Using capacitance sensors to monitor soil moisture

Interpreting the numbers

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MEASURES OF SOIL WATER STATUS

- There are two ways to describe the soil moisture:

- Volumetric Water content (%, in/ft)
  - Quantitative

- Soil Water Potential. (Centibars suction)
  - Qualitative

Volume Units

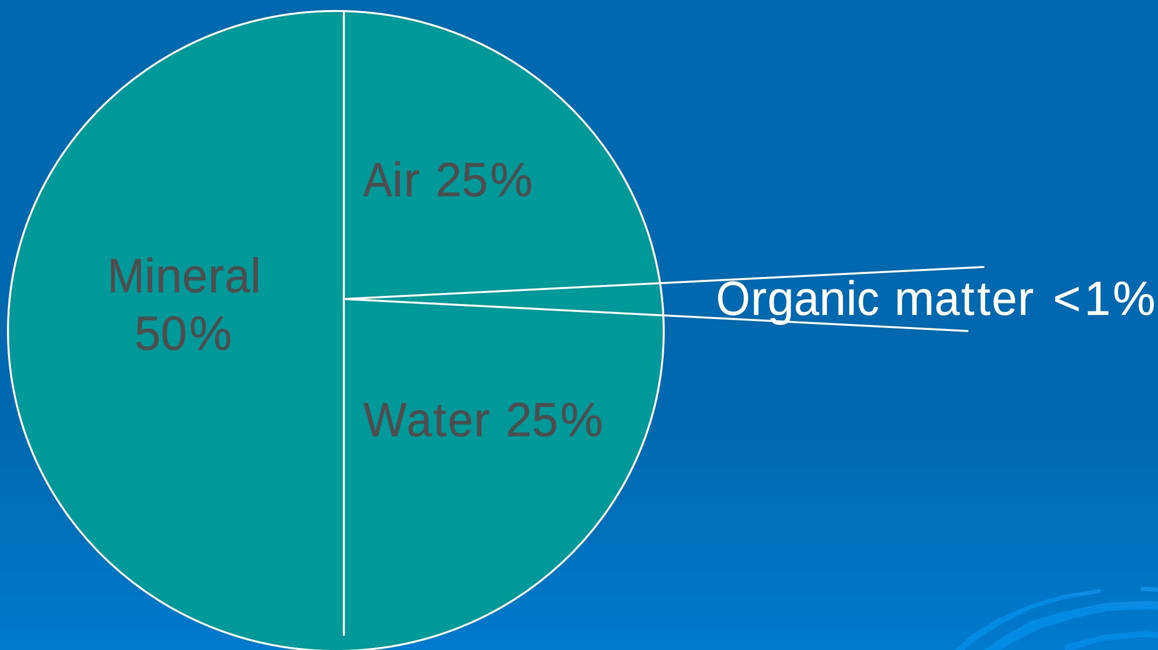
- Rainfall inches/depth
- Crop Water Use inches/depth
- Soil moisture inches/depth

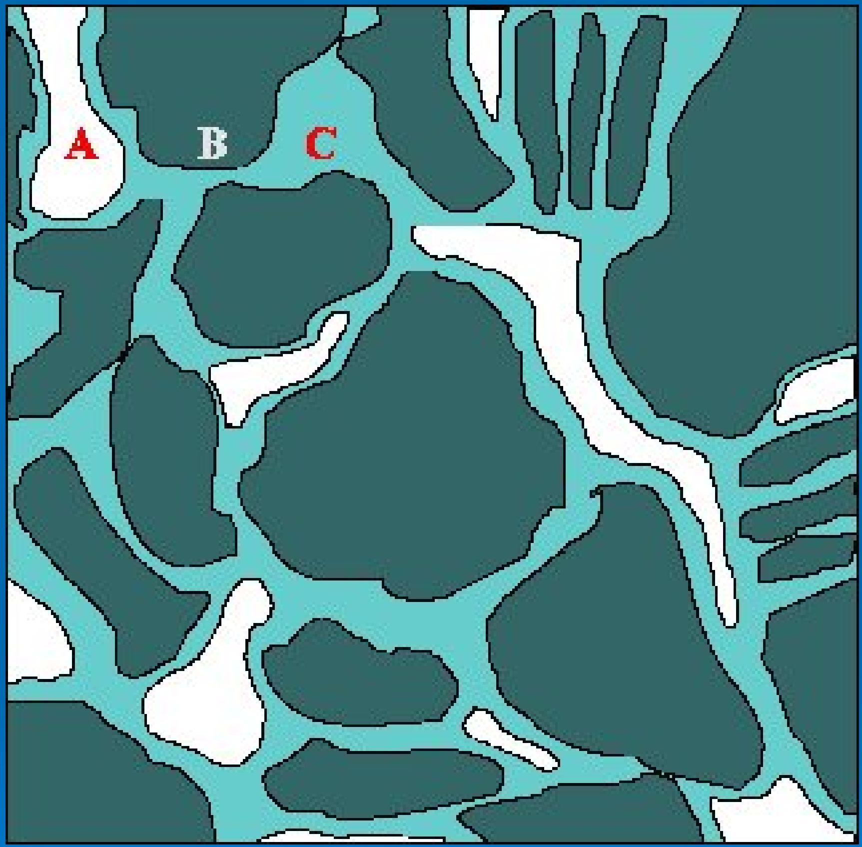
% = in / in

% x 12 inches = inches / foot soil

% x rootzone depth = inches in rootzone

Soil Constituents by Volume
At field capacity




A
B
C

Direct / Indirect Methods

- Direct
  - Soil sampling by volume
    - Or--- by weight x soil bulk density

- Indirect

  any method which relates a “reading” to soil sampling moisture content

Indirect Methods

- **<u>Soil Dielectric</u>**

  Time Domain Reflectometry (TDR)

  Ground Penetrating Radar (GPR)

  Frequency Domain Reflectometry (FDR or capacitance)

- **<u>Neutron Scatter</u>**

Soil Dielectric

- The dielectric permittivity is a measure of the capacity of a non-conducting material to transmit electromagnetic waves or pulses.

- Dielectric Permittivity
  - Air = 1
  - soil minerals = 3 to 5

    (denser soils have higher apparent permittivities).
  - Water 81

Influencing Factors

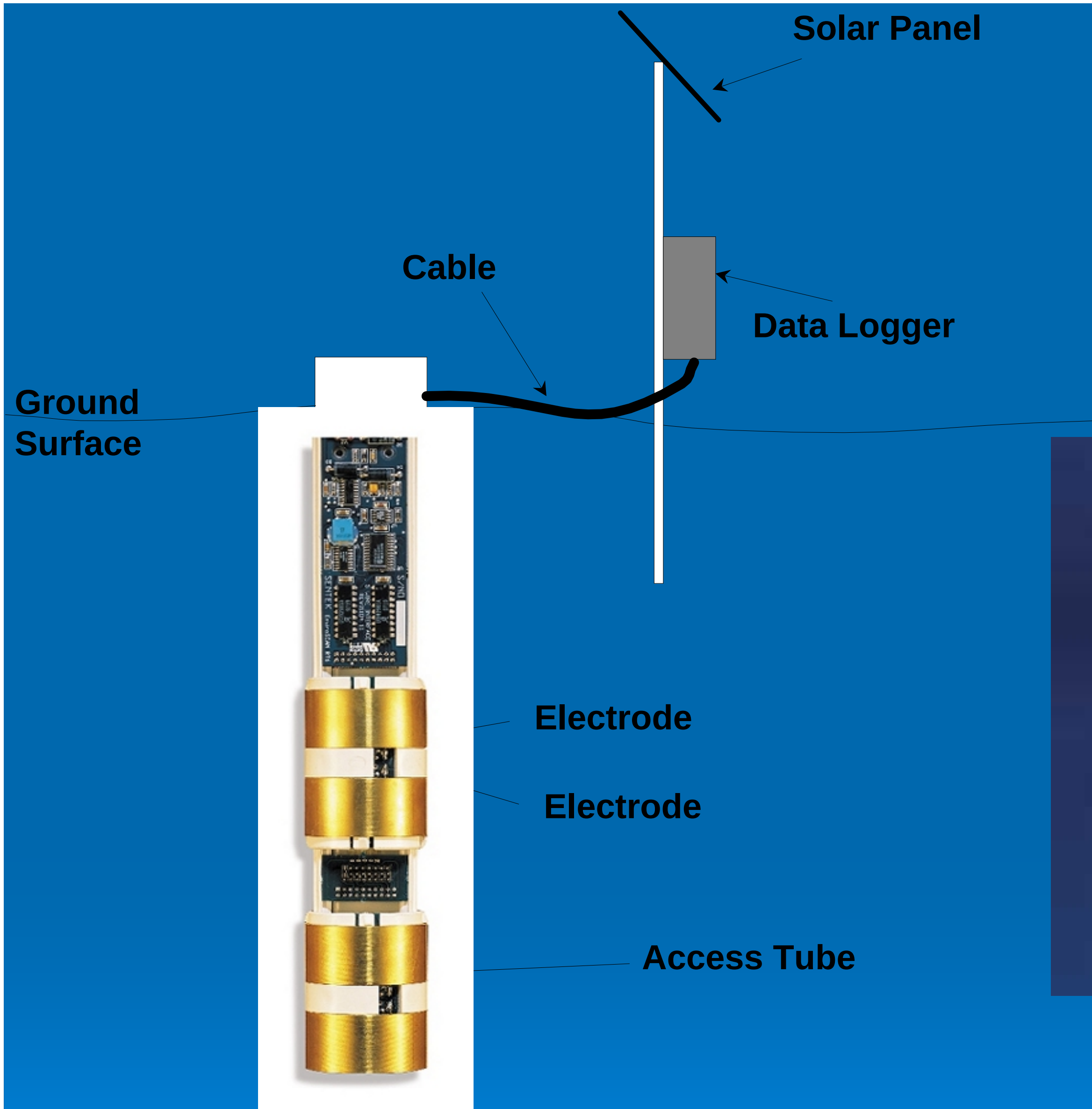
- Water Content
- Soil Temperature (small in most cases)
- Soil Porosity and Bulk Density
- Minerals (2:1 clays)
- Measurement Frequency
- Air Gaps (instalation– swelling soils)

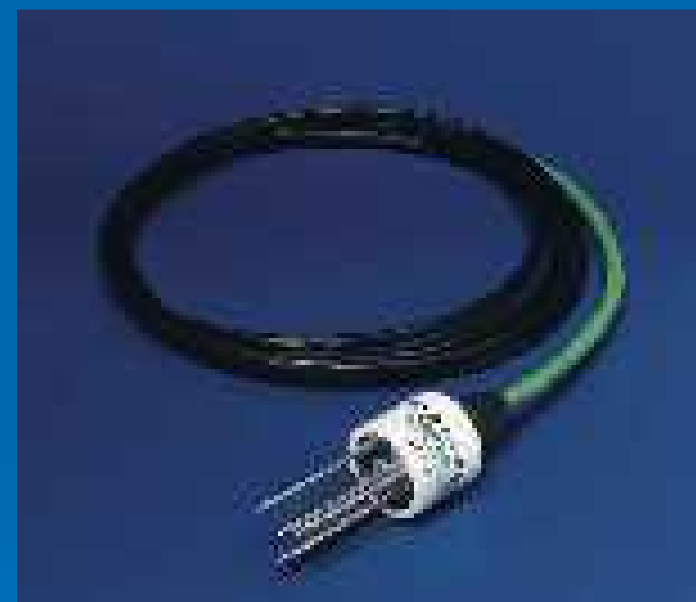
Frequency Domain/Capacitance

- A couple different methods are used however, they all use:
  - Electronic circuit in which the two plates, rods or rings use the soil between them as dielectric of a capacitor
- The change in the circuit output is related to the dielectric permittivity

Capacitance (*C*), measured in Farads (F), is defined as:

- the amount of charge (*Q*) required to increase the voltage (*V*) by one volt between two plates separated by a known distance containing an insulating material



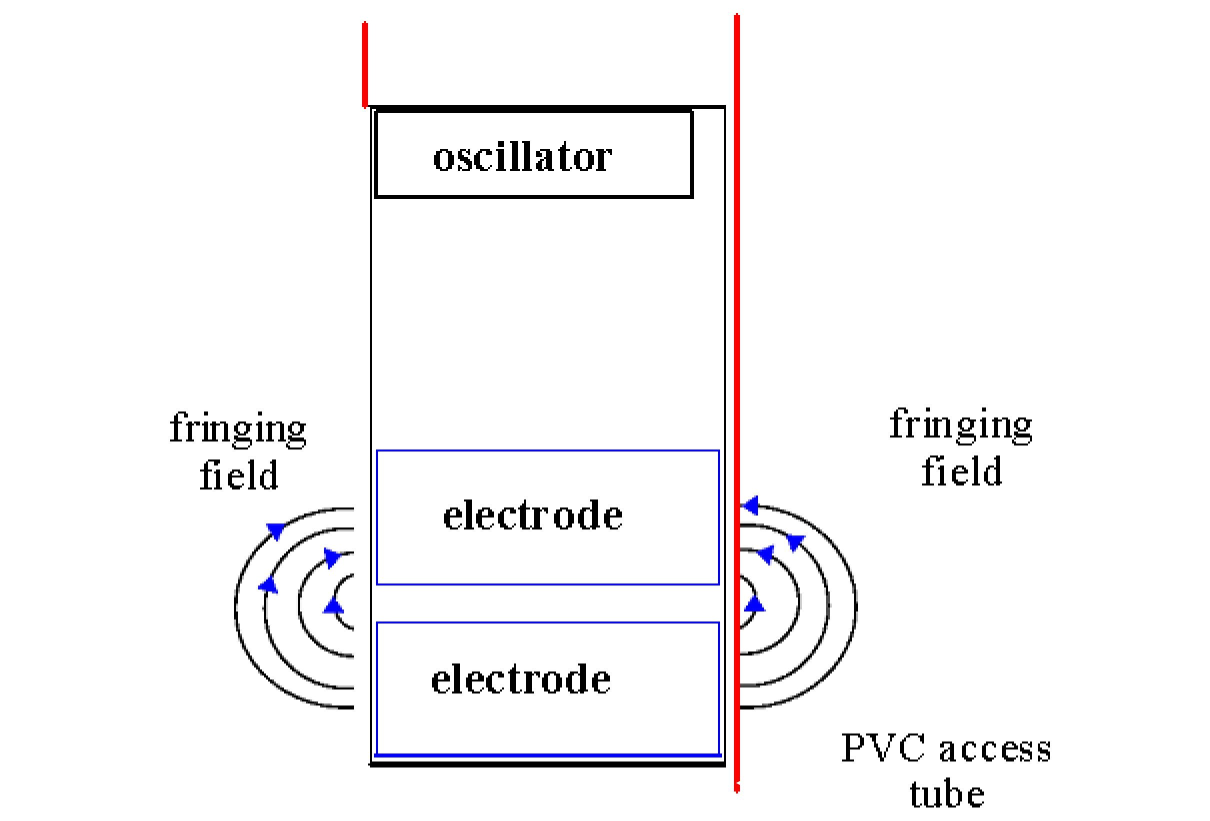


Permanent/logging
Multi depth

Portable

Single point measure

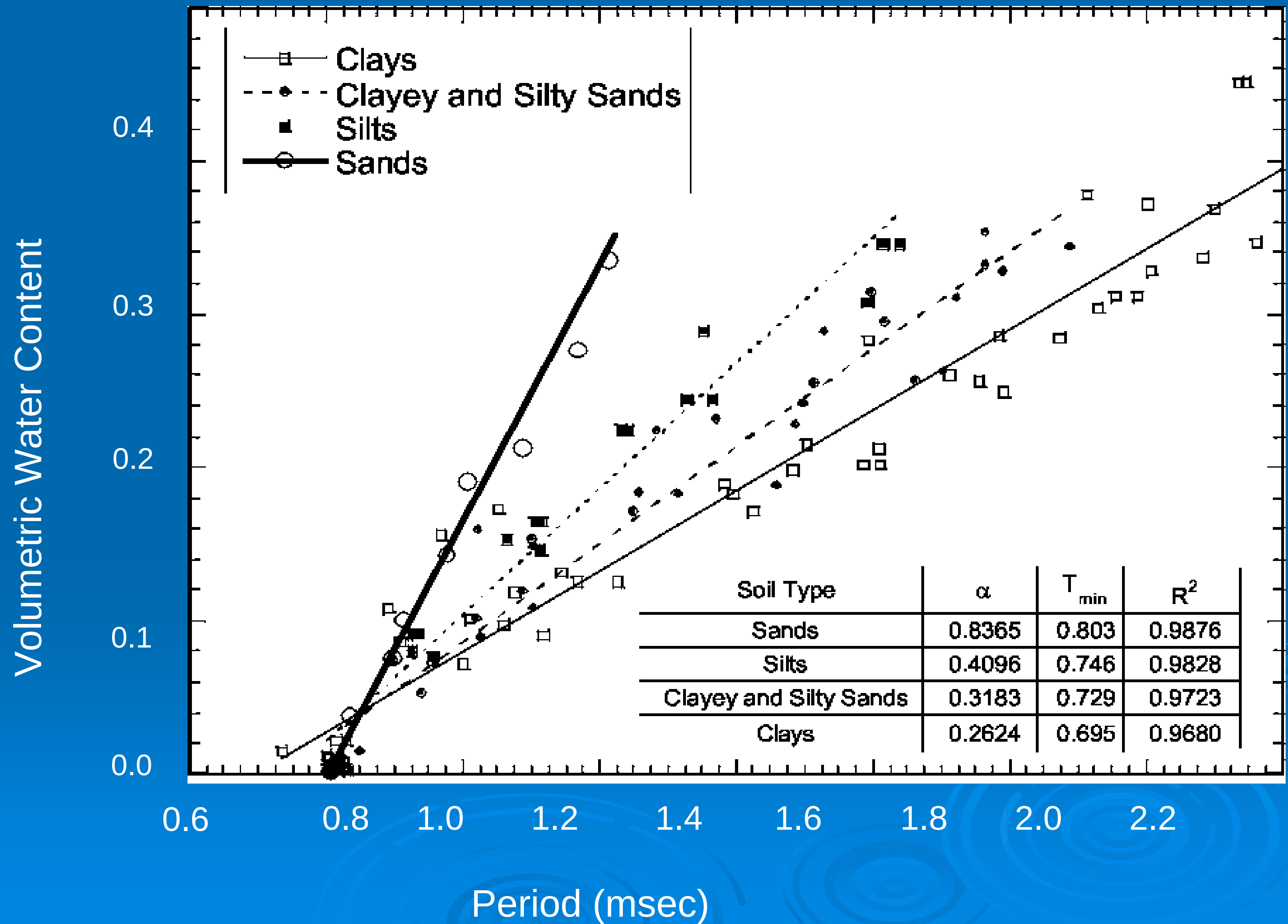
Capacitance Probe



FDR

- Soil specific calibration curves are needed for soils that are highly conductive, have high organic content, or contain 2:1 clays

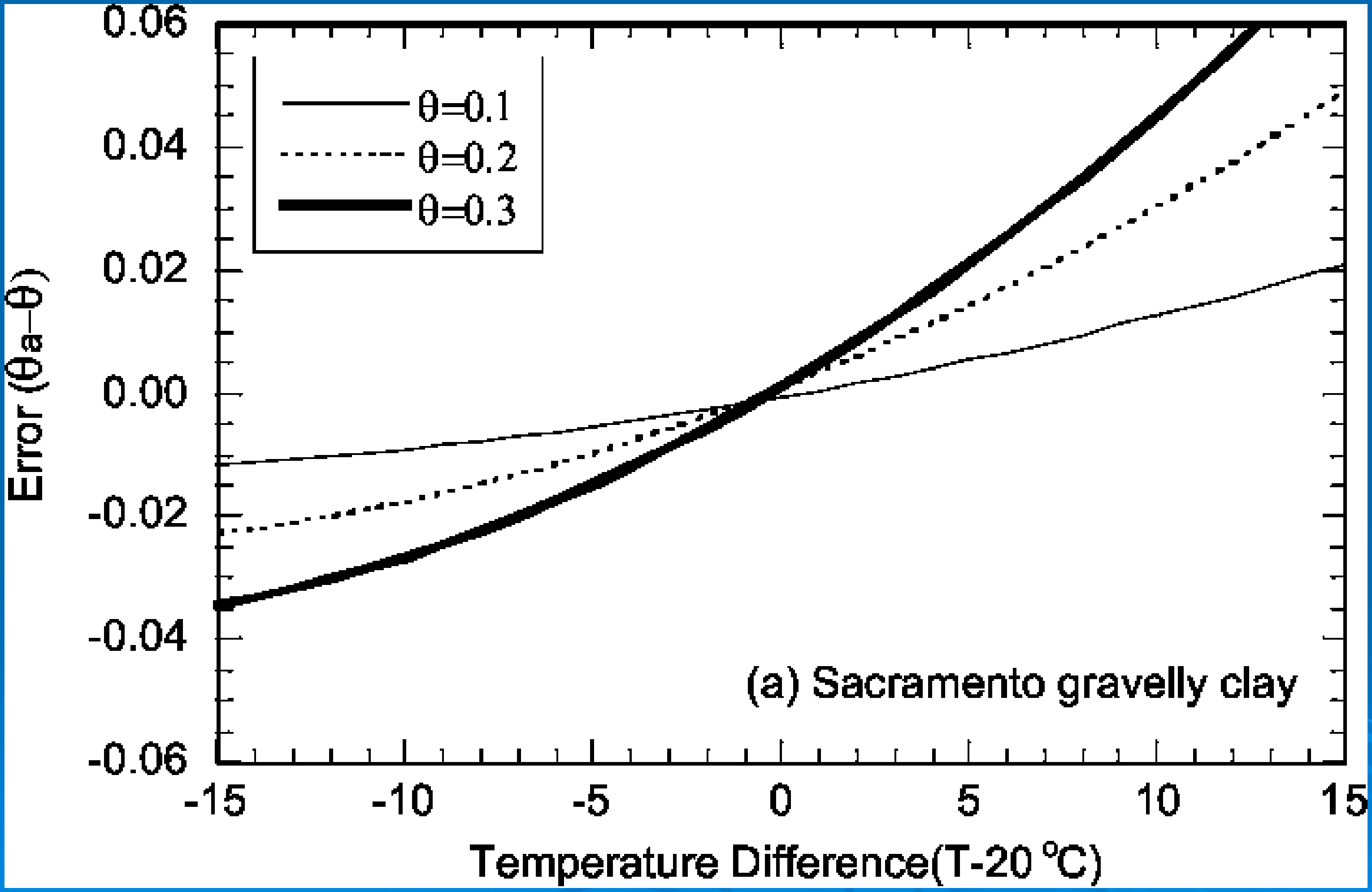
Soil Specific Calibration



Soil Type	α	T_{min}	R^2
Sands	0.8365	0.803	0.9876
Silts	0.4096	0.746	0.9828
Clayey and Silty Sands	0.3183	0.729	0.9723
Clays	0.2624	0.695	0.9680

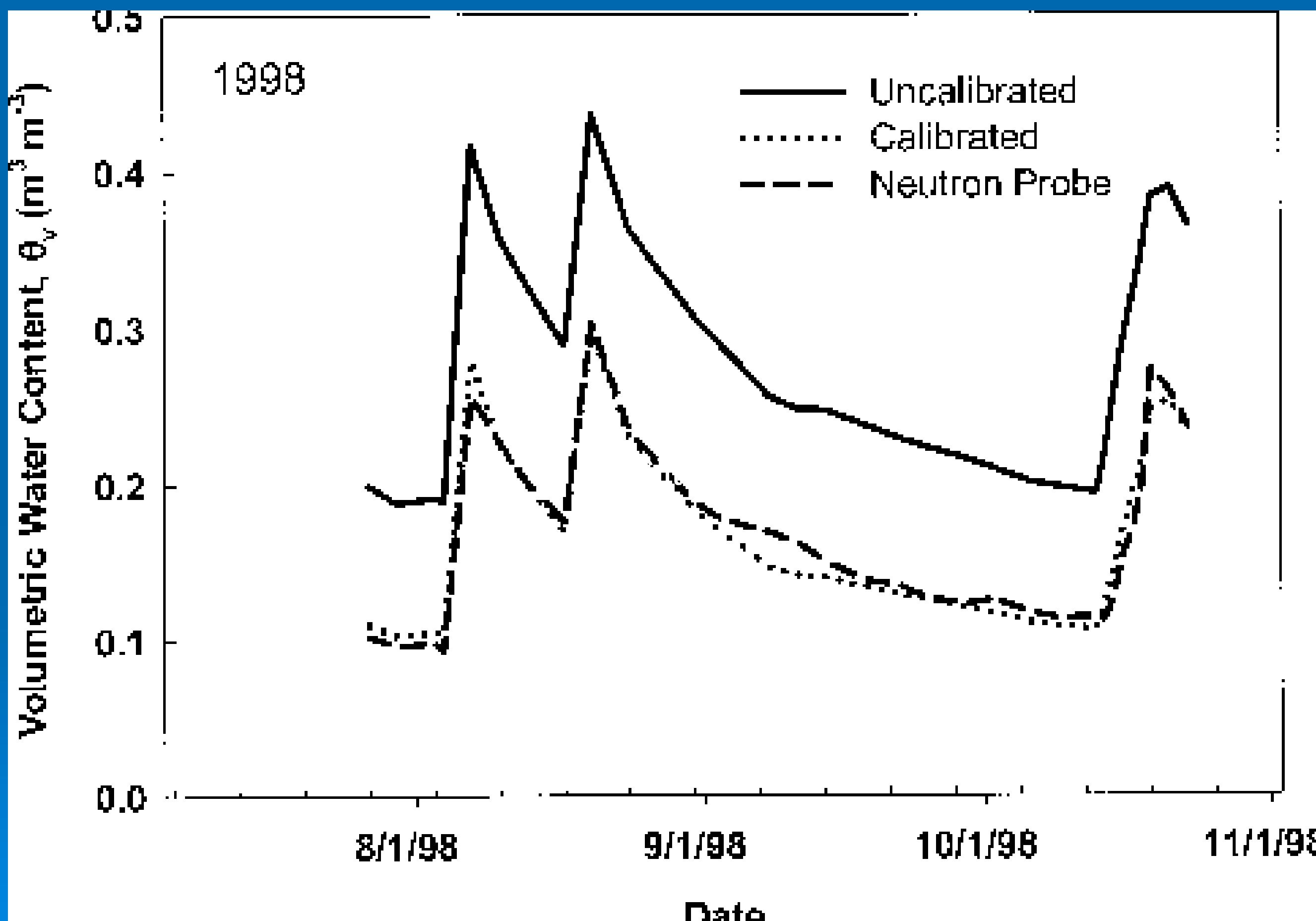
After Kim and Benson 2002

FDR

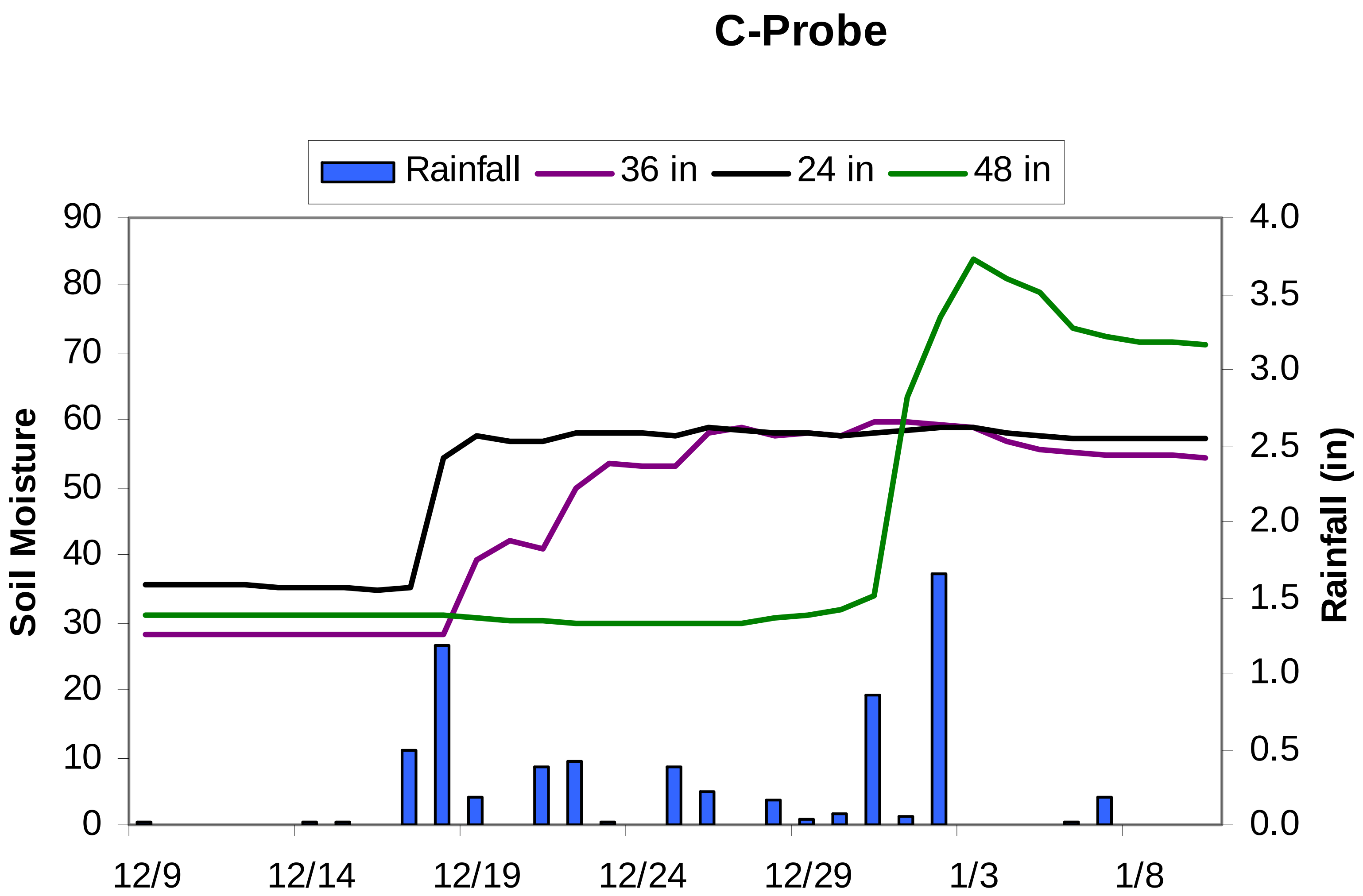


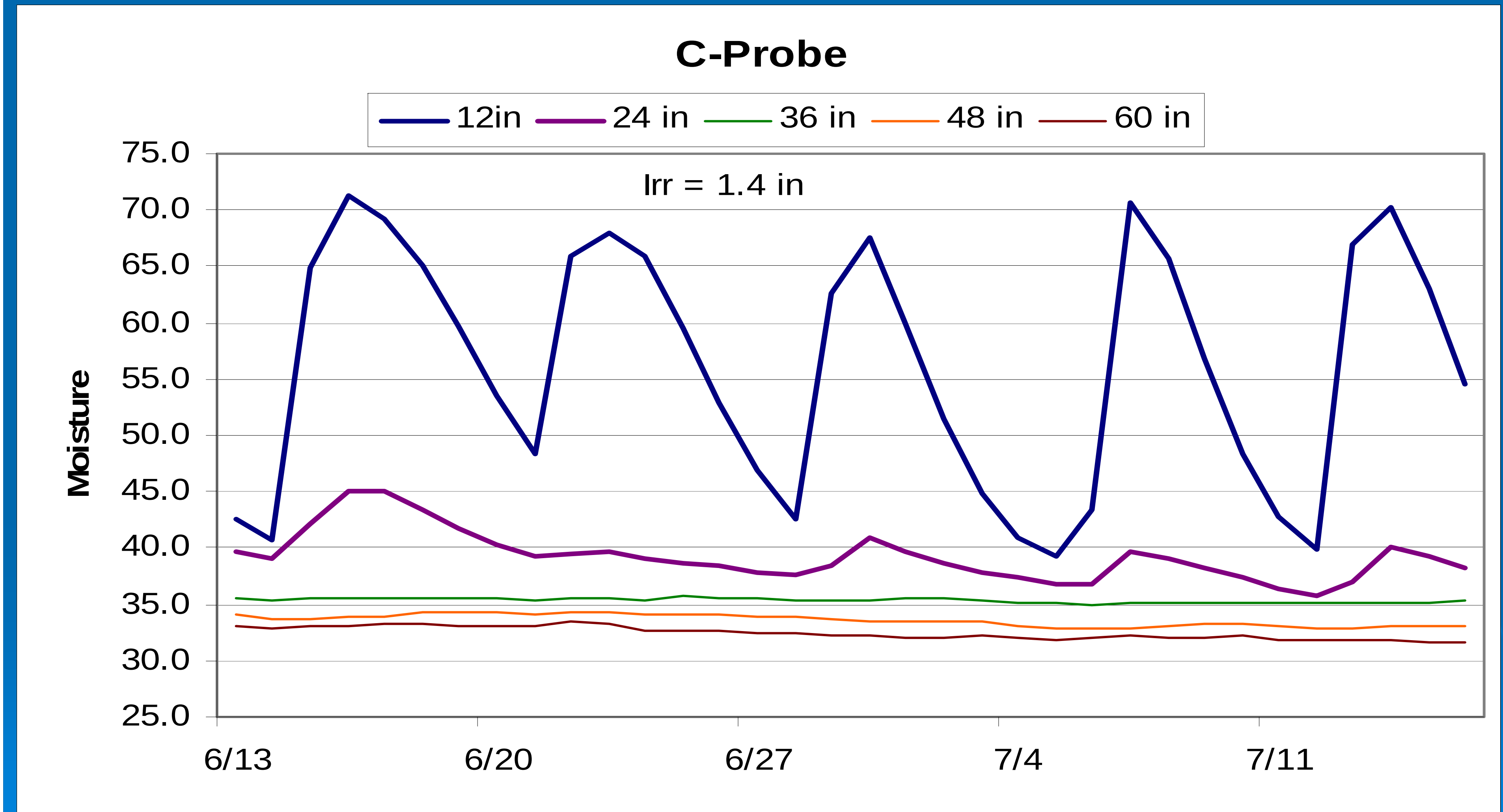
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
Error (θa−θ)
θ=0.1
θ=0.2
θ=0.3
(a) Sacramento gravelly clay
-15
-10
-5
0
5
10
15
Temperature Difference(T-20 °C)

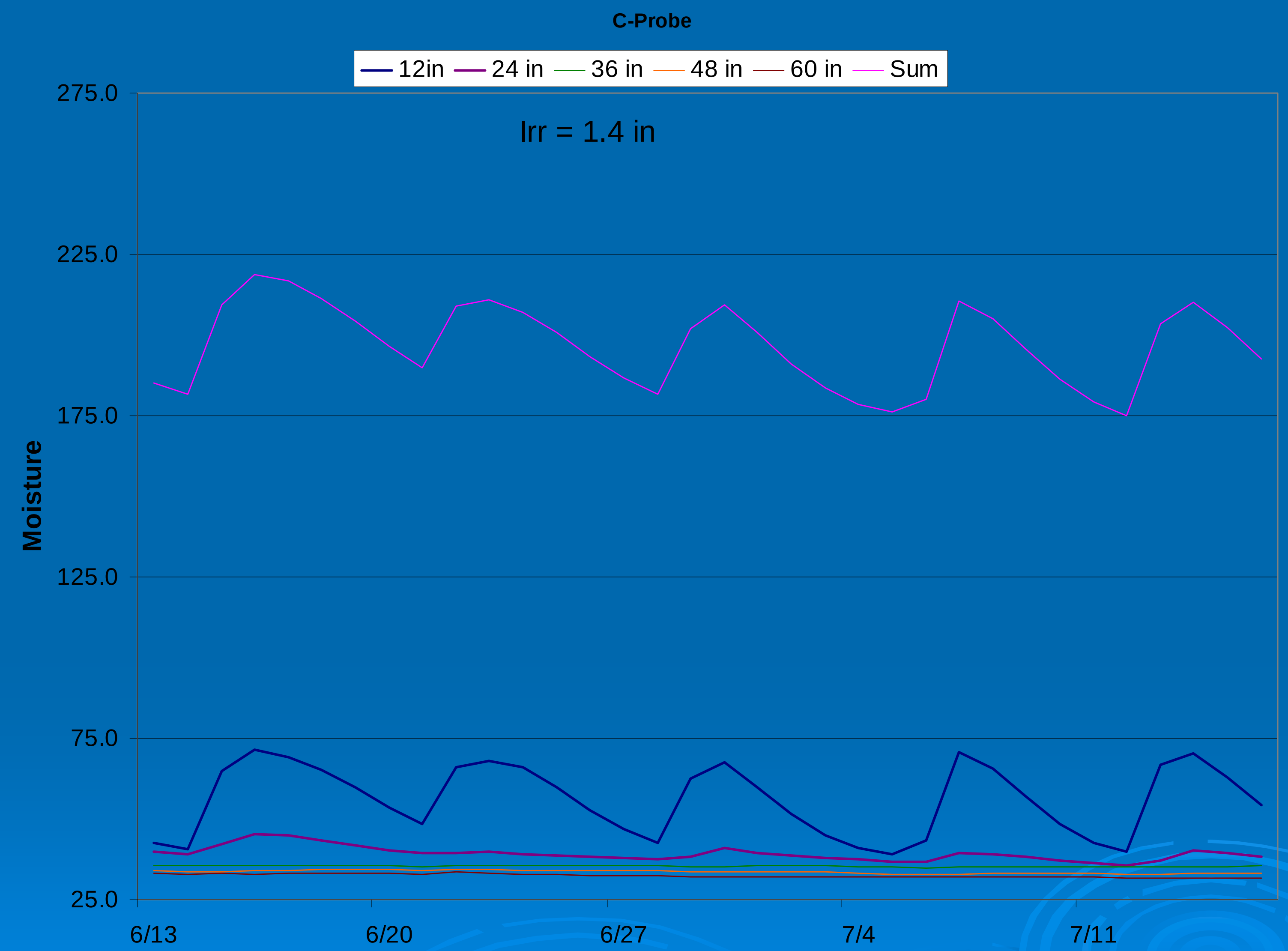
FDR



1998
Uncalibrated
Calibrated
Neutron Probe
Volumetric Water Content, θ_v (m^3 m^{-3})
0.0
0.1
0.2
0.3
0.4
0.5
8/1/98
9/1/98
10/1/98
11/1/98
Date


C-Probe
Rainfall
36 in
24 in
48 in
Soil Moisture
Rainfall (in)
90
80
70
60
50
40
30
20
10
0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
12/9
12/14
12/19
12/24
12/29
1/3
1/8


C-Probe
12in
24 in
36 in
48 in
60 in
Irr = 1.4 in
Moisture
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
6/13
6/20
6/27
7/4
7/11

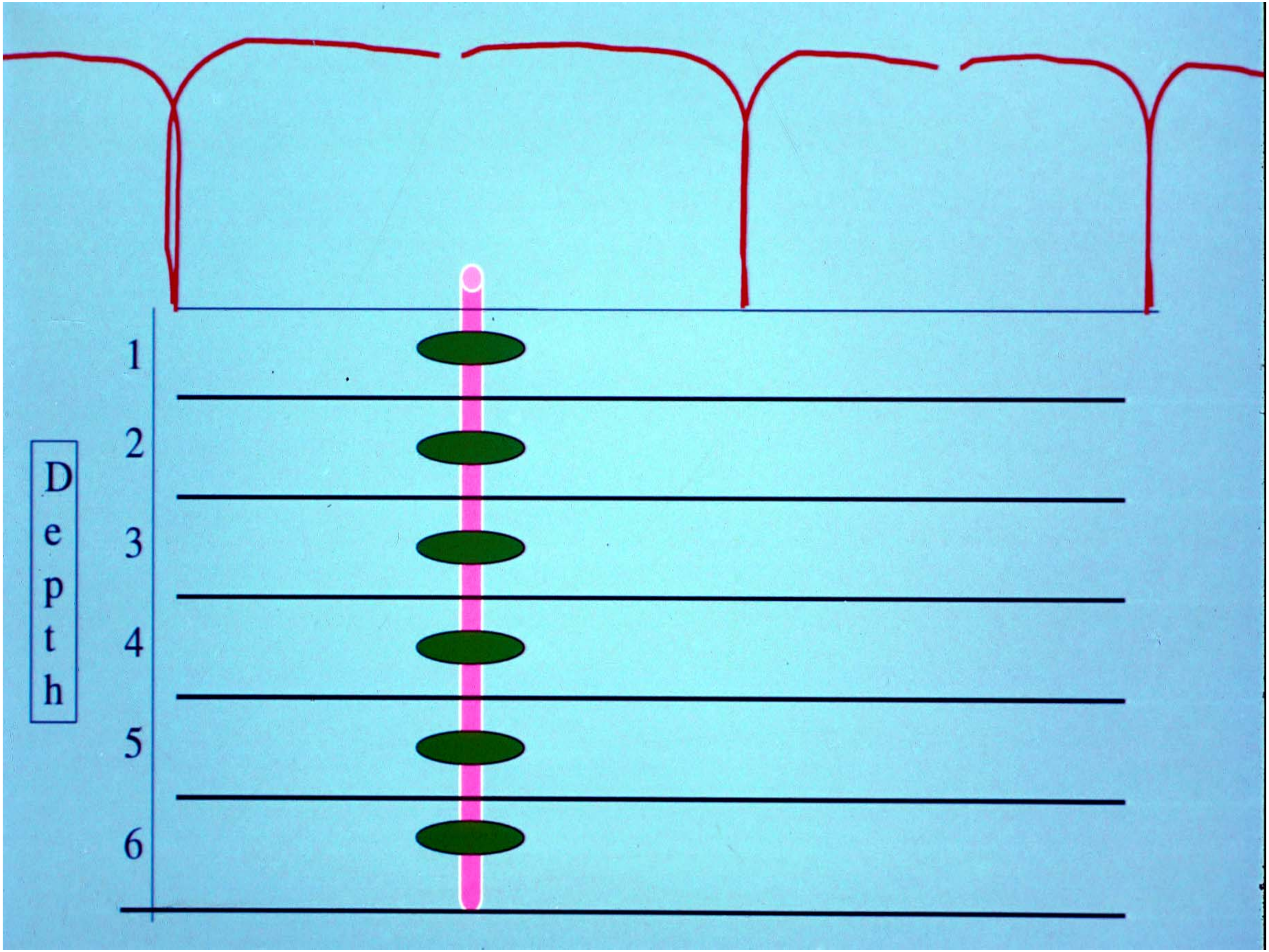

C-Probe
12in
24 in
36 in
48 in
60 in
Sum
Irr = 1.4 in
Moisture
275.0
225.0
175.0
125.0
75.0
25.0
6/13
6/20
6/27
7/4
7/11

FDR Advantages

- Relatively inexpensive
  - low frequency standard circuitry
- No radiation hazard / hassles
- Fast response time
- Logging capable
- Portable

FDR Disadvantages

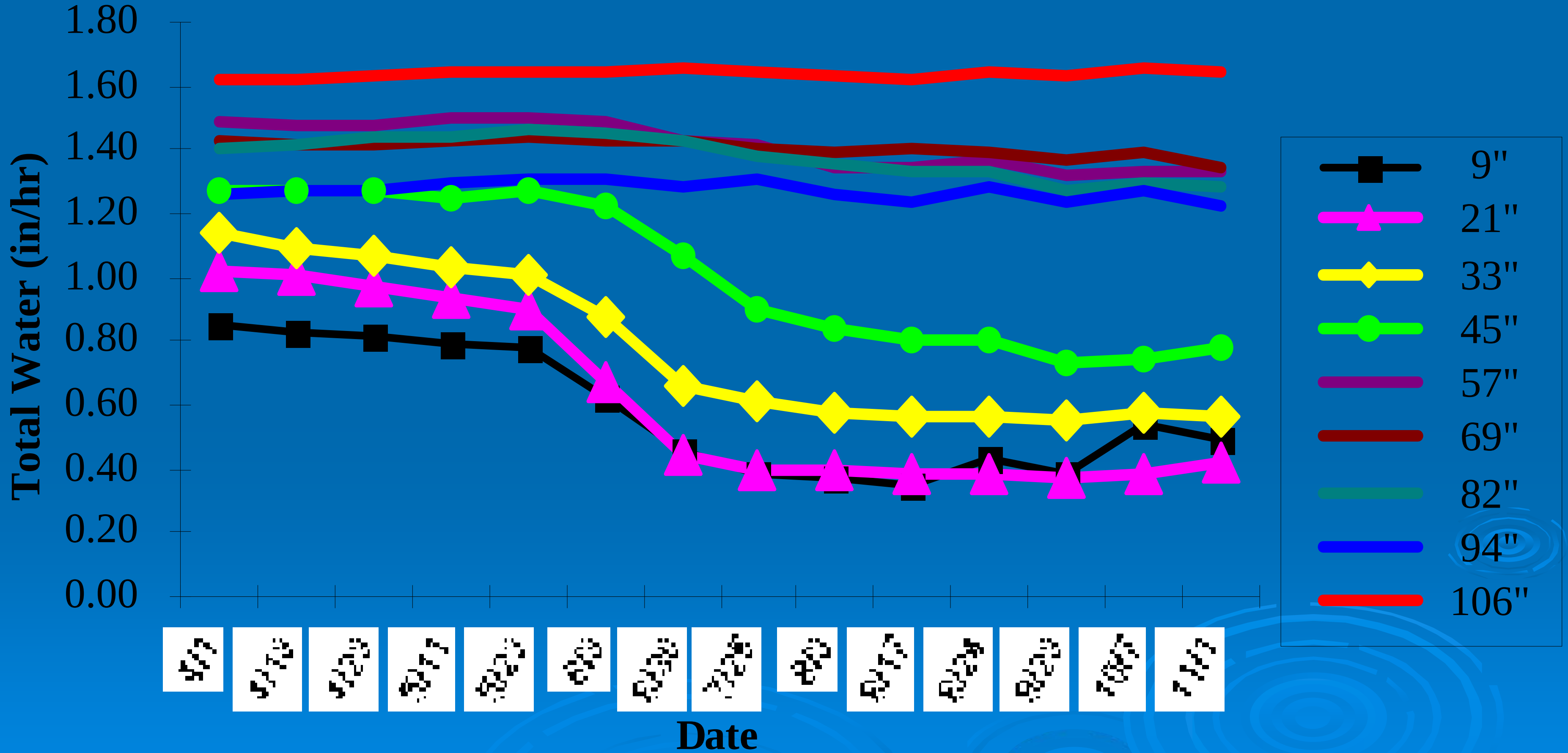
- Small measurement volume sensitive to small-scale soil variations (most in 5cm)
- Sensitivity to installation
- Site specific calibration is necessary for accurate soil volumetric water content
- Tends to have larger sensitivity to salinity, temperature, bulk density, clay content and air gaps than TDR



1
2
3
4
5
6
Depth

Using Neutron Probe Data

Figure B-2. Winegrape non-irrigated in/ft by depth



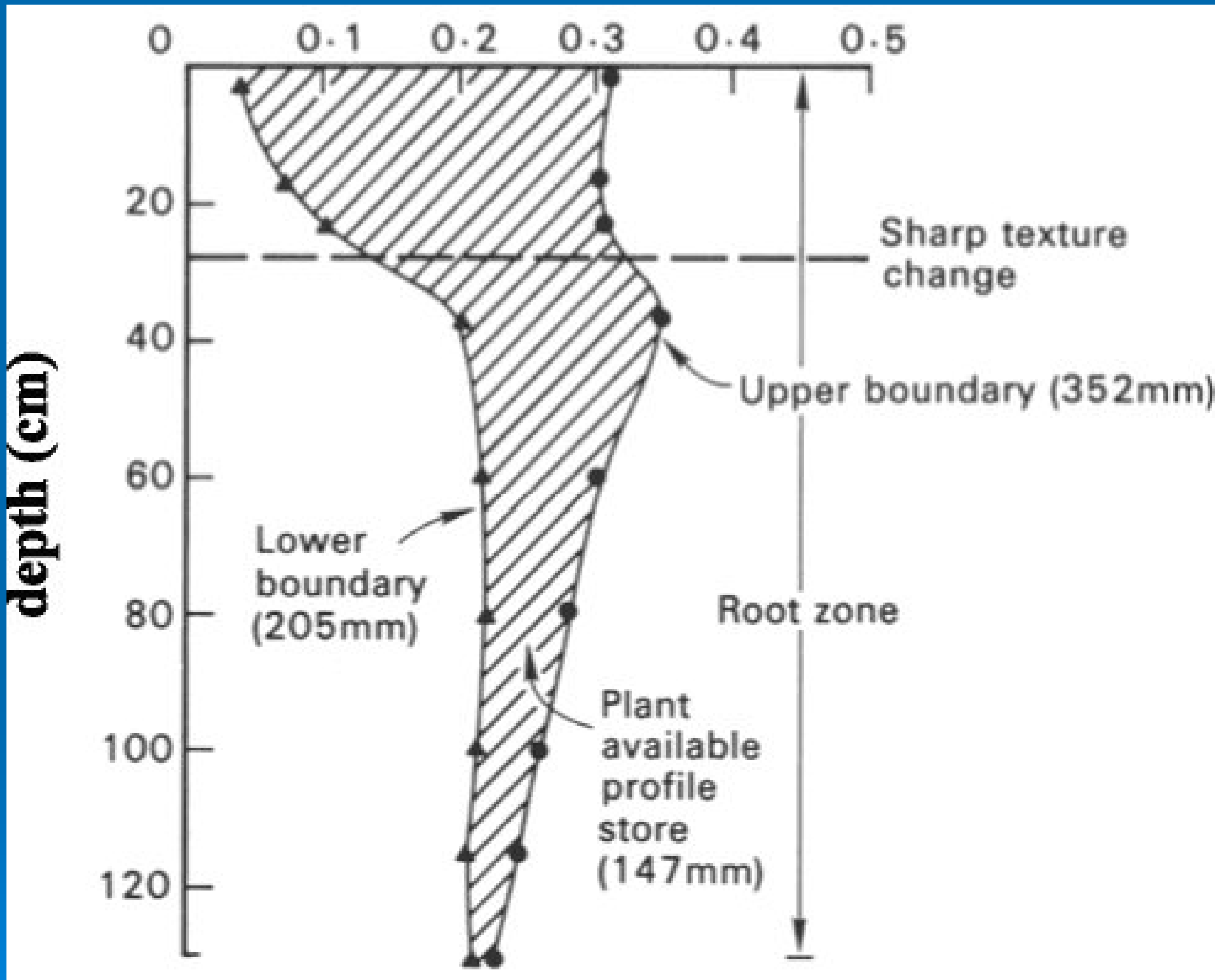
Available Soil Moisture

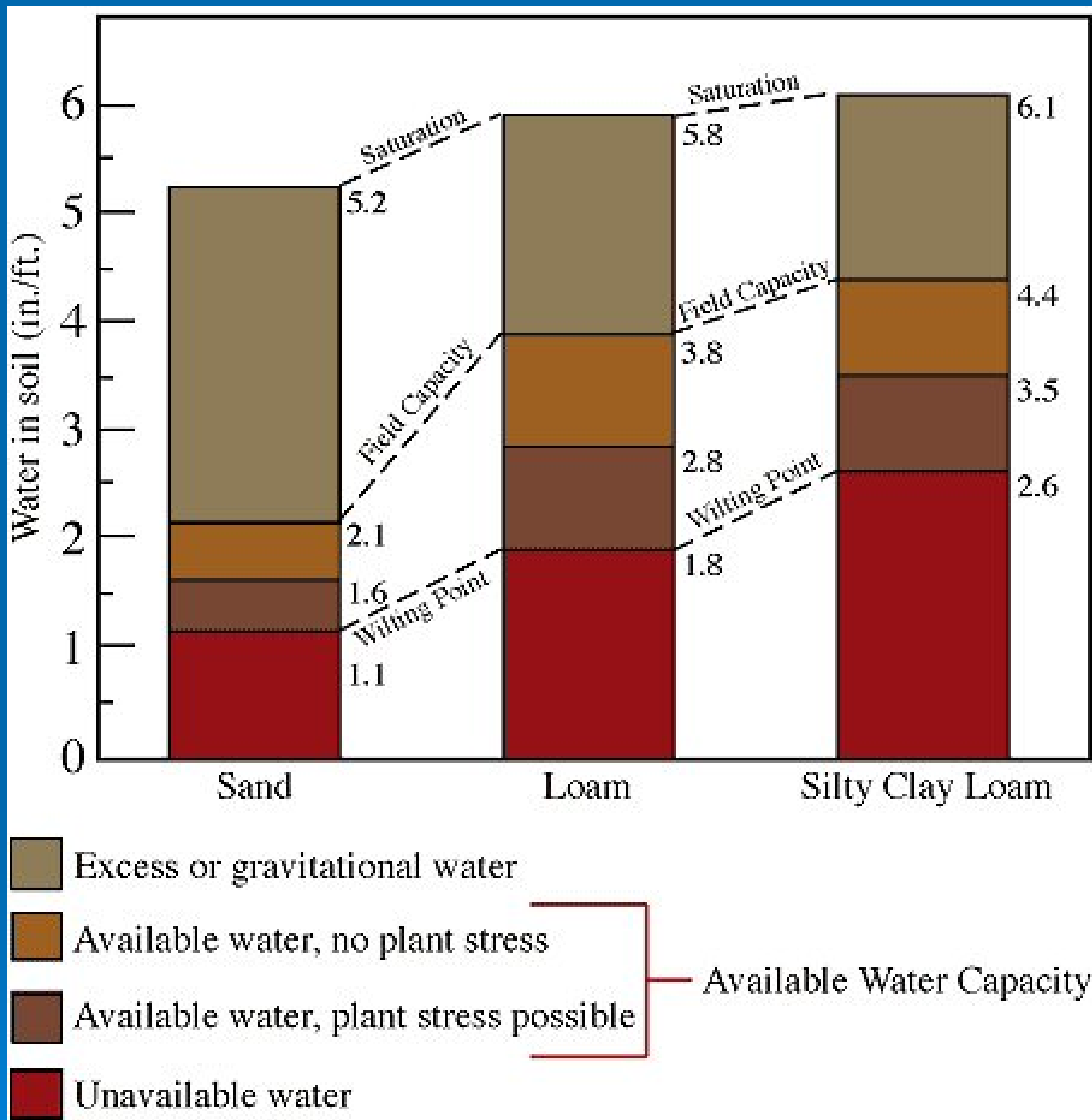
- Field Capacity – Perm wilt point

- Field Capacity
  - Upper limit when drainage ceases

- Permanent Wilting point
  - Lower limit when plants cannot extract moisture

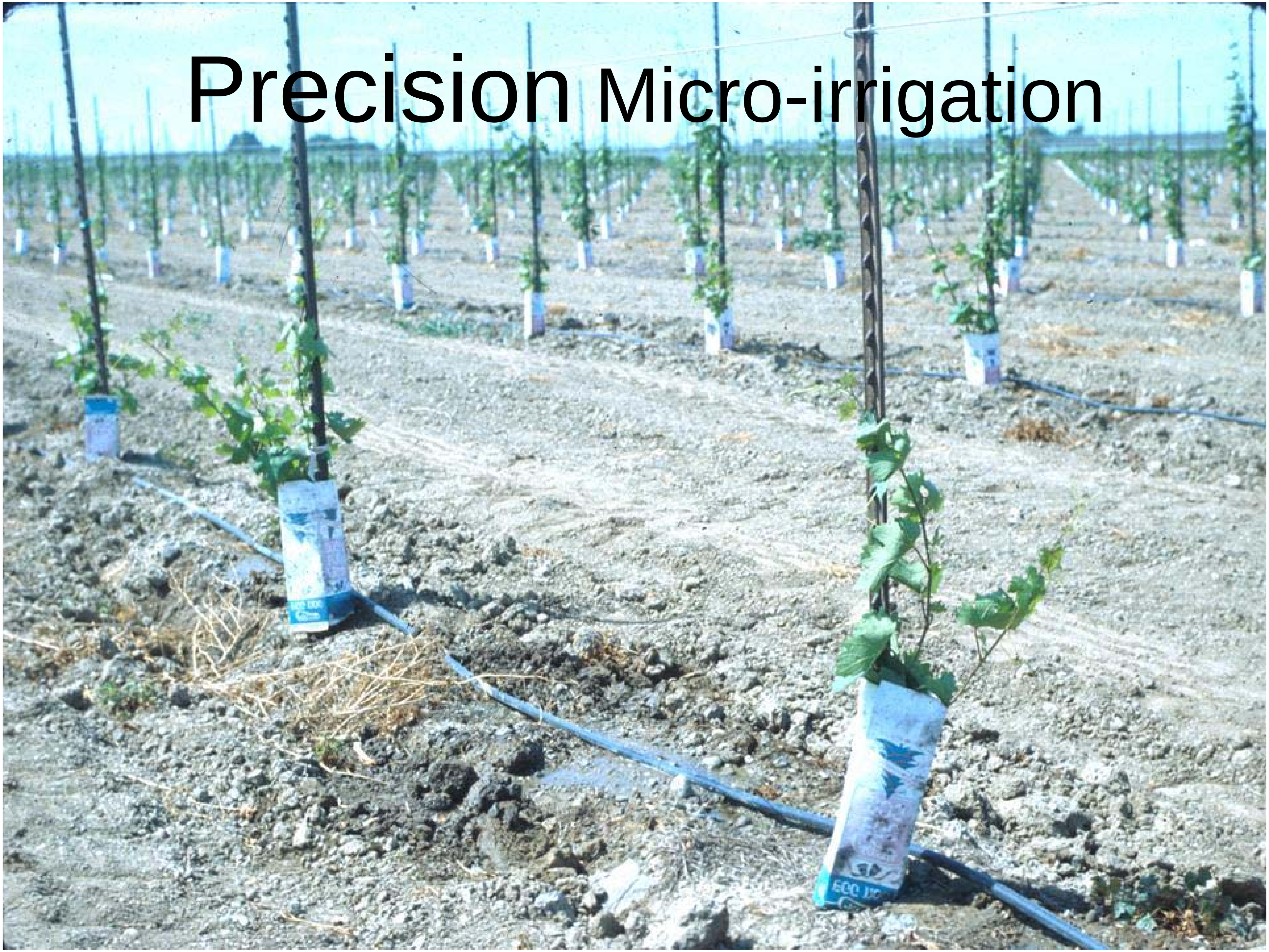
water content (m3 m-3)





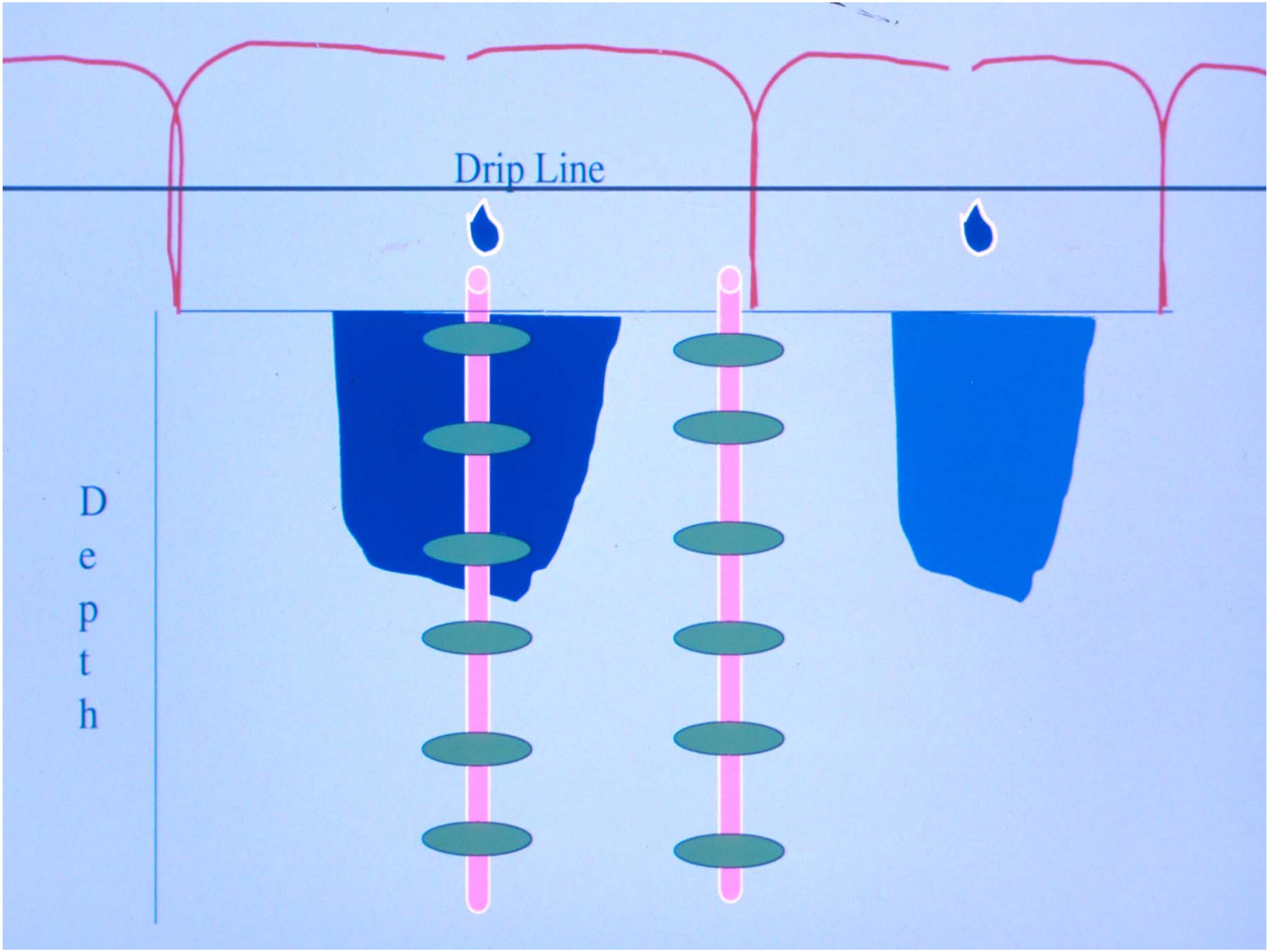
Water in soil (in./ft.)
0
1
2
3
4
5
6
Saturation
Field Capacity
Wilting Point
5.2
2.1
1.6
1.1
5.8
3.8
2.8
1.8
6.1
4.4
3.5
2.6
Sand
Loam
Silty Clay Loam
Excess or gravitational water
Available water, no plant stress
Available water, plant stress possible
Unavailable water
Available Water Capacity

Precision Micro-irrigation



Sensor Placement

- Depends on the goal of the measurement
- If measuring soil water depletion before irrigation--- not too important
- If measuring after irrigation– proximity to the emitter will effect the reading



Drip Line
Depth

When To Measure Soil Moisture Quantitative(N Probe)

- Most valuable times:
  - Bud break
  - Just prior to 1st irrigation
  - Dry point

Bud break – Dry Point = Available water

Bud break – Prior to 1st irr = Water consumed

Prior to 1st irr – Dry Point = water remaining

Looking Ahead

- Increased use of devices which can log transmit and allow automatic data processing. --- Dielectric methods