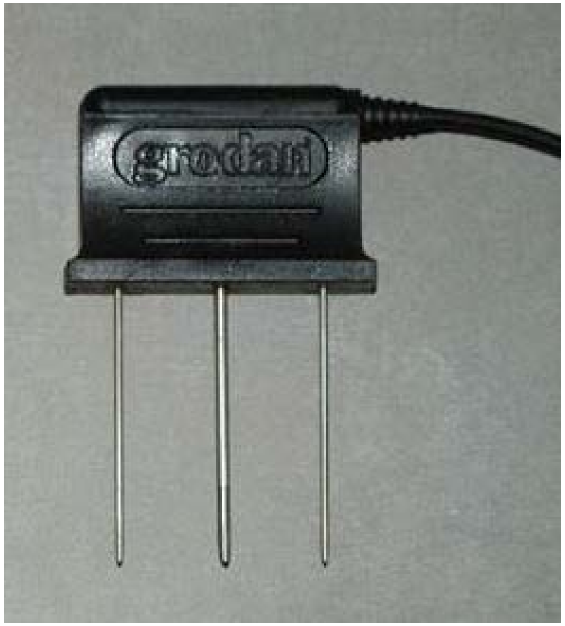
- Sensors
  - Granular matrix sensor
  - Watermark

Soil Moisture-Based Irrigation Controllers

- Sensors
  - Tensiometer

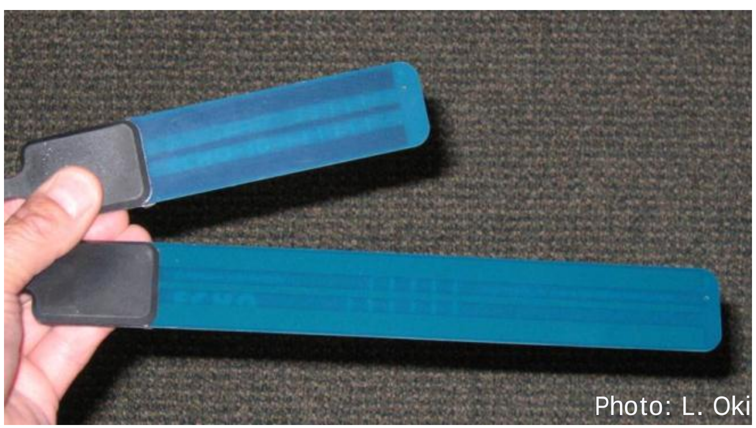
Soil Moisture-Based Irrigation Controllers

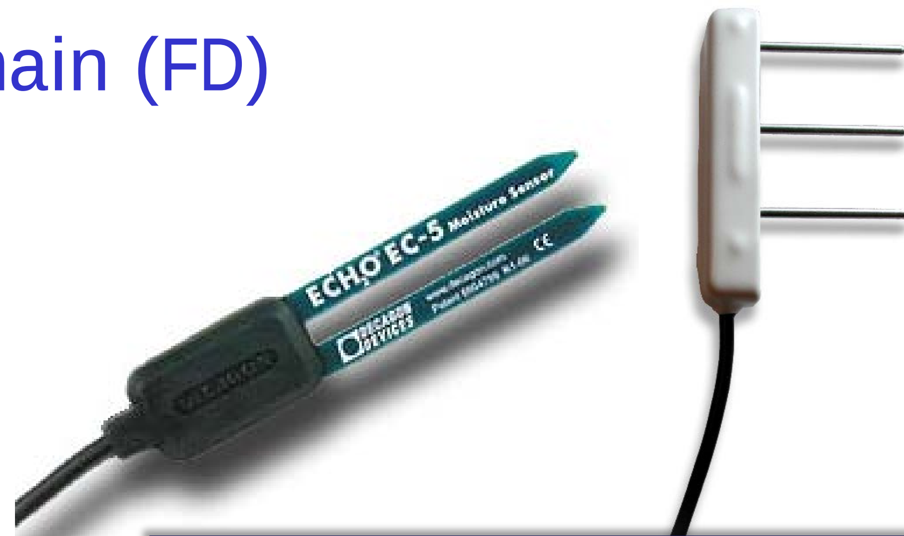
- Sensors
  - Time Domain Reflectometry (TDR)
  - Time Domain Transmissometry (TDT)



Soil Moisture-Based Irrigation Controllers

- Sensors
  - Frequency Domain (FD)





Conductance-based sensors are NOT appropriate

Soil Moisture-Based Irrigation Controllers

- Sensors- Be aware of what is measured
- Matric Potential
  - Granular matrix sensor
  - Tensiometer
- Volumetric Water Content
  - TDR, TDT
  - FD

Topics

- Irrigation objectives
- What are SMART controllers?
- Types of SMART controllers
  - Weather
  - Soil moisture
- How do they work?

Photo: L.Oki

Soil Information

The best way to get PAW information:

SoilWeb

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

For PC, iPhone, and Android

also look for in Apple Store and Google Play

For PAW information, Look for:

"Available Water Storage (0-100 cm)"

Given as ZZ cm, so it can be converted directly to percent