CAN WE TRUST SURFACE IRRIGATION HYDRAULIC MODELS?

Eduardo Bautista, Research Hydraulic Engineer
USDA-ARS U.S. Arid Land Agricultural Research Center
21881 N. Cardon Lane, Maricopa Arizona 85138
Eduardo.Bautista@ars.usda.gov

Prepared for:
INOVAGRI International Meeting & IV Winotec

ARID-LAND AGRICULTURAL RESEARCH CENTER

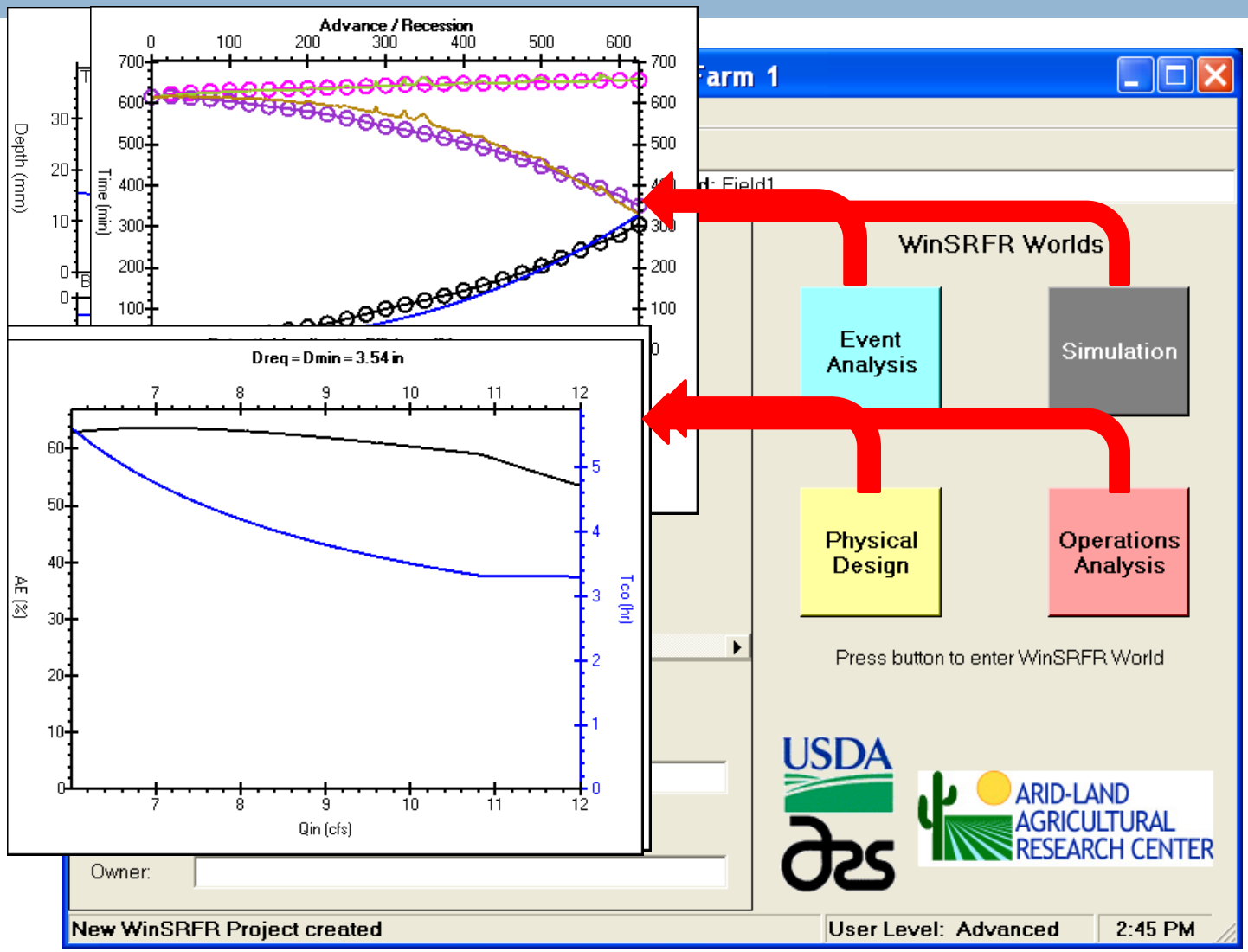
USDA ars United States Department Of Agriculture Agricultural Research Service

Discussion topics

- WinSRFR 4/SRFR 5
- Robust design/operational analysis

WinSRFR 4/ SRFR 5

WinSRFR: Software for surface irrigation analysis



Release history

- V1 (August, 2006)
  - Integrates functionality from BASIN, BORDER & SRFR
  - Adds irrigation event analysis functions
- V2 (Dec 2007)
  - Enhancements to event analysis functions
  - Incorporates design and operations analysis procedures for open-end furrows
  - Enhancements to simulation engine
- V3 (Mar 2009)
  - Replaces design and operational analysis procedures for borders and basins
  - Design/analysis procedures for close-end borders and furrows, level furrows, and furrows with cutback

(Bautista et al., 2009a, 2009b)

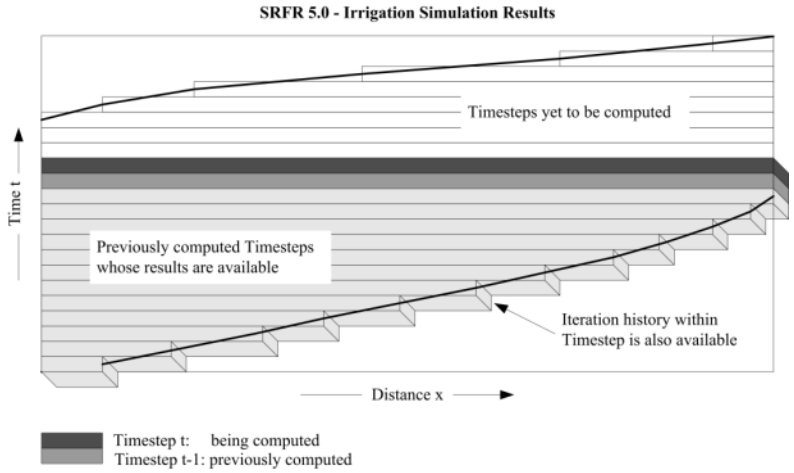
WinSRFR 4 Development Objectives

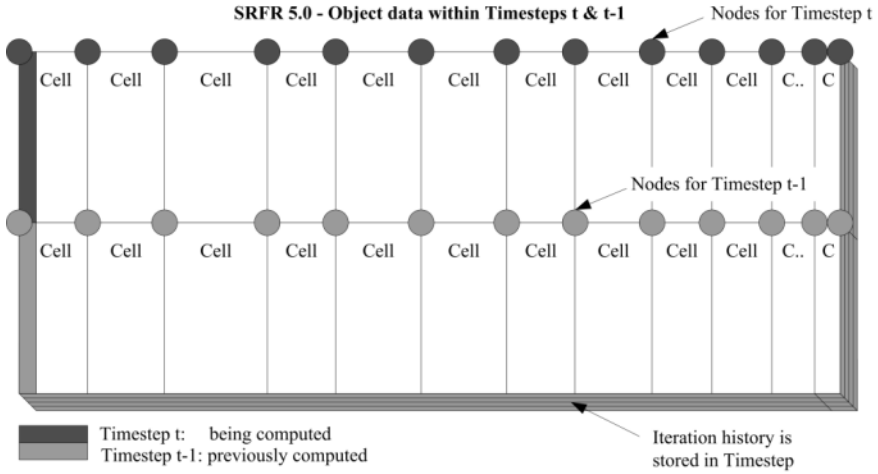
- Reprogram the SRFR engine (SRFR 5)
  - Unsupported development platform
  - Modularity, extensibility, and maintainability
  - Application Programming Interface (API)
  - Develop debugging and diagnostic tools

SRFR 5.0 object-oriented architecture

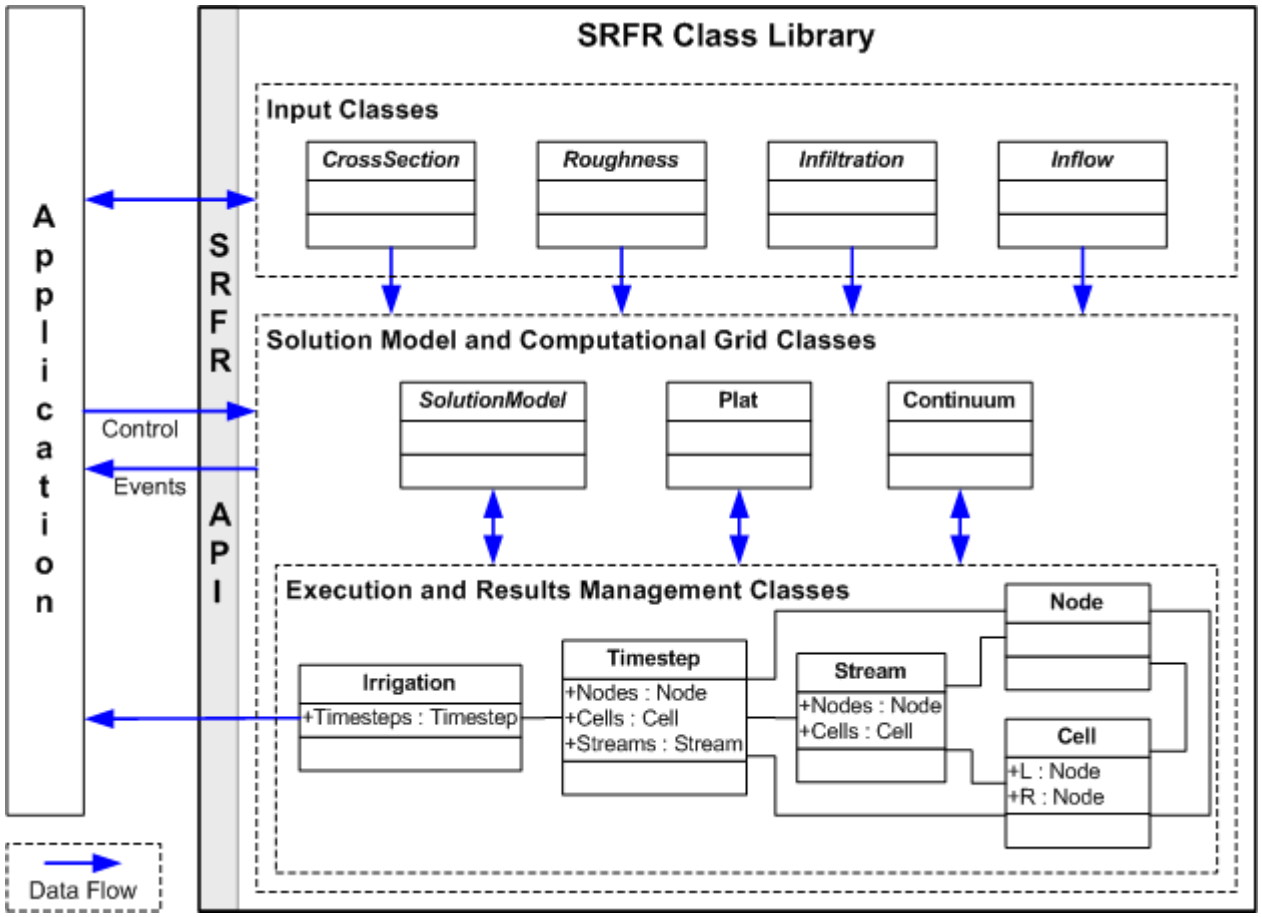
$$RC = 0 = [\theta \cdot (Q_L - Q_R) + (1-\theta)(Q_J - Q_M)]\delta t$$
$$+ [\varphi \cdot (A_J + Z_J) + (1-\varphi)(A_M + Z_M)] \cdot \delta x_{JM}$$
$$- [\varphi \cdot (A_L + Z_L) + (1-\varphi)(A_R + Z_R)] \cdot \delta x_{LR}$$

$$RM = 0 = [\varphi \cdot A_L + (1-\varphi)A_R] - (S_0 - S_{f\,LR}) \cdot \delta x_{LR}$$





The SRFR 5.0 API

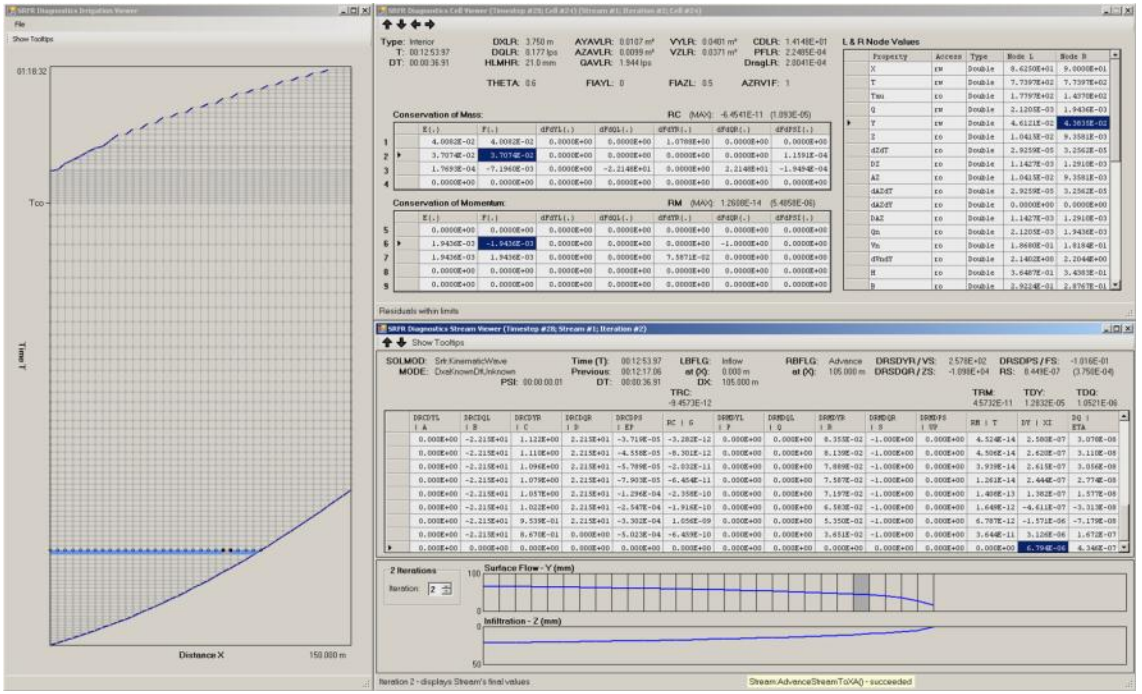


SRFR 5.0 Diagnostic screen

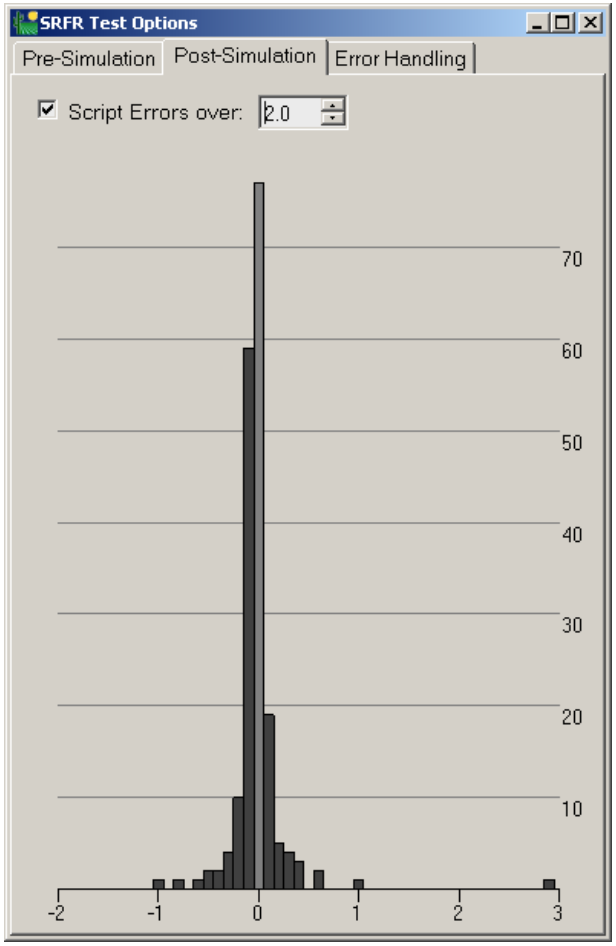
SrfrDiag.txt - Notepad

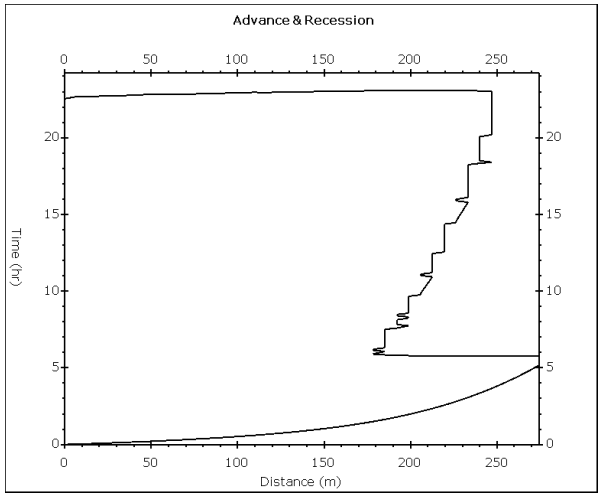
File Edit Format View Help

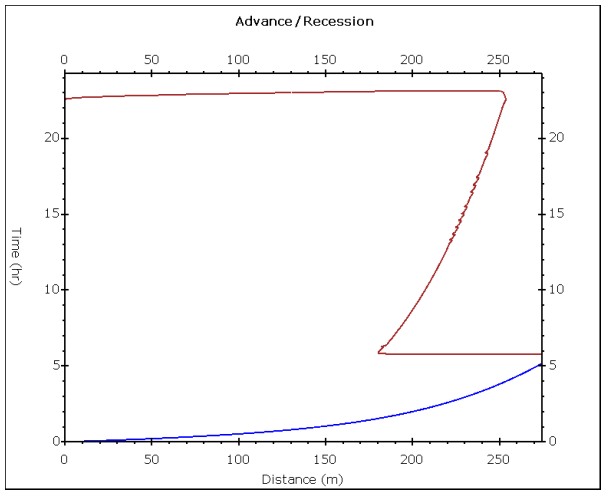
```
   2  0.2821E+00  0.1523E+01 -0.2104E-01 -0.5066E+00 -0.4154E-01  0.1571E+00  0.8502E+00  0.
   3  0.2821E+00  0.1482E+01 -0.1484E-04 -0.5059E+00 -0.2934E-04  0.1550E+00  0.8270E+00  0.
YUPF ENTRY.  IDIAG= 1  IDZ=**  IDIAG_CHNLGZ= 0
 FILE A1.f95 line 934 FORCES WRITING YUPF DIAGNOSTICS TO SRFRdiag

YUPF. AT ENTRY.  QUP=0.1000E+01  S0=0.1000E+01  EBBETA= 0.4500E+00  ERRFLG= 0
          RCMXR=0.1000E-03  EPSILN=0.1000E-05

JYUP     YUP          SF           G          DGDY         DYUP
   1  0.4468E+01  0.3174E-02 -0.1175E+01 -0.4290E-01 -0.2739E+02
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.2234E+01
   2  0.2234E+01  0.5241E-01 -0.1037E+01 -0.1302E+00 -0.7961E+01
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.1117E+01
   3  0.1117E+01  0.6764E+00 -0.3682E+00 -0.2191E+01 -0.1680E+00
   4  0.9489E+00  0.1202E+01  0.1642E+00 -0.4479E+01  0.3667E-01
   5  0.9856E+00  0.1052E+01  0.1301E-01 -0.3792E+01  0.3431E-02
   6  0.9890E+00  0.1040E+01  0.9890E-04 -0.3735E+01  0.2648E-04
DYUPF EXIT
   8 0.9209E+01  0.1467E+01  0.1000E+01  0.1000E+01 1  1   8  4 0   3 0.0000E+00  0.1974E+0

VOLUME-BASED DT. ITERATIONS.  DXAV_B= 0.2821E+00  AYR= 0.2196E+01    QLAVG= 0.5061E+00
   G_0= 0.6194E+00  DELTA_AZ_KRB(1)= 0.0000E+00  AYL= 0.2675E+01  DVY_KRB= 0.6194E+00  DELT
 JDT     DXA_          DTV          G          DGDTV        D_DTV        DVZ_KRB      DVQ_KRB
   1  0.2821E+00  0.4401E+01 -0.1341E+01 -0.4757E+00 -0.2818E+01  0.2671E+00  0.2227E+01  0.
   2  0.2821E+00  0.1583E+01 -0.2140E-01 -0.4555E+00 -0.4698E-01  0.1602E+00  0.8010E+00  0.
   3  0.2821E+00  0.1536E+01 -0.1790E-04 -0.4547E+00 -0.3936E-04  0.1578E+00  0.7772E+00  0.
YUPF ENTRY.  IDIAG= 1  IDZ=**  IDIAG_CHNLGZ= 0
 FILE A1.f95 line 934 FORCES WRITING YUPF DIAGNOSTICS TO SRFRdiag

YUPF. AT ENTRY.  QUP=0.1000E+01  S0=0.1000E+01  EBBETA= 0.4500E+00  ERRFLG= 0
          RCMXR=0.1000E-03  EPSILN=0.1000E-05

JYUP     YUP          SF           G          DGDY         DYUP
   1  0.4468E+01  0.3174E-02 -0.1175E+01 -0.4290E-01 -0.2739E+02
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.2234E+01
   2  0.2234E+01  0.5241E-01 -0.1037E+01 -0.1302E+00 -0.7961E+01
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.1117E+01
   3  0.1117E+01  0.6764E+00 -0.3682E+00 -0.2191E+01 -0.1680E+00
   4  0.9489E+00  0.1202E+01  0.1642E+00 -0.4479E+01  0.3667E-01
   5  0.9856E+00  0.1052E+01  0.1301E-01 -0.3792E+01  0.3431E-02
   6  0.9890E+00  0.1040E+01  0.9890E-04 -0.3735E+01  0.2648E-04
DYUPF EXIT
   9 0.1073E+02  0.1522E+01  0.1000E+01  0.1000E+01 1  1   9  4 0   3 0.0000E+00  0.2256E+0

VOLUME-BASED DT. ITERATIONS.  DXAV_B= 0.2821E+00  AYR= 0.2028E+01    QLAVG= 0.4604E+00
   G_0= 0.5720E+00  DELTA_AZ_KRB(1)= 0.0000E+00  AYL= 0.2524E+01  DVY_KRB= 0.5720E+00  DELT
 JDT     DXA_          DTV          G          DGDTV        D_DTV        DVZ_KRB      DVQ_KRB
   1  0.2821E+00  0.4566E+01 -0.1258E+01 -0.4306E+00 -0.2922E+01  0.2721E+00  0.2102E+01  0.
   2  0.2821E+00  0.1644E+01 -0.2176E-01 -0.4108E+00 -0.5297E-01  0.1632E+00  0.7570E+00  0.
   3  0.2821E+00  0.1591E+01 -0.2155E-04 -0.4099E+00 -0.5256E-04  0.1606E+00  0.7326E+00  0.
YUPF ENTRY.  IDIAG= 1  IDZ=**  IDIAG_CHNLGZ= 0
 FILE A1.f95 line 934 FORCES WRITING YUPF DIAGNOSTICS TO SRFRdiag

YUPF. AT ENTRY.  QUP=0.1000E+01  S0=0.1000E+01  EBBETA= 0.4500E+00  ERRFLG= 0
          RCMXR=0.1000E-03  EPSILN=0.1000E-05

JYUP     YUP          SF           G          DGDY         DYUP
   1  0.4468E+01  0.3174E-02 -0.1175E+01 -0.4290E-01 -0.2739E+02
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.2234E+01
   2  0.2234E+01  0.5241E-01 -0.1037E+01 -0.1302E+00 -0.7961E+01
DYUP TOO LARGE FOR YUP. REDUCED IN ABSOLUTE SIZE TO DYUP=-.1117E+01
   3  0.1117E+01  0.6764E+00 -0.3682E+00 -0.2191E+01 -0.1680E+00
   4  0.9489E+00  0.1202E+01  0.1642E+00 -0.4479E+01  0.3667E-01
   5  0.9856E+00  0.1052E+01  0.1301E-01 -0.3792E+01  0.3431E-02
   6  0.9890E+00  0.1040E+01  0.9890E-04 -0.3735E+01  0.2648E-04
DYUPF EXIT
  10 0.1231E+02  0.1579E+01  0.1000E+01  0.1000E+01 1  1  10  4 0   3 0.0000E+00  0.2539E+0

VOLUME-BASED DT. ITERATIONS.  DXAV_B= 0.2821E+00  AYR= 0.1877E+01    QLAVG= 0.4206E+00
```



Testing Program







New Features and Enhancements

- Introduction of a Scripting Language. This language provides a mechanism for batch executions of the simulation engine from text/ spreadsheet files
- Simulation of surge irrigation
- Simulation with spatially variable infiltration, roughness, and cross-sectional geometry
- Simulation with the physically-based Green-Ampt infiltration
- Operations analysis: examine furrow set width vs. cutoff time for a specified inflow rate
- Improved user interface
- Improved User Manual

In Summary …

- WinSRFR 4.1 will be available later this year
- We are interested in collaborating with interested researchers

Robust Operations and Design Analysis

- The issues
  - Spatially and temporally variable infiltration and hydraulic resistance
  - Inflow rate may not be constant
- The consequences
  - System failure
  - Irrigator needs to adjust the operation in response to actual performance
  - Degradation in system performance

Our objective

- Determine solutions that will perform adequately if actual field conditions deviate from those assumed in the analysis
- Recommend system adjustments

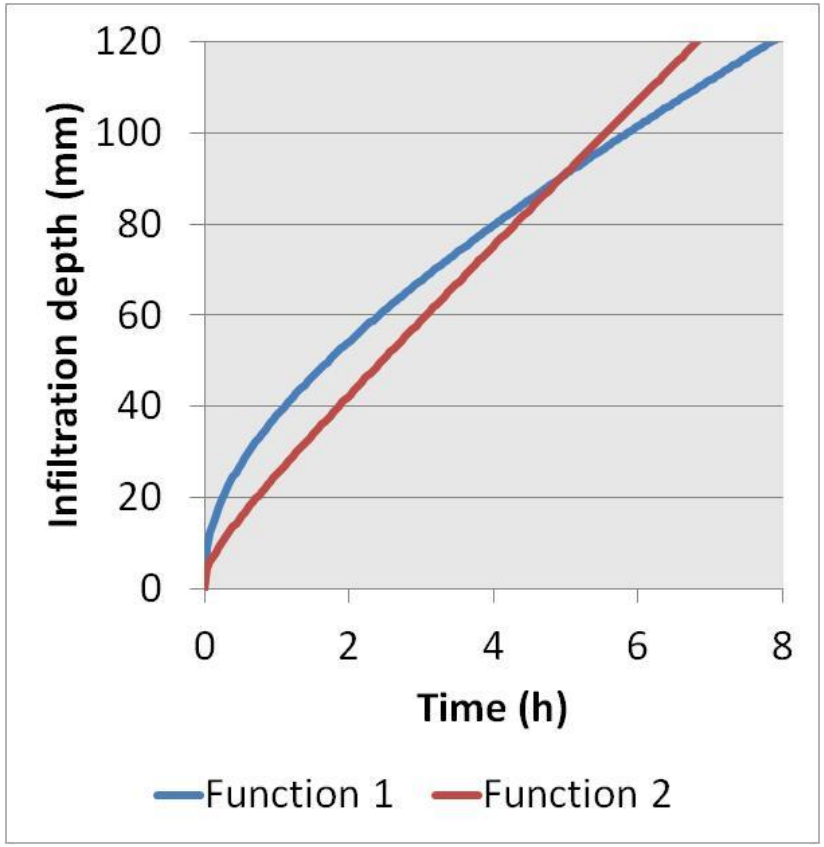
Characteristic Time Concept

- For a generic infiltration formulation:

$$D_{req} = f(T_{req}, \alpha_1, \alpha_2, ..., \alpha_n)$$

- If infiltration is represented with the Modified Kostiakov equation:

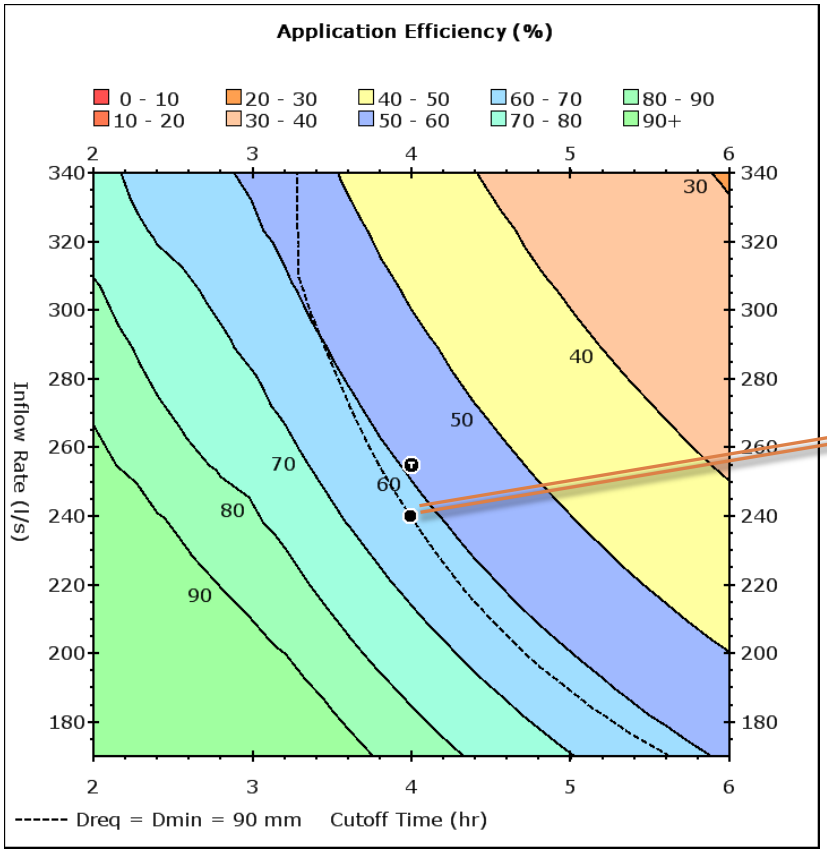
$$D_{req} = k \cdot T_{req}^{\ a} + b \cdot T_{req}$$

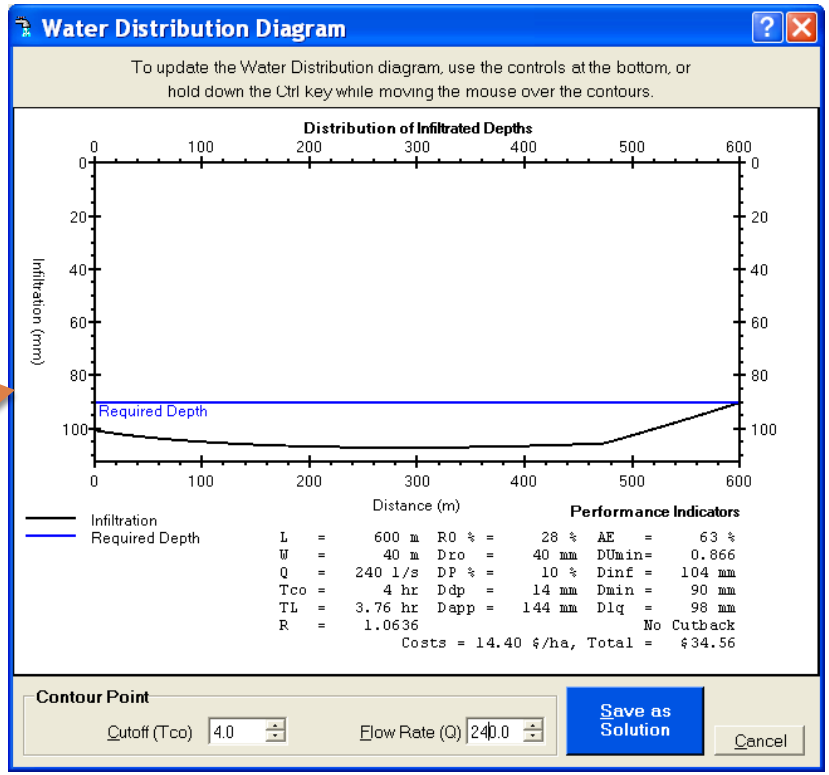


Operational Analysis Example

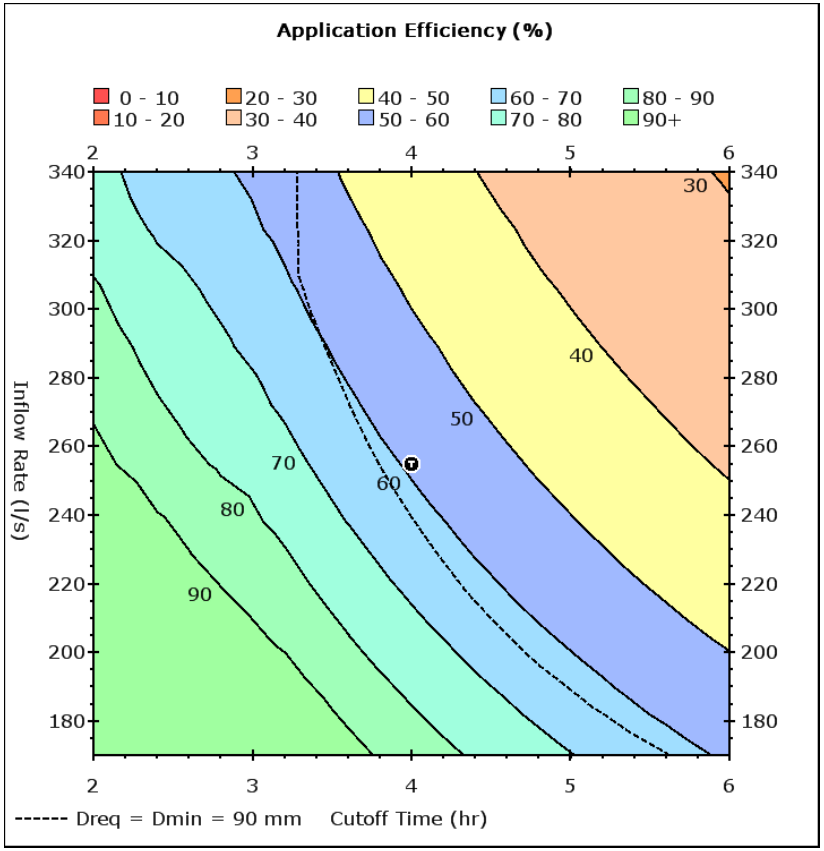
- Border
- 600 m long X 40 m wide
- Slope = 0.002
- Open-end
- Dreq = 90 mm
- Infiltration
  - Treq = 3.95 h
  - NRCS Intake Family
- Manning n = 0.15

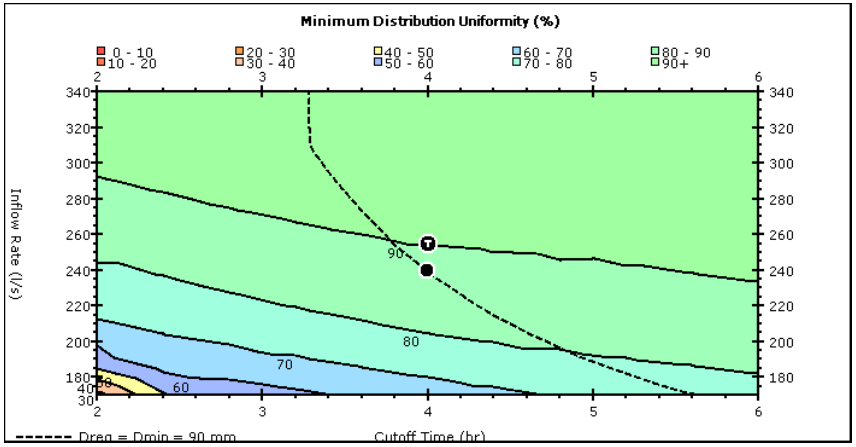
Operational Analysis Application Efficiency Contour

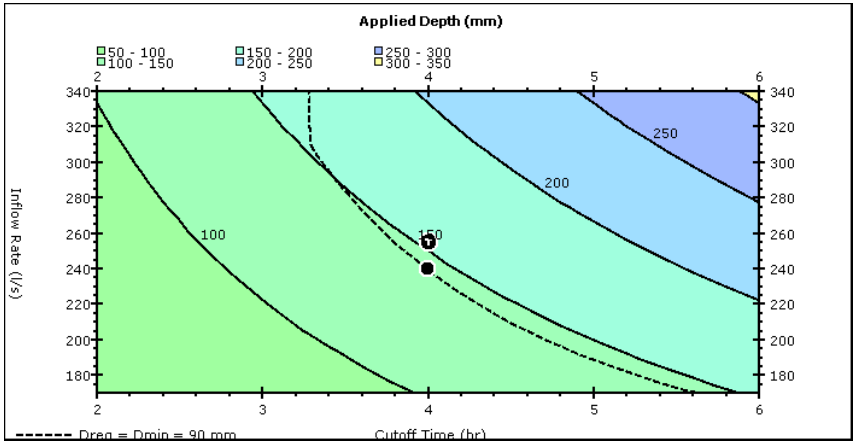




WinSRFR Operational Analysis Countours



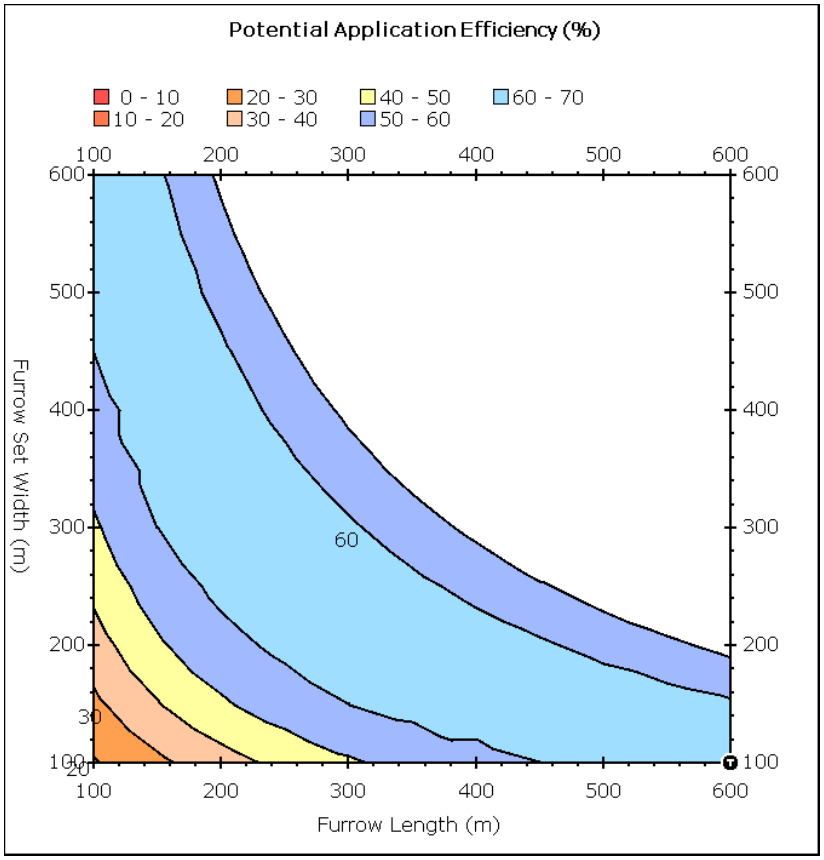


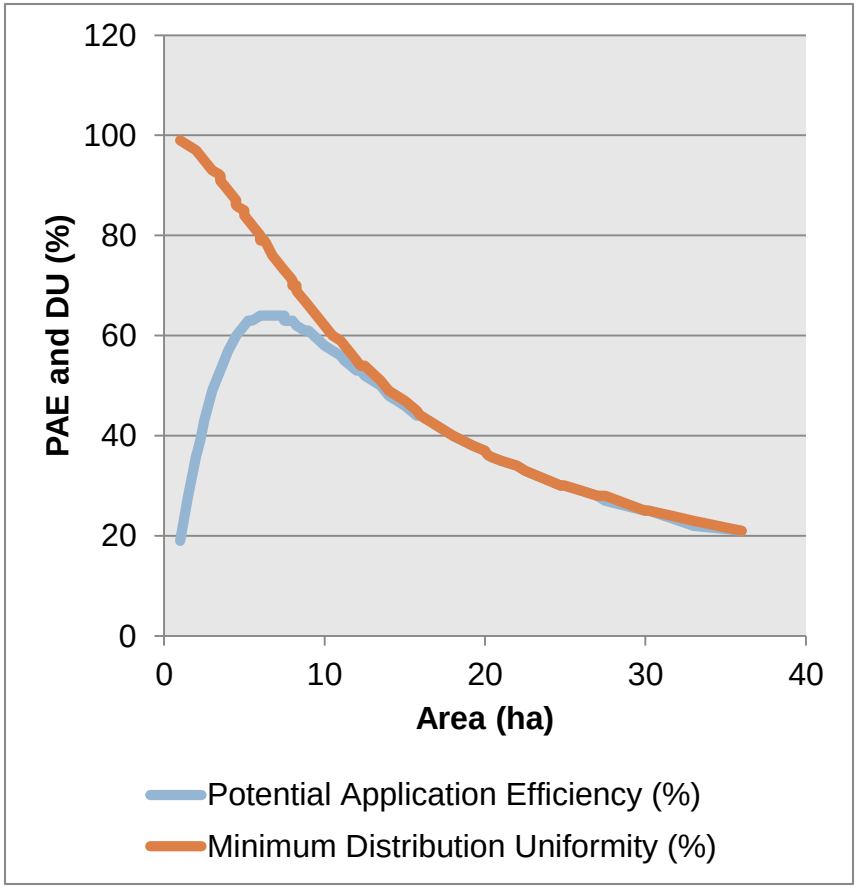


Design Example

- Furrow
- Slope = 0.002
- Open-end, no recovery
- Dreq = 90 mm
- Treq = 8.56 h
- Manning n = 0.04
- Qin = 150 l/s

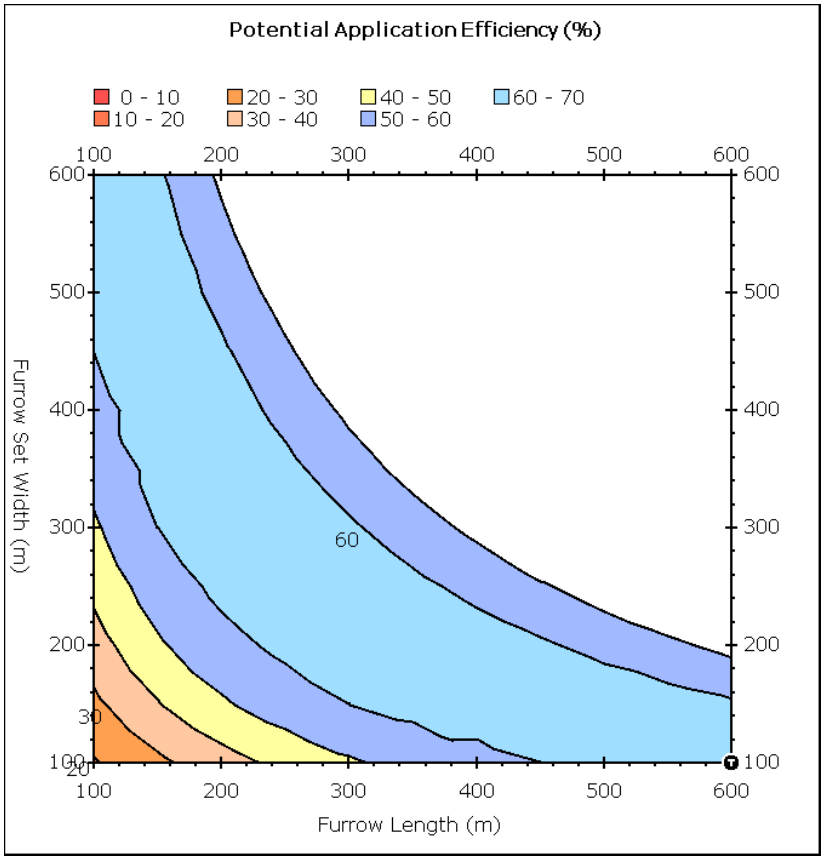
PAEmin Design Contour





What field layout should we recommend?

- Hydraulic performance
- Farm equipment
- Flow depth and velocity
- Sensitivity



Evaluating sensitivity to infiltration

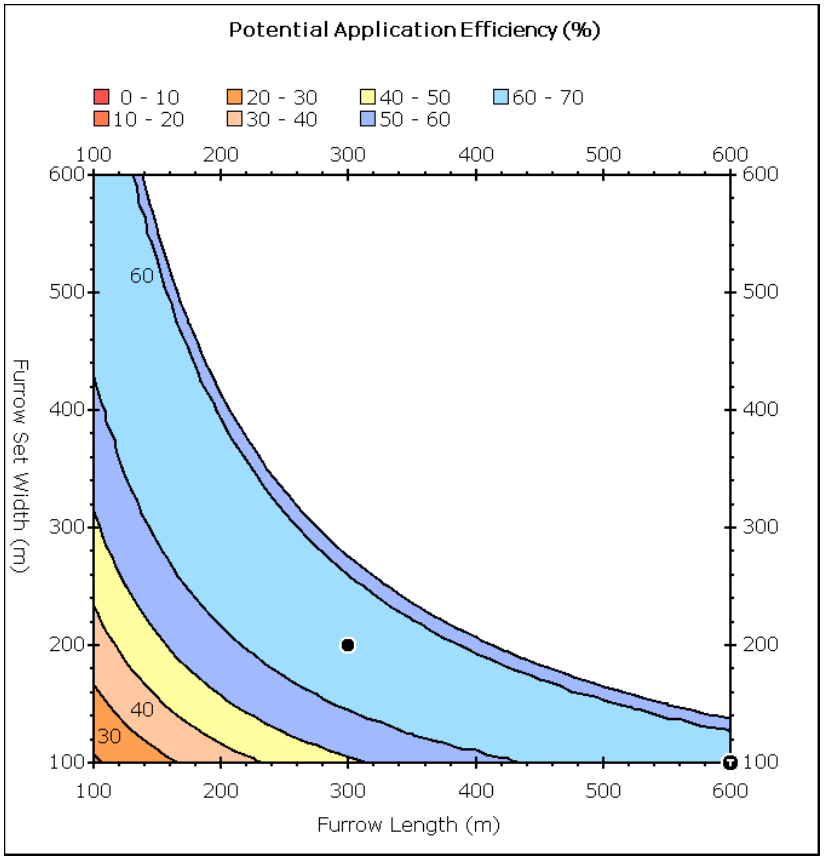
- Treq – opportunity time for Dreq
- λ – contribution of the steady infiltration rate term to Dreq

If infiltration is represented with the Modified Kostiakov equation:

$$D_{req} = k \cdot T_{req}^{\ a} + b \cdot T_{req}$$

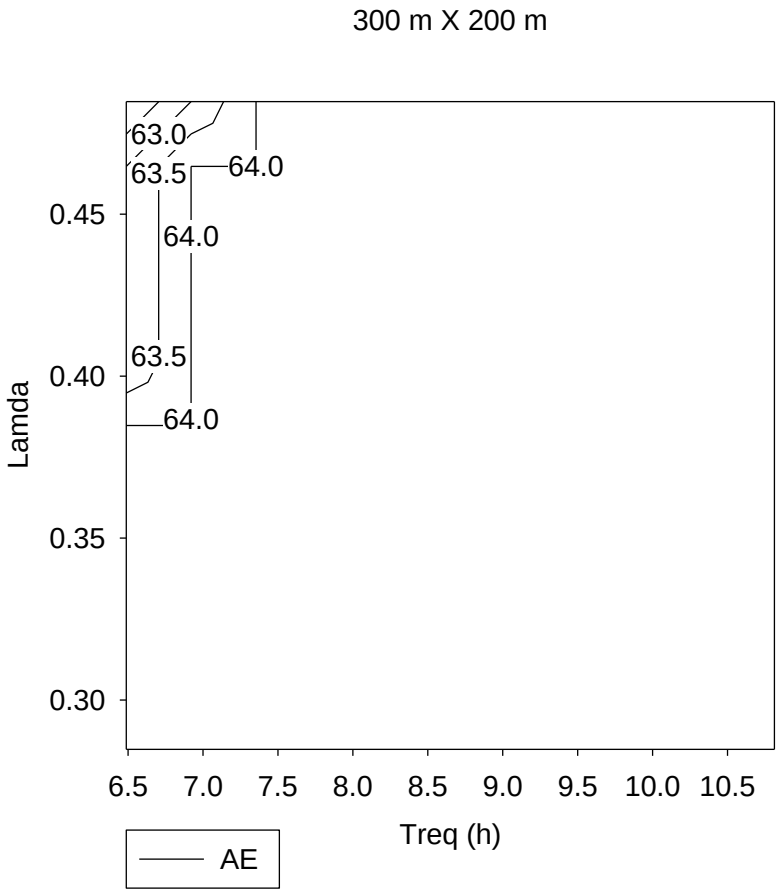
$$\lambda = \frac{bT_{req}}{D_{req}}$$

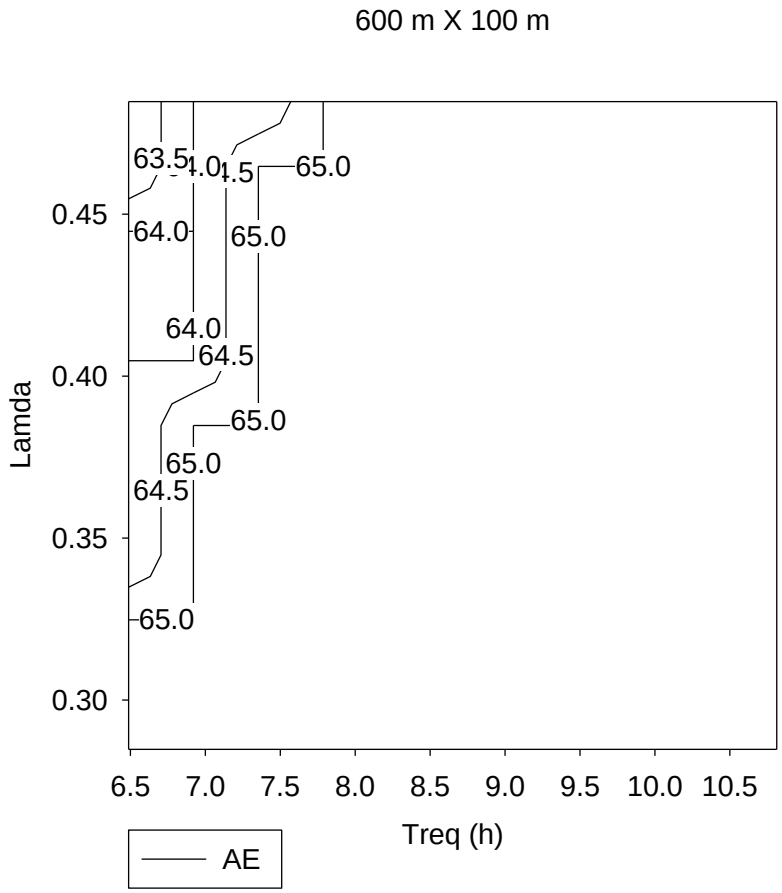
Sensitivity Analysis



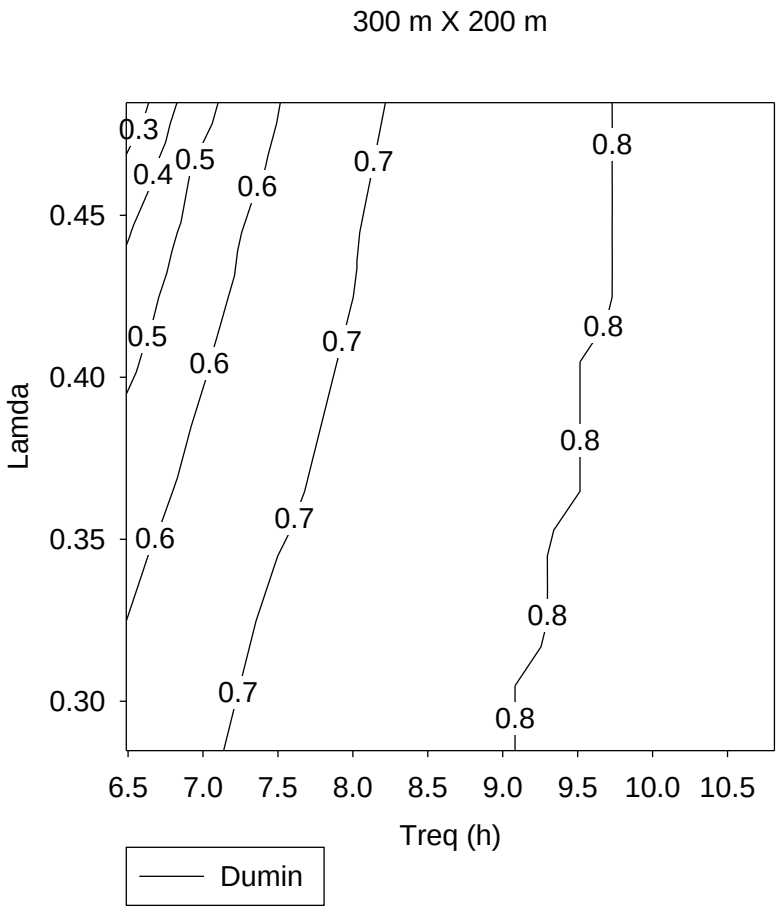
- Selected 2 solutions
  - 300 m * 200 furrows
  - 600 m * 100 furrows
- Both solutions yield similar PAEmin and Dumin
- Simulated each solution with varying infiltration, with Treq and λ as decision variables
- Simulations were conducted on an 11 X 11 grid
- Developed performance contours as a function of Treq and λ

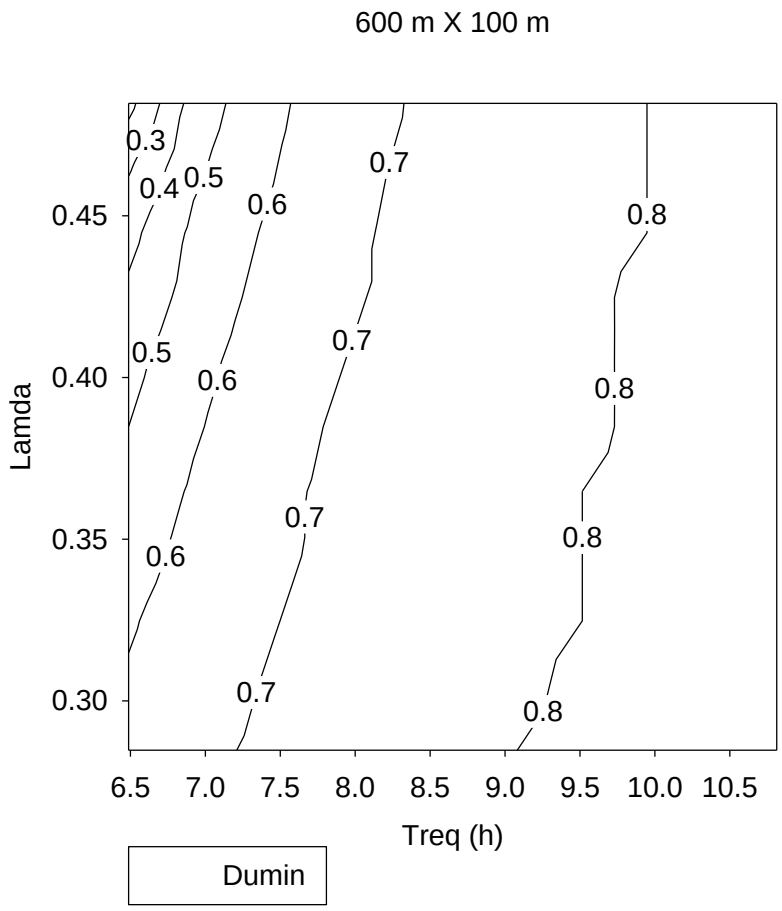
Application efficiency



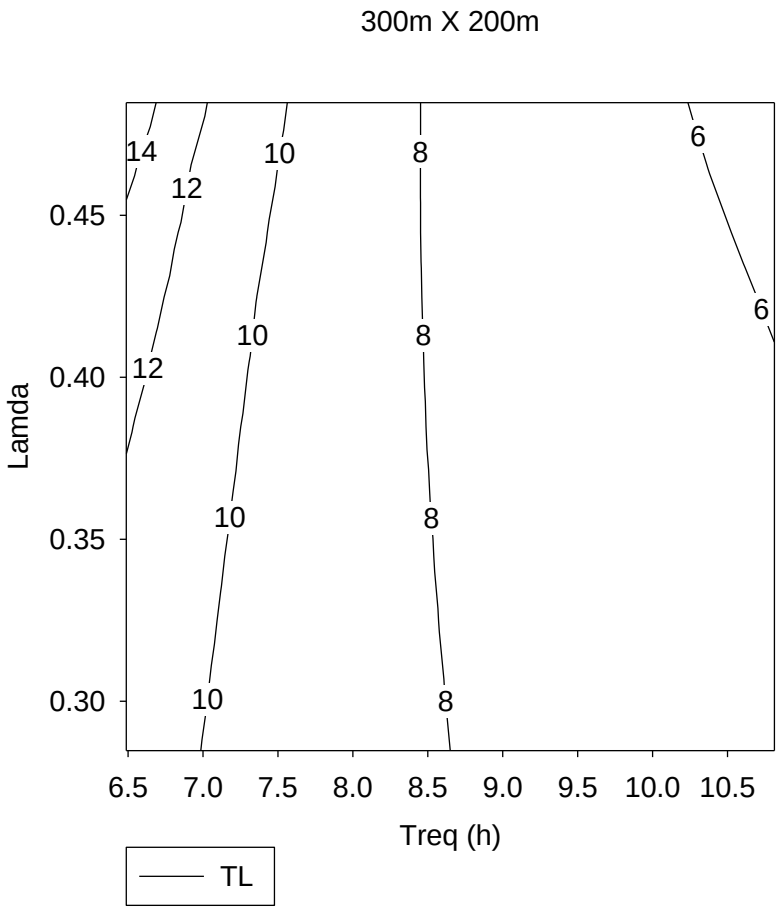


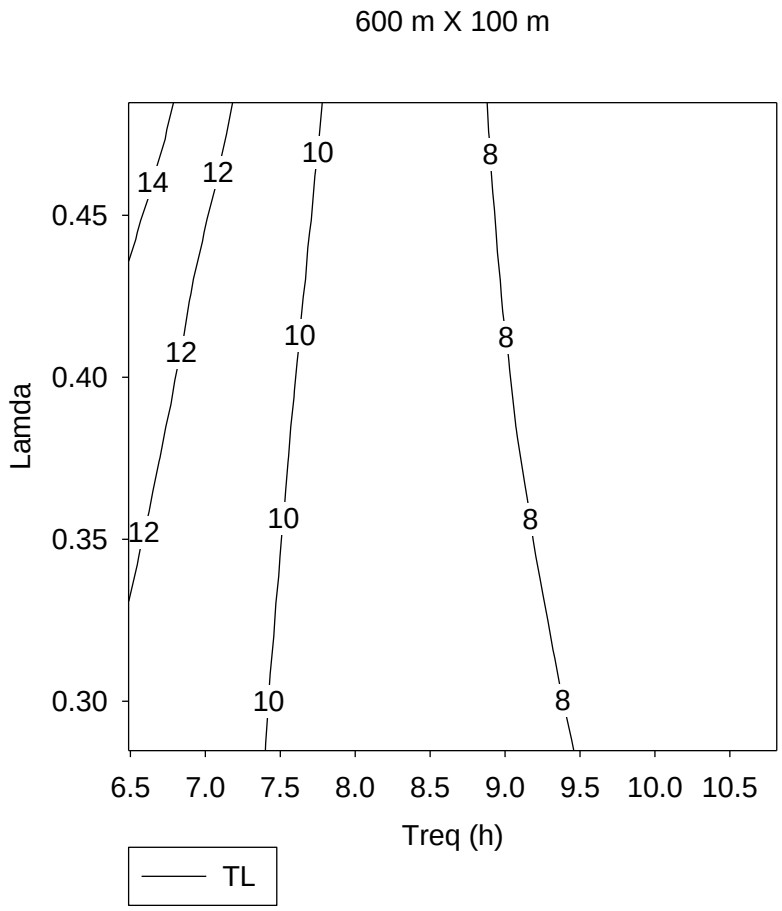
Distribution uniformity of the minimum





Final advance time





In Summary…

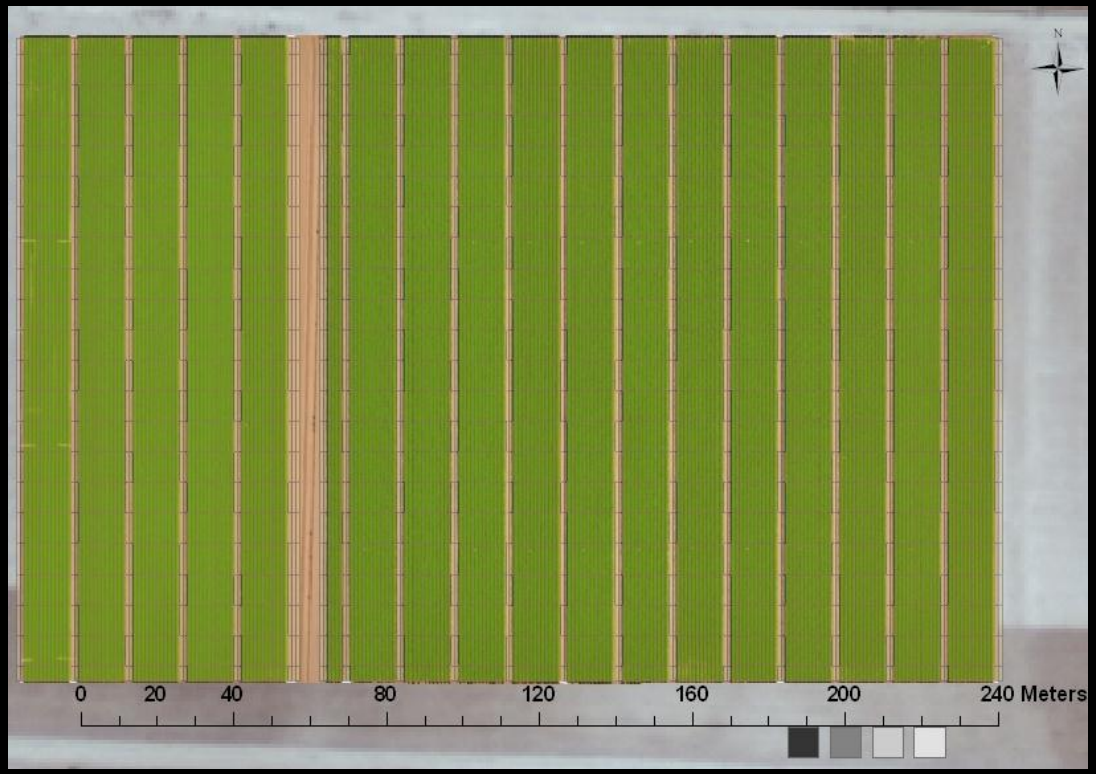
- Performance contours are powerful tools for understanding the performance of irrigation systems
- Sensitivity analysis are critical to the development of practical design and operational recommendations
- Knowledge of the steady-state infiltration rate is critical for operational and especially design analysis

Is this just theory?

Seasonal Irrigation Evaluations

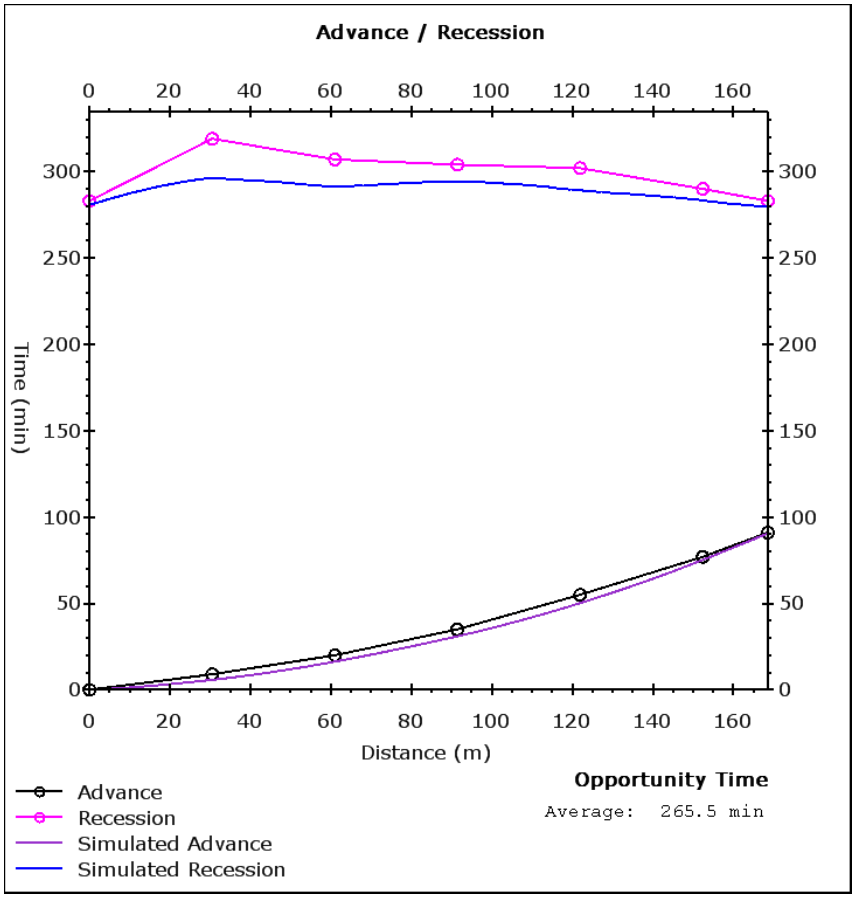
- Measure infiltration at the scale of irrigation sets
- Evaluate infiltration variability over the field and the irrigation season
- Examine relationship between infiltration spatial variability and soil physical properties
- Examine relationship between model-predicted and field-measured infiltration distribution uniformity.

Near-level furrow system,16 basins, 9 irrigation events

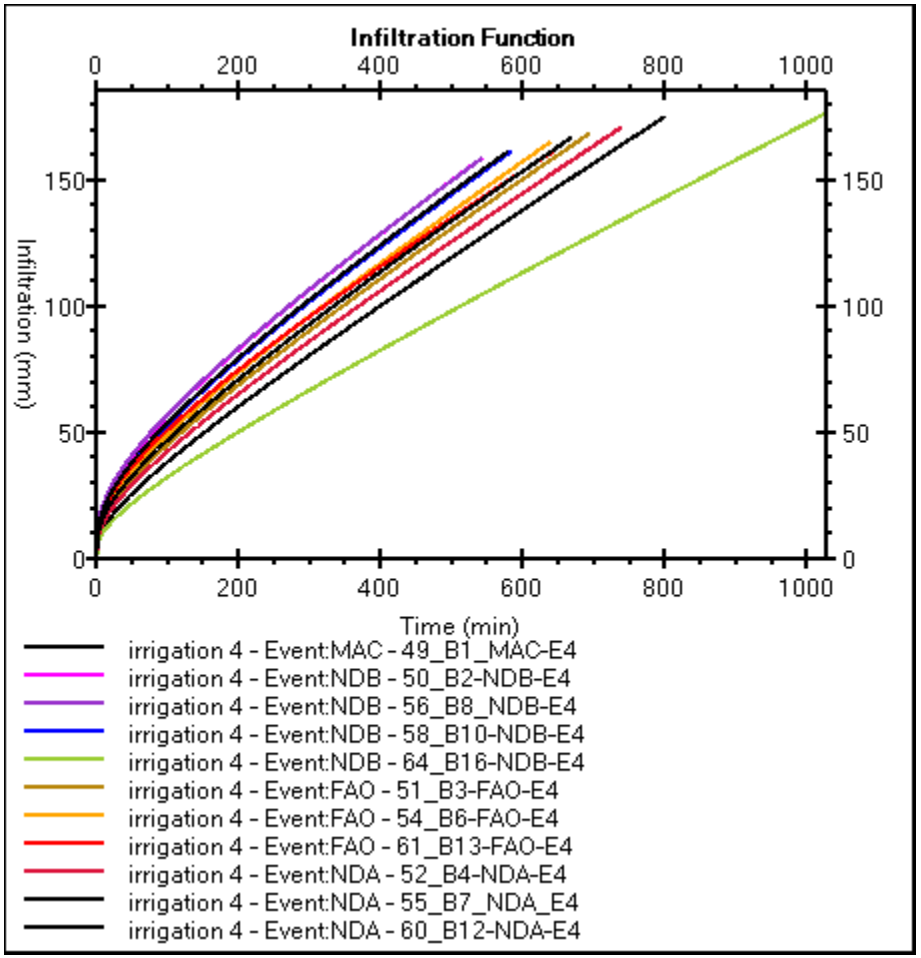


Evaluation of infiltration

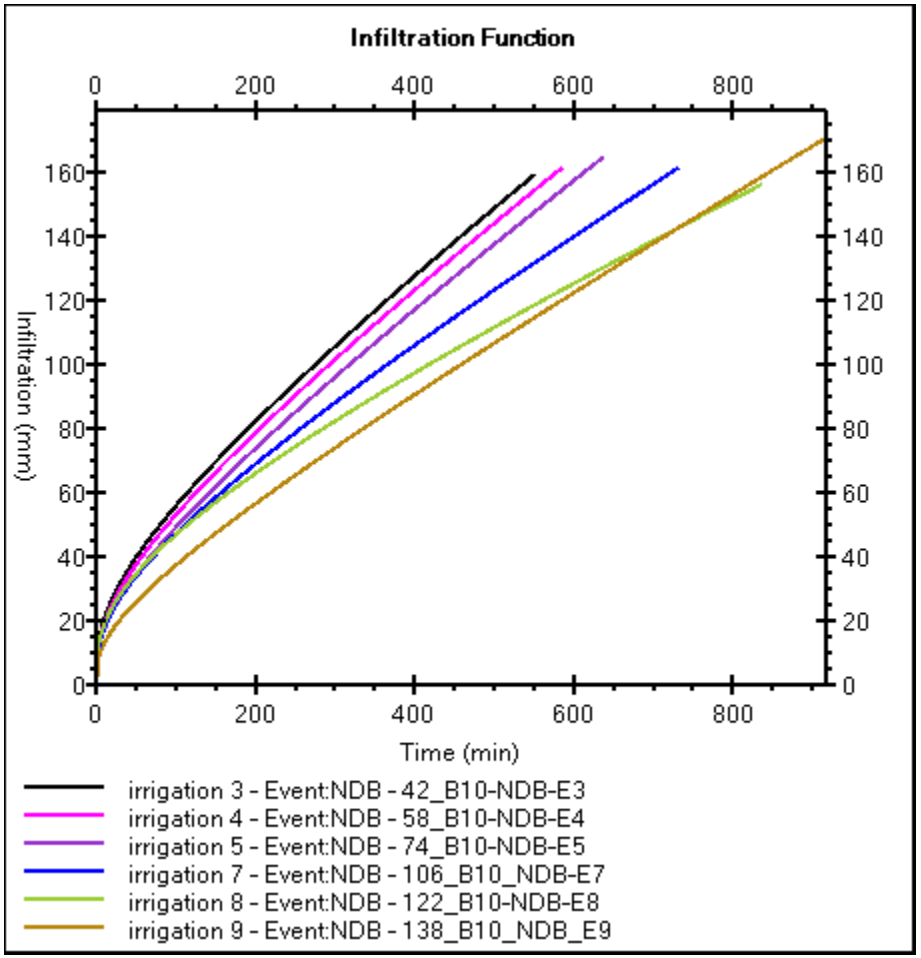
- Post-irrigation volume balance (Merriam-Keller, 1978)



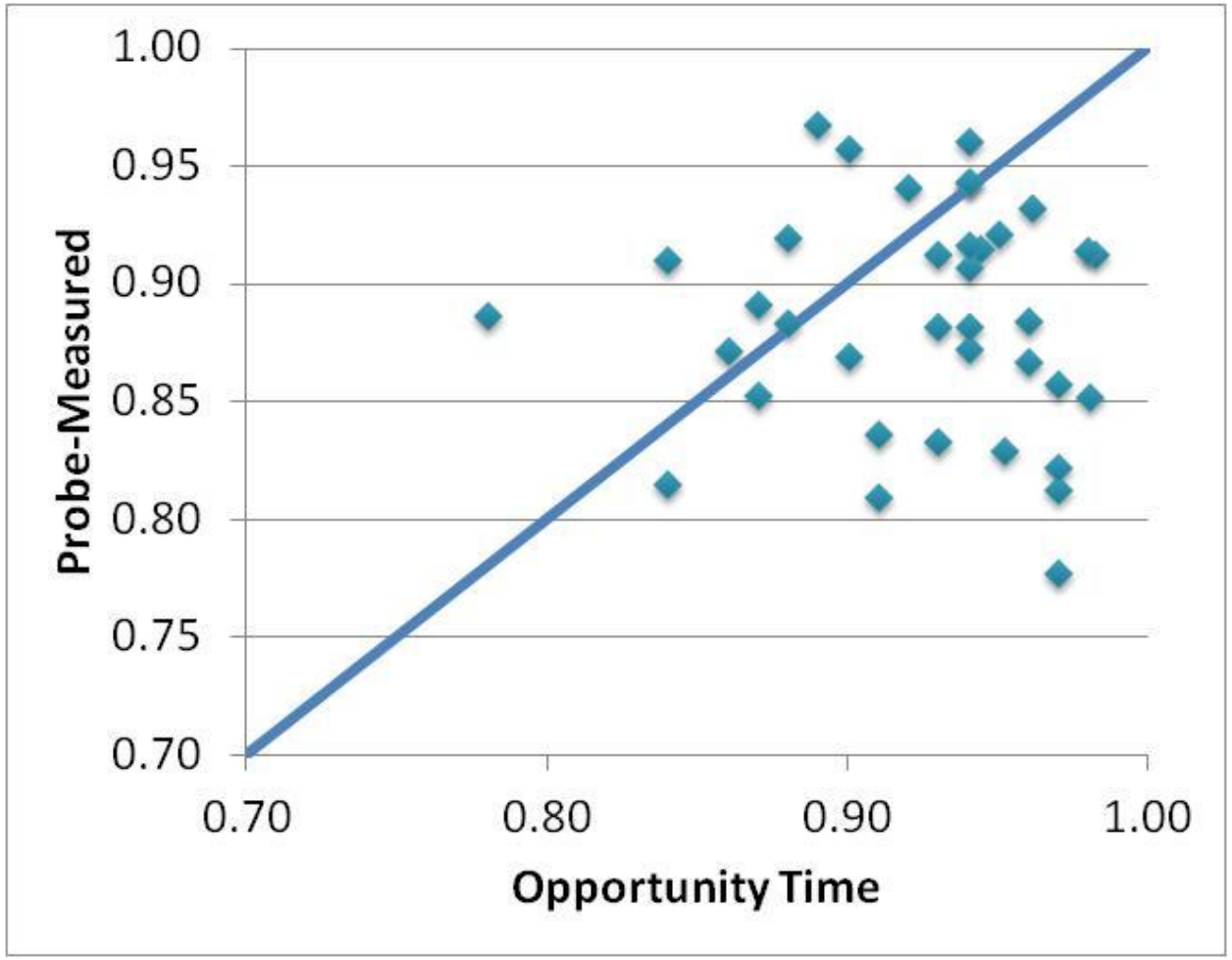
Spatial Variability of Infiltration: Irrigation 4



Temporal Infiltration Variability: Basin 10



Effect of Infiltration Variability on Distribution Uniformity

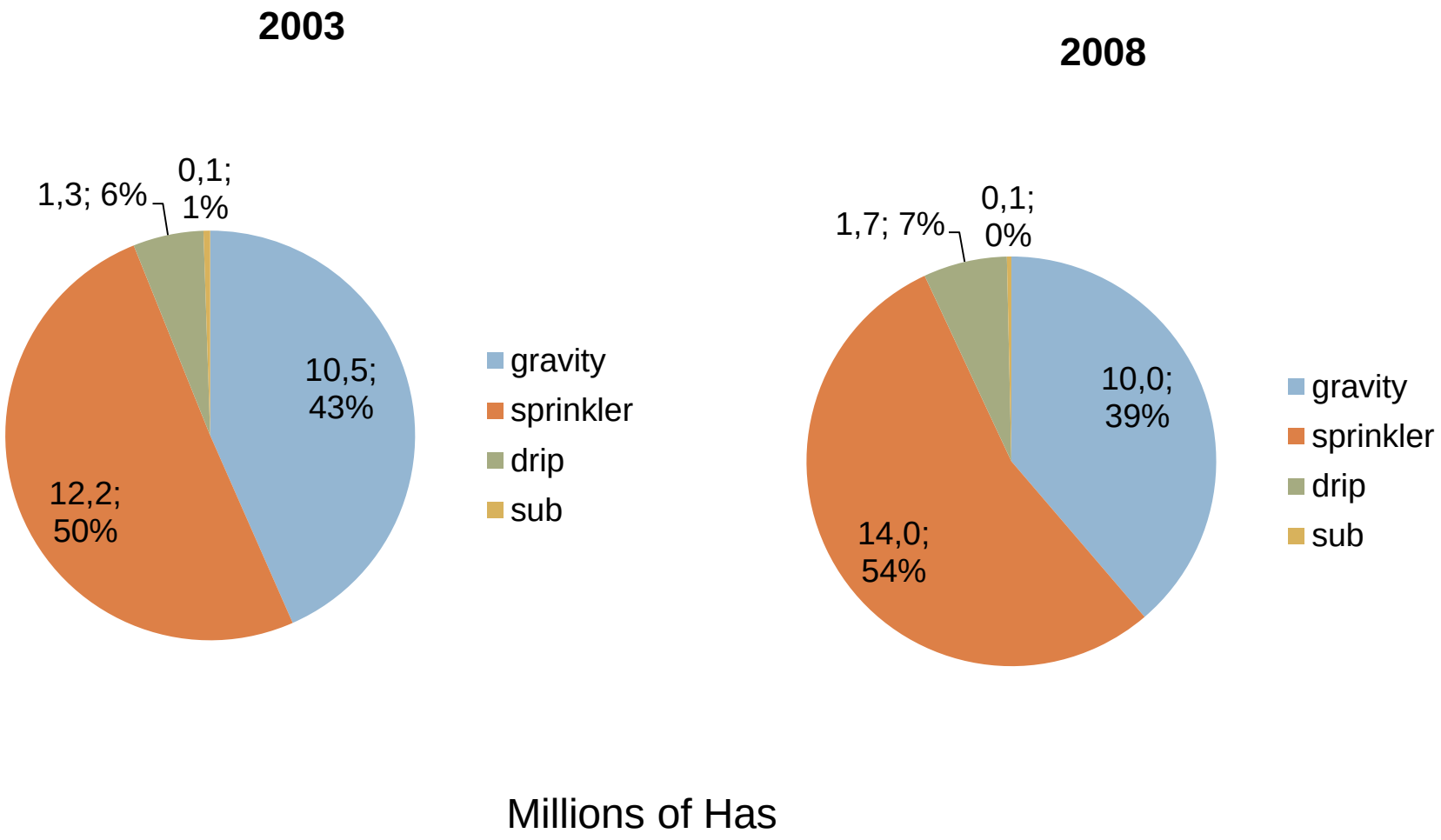


Can we trust irrigation models?

- No, if we are looking for accurate answers
- Yes, if we are looking for useful answers
- Factors to consider when using models
  - Uncertainty of inputs
  - Availability and quality of data
  - Theoretical and computational limitations

Questions?

Irrigation by water application method, USA (FRIS, 2010)



Irrigation by water application method, Arizona (FRIS, 2010)