Improving the Efficiency of Surface Irrigation Systems in California

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Irrigation: Controlled amount of water is applied to plants at specific intervals

Irrigation Methods:

1- Surface irrigation (flood or gravity):

- **Border strip (flat) irrigation (slope 0.1-0.2%)**
- **Furrow irrigation (slope)**
- **Basin irrigation (zero slope)**

2- Sprinkler Irrigation (various types)

3- Drip Irrigation (various types)

- **Surface drip**
- **Subsurface drip**

Surface (flood) irrigation:

- Water application methods where water is applied over the soil surface by gravity (no energy is needed).

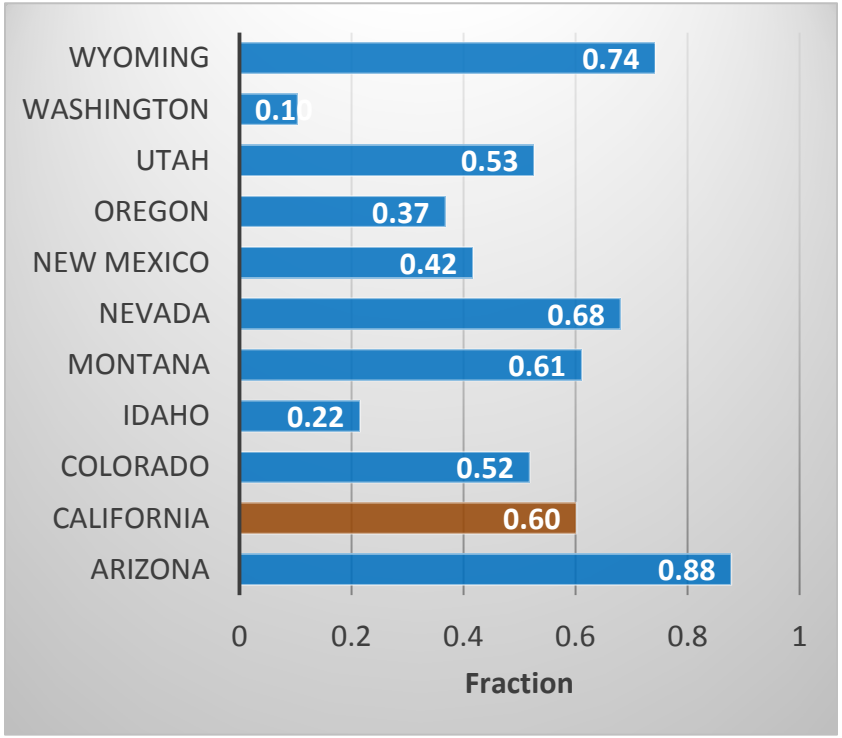
- Most common irrigation system throughout the world

- High efficiency possible on medium and heavy soils

- Mostly for field crops in California

Reduction in field crops in CA from 3,805,800 acres in 2006 to 2,639,200 acres in 2015 (-30%)

System	$Eff._{APP}$
Surface	70-85%
Drip	85-90%
Micro-sprinkler	80-90%
Sprinkler	70-90%



2013 Fraction of irrigated land totally or partially irrigated with gravity methods in western states.

Source: USDA Farm and Ranch Irrigation Survey -FRIS, 2013

How Much Water do I need to Apply?

- Need to know crop water use (ETc) since last irrigation
- ETc from (Reference evapotranspiration and crop coefficient)

- Typical application rates (vary widely depending on soil type, etc):

- Surface: ~ 3-5 in/irrigation (much higher rate for light soils)

- Sprinkler: ~ 0.5-1.2 in/irrigation

- Drip: ~ 0.5 in/irrigation

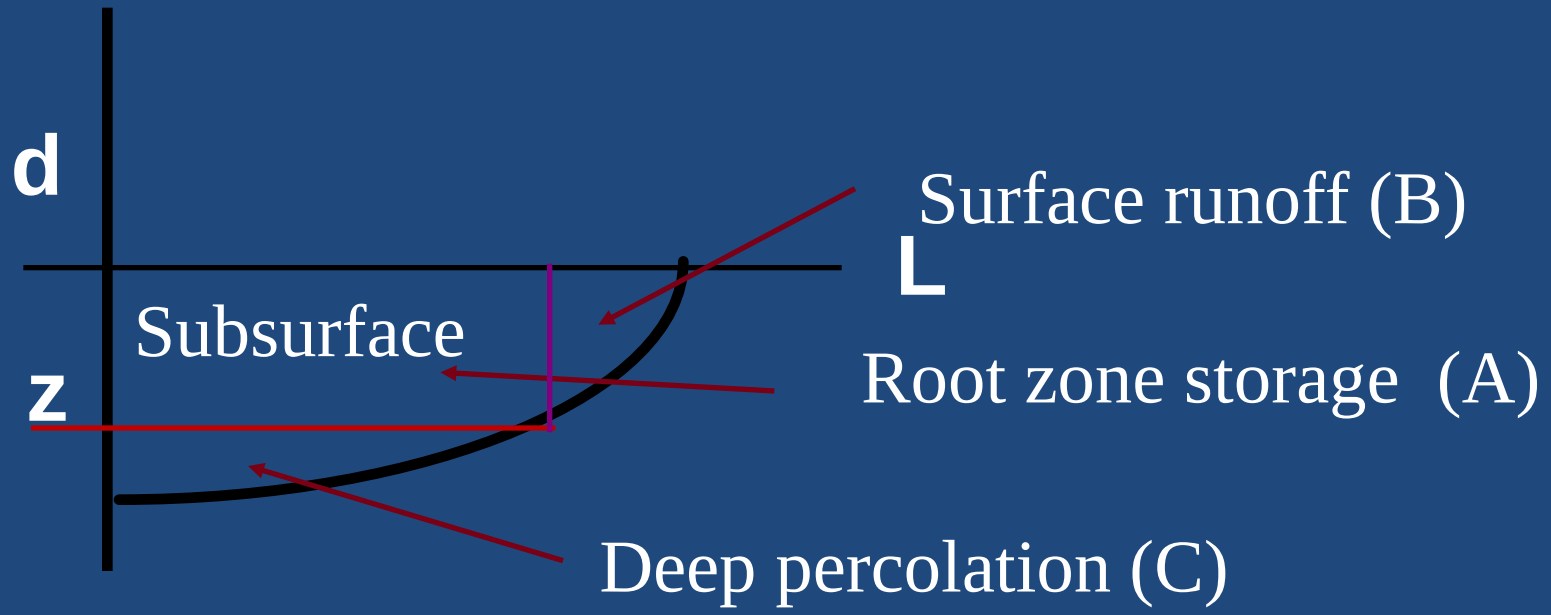
- Delivery system designed for surface irrigation

Improving Irrigation System Efficiency

- Reduce losses (nutrients, pesticides, water)
- Limited water supplies and increased demands
- Labor cost (minimum wage in CA from $10.5 to $15/hr by 2022)
- What is efficiency?
  - Distribution system efficiency (district level, canals, reservoirs, etc.)
  - On farm or field application efficiency (AE) , distribution uniformity (DU), and other parameters

Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation



On-Farm Water Conservation =Higher Application Efficiency (AE)

IRRIGATION = Root zone storage (ETc) + DEEP PERCOLATION + Runoff

A + B + C

Application Efficiency (AE)= A/(A+B+C)

To achieve higher efficiency, reduce B and/or C

BUT

Need to have a balance,

Deep Percolation sometimes is needed for salinity control

(700 ppm ~ 0.96 tons of salt/ac-ft but NOT with every irrigation)

Runoff is needed for Uniformity (100% AE means under irrigation)

On-Farm Water Conservation =Higher Application Efficiency (AE)

IRRIGATION = Root zone storage (ETc) + DEEP PERCOLATION + Runoff

A + B + C

Application Efficiency (AE)= A/(A+B+C)

Deep Percolation Ratio= B/(A+B+C)

Runoff Ratio= C/(A+B+C)

Irrigation Water Requirements (IR)

IR= Crop ET/AE

Distribution Uniformity (DU)

DU= Average depth in low quarter/Average depth infiltrated

Many other efficiency parameters
BUT

KEEP IT SIMPLE, AE and DU are all you need

Field Crops

Mostly surface irrigation methods:

- Border (flat) irrigation

  Runoff rate: 5-20% (vary)

- Furrow (bed) irrigation

  Runoff rate: 15-30% (vary)

Surface runoff:

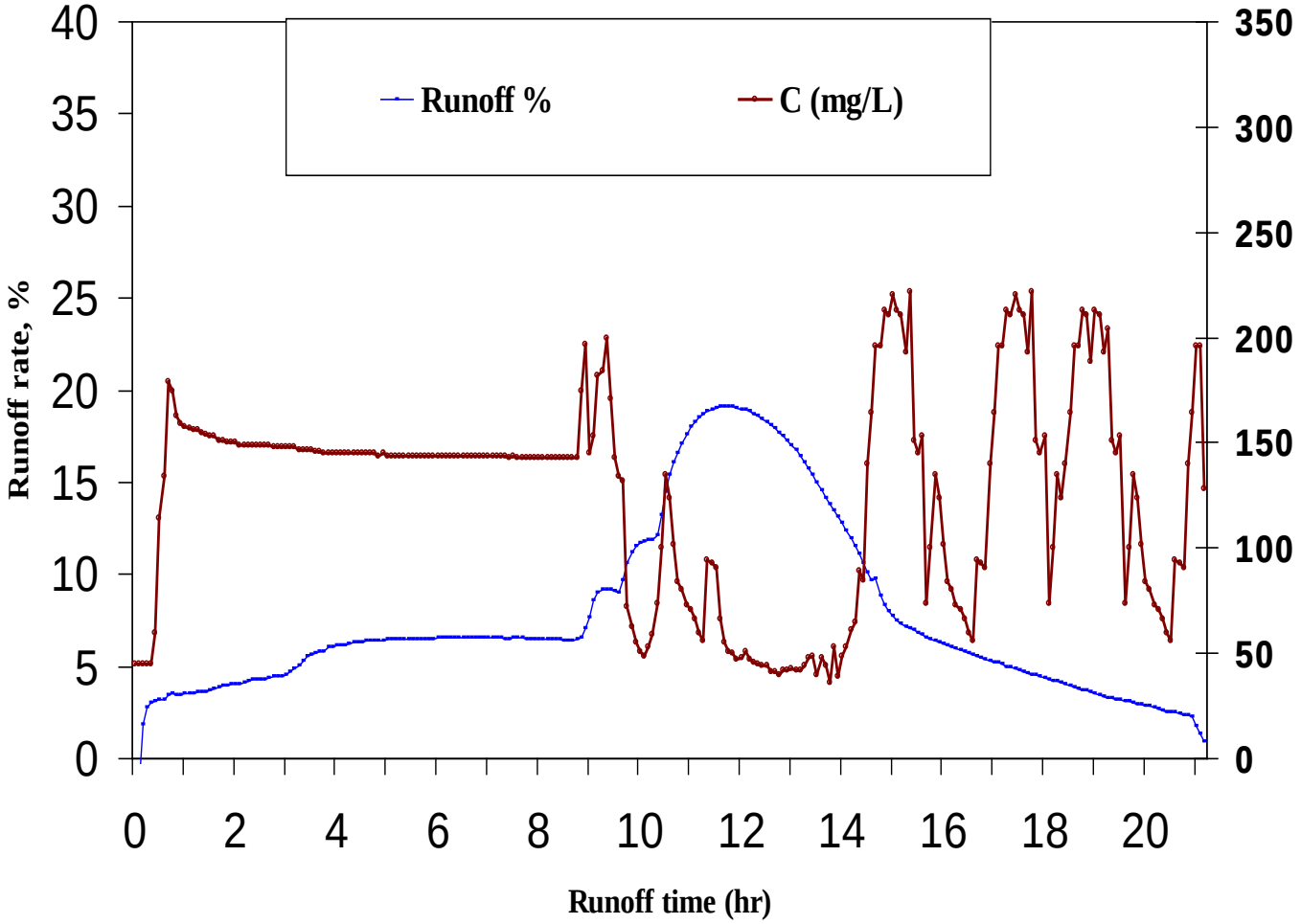
Nutrient losses: surface runoff & deep percolation

Pesticides losses: mostly surface runoff &

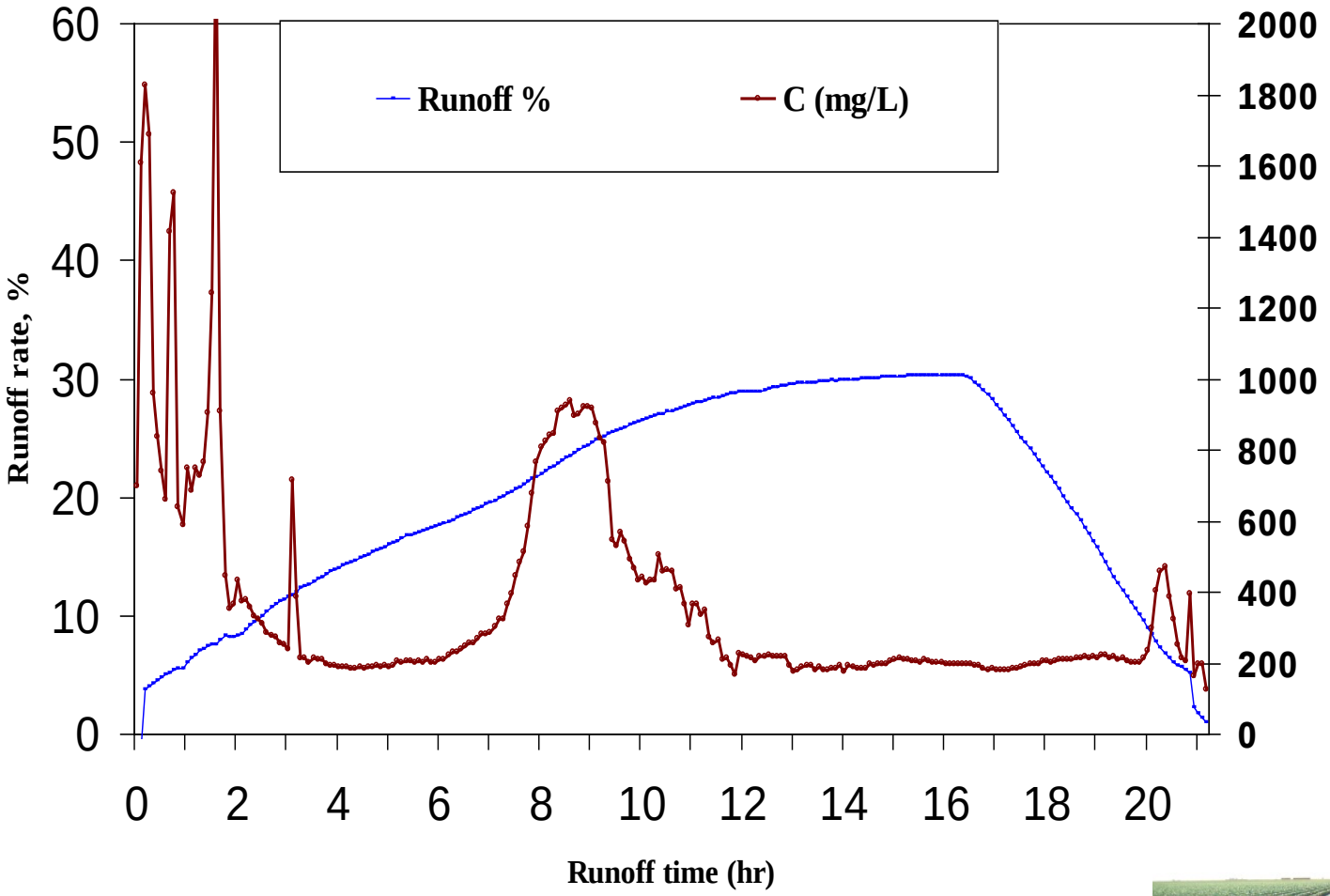
some with deep percolation

*** Usually no runoff with basin irrigation**

Field A (Alfalfa, Border, UCDREC)

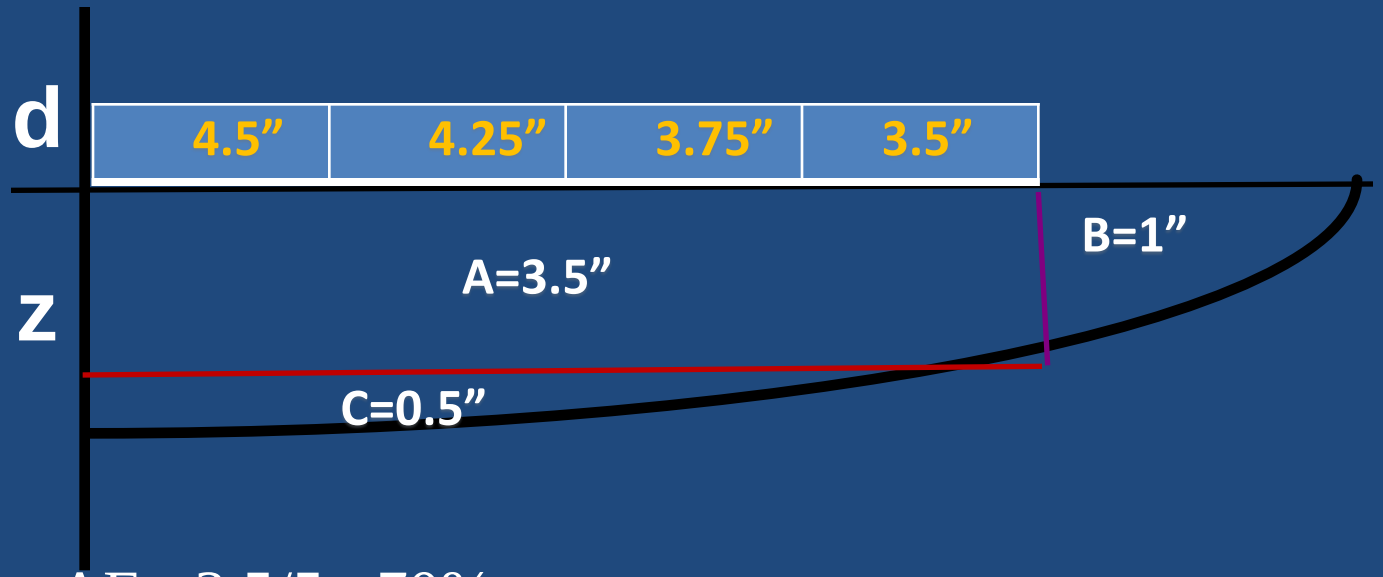


Field B (Alfalfa, Furrow, UCDREC)



Surface Irrigation (uniform soil?)

Applied water = Root zone storage (A) + runoff (B)+ deep percolation (C)



AE= 3.5/5= 70%

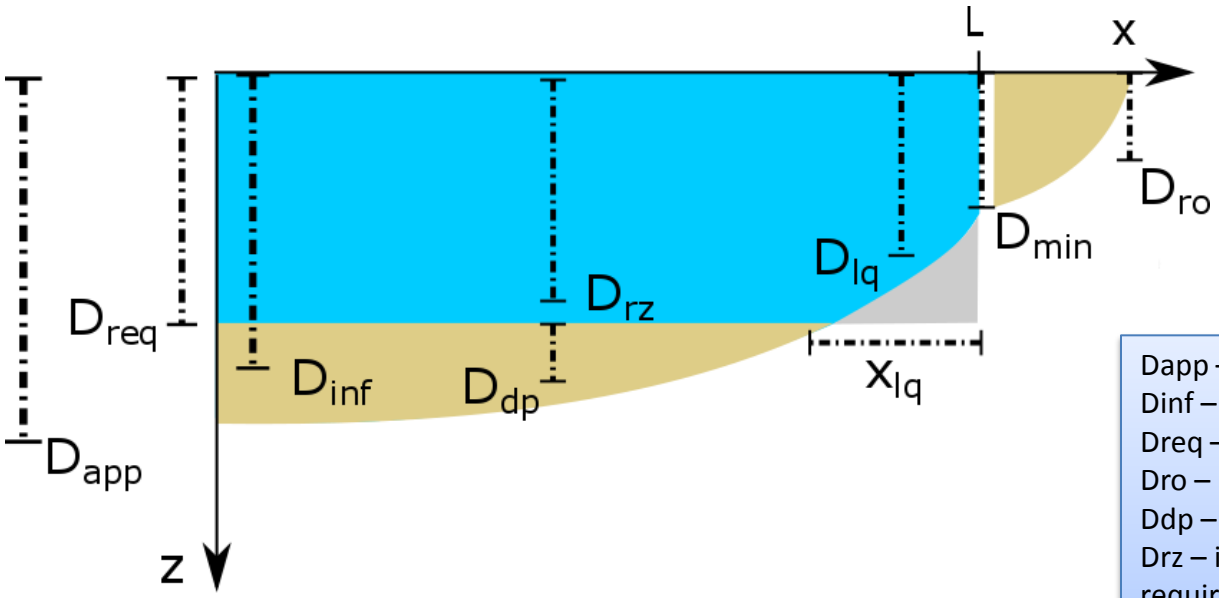
ROR=1/5=20%

DPR=0.5/5=10%

DU=3.5/4= 87.5%

Final infiltration profile and irrigation performance measures

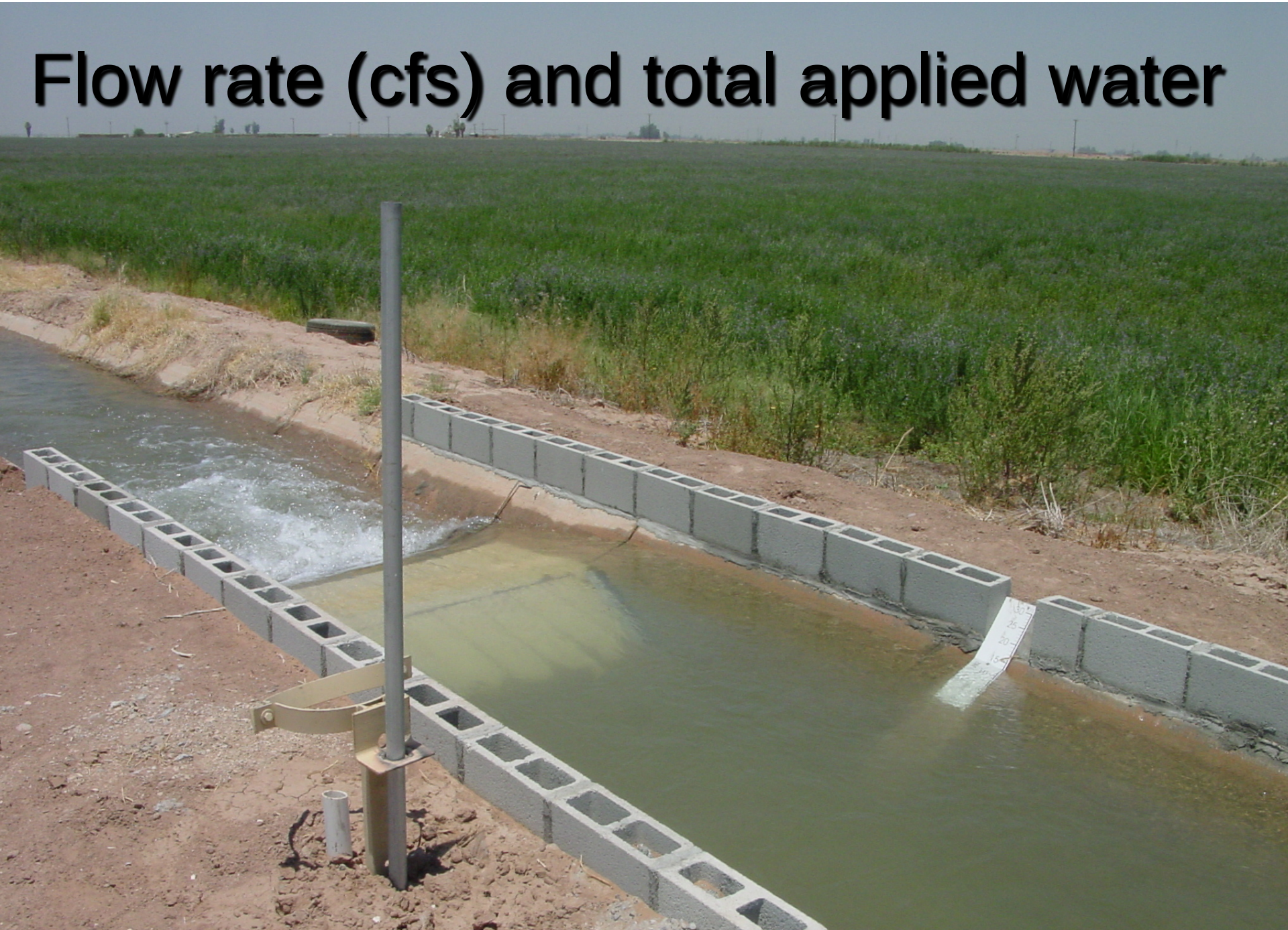
Application Efficiency (AE) and Distribution Uniformity (DU)



Dapp – applied depth
Dinf – infiltrated depth
Dreq – required depth
Dro – runoff depth
Ddp – deep percolation depth
Drz – infiltrated depth contributing to the required (Dz in WinSRFR manual)
Dmin = minimum depth
Dlq – low-quarter depth

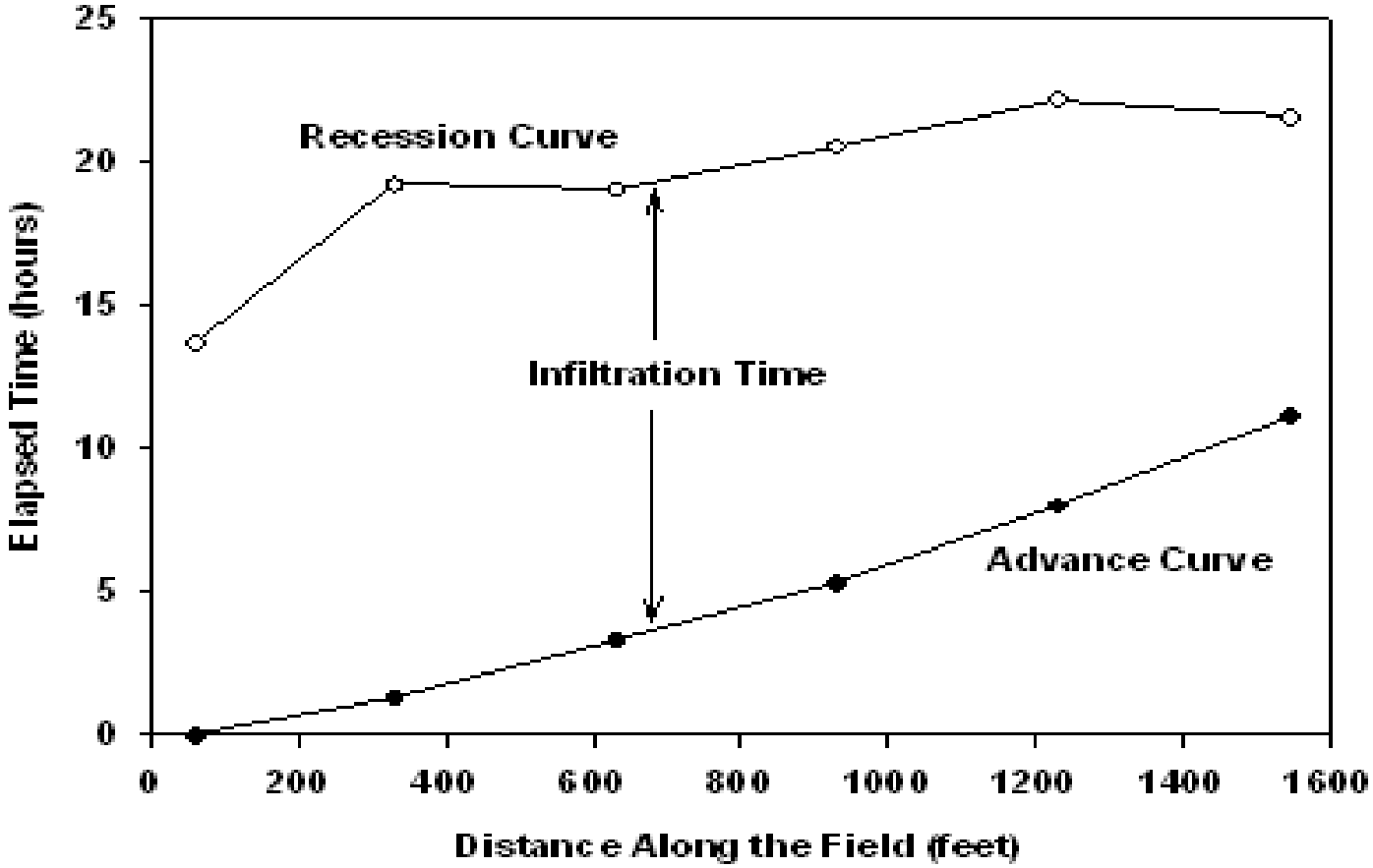
$$AE(\%) = \frac{D_{rz}}{D_{app}} \times 100 \qquad DU_{lq} = \frac{D_{lq}}{D_{\inf}} \qquad DU_{\min} = \frac{D_{\min}}{D_{\inf}}$$

Flow rate (cfs) and total applied water



Advance and Recession Curves

(also other parameters are need for system evaluation, flow rates, slope, n, soil type, etc)

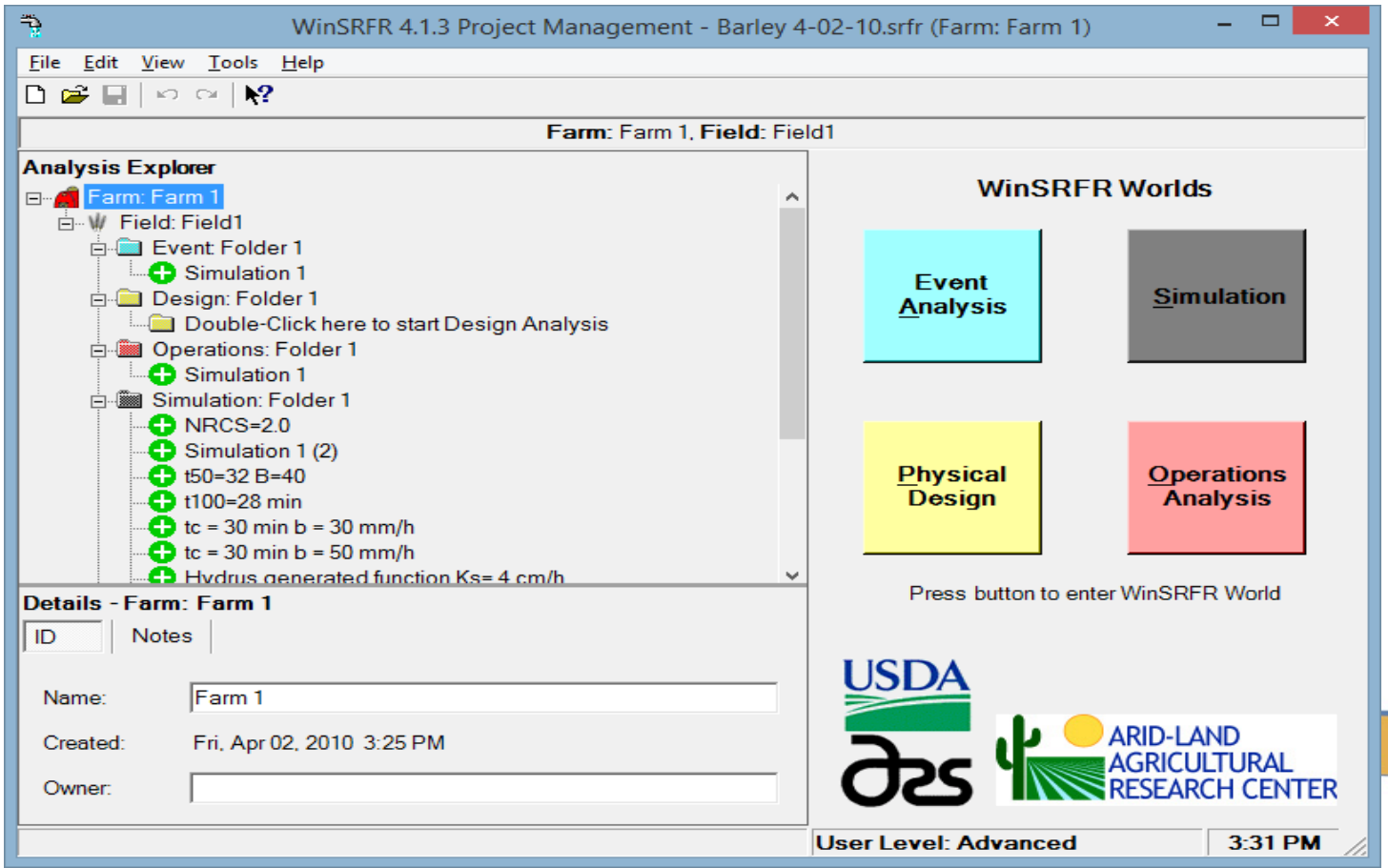


Tools to Improve Efficiency

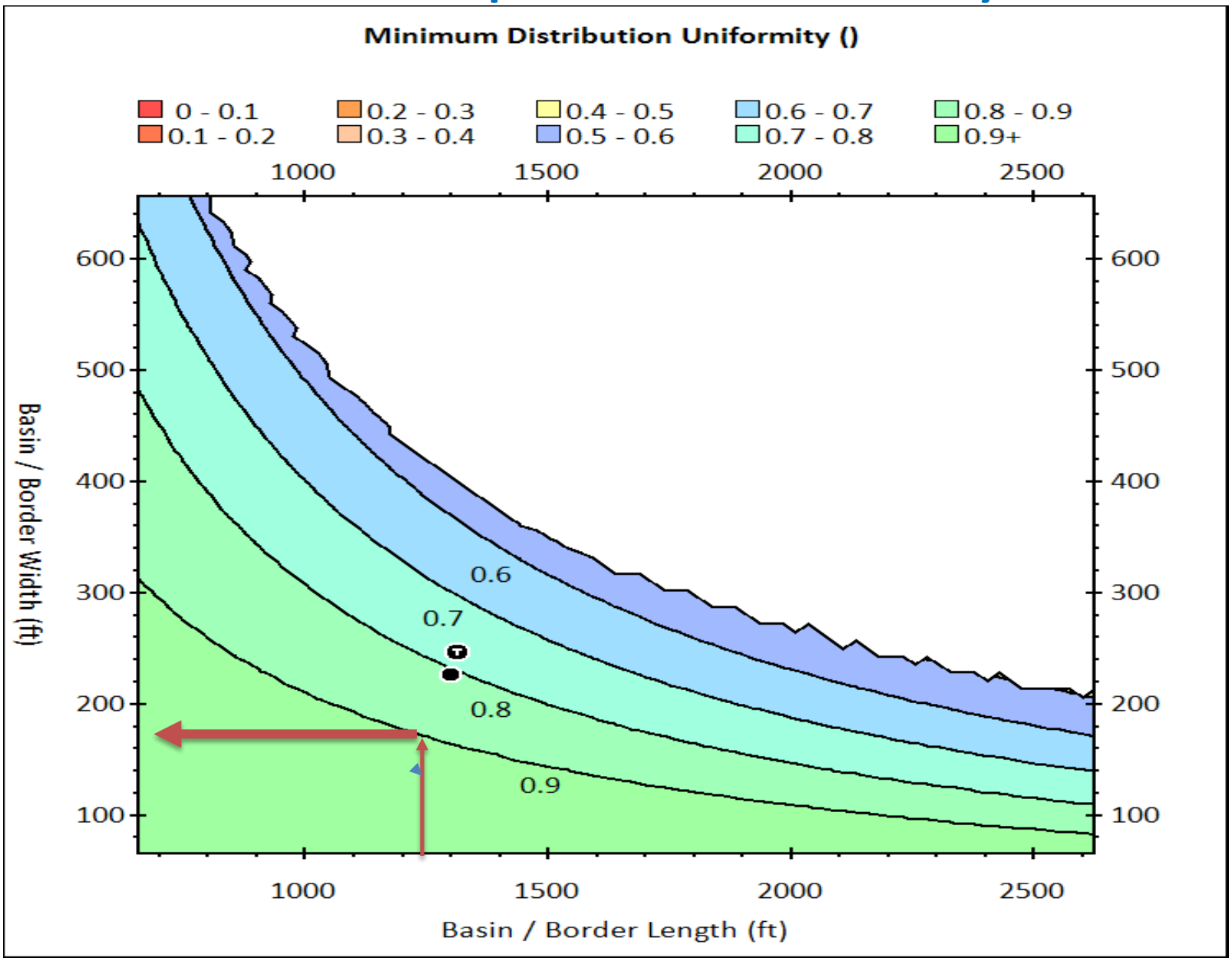
- Increasing check flow rate (to increase advance rate, avoid erosion, time of the year)
- Reducing field length: to improve DU and reduce DP (good option for light soils, not effective on heavy ground)
- Tailwater recovery systems: to reduce RO (good option for heavy soils, not effective for light soils)
- Selecting an appropriate irrigation water cutoff time (good option for heavy soils to reduce or eliminate runoff)
- Automation of surface irrigation

Tools to Improve Efficiency

- Evaluation of current irrigation system (AE and DU)
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate)
- WinSRFR (surface irrigation design and simulation model)

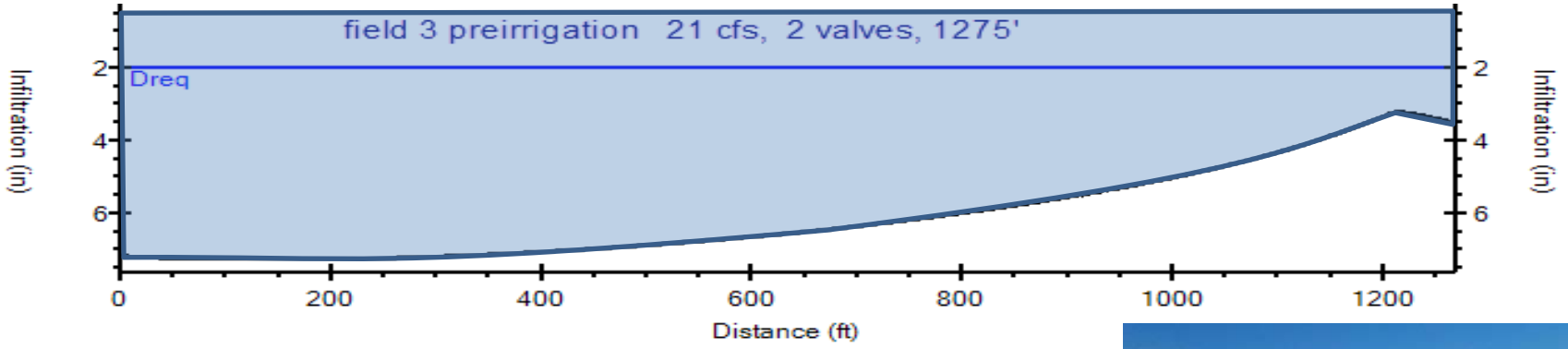


Tools to Improve Efficiency

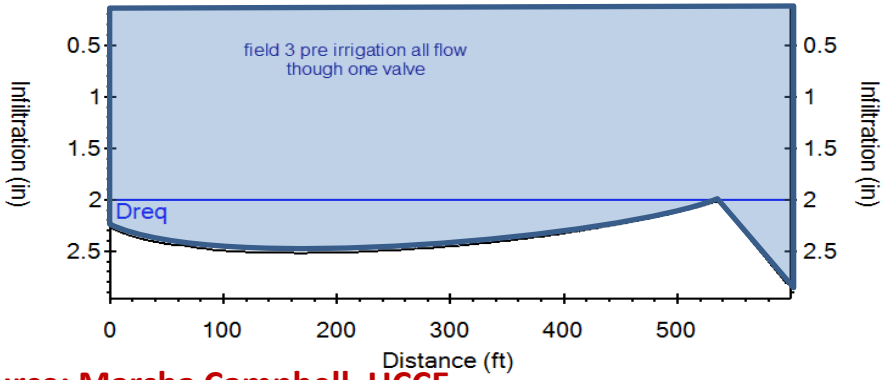


Reducing field length: to improve DU and reduce DP
(good option for light soils, not effective on heavy ground)

1275 ft, 2 valves, 21.4 cfs **6.1 inches applied**

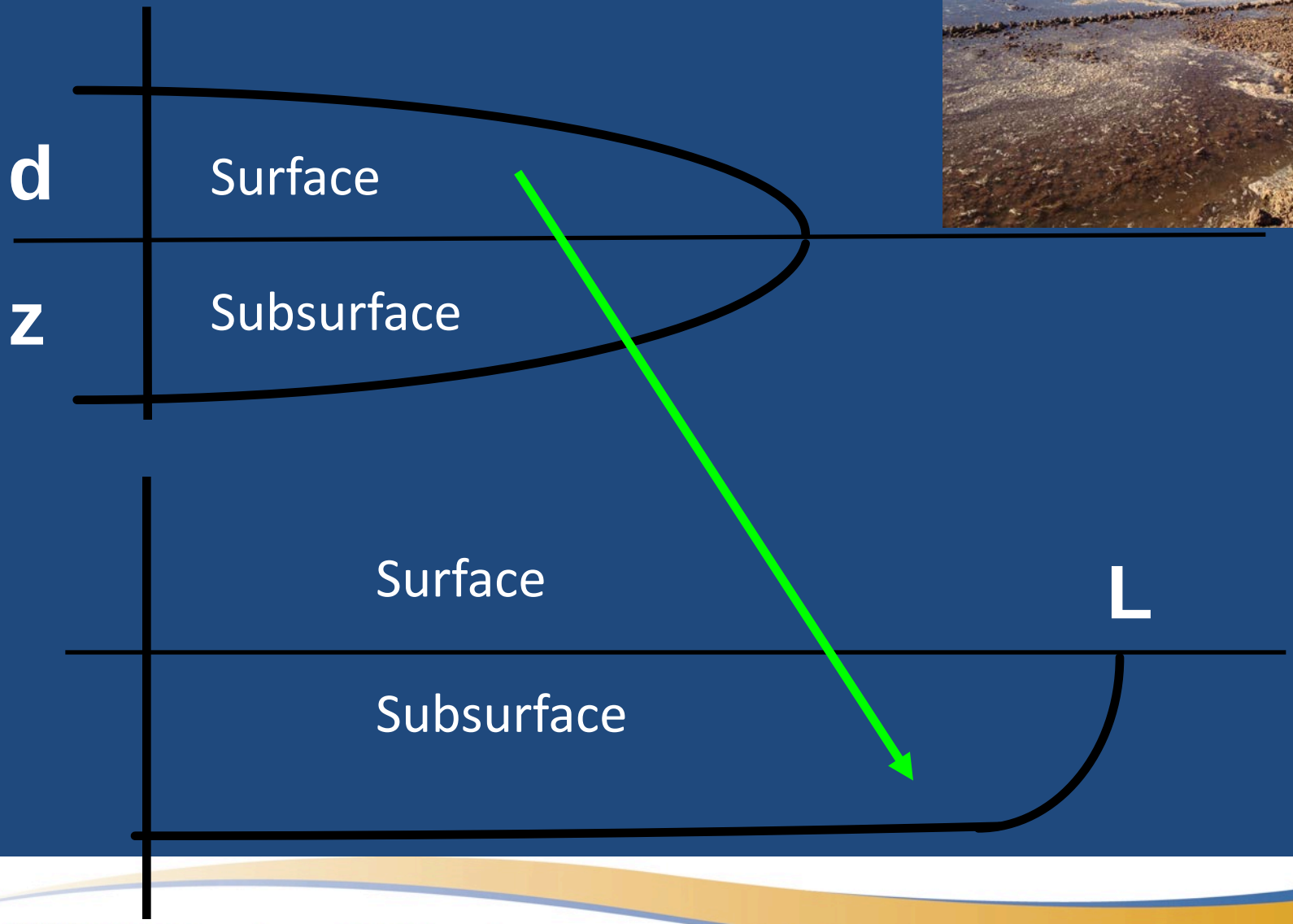


600 ft, 1 valve, 21.5 cfs **2.5 inches applied (NO3 in G**



Source: Marsha Campbell, UCCE

Irrigation management – applying the right amount of water



Tailwater Recovery Systems

- For water conservation
- Improving the quality of drainage water (TMDL)

Automation of Surface Irrigation Systems

Summary

- Need more emphasis on evaluation of surface irrigation systems

- Room for improvement but you cannot improve what you do not measure

- New tools to analyze and improve the design and management of surface irrigation (technology, modeling, automation)

- Higher efficiency is possible at a reasonable cost

- Higher labor costs will be a key factor in increasing efficiency

Thank You