Opportunities for Automation Optimization of Surface Irrigation

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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)**

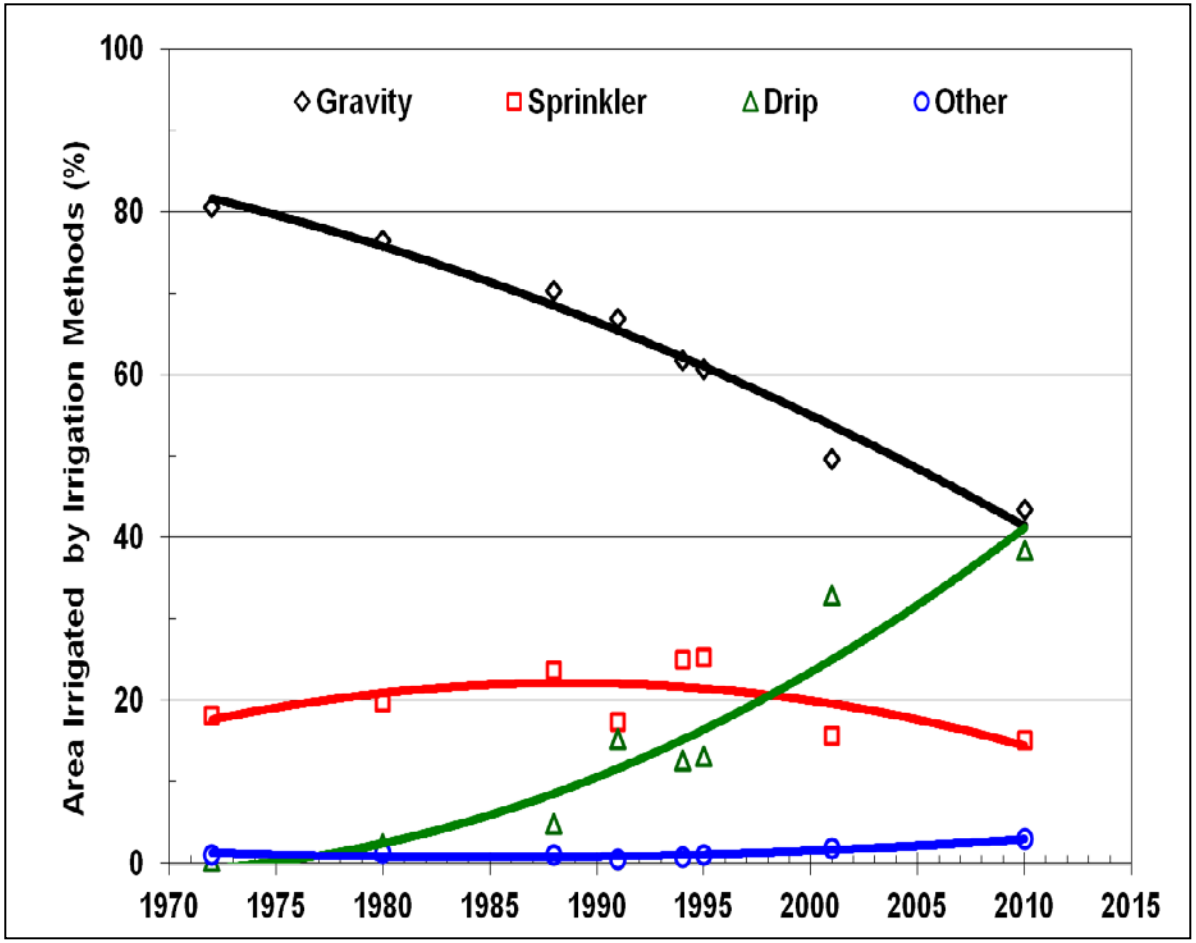
2- Sprinkler Irrigation (various types)

3- Drip Irrigation (various types)

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

TRENDS IN CALIFORNIA IRRIGATED AGRICULTURE

- Water Agencies and regulators provide financial incentives to growers to shift to micro-irrigation systems (SWEEP, EQIP, CEC)



Approximately 30% decline in field crops between 2006 and 2015 and increase in permanent crops

Source: Irrigation Survey 2010, *(Tindula, Orang & Snyder, 2013)*

Alfalfa Crop Water Use and Irrigation Efficiency

Crop ET = Reference ET x Crop Coefficient

$$ET_C = ET_O \times k_C$$

$$D_{\max} = \left[\frac{ETc_{(peak)}}{Eff_{APP}} \right] = in/day$$

ETc is also used in system design: Max irrigation depth to be applied (D_{MAX})

System	Potential $Eff._{APP}$	Actual $Eff._{APP}$
Gravity	70-85%	50-90%
Drip	85-90%	50-95%
Micro-sprinkler	80-90%	50-90%
Sprinkler	70-90%	60-90%

Traditional drip (SDI) or sprinkler example:

Peak ETo= 0.40/day Max Kc=1.2 AE=80%

Max application depth=(0.4*1.2/.8)=0.60 in/day

80 acre field with just one zone, need to apply this in

~ 8-20 hr/day (4 ac-ft/day) for drip

~ 4-10 hr/day (4 ac-ft/day) for sprinkler

For flood application rate as high 10 times the above figures (3-4" per irrigation)

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)

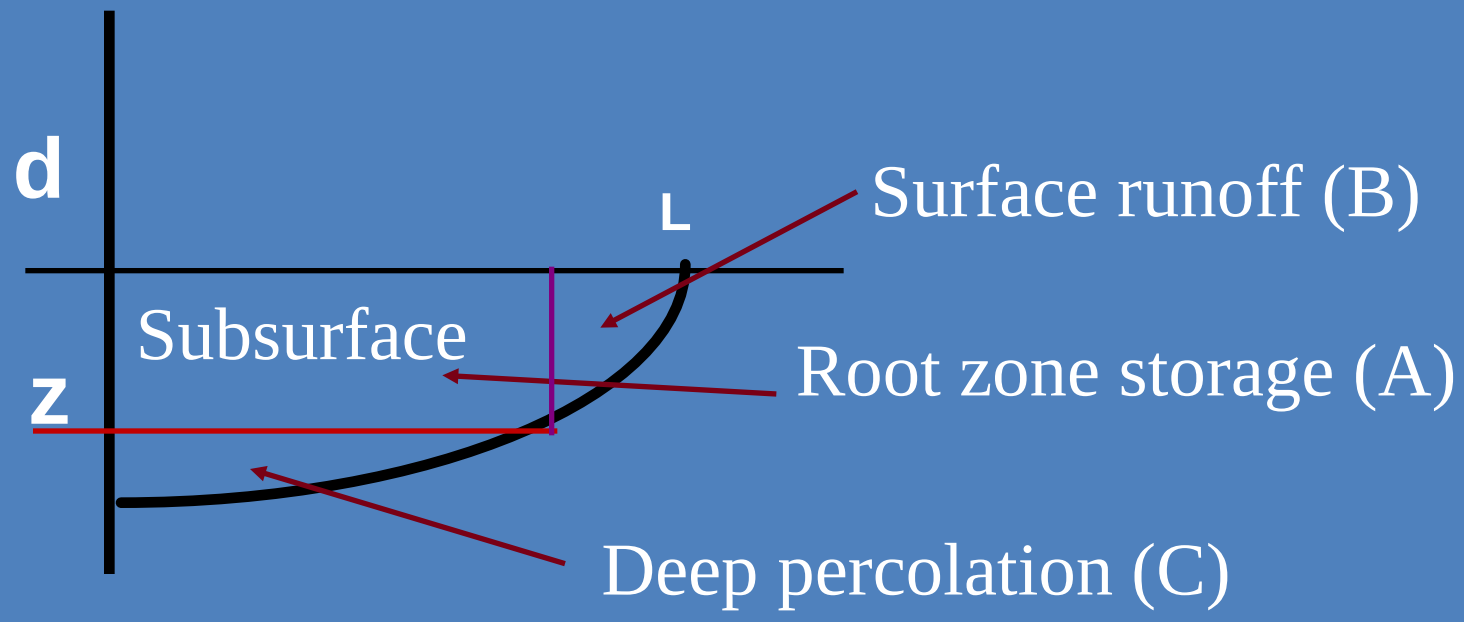
- Sprinkler: ~ 0.5-1.2 in/irrigation

- Drip: ~ 0.5 in/irrigation

- Delivery system designed for surface irrigation

Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation



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

IRRIGATION = Evapotranspiration (ET)+ 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,

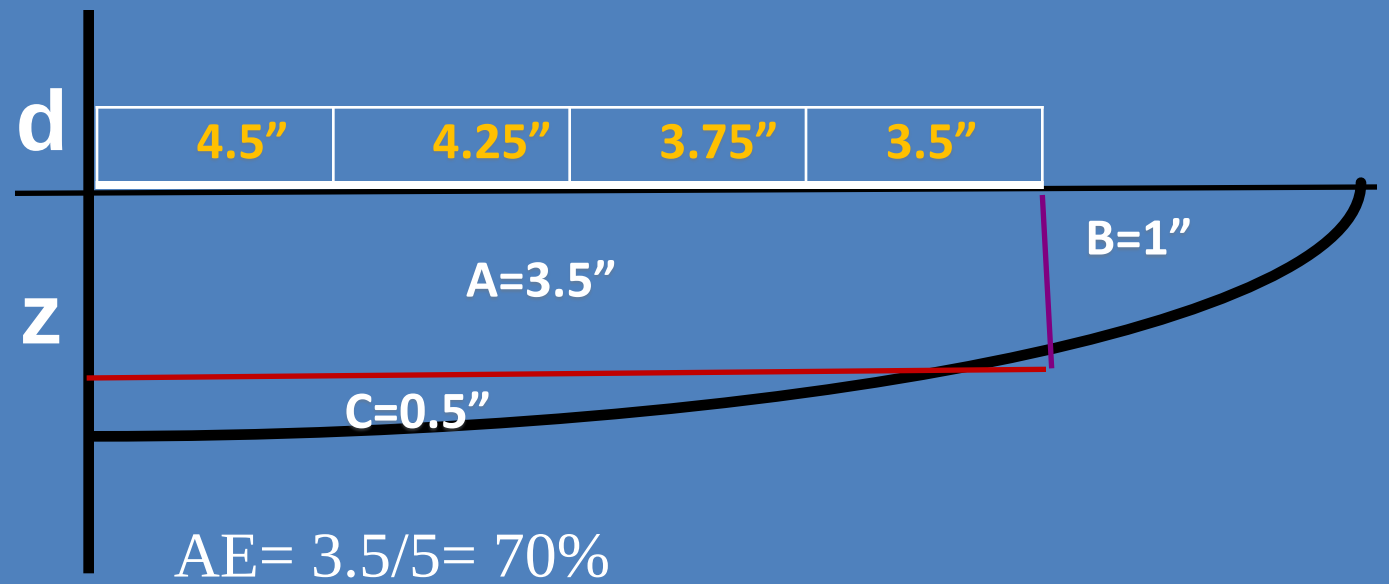
Deep Percolation sometimes is needed for salinity control

(650 ppm ~ 0.9 tons of salt/ac-ft)

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

Surface Irrigation (uniform soil?)

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



AE= 3.5/5= 70%

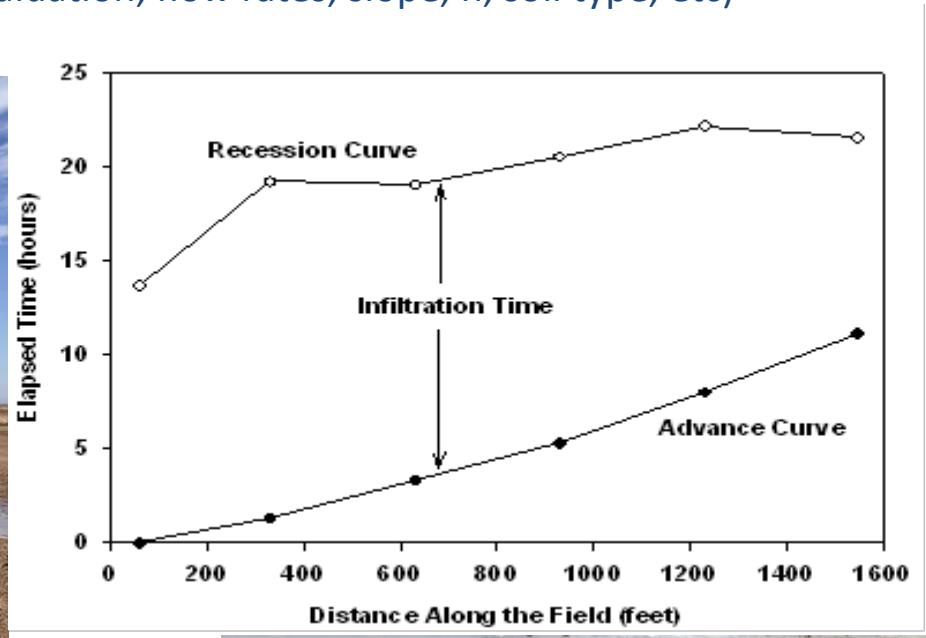
ROR=1/5=20%

DPR=0.5/5=10%

DU=3.5/4= 87.5% (Distribution Uniformity)

Advance and Recession Curves

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

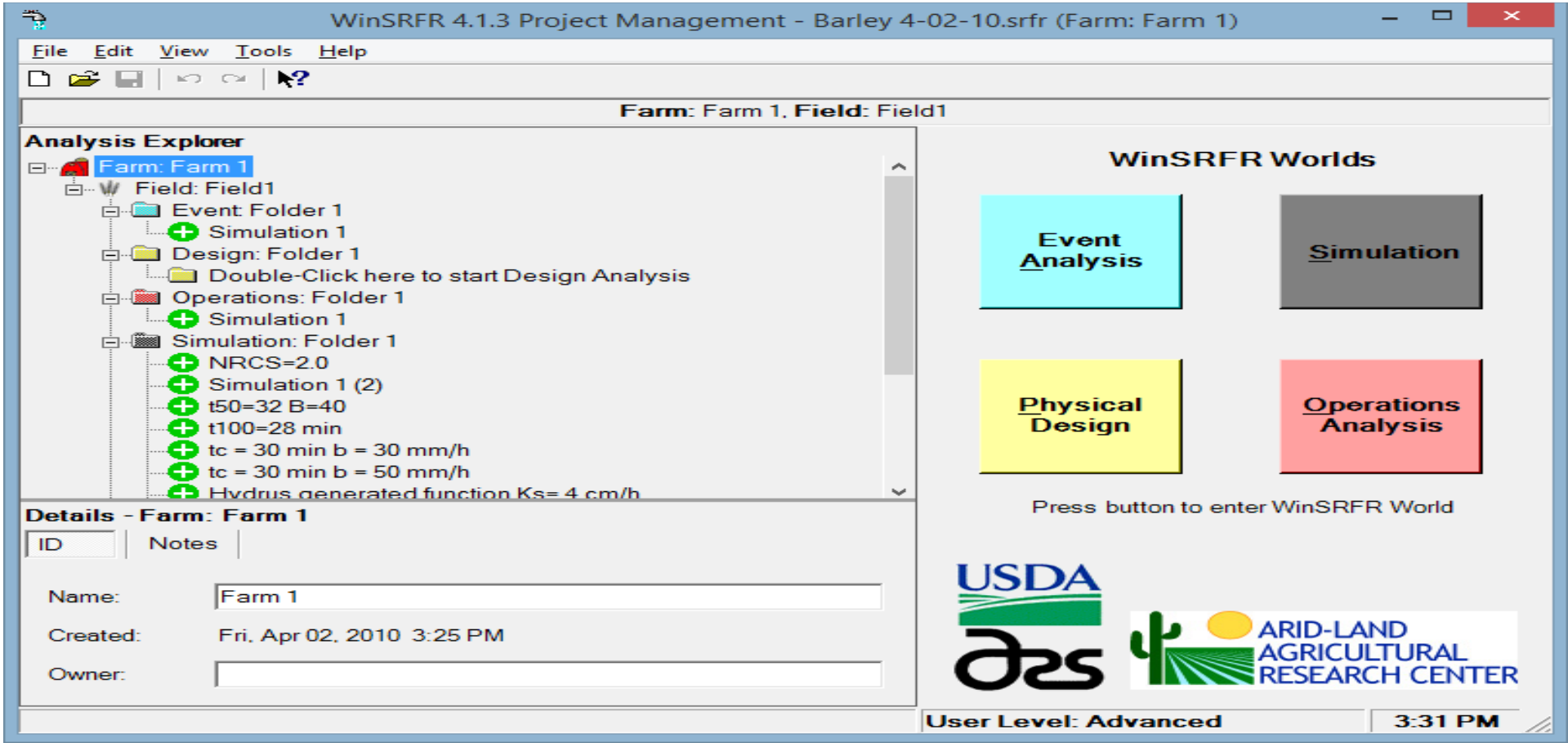


Advance and Recession Curves

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

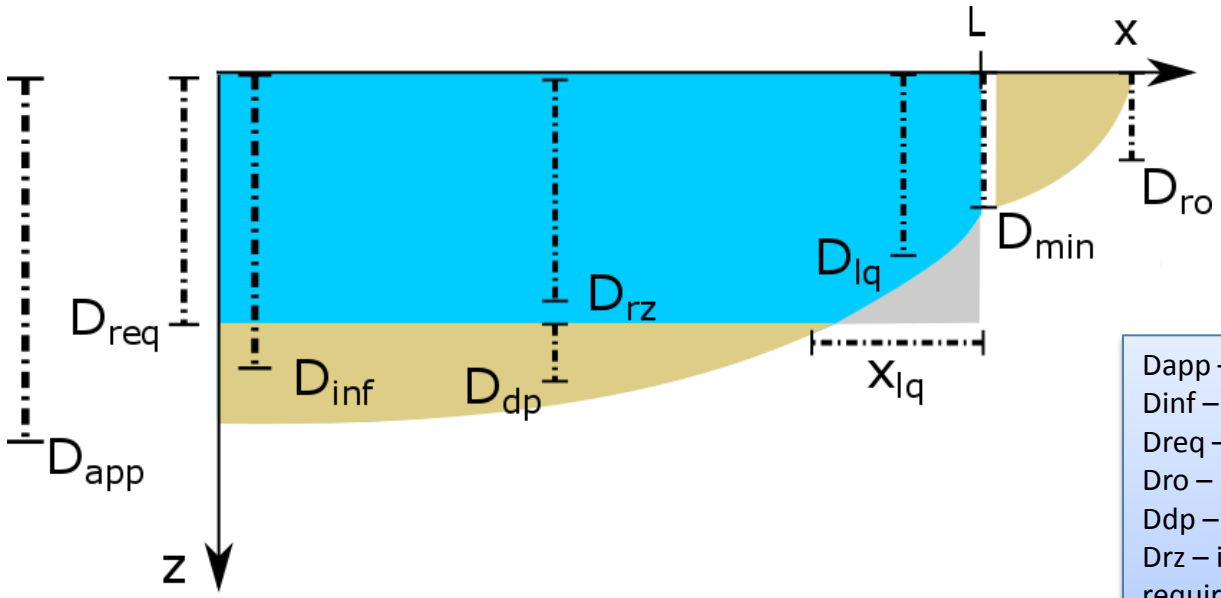
Tools to Improve Surface Irrigation Efficiency

- Evaluation of current irrigation system (AE and DU)-Application Efficiency and Distribution Uniformity
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate) using wireless advance sensors
- WinSRFR (surface irrigation design and simulation model)



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

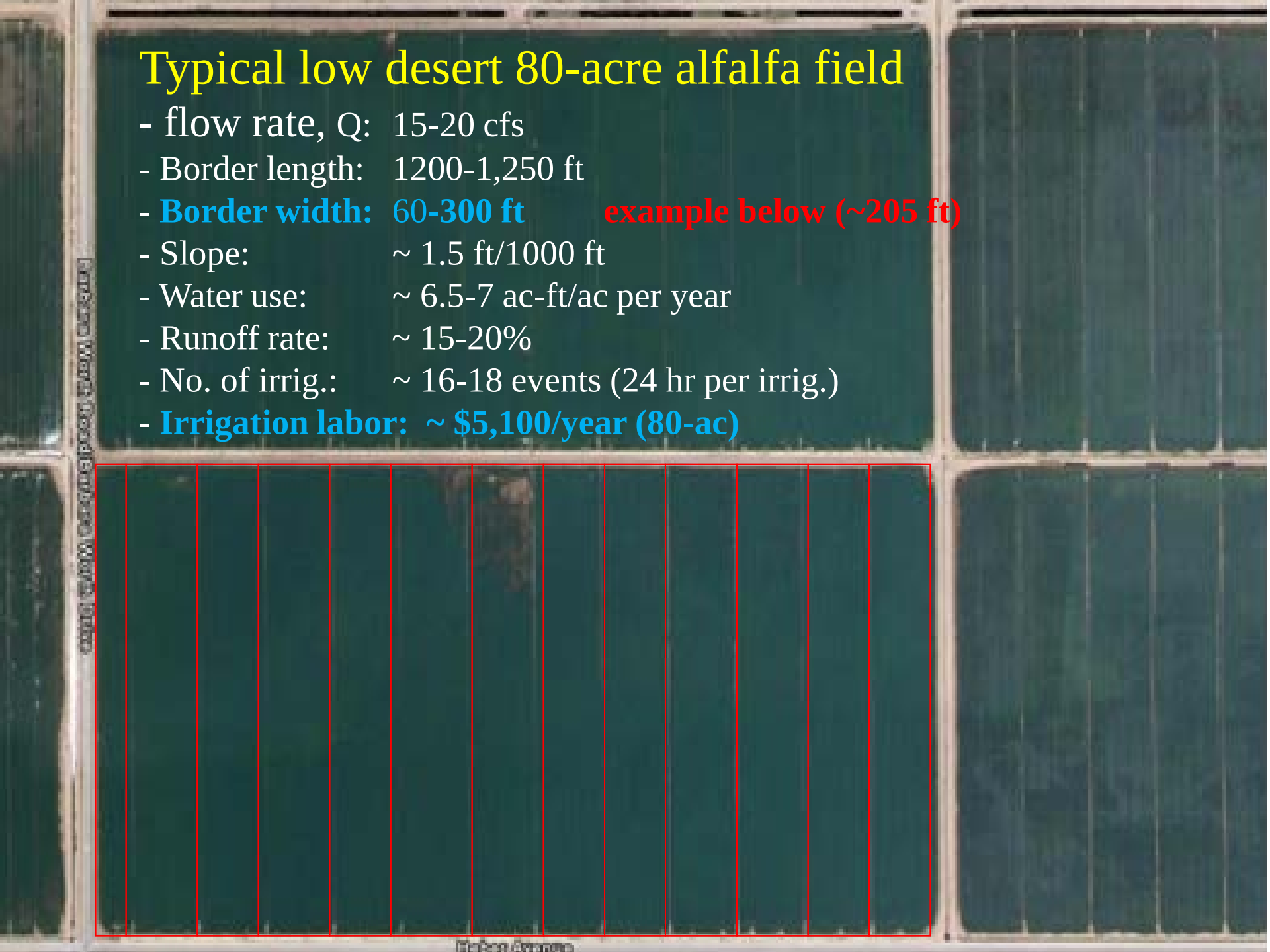
$$AE(\%) = \frac{D_{rz}}{D_{app}} \times 100$$

$$DU_{lq} = \frac{D_{lq}}{D_{\inf}}$$

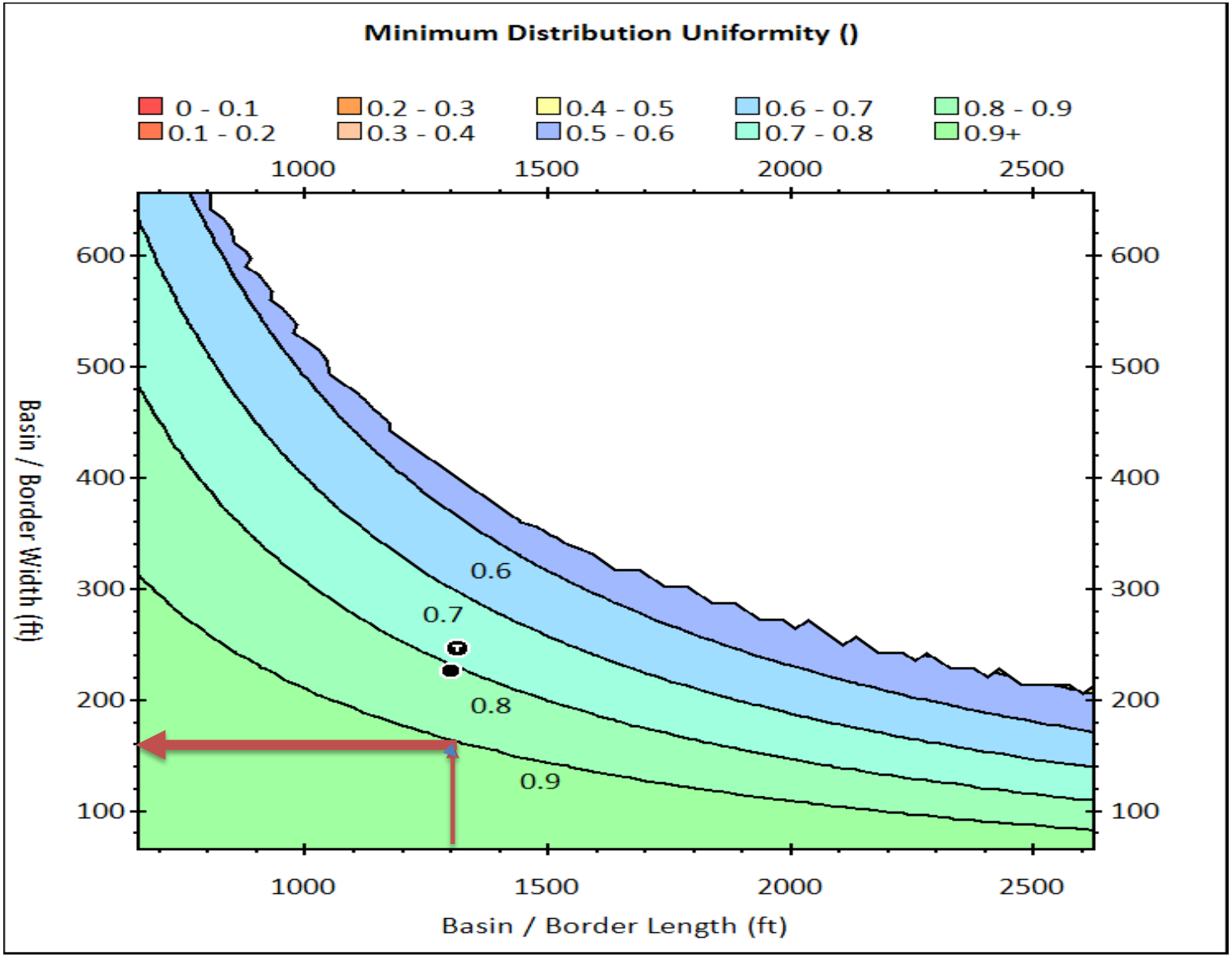
$$DU_{\min} = \frac{D_{\min}}{D_{\inf}}$$

Typical low desert 80-acre alfalfa field

- flow rate, Q: 15-20 cfs
- Border length: 1200-1,250 ft
- **Border width: 60-300 ft** **example below (~205 ft)**
- Slope: ~ 1.5 ft/1000 ft
- Water use: ~ 6.5-7 ac-ft/ac per year
- Runoff rate: ~ 15-20%
- No. of irrig.: ~ 16-18 events (24 hr per irrig.)
- **Irrigation labor: ~ $5,100/year (80-ac)**

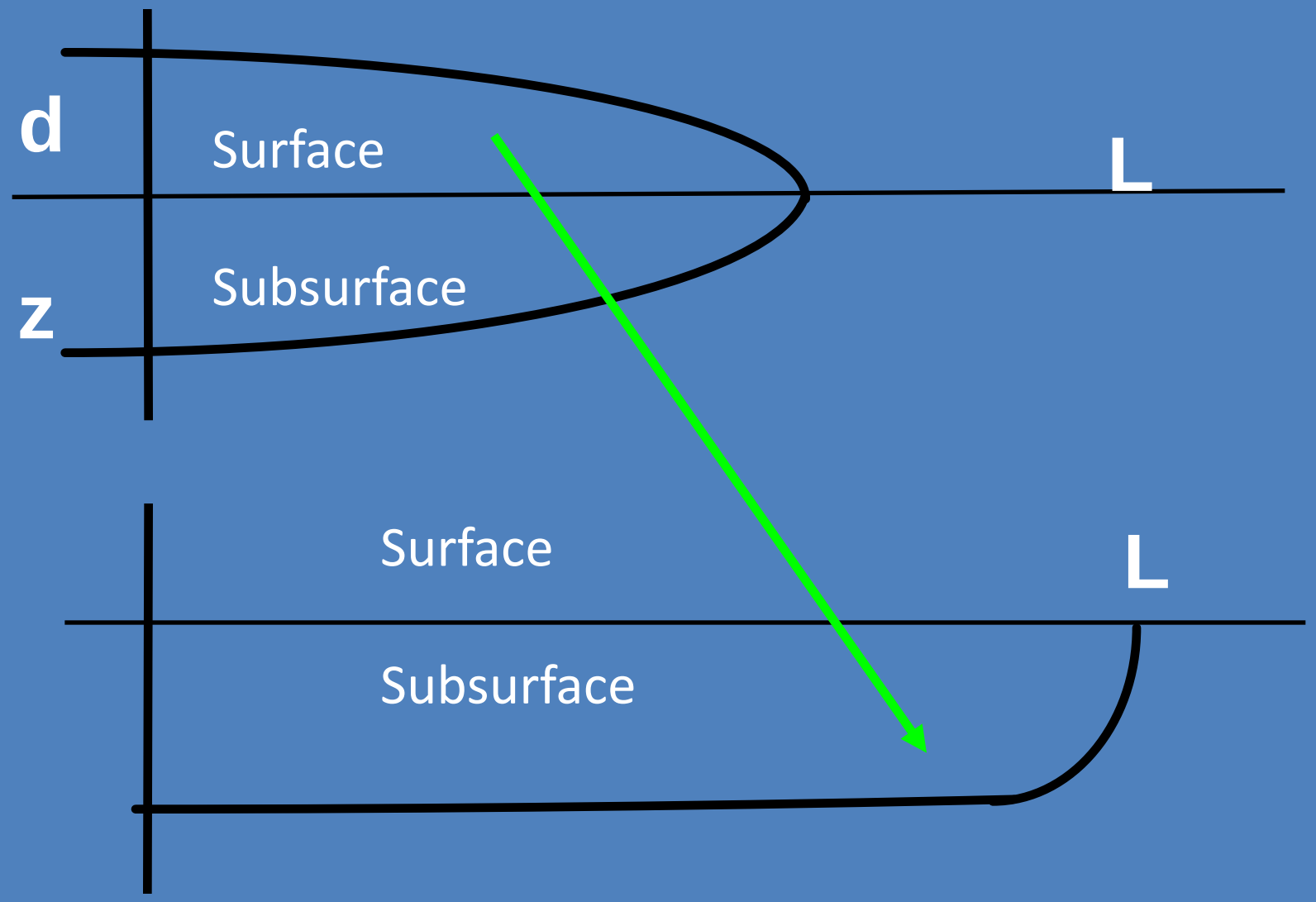


Results: Tools and practical charts to help growers design efficient surface irrigation system to meet their needs and maximize water use efficiency



Volume applied= Surface storage +Subsurface storage

flow rate*time= **d***L + **z***L



Optimization

(Automation of surface irrigation systems)

- The process of considering all flood irrigation variables to improve on-farm irrigation efficiency

- Adjust irrigation time to allow for changing crop roughness (height and density of the crop)

- Adjusting border/set length to allow for variable soil type across the field

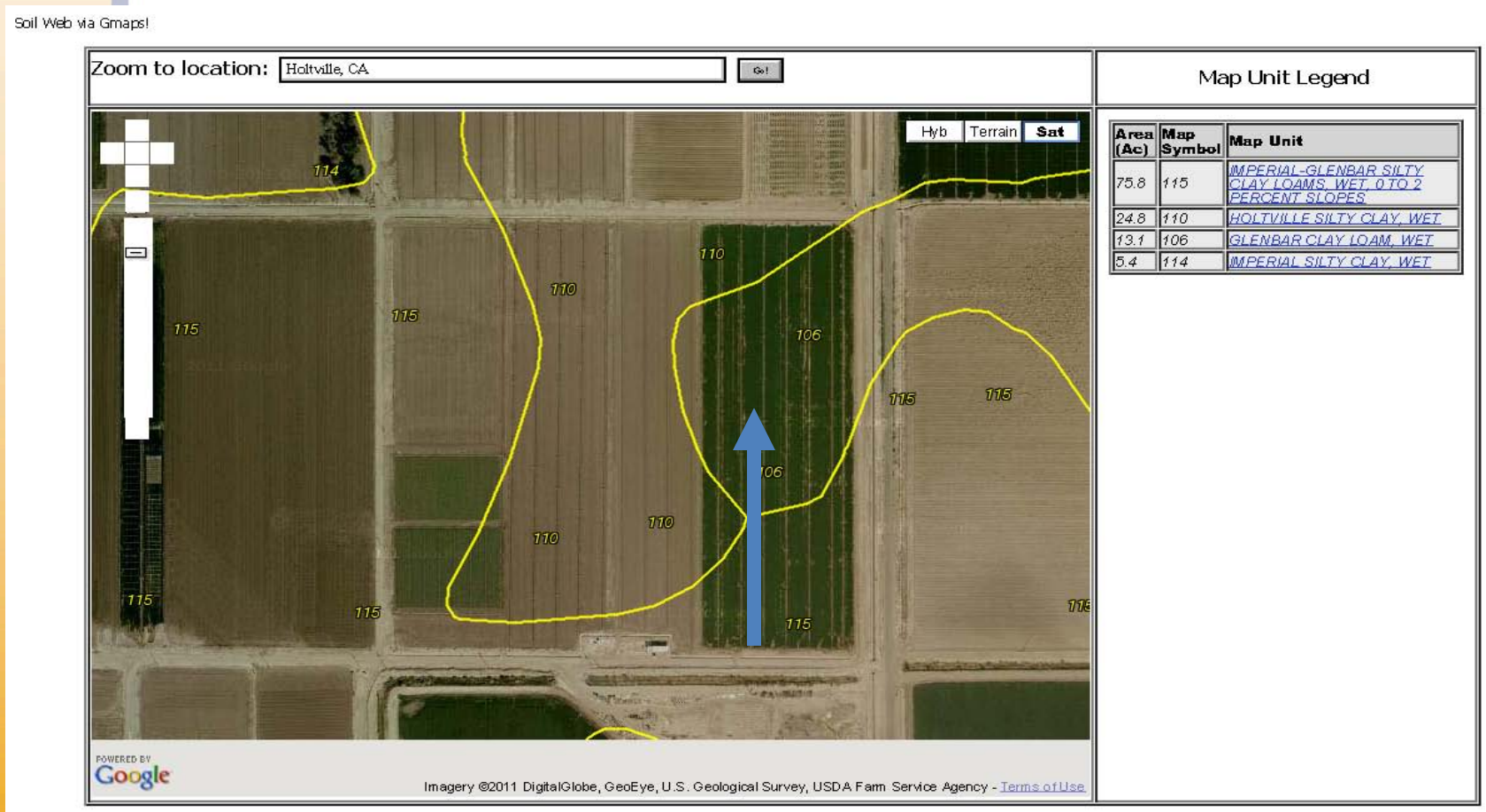
- Adjusting flow rate to an irrigation set (one or more border/land) to improve efficiency

- Computer simulation models are needed

- Accurate measurements during irrigation events (flow rate and advance rate)

Optimization

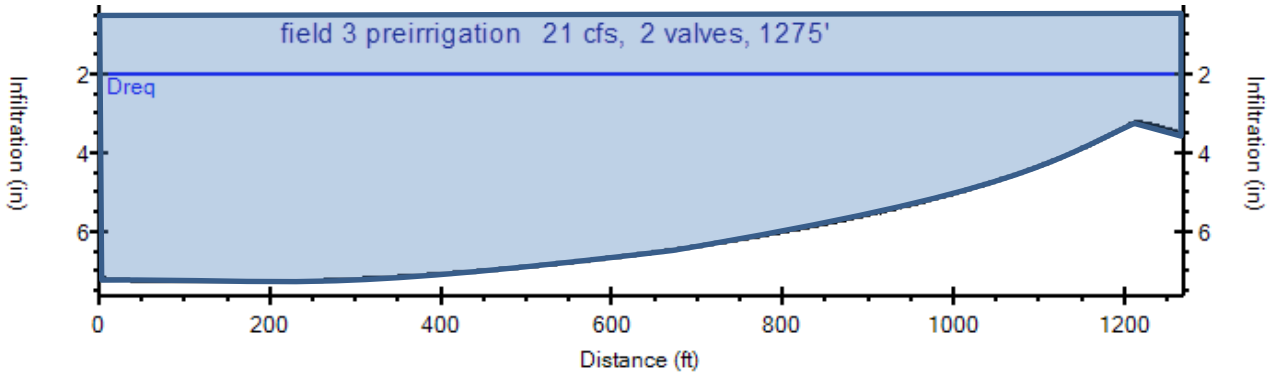
- Soil type 114 & 115 (heavy soils)- lower flow rate or high flow rate will work depending on the time of the year (considerations: erosion rate & scalding)
- Soil type 106 or 110 (lighter soil)- higher flow rate to increase efficiency
- Soil type 115 & 106 (change flow rate during the irrigation event)



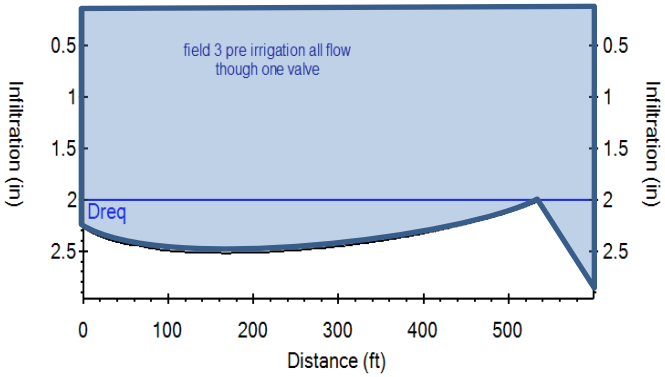
Area (Ac)	Map Symbol	Map Unit
75.8	115	IMPERIAL-GLENBAR SILTY CLAY LOAMS, WET, 0 TO 2 PERCENT SLOPES
24.8	110	HOLTVILLE SILTY CLAY, WET
13.1	106	GLENBAR CLAY LOAM, WET
5.4	114	IMPERIAL SILTY CLAY, WET

Reducing field length (light soil): to improve DU and reduce DP (and nitrate into GW)
(good opt*i*on for light soils, not effective on heavy ground)-SWEEP

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



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



Source: Marsha Campbell, UCCE

Automation of Surface Irrigation Systems

- Irrigators typically work in 24-hr shifts
- Make decisions on when to turn the water off based on a number of variables (flow rate, advance rate, crop height, etc)
- Automation: smart decisions based on accurate and real-time data (flow rate, advance rate, automated gates, ETc , and other variables)
- Water conservation and labor savings (CA min. wage $15/hr in 2022)

Automation of Surface Irrigation Systems
UC Desert Research and Extension Center






Automation Systems in CA

Commercial fields and UC Research Centers



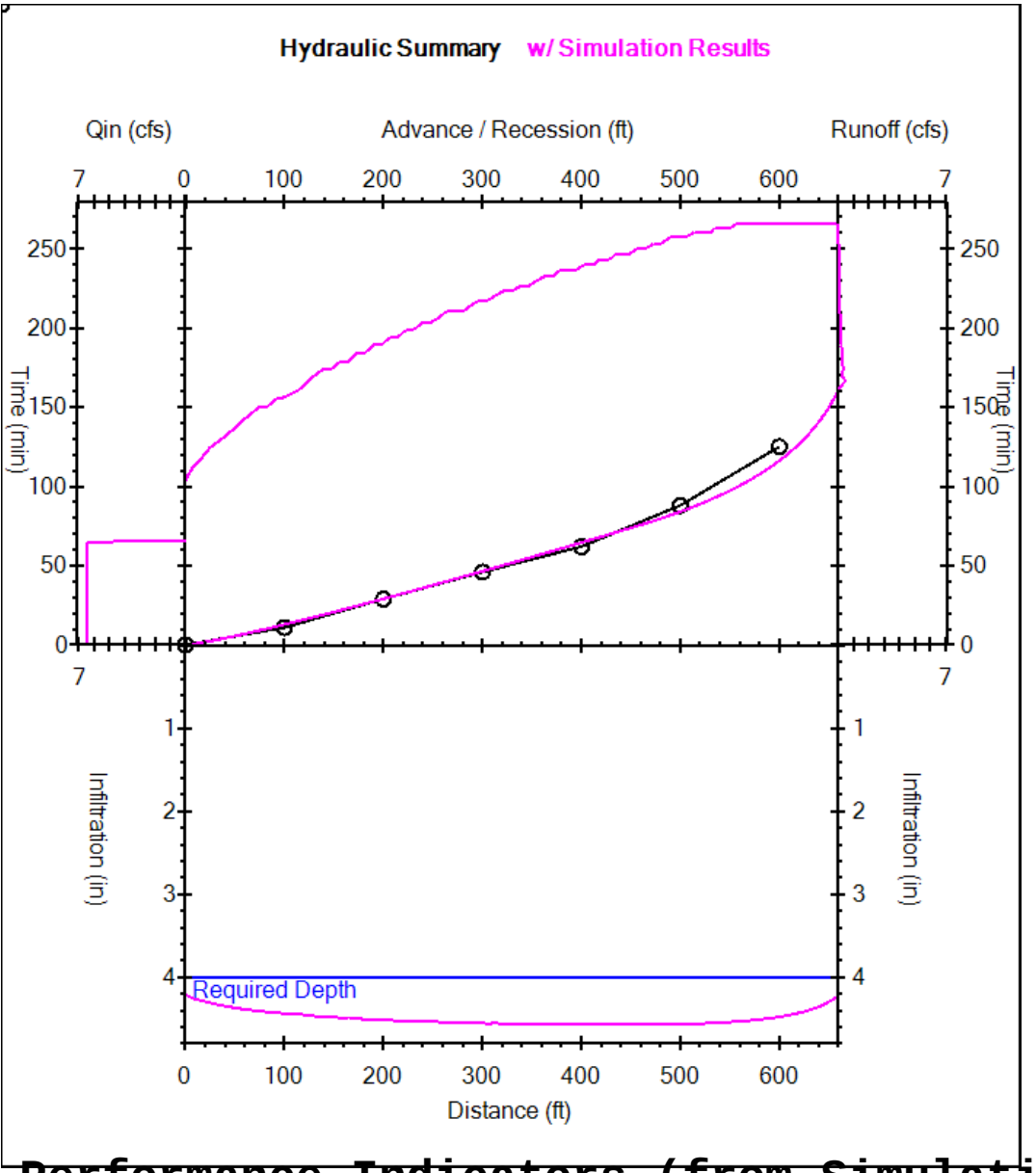


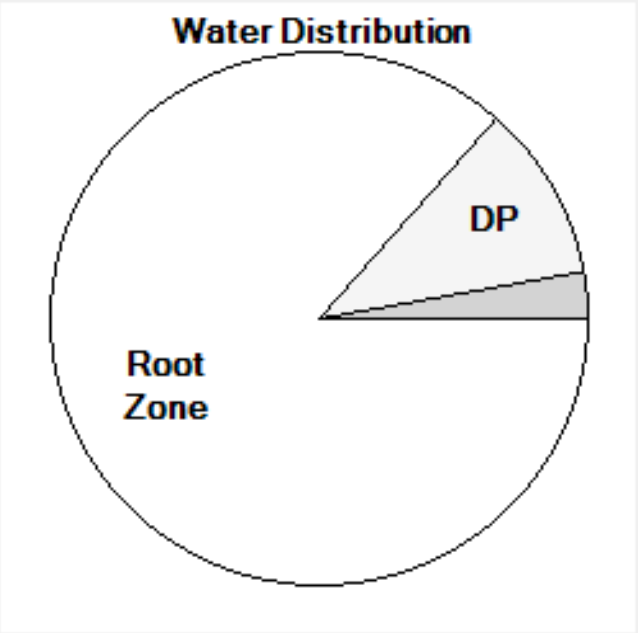

Rubicon Water

https://www.rubiconwater.com/

Watch Technologies

https://watchtechnologies.com/





Efficiency & Uniformity Indicators

AE = 87 %

DUmin = 0.94 DUlq = 0.97

DP% = 11 %

RO% = 3 %

Warning(s)

-- None --

Performance Indicators (from Simulation)Hydraulic Summary

Dapp = 4.61 in Dinf = 4.5 in Dro = 0.13 in
Ddp = 0.5 in Dmin = 4.2 in Dlq = 4.37 in
Tco = 65 min TL = 161.1 min XR = 0.61
Xmax = 660 ft Ymax = 4.84 in Verr% = -0.01 %

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