

# Precipitation, Infiltration, Evapotranspiration, and Wind

**Alex Sánchez, Ph.D.**

Senior Hydraulic Engineer

USACE, Institute for Water Resources, Hydrologic Engineering Center



US Army Corps  
of Engineers®





# Overview

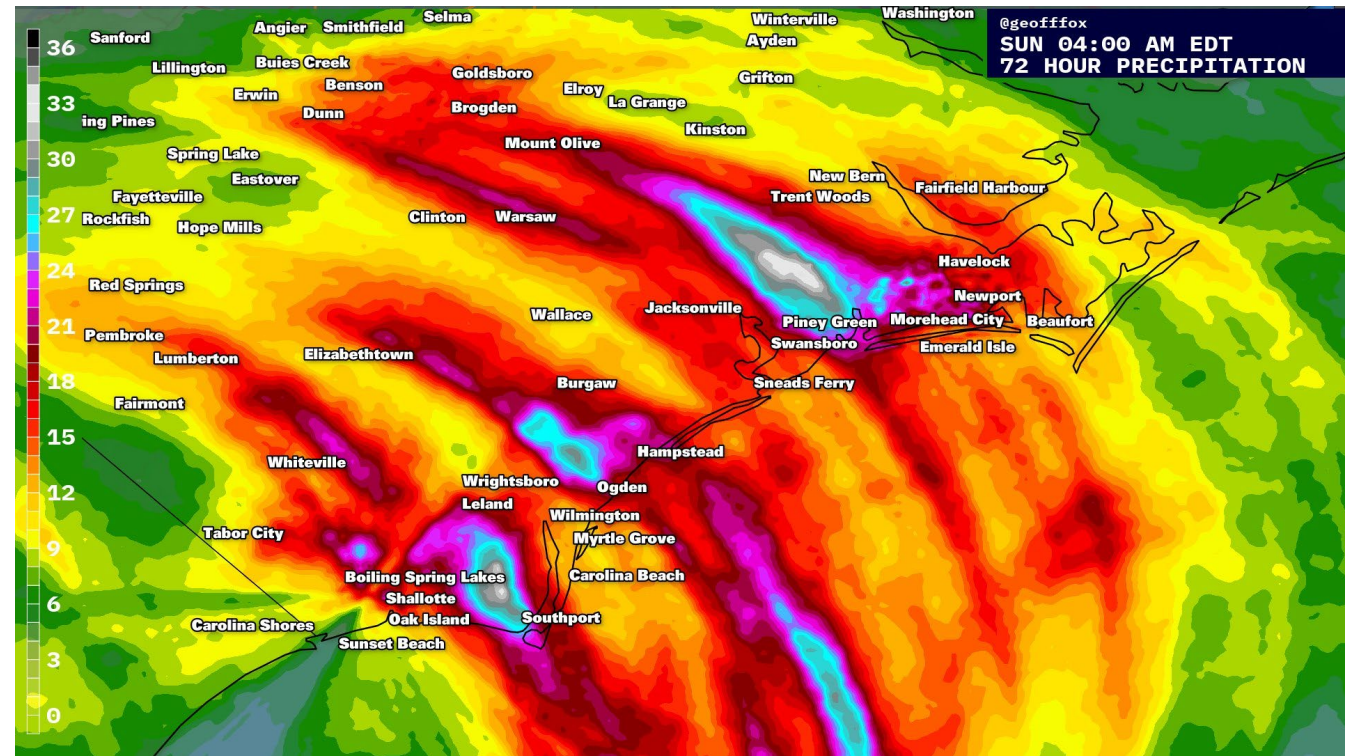
- Precipitation
  - Input Data Types
- Infiltration
  - Methods
  - Input Data
- Evapotranspiration
  - Methods
- Percent Impervious
- Wind
  - Formulation and Options
  - Input Data





# Precipitation

- Per 2D Flow Area
- Global
  - Constant Rate
  - Gridded Data
    - HEC-DSS file format (from HEC-MetView)
    - National Weather Service
      - GRIB
      - NetCDF
    - National Centers for Environmental Information
      - NetCDF
  - Point Gage Data
    - HEC-DSS time series
      - Regular Interval
      - Irregular Interval
    - User-specified time-series





# Boundary Conditions

- Single Hyetograph per 2D Flow Area

Precipitation Hydrograph

2D: BaldEagleCr

Read from DSS before simulation Select DSS file and Path

File:

Path:

Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 20JUN1972 Time: 0000

Fixed Start Time: Date:  Time:

No. Ordinates

Hydrograph Data			
	Date	Simulation Time (hours)	Precipitation (in)
1	19Jun1972 2400	0:00:00	0
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19	20Jun1972 2000	20:00:00	0.01
20	20Jun1972 1900	19:00:00	0.01
21	20Jun1972 2000	20:00:00	0.02

Precipitation Hydrograph

Unsteady Flow Data - Precipitation State College 1972

File Options Help

Description:

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

**Boundary Condition Types**

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	<b>Precipitation</b>		

**Add Boundary Condition Location**

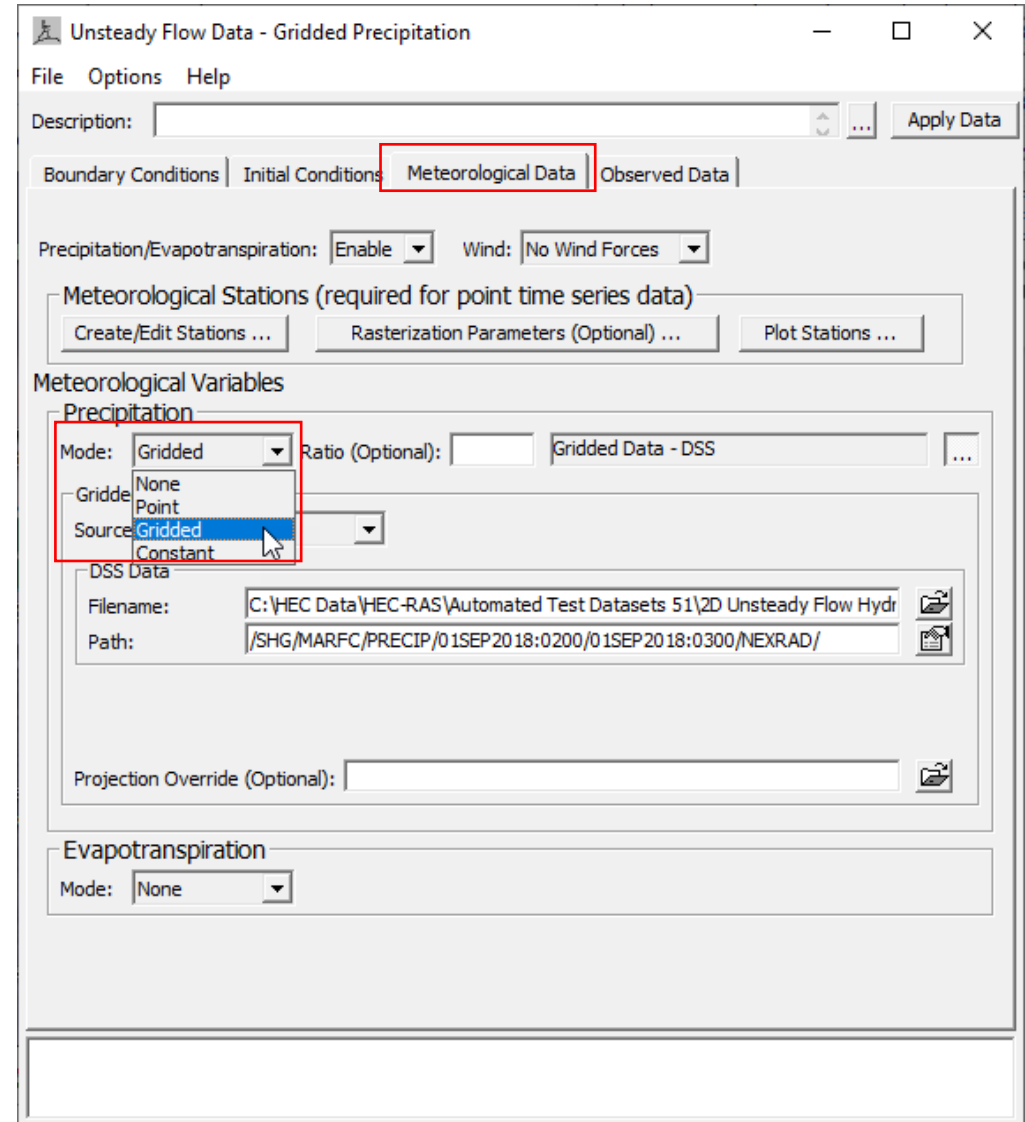
Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
<b>Storage/2D Flow Areas</b>			
1	BaldEagleCr		Precipitation
2	BaldEagleCr	BCLine: Upstream Inflow	Flow Hydrograph
3	BaldEagleCr	BCLine: DSNormalDepth	Normal Depth
<b>SA/2D Area Conns</b>			
1	Dam		T.S. Gate Openings



# Meteorological Data - Precipitation

- Gridded Data
  - HEC-DSS file format (from HEC-MetView)
  - National Weather Service
    - GRIB
    - NetCDF
  - National Centers for Environmental Information
    - NetCDF
- Meteorological Station Data
  - HEC-DSS time series
    - Regular Interval
    - Irregular Interval
  - User Entered into a Table
- Constant Rate

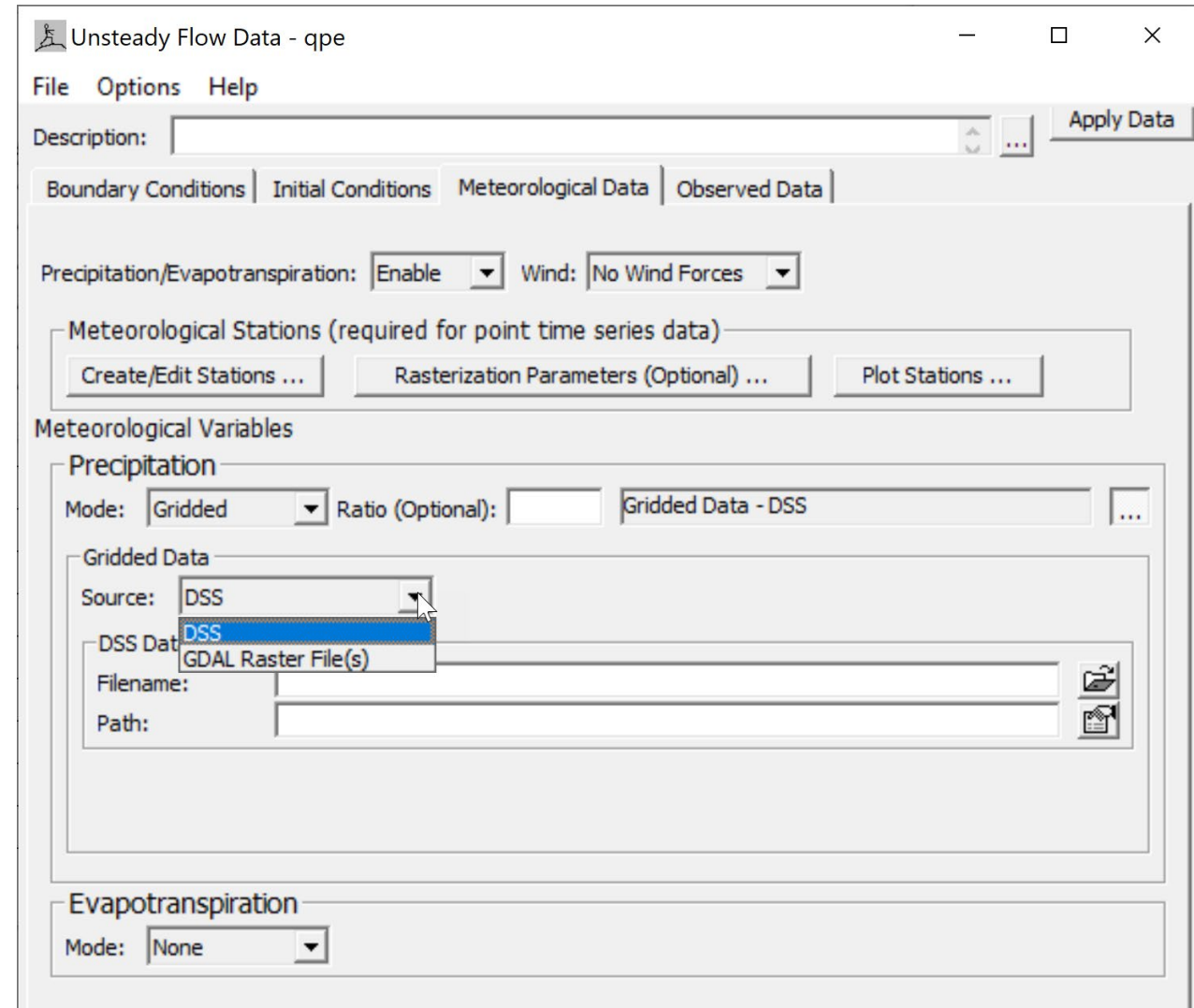






# Gridded Precipitation

- Input Formats
  - DSS Grids
  - GDAL Raster File(s)
    - NetNCDF
    - GRIB
    - etc.
- Ratio (Optional)
  - Used to scale precipitation





# Gridded Precipitation

- Projection Override
  - If data has a different projection from RAS project

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

Precipitation/Evapotranspiration:  Wind:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode:  Ratio (Optional):

Gridded Data

Source:

DSS Data:

Filename:

Path:

Projection Override (Optional):

Evapotranspiration

Mode:



# Gridded Precipitation - GRIB

Boundary Conditions | Initial Conditions | **Meteorological Data** | Observed Data

Precipitation/Evapotranspiration: **Enable** Wind: **No Wind Forces**

Meteorological Stations (required for point time series data)

Create/Edit Stations ... Rasterization Parameters (Optional) ... Plot Stations ...

Meteorological Variables

**Precipitation**

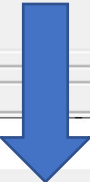
Mode: **Gridded** Ratio (Optional): Gridded Data - GDAL Raster File(s)

Gridded Data

Source: **GDAL Raster File(s)**

Import Grids from Files (NetCDF, GRIB, GDAL)

Import Raster Data ...



Import Gridded Data - Select Files

Select Single File

Filename: \_\_\_\_\_

Select Multiple Files

Folder: **C:\Data\Precip**

File Filter (\*.nc): **\*.grib2**

Show List of Filtered Files ...

Import Grids ... Cancel



Import Gridded Meteorology Datasets for Precipitation

Data Type: **per-cum** Units: **mm** (File Metadata: "[mm]") First Timestep Duration (Optional) \_\_\_\_\_ hrs

Filename	Band Index	Use Band	Timestamp	Forecast Time
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-000000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 00:0...	2018-09-08 00:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-010000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 01:0...	2018-09-08 01:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-020000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 02:0...	2018-09-08 02:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-030000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 03:0...	2018-09-08 03:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-040000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 04:0...	2018-09-08 04:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-050000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 05:0...	2018-09-08 05:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-060000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 06:0...	2018-09-08 06:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-070000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 07:0...	2018-09-08 07:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-080000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 08:0...	2018-09-08 08:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-090000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 09:0...	2018-09-08 09:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-100000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 10:0...	2018-09-08 10:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-110000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 11:0...	2018-09-08 11:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-120000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 12:0...	2018-09-08 12:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-130000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 13:0...	2018-09-08 13:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-140000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 14:0...	2018-09-08 14:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-150000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 15:0...	2018-09-08 15:0...
.MRMS_GaugeCorr_QPE_01H_00.00_20180908-160000.grib2	1	<input checked="" type="checkbox"/>	2018-09-08 16:0...	2018-09-08 16:0...

Check Ok Cancel





# Point Gage Precipitation

Unsteady Flow Data - Point Precipitation Data 1972

File Options Help

Description:  ... Apply Data

Boundary Conditions Initial Conditions Meteorological Data Observed Data

Precipitation/Evapotranspiration:  Wind:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode:  Ratio (Optional):  Point Time Series Mode

Point Time Series Data

Interpolation Method:

	Station Name	Summary
1	ALVIN BUSH DAM	DSS: data range = 0.000 to 0.500 (inches)
2	DRIFTWOOD	DSS: data range = 0.000 to 0.390 (inches)
3	HOLLIDAYSBURG 2	DSS: data range = 0.00 to 2.90 (inches)
4	PHILIPSBURG 8 E	DSS: data range = 0.000 to 0.550 (inches)
5	WILLIAMSPORT RGNL AP	DSS: data range = 0.000 to 0.850 (inches)
6	CRESSON 1 SE	DSS: data range = 0.000 to 0.470 (inches)
7	CURWENSVILLE LAKE	DSS: data range = 0.000 to 0.300 (inches)

Evapotranspiration

Mode:

Meteorological Stations

Detailed

	Point Name	Gauge Height(m)	Latitude	Longitude	Project X	Project Y
1	ALVIN BUSH DAM	10	41.35	-77.9166667	1922740.6	431189.94
2	DRIFTWOOD	10	41.3383333	-78.1333333	1863234.88	427128.04
3	HOLLIDAYSBURG 2	10	40.4272222	-78.3888889	1790610.4	95591.73
4	MILROY 2 WNW	10	40.7138889	-77.5905556	2012703.14	199422.25
5	PHILIPSBURG 8 E	10	40.8963889	-78.2205556	1838408.6	266227.39
6	RAYSTOWN LAKE 2	10	40.4333333	-78.0069444	1896963.52	97268.31
7	TYRONE	10	40.6705556	-78.2386111	1832952.79	183975.72
8	WILLIAMSPORT RGNL AP	10	41.2452	-76.9188889	2197049.88	394058.28
9	CRESSON 1 SE	10	40.45	-78.5916667	1734232.01	104373.03
10	CURWENSVILLE LAKE	10	41.05	-78.41	1786461.52	322534.71
11	DU BOIS 7 E	10	41.1208333	-78.7583333	1690689.7	349266.08
12	MADERA 2 SE	10	40.8283333	-78.435	1778927.51	241828.17
13	MTI HFTM	10	40.8908333	-77.4766667	2044073.29	263969.12



# Point Gage Precipitation

**Unsteady Flow Data - Point Precipitation Data 1972**

File Options Help

Description: [ ] [Apply Data]

Boundary Conditions | Initial Conditions | **Meteorological Data** | Observed Data

Precipitation/Evapotranspiration: **Enable** Wind: **No Wind Forces**

**Meteorological Stations (required for point time series data)**

[Create/Edit Stations ...] **Rasterization Parameters (Optional) ...** [Plot Stations ...]

**Meteorological Variables**

**Precipitation**

Mode: **Point** Ratio (Optional): [ ] Point Time Series Mode (Thiessen Poly)

Point Time Series Data

Interpolation Method: **Thiessen Polygon** [Edit ..]

Station Name	Summary
1 ALVIN BUSH DAM	DSS: data range = 0.000 to 0.500 (inches)
2 DRIFTWOOD	DSS: data range = 0.000 to 0.390 (inches)
3 HOLLIDAYSBURG 2	DSS: data range = 0.00 to 2.90 (inches)
4 PHILIPSBURG 8 E	DSS: data range = 0.000 to 0.550 (inches)
5 WILLIAMSPORT RGNL AP	DSS: data range = 0.000 to 0.850 (inches)
6 CRESSON 1 SE	DSS: data range = 0.000 to 0.470 (inches)
7 CURWENSVILLE LAKE	DSS: data range = 0.000 to 0.300 (inches)

**Evapotranspiration**

Mode: **None**

**Raster Parameters**

Left: 1600000 Top: 450000 Rows: 200 Cols: 350 Cell Size: 2000

Fix Raster Parameters based on current Met Stations Extent

Fix Raster Parameters based on current Met Stations and Current Geometry Extent

Clear (use Met Stations Extent at runtime)

[Plot Raster Extents ...] [OK] [Cancel]

**Meteorological Stations**

Plot | Table

700000  
600000  
500000  
400000  
300000  
200000  
100000  
0  
-100000

1400000 1600000 1800000 2000000 2200000 2400000 2600000 (ft)

**Legend**

- SA/2D
- Meteorological Stations
- User-Defined Raster Param Extent
- Met Sta - Default



# Point Gage Interpolation Methods

Unsteady Flow Data - Point Precipitation Data 1972

File Options Help

Description:

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

Precipitation/Evapotranspiration:  Wind:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode:  Ratio (Optional):  Point Time Series Mode (Thiessen Polygon)

Point Time Series Data

Interpolation Method:

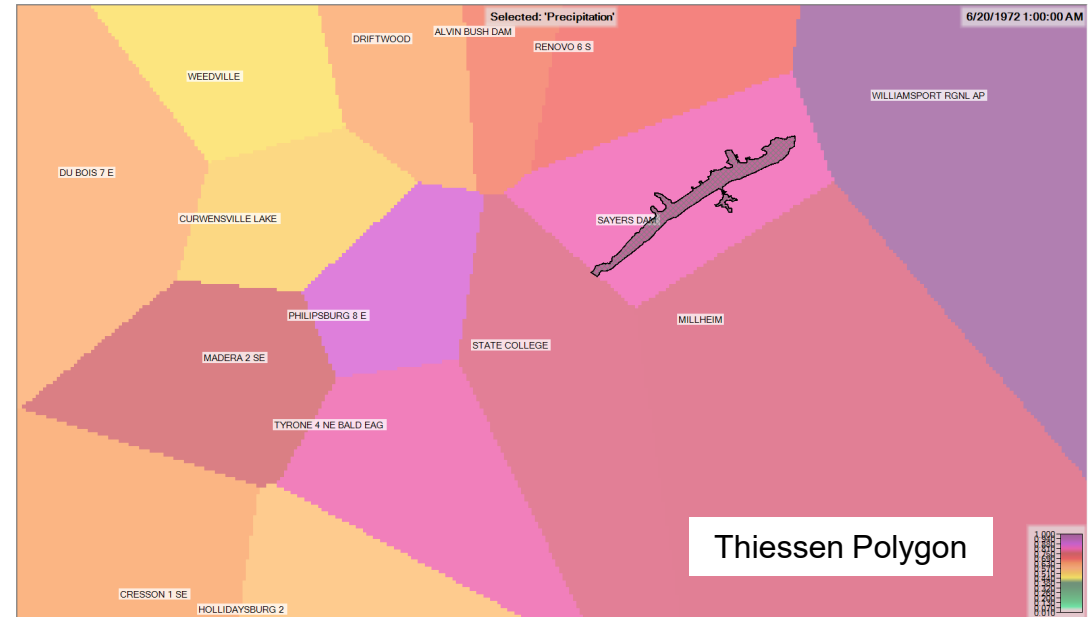
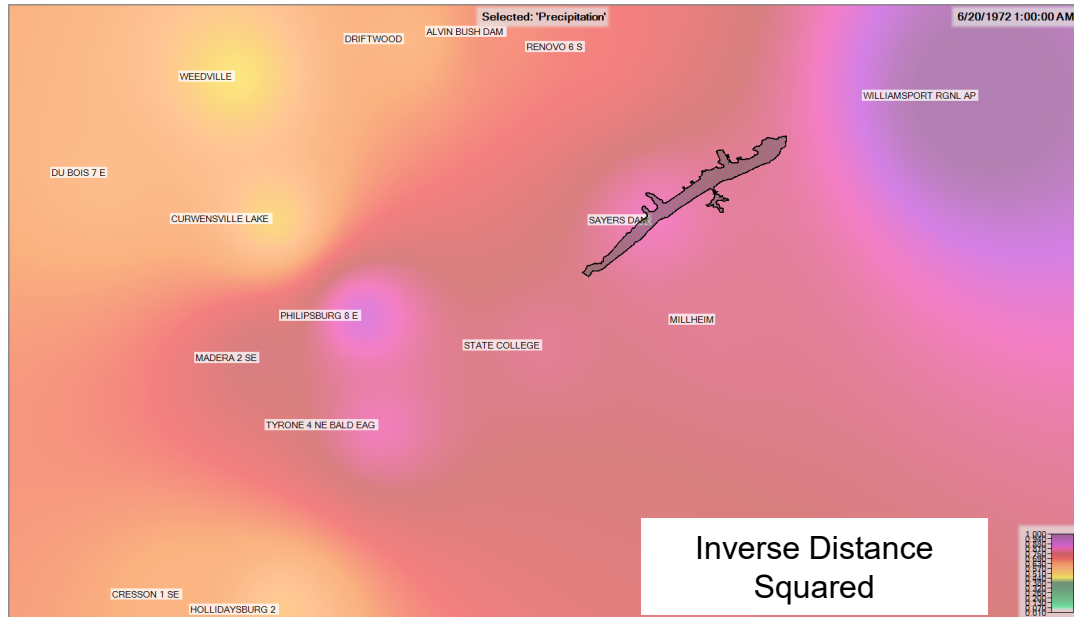
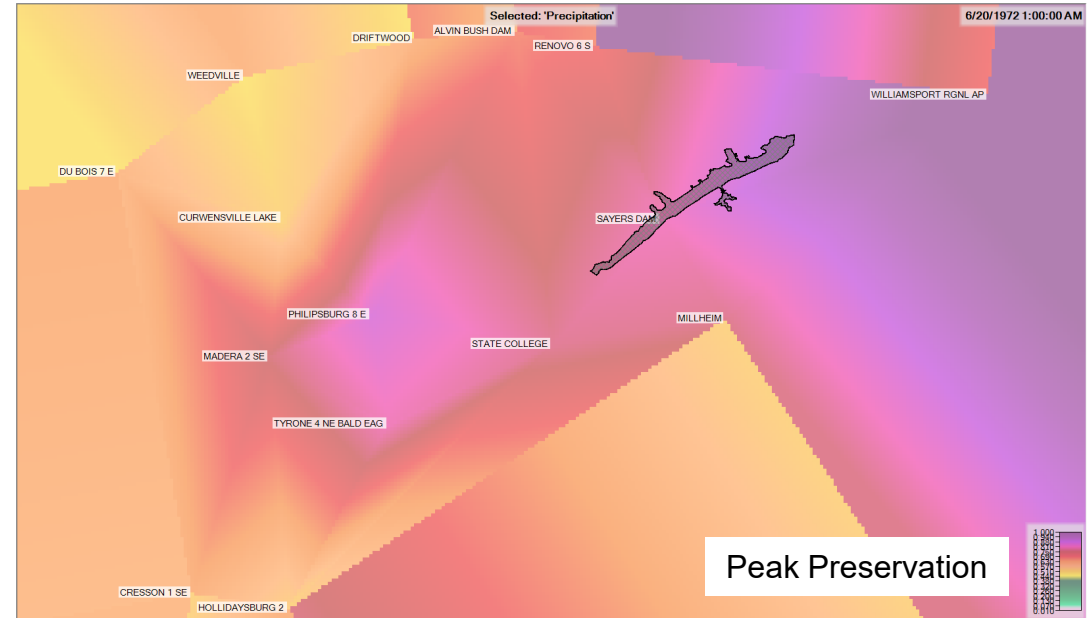
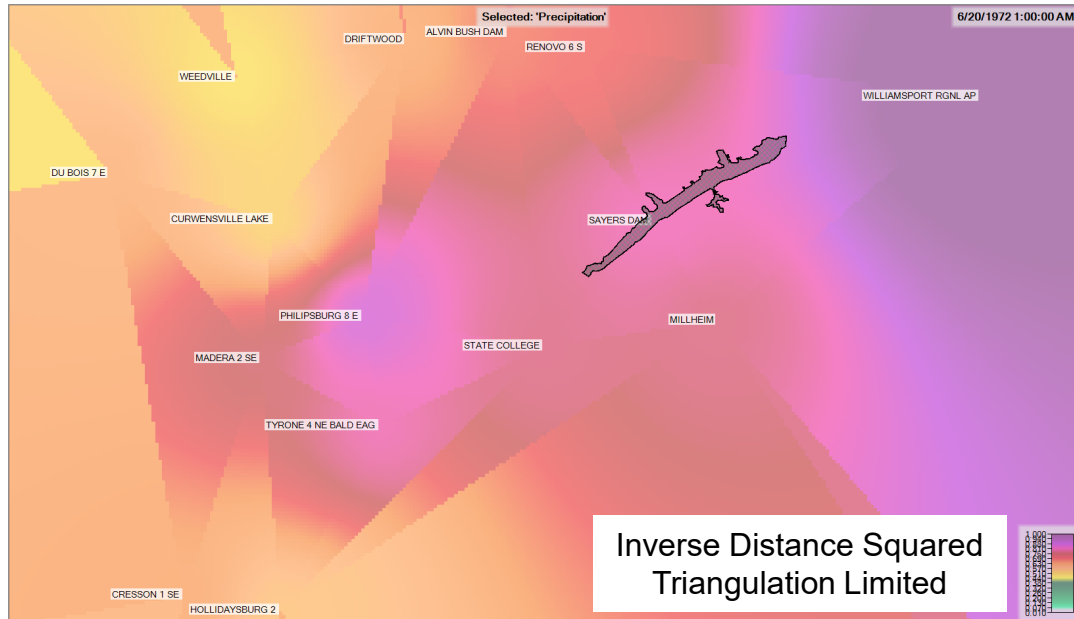
Station Name	Interpolation Method	Distance	Edit
1 ALVIN BUSH DAM	Inv Distance	to 0.500 (inches)	...
2 DRIFTWOOD	Inv Distance Sq	to 0.390 (inches)	...
3 HOLLIDAYSBURG	Inv Distance Sq (Restricted)	to 2.90 (inches)	...
4 PHILIPSBURG 8 E	Triangulation	to 0.550 (inches)	...
5 WILLIAMSPORT	Peak Preservation	to 0.850 (inches)	...
6 CRESSON 1 SE	Shape Preservation	DSS: data range = 0.000 to 0.470 (inches)	...
7 CURWENSVILLE LAKE	Laplace	DSS: data range = 0.000 to 0.300 (inches)	...

Evapotranspiration

Mode:

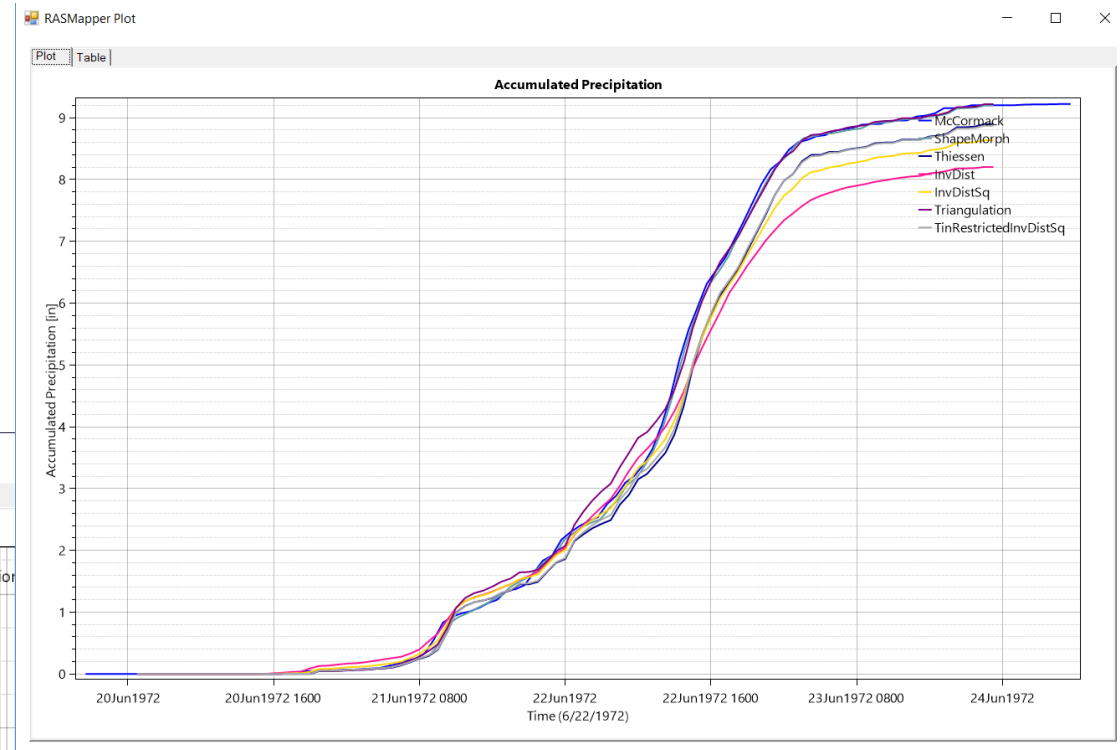
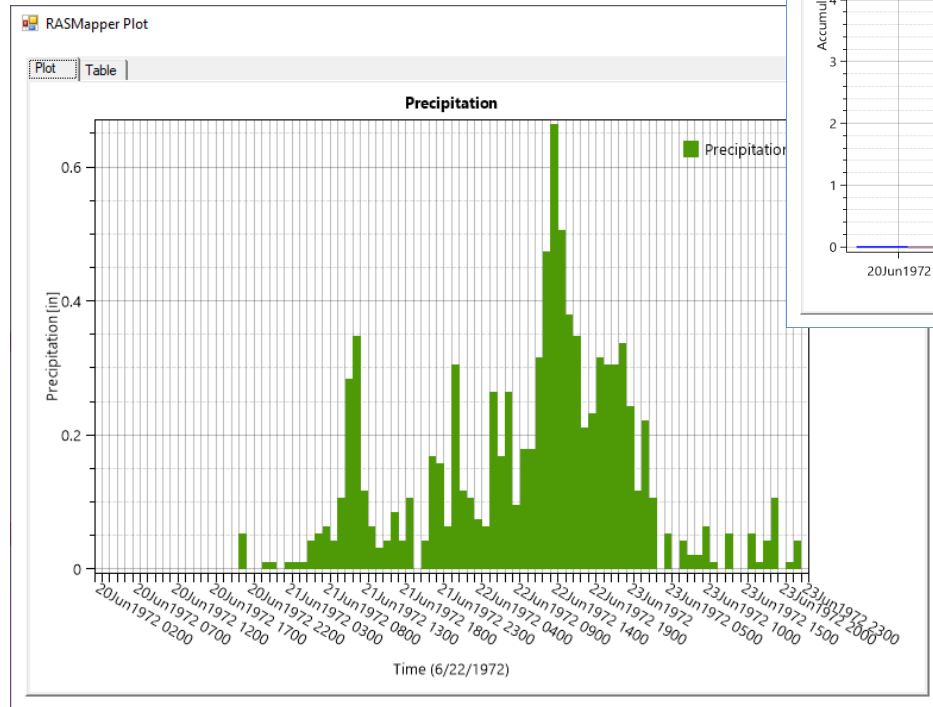


# Cumulative Rainfall





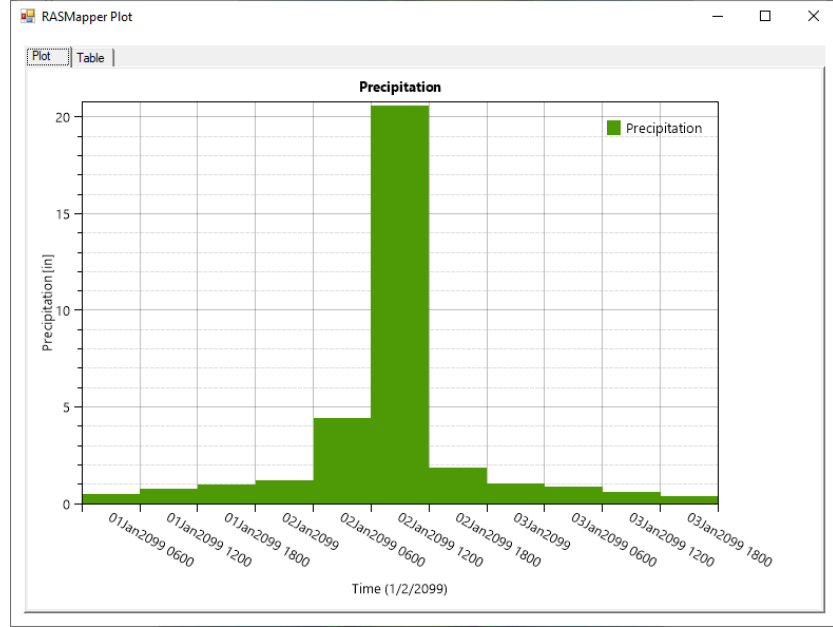
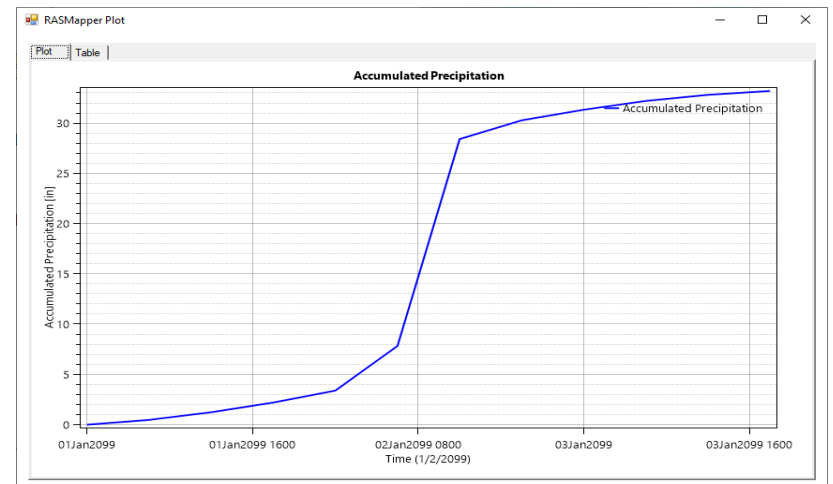
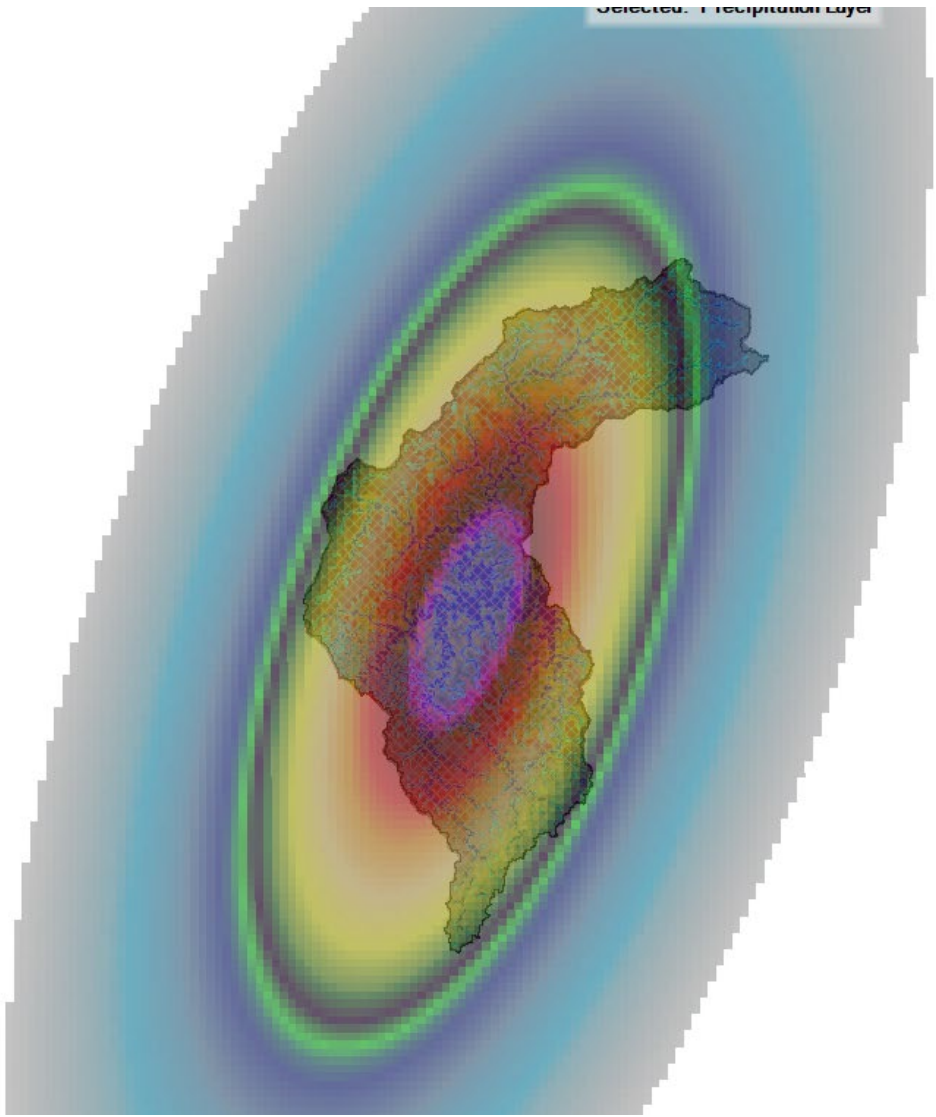
# Rainfall Time Series Plots







# Probable Max Precipitation Example





# Infiltration



- Computed at 1D XS's, Storage Areas, and 2D Cells
- Supported in all Equation Sets
- Methods
  - Deficit-Constant (DC)
  - SCS Curve Number (CN)
  - Green and Ampt without (GA) and with Redistribution (GAR)
- Parameterization based on
  - Soils
  - Land cover
- Other Optional Data
  - Percent Impervious

# Deficit-Constant Method

- Governing Equation

$$\frac{dD}{dt} = E_v - f + p$$

where

$D$  : Soil moisture deficit [L]

$E_v$  : Soil evaporatranspiration [L/T]

$f$  : Infiltration [L/T]

$p$  : Percolation [L/T]

- Input

- ▶ Initial deficit [L]
- ▶ Maximum deficit [L]
- ▶ Potential percolation rate (loss rate) [L/T]

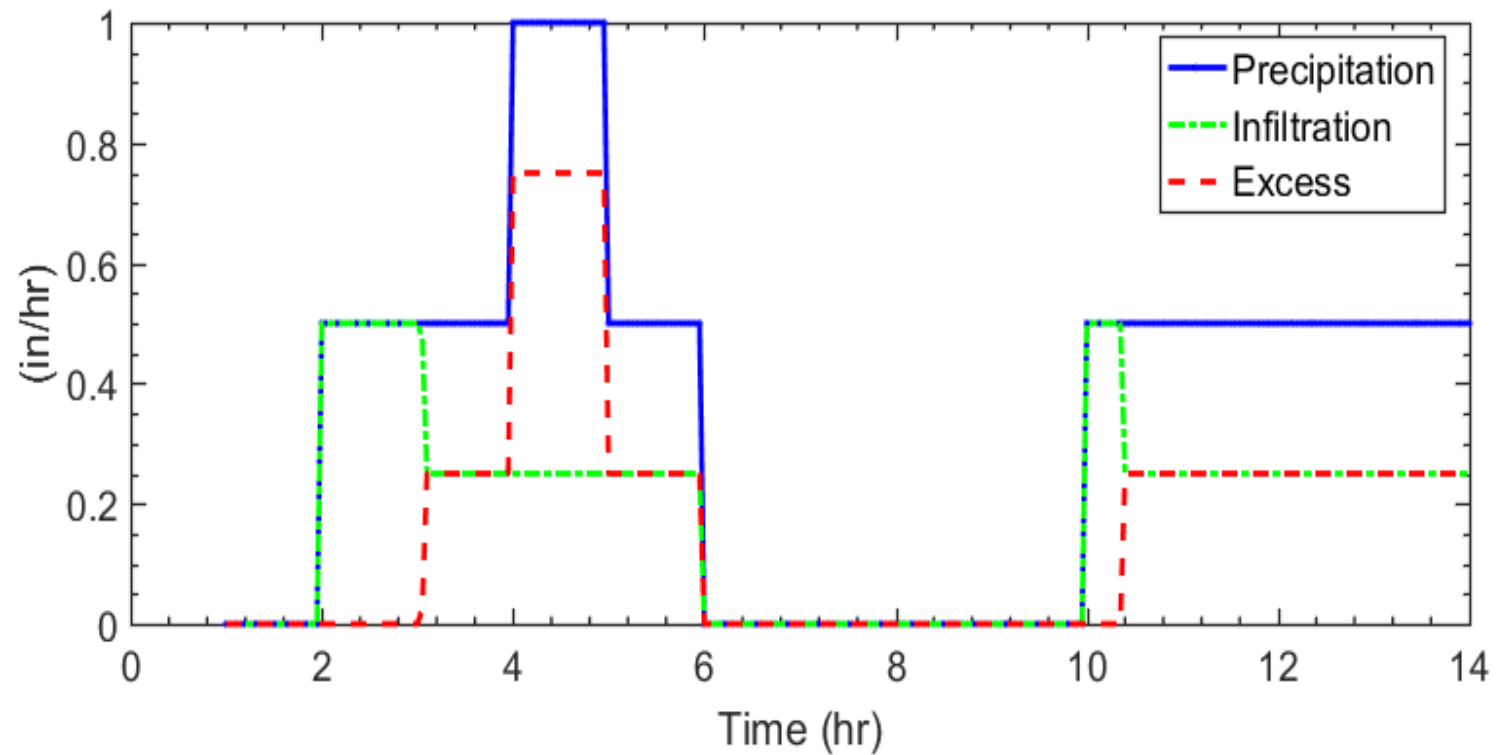
SCS Soil Group	Description	Loss Rates (in/hr)
A	Deep sand, deep loess, aggregated silts	0.3 - 0.45
B	Shallow loess, sandy lam	0.15 - 0.30
C	Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay	0.05 - 0.15
D	Soils that swell significantly when wet, heavy plastic clays, and certain saline soils	0.00 – 0.05



# Deficit-Constant Verification

- Comparison with HEC-HMS dataset from PROSPECT Class

Time (hrs)	Precipitation (in)	Deficit (in)	Loss (in)	Excess (in)
1	0.0	0.5	0.0	0.0
2	0.5	0.0	0.5	0.0
3	0.5	0.0	0.25	0.25
4	1.0	0.0	0.25	0.75
5	0.5	0.0	0.25	0.25
6	0.0	0.05	0.0	0.0
7	0.0	0.1	0.0	0.0
8	0.0	0.15	0.0	0.0
9	0.0	0.2	0.0	0.0
10	0.5	0	0.35	0.15
11	0.5	0	0.25	0.25
12	0.5	0	0.25	0.25
13	0.5	0	0.25	0.25
14	0.5	0	0.25	0.25



# SCS Curve Number Method

## Equations

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \quad S = \frac{1000}{CN} - 10 \quad I_a = r_a S$$

where

$P_e$  : Accumulated excess depth [L]

$P$  : Accumulated rainfall depth [L]

$CN$  : Curve number [-]

$I_a$  : Initial abstraction [L]

$r_a$  : Abstraction ratio [-]

$S$  : Potential maximum retention [L]

## Input

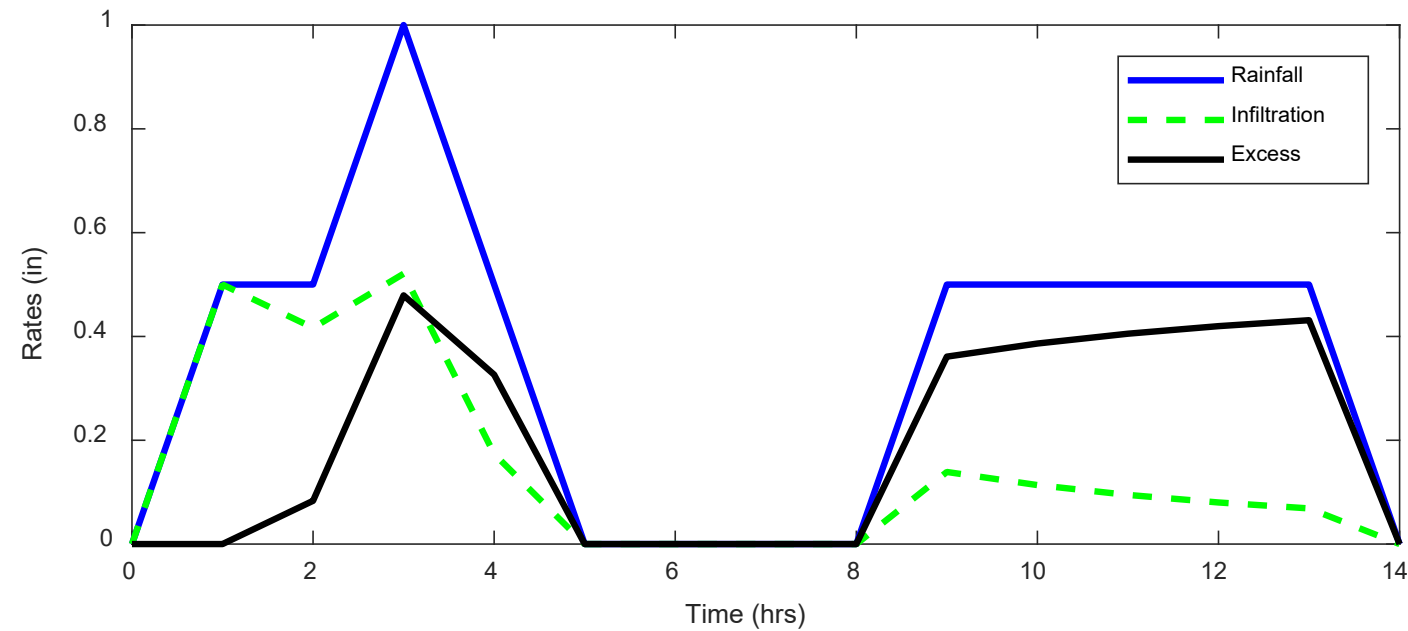
- ▶ Curve Number
- ▶ Abstraction ratio
- ▶ Minimum infiltration rate (optional)
- ▶ Dry period used to reset method (optional)

Cover			Hydrologic Soil Group			
Land Use	Treatment or Practice	Hydrologic Condition	A	B	C	D
Fallows	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
Contoured and terraced	Poor	66	74	80	82	
	Good	62	71	78	81	
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range	Contoured	Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
		Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads (dirt)			72	82	87	89
			74	84	90	92
Roads (hard surface)						





# SCS CN Verification



		HEC-HMS	Computed	HEC-HMS	Computed
Time	Precip (in)	Loss (in)	Loss (in)	Excess (in)	Excess (in)
1:00	0	0	0	0	0
2:00	0.5	0.5	0.5	0	0
3:00	0.5	0.417	0.4167	0.083	0.0833
4:00	1	0.521	0.5208	0.479	0.4792
5:00	0.5	0.174	0.1736	0.326	0.3264
6:00	0	0	0	0	0
7:00	0	0	0	0	0
8:00	0	0	0	0	0
9:00	0	0	0	0	0
10:00	0.5	0.139	0.1389	0.361	0.3611
11:00	0.5	0.114	0.1136	0.386	0.3864
12:00	0.5	0.095	0.0947	0.405	0.4053
13:00	0.5	0.08	0.0801	0.42	0.4199
14:00	0.5	0.069	0.0687	0.431	0.4313



# Green-Ampt Method

- Equations

$$\frac{dF}{dt} = f \quad f = \min(f_*, R) \quad f_* = K_s \left( 1 + \frac{\psi \theta_d}{F} \right)$$

where

$f$  : Infiltration potential [L/T]

$f_*$  : Infiltration potential (infiltration rate given unlimited [L/T]

$R$  : Rainfall [L/T]

$\psi$  : Wetting front suction [L]

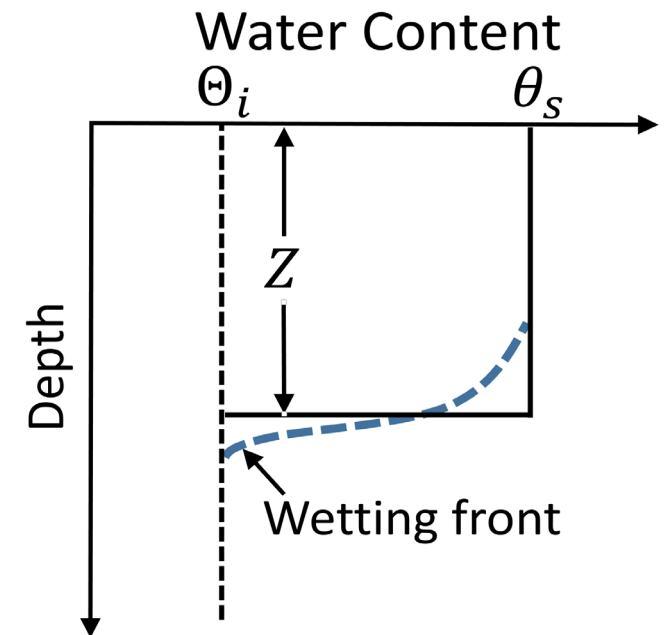
$K_s$  : Saturated hydraulic conductivity [L/T]

$F$  : Cumulative infiltration depth [L]

$\theta_d = \theta_s - \theta_i$  : Moisture deficit [-]

$\theta_s$  : Saturated moisture content [-]

$\theta_i$  : Initial moisture content [-]





# Green-Ampt Input Parameters

- GA
  - ▶ Initial soil water content [-]
  - ▶ Saturated hydraulic conductivity []
  - ▶ Wetting Front Suction [L]
- GAR (optional)
  - ▶ Same GA plus
  - ▶ Residual Water Content [-]
  - ▶ Pore-size distribution index
  - ▶ If either parameter is missing GA is used

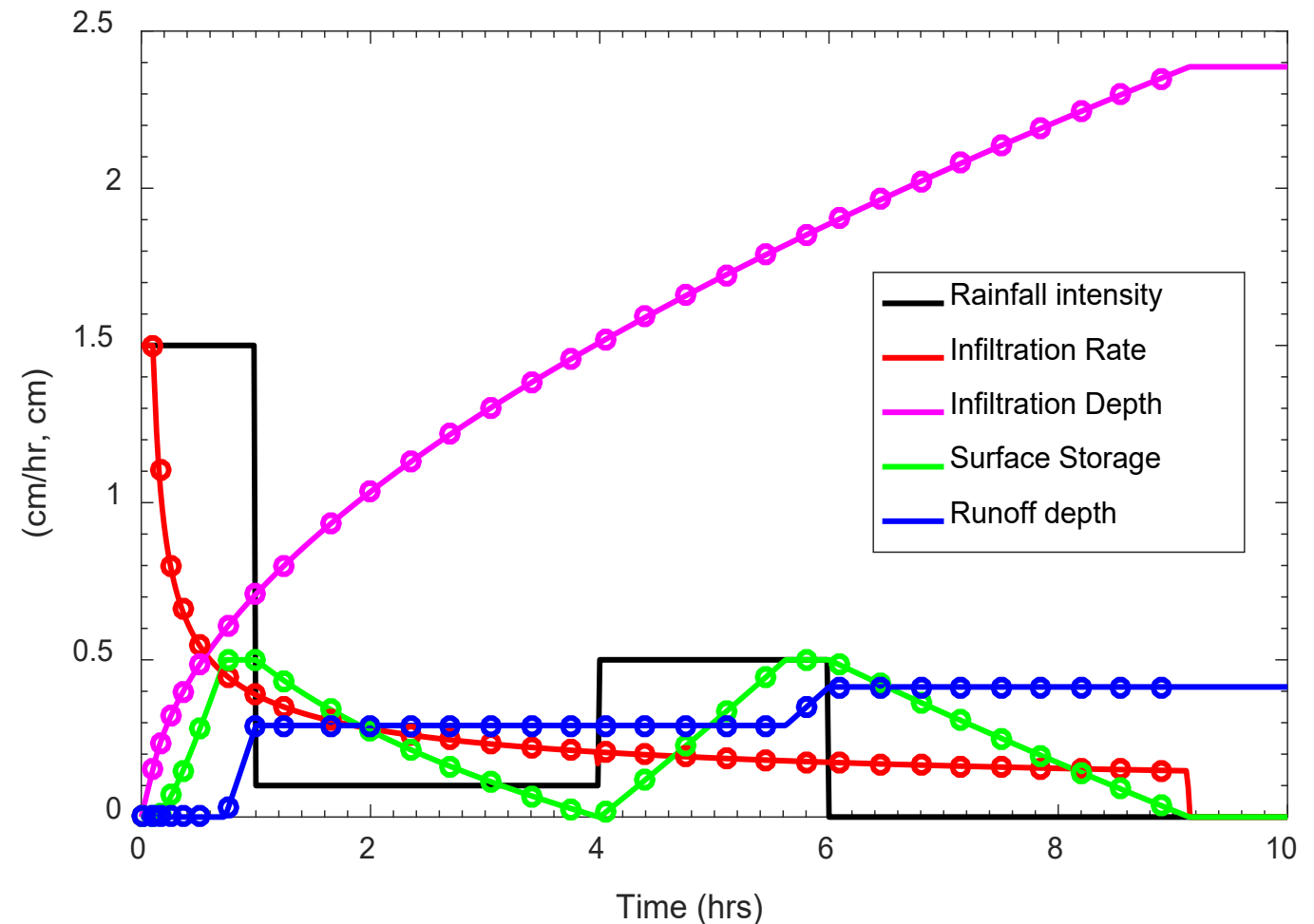
Soil Texture	Residual Water Content (-)	Total Porosity (-)	Pore-size Distribution Index (-)	Saturated Hydraulic Conductivity (cm/hr)	Wetting Front Suction (cm)
Sand	0.02	0.437	0.694	21.0	10.6
Loamy sand	0.035	0.437	0.553	6.11	14.2
Sandy loam	0.041	0.453	0.378	2.59	22.2
Loam	0.027	0.463	0.252	1.32	31.5
Silt loam	0.015	0.501	0.234	0.68	40.4
Sandy clay loam	0.068	0.398	0.319	0.43	44.9
Clay loam	0.075	0.464	0.242	0.23	44.6
Silty clay loam	0.040	0.471	0.177	0.15	58.1
Sandy clay	0.109	0.430	0.223	0.12	63.6
Silty clay	0.056	0.479	0.150	0.09	64.7
Clay	0.09.	0.475	0.165	0.06	71.4



# Green-Ampt Verification

- Comparison with code by Daliakopoulos (2015)
  - Computed – solid lines
  - Daliakopoulos (2015) - Circles

Parameter	Value
Saturated hydraulic conductivity (cm/hr)	0.044
Wetting front suction (cm)	22.4
Saturated water content (-)	0.499
Residual water content (-)	0.03
Initial water content (-)	0.25



# Redistribution Method (GAR)

- Governing Equation (Ogden and Saghafian 1997)

$$\frac{d\theta_0}{dt} = \frac{1}{Z_0} \left\{ f - E_v - K_i - \left[ K_0 + \frac{K_s G(\theta_i, \theta_o)}{Z_0} \right] \right\}$$

where

$G(\theta_i, \theta_o)$ : Integral of the capillary drive through the saturated front [L]

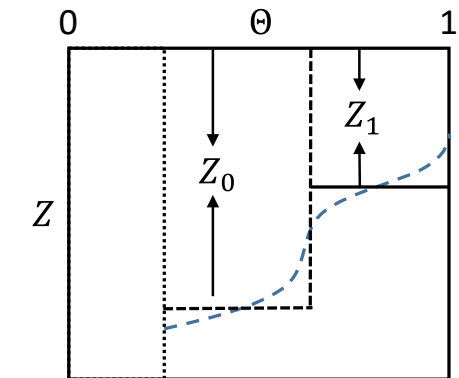
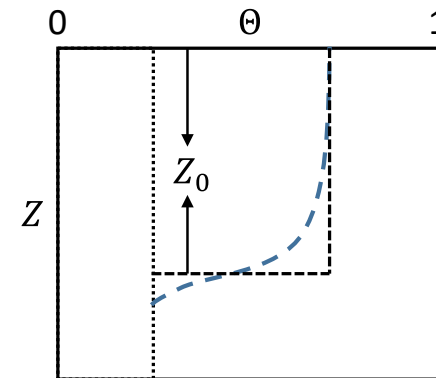
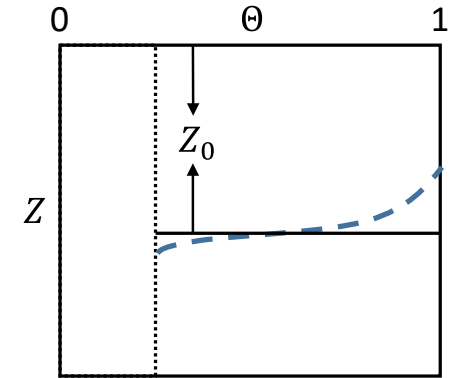
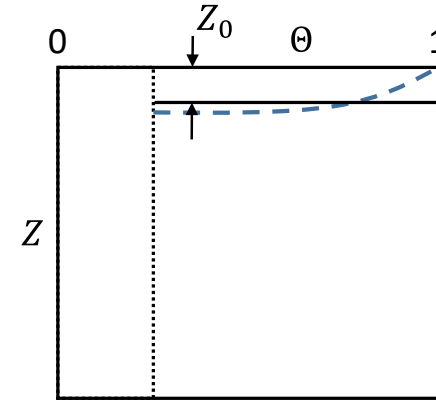
$Z_0 = F_0 / (\theta_0 - \theta_i)$ : Depth of wetting front [L]

$F_0$ : Cumulative infiltration [L]

$\theta_0$ : Soil moisture content corresponding to unsaturated front [L]

$K_0 = K(\theta_0)$ : Unsaturated hydraulic conductivity corresponding to  $\theta_0$  [L/T]

$K_i = K(\theta_i)$ : Unsaturated hydraulic conductivity corresponding to  $\theta_i$  [L/T]



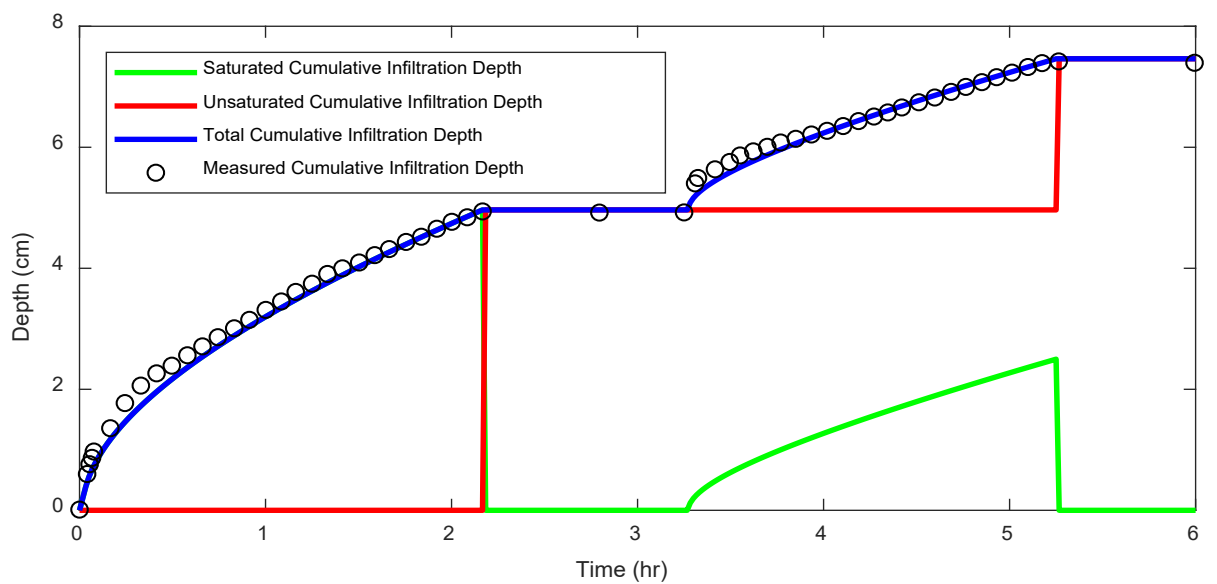
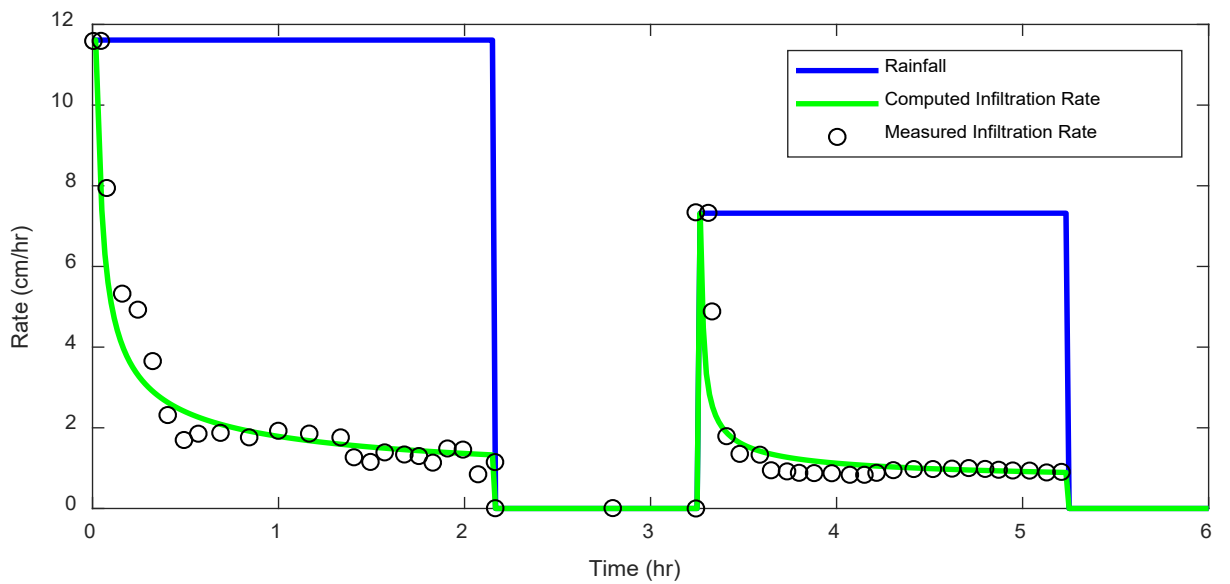




# GAR Validation

- Comparison with Alapaha Sand Tests (Rawls et al. 1976)

Parameter	Value
Saturated hydraulic conductivity (cm/hr)	0.47
Suction at the wetting front (cm)	45
Saturated water content (-)	0.38
Residual water content (-)	0.06
Initial water content (-)	0.19
Pore distribution index	0.45





# Percent Impervious and Surface Excess

- Percent Impervious
  - ▶ Associated with **Land Cover** classification layer
  - ▶ Between 0 and 100
  - ▶ Usually set to 100 for open water

- Surface Excess Rate

$$v = R - \left(1 - \frac{P_{imp}}{100}\right) f$$

$v$ : Excess [L/T]

$R$ : Rainfall [L/T]

$f$ : Infiltration [L/T]

$P_{imp}$ : Percent impervious [%]

# Evapotranspiration

- Evapotranspiration Potential  $ET_0$
- Actual Evapotranspiration

$$ET = E_h + E_v$$

where

$E_h = \min(ET_0, h / \Delta t)$ : Surface water evaporation [L/T]

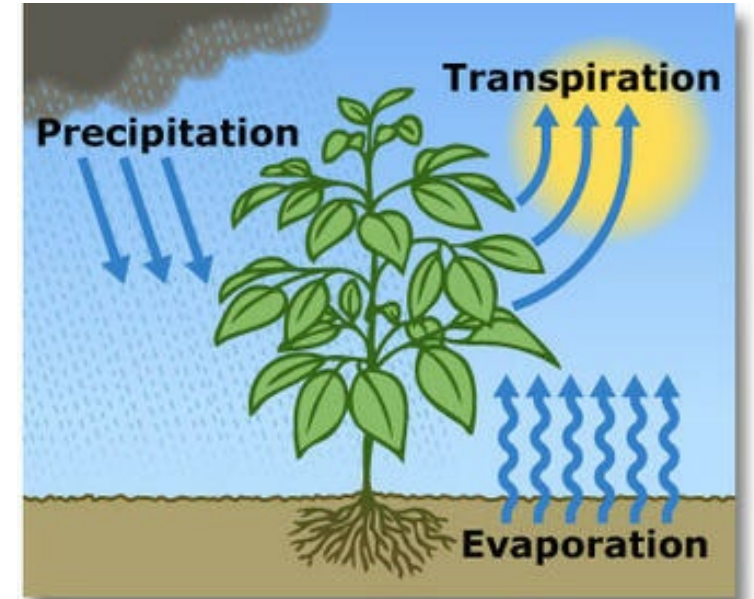
$E_v = \min(ET_0 - E_h, S_w / \Delta t)$ : Evapotranspiration [L/T]

$h$ : Water depth [L]

$S_w$ : Soil water [L]

$\Delta t$ : Time step [T]

- Input Data Modes
  - ▶ Constant, Point Gage, or Gridded



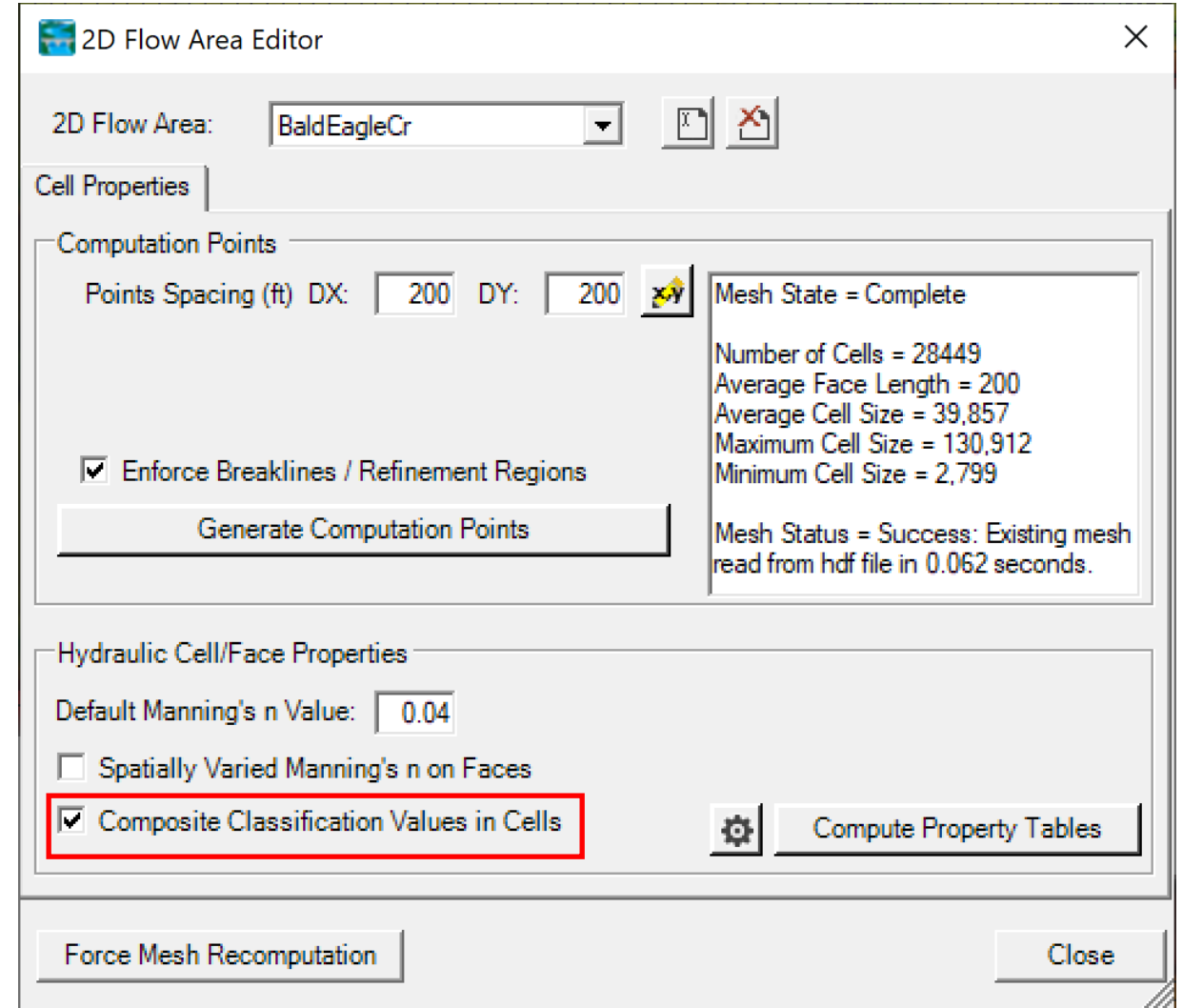


# Spatial Compositing of Classification Values in Cells

- Applies to
  - ▶ Infiltration parameters (e.g. max deficit, CN, etc.)
  - ▶ % impervious
  - ▶ Manning's n
- Cell composite values computed as

$$X_c = \frac{\sum_i A_i X_i}{\sum_i A_i}$$

$A_i$  : Area  
 $X_i$  : Classification





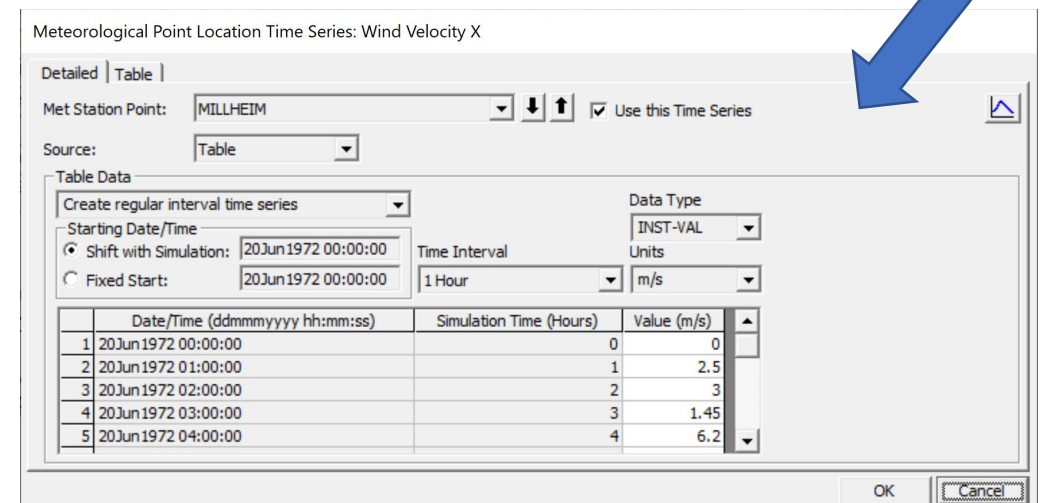
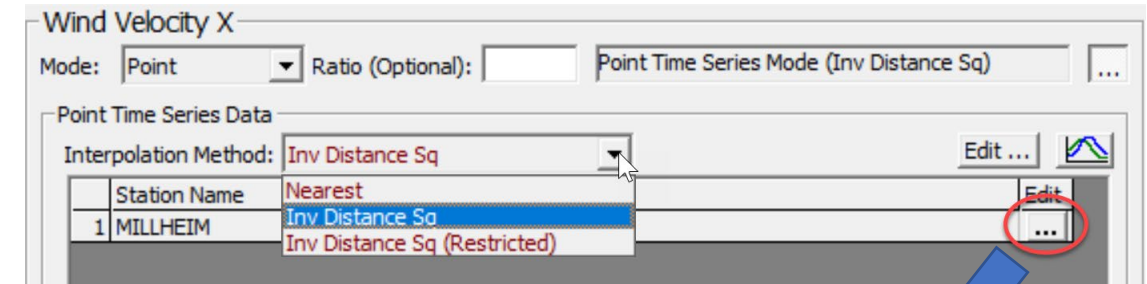
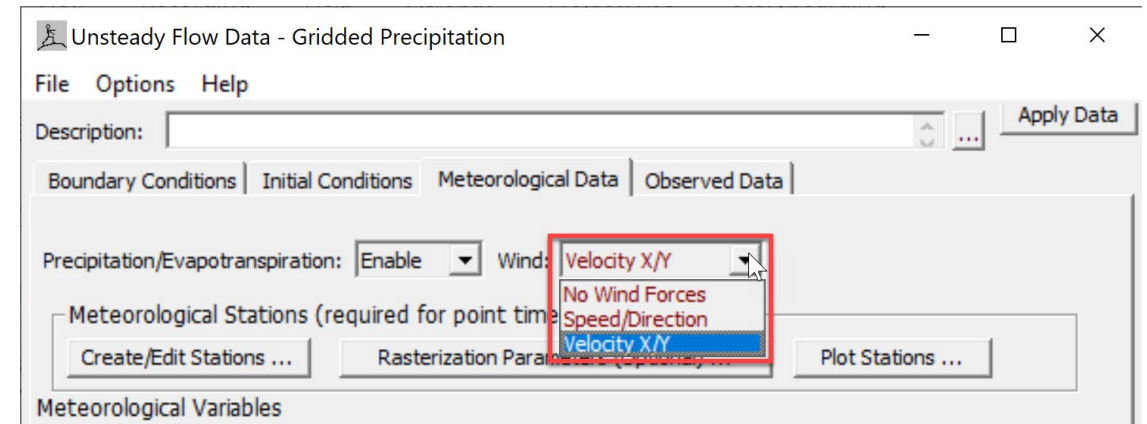
# Limitations

- Surface water cannot infiltrate
- Does not include
  - ▶ Inter-flow
  - ▶ Base-flow
  - ▶ Ground water flow
  - ▶ Canopy storage and dynamics
  - ▶ Depression storage



# Meteorological Data - Wind

- Enabled in **Meteorological Data** tab of **Unsteady Flow Data** editor
- Velocities defined at 10-m height
- Input Data Modes
  - Gridded
    - HEC-DSS file format (from HEC-MetView)
    - GDAL Formats
  - Meteorological Station Data
    - HEC-DSS time series
    - User Entered into a Table
  - Constant Rate
- Interpolation Methods
  - Nearest
  - Inverse Distance
  - Inverse Distance Squared
- Ratio (optional)
  - Used to scale the wind velocities or convert height to 10-m





# Wind Options

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

1D Unsteady Flow Options

Theta [implicit weighting factor] (0.6-1.0):	1.
Theta for warm up [implicit weighting factor] (0.6-1.0):	1.
Water surface calculation tolerance [max=0.2](ft):	0.02
Storage Area elevation tolerance [max=0.2](ft):	0.02
Flow calculation tolerance [optional] (cfs):	
Max error in water surface solution (Abort Tolerance)(ft):	100.
Maximum number of iterations (0-40):	20
Maximum iterations without improvement (0-40):	

1D/2D Unsteady Flow Options

Number of warm up time steps (0 - 100,000):	20
Time step during warm up period (hrs):	0
Minimum time step for time slicing (hrs):	0
Maximum number of time slices:	20
Lateral Structure flow stability factor (1.0-3.0):	2.
Inline Structure flow stability factor (1.0-3.0):	1.
Weir flow submergence decay exponent (1.0-3.0):	1.
Gate flow submergence decay exponent (1.0-3.0):	1.
Gravity (ft/s <sup>2</sup> ):	32.174

Wind Forces

Reference Frame: Eulerian

Drag Formulation: Hsu (1988)

Geometry Preprocessor Options

Family of Rating Curves for Internal Boundaries

- Use existing internal boundary tables when possible.
- Recompute at all internal boundaries

1D Numerical Solution

- Finite Difference (classic HEC-RAS methodology)
  - Finite Difference Matrix Solver
    - Skyline/Gaussian (Default: faster for dendritic systems)
    - Pardiso (Optional: may be faster for large interconnected systems)
- Finite Volume (new approach)

Number of cores to use with Pardiso solver: All Available

OK Cancel Defaults ...



# Wind Surface Stress

- Only for Shallow Water Equations
- Surface Stress is given by

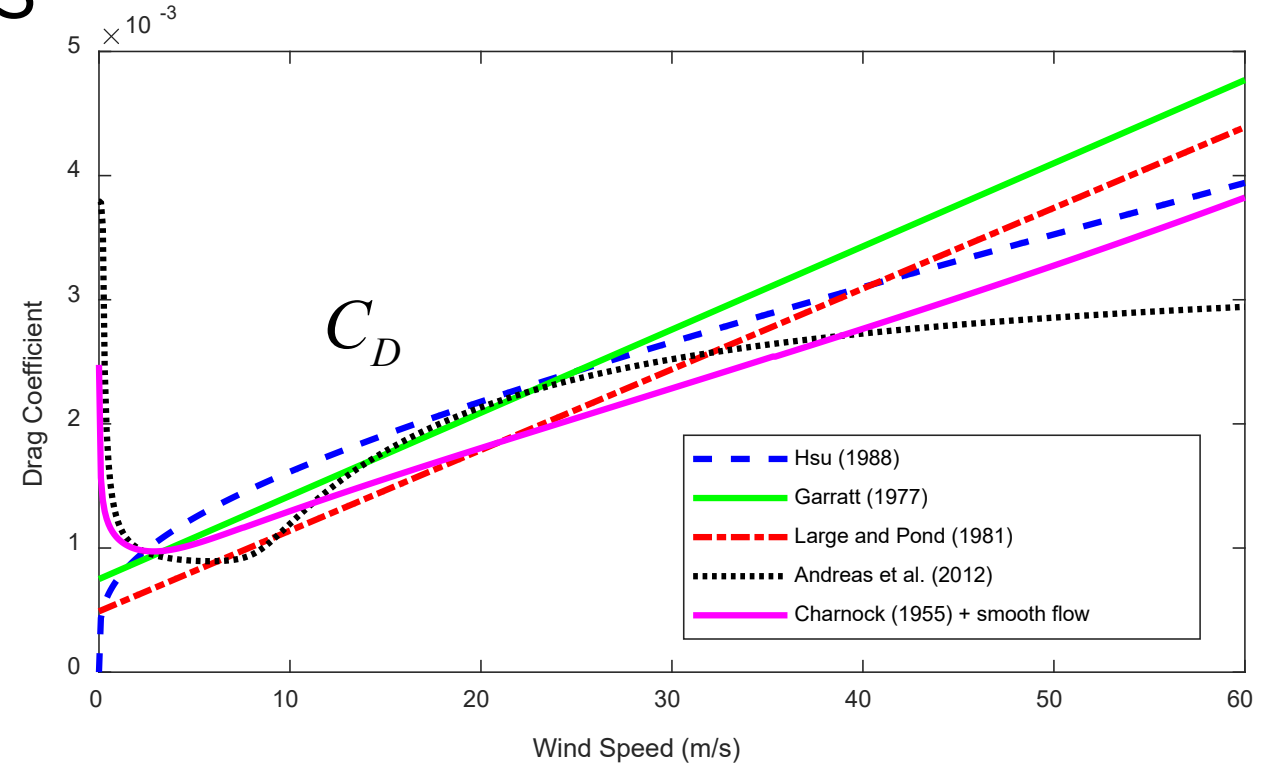
$$\tau_s = \rho_a C_D |W_{10}| W_{10}$$

- Wind Reference Frame

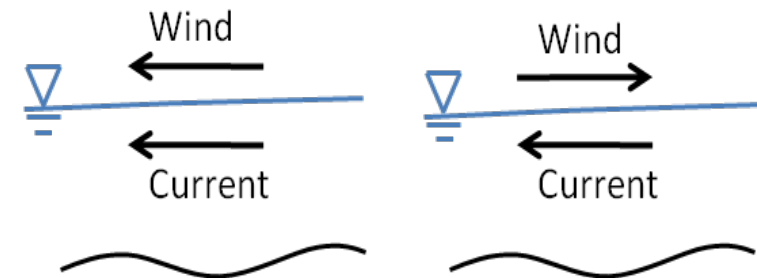
$$W_{10} = \begin{cases} W_{10}^E - V & \text{for Lagrangian} \\ W_{10}^E & \text{for Eulerian} \end{cases}$$

- Input Data Modes

- Constant
- Point Gages
- Gridded



## Lagrangian Reference Frame



# Thank You!

HEC-RAS Website:

<https://www.hec.usace.army.mil/software/hecras/>

Online Documentation:

<https://www.hec.usace.army.mil/confluence/rasdocs>