RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

HEC-HMS PREPROCESSOR USER MANUAL AND HEC-HMS GUIDANCE DOCUMENT

Ver. 1.0; July 2016

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Disclaimer

The instructions in this manual should not be understood to be official instructions or training in Riverside County Flood Control and Water Conservation District (District) methods or the use of U.S. Army Corps of Engineers' HEC-HMS program. This document shall be used as a guide for preparing a HEC-HMS model that incorporates District methods outlined in the District's Hydrology Manual.

The District reserves the right to modify the preprocessor software without prior notification.

Introduction

In the past, the District has accepted synthetic unit hydrograph (SUH) models prepared with the U.S. Army Corps of Engineers' (Corps) HEC-1 program in conjuction with the LAPRE-1 Preprocessor. The HEC-1 software has been superceded by HEC-HMS and is no longer supported by the Corps. In an effort to allow the use of HEC-HMS for District projects, District staff has developed the HEC-HMS Preprocessor web-based program to assist the user in calculating input parameters for preparing a SUH model in HEC-HMS consistent with District methods. More specifically, the HEC-HMS Preprocessor incorporates the District's rainfall distribution patterns, areal adjustment factors, and loss rate methods to calculate the effective rainfall for the 1-, 3-, 6- and 24-hour storm durations. The Preprocessor has a calcualtor to determine lag time and also provides the S-graph ordinates to be input into HEC-HMS. The effective rainfall, lag time, and S-graph ordinates are copied and pasted into HEC-HMS.

This document provides guidance on how to use the District's HEC-HMS Preprocessor and how to model a watershed in HEC-HMS using the District's SUH method. Pages and Plates listed in this document refer to the District's Hydrology Manual. Links to the District's Hydrology Manual, District's HEC-HMS Preprocessor, and the Corps' HEC-HMS program are listed below.

District's Hydrology Manual

http://rcflood.org/downloads/Planning/Hydrology%20Manual%20-%20Complete.pdf

District's HEC-HMS Preprocessor Web-Based Program

http://www.rcflood.org/hechms/

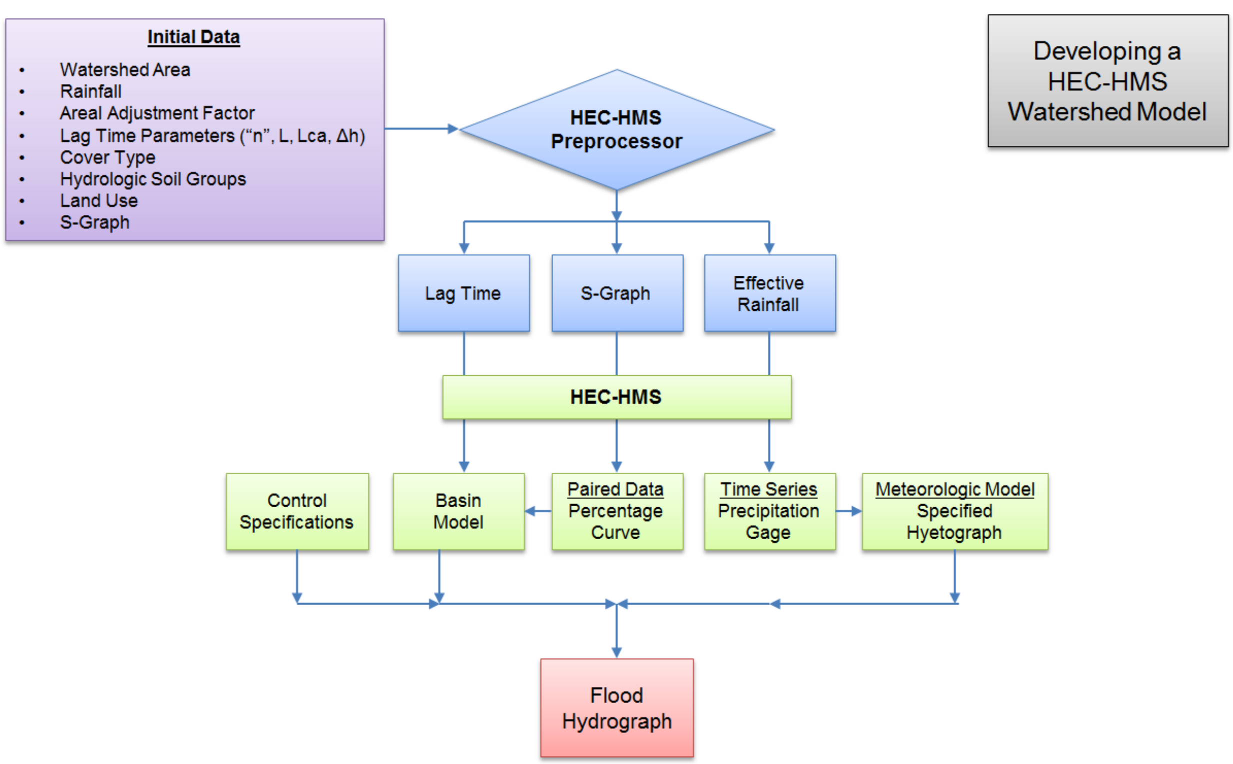
HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System)

http://www.hec.usace.army.mil/software/hec-hms/downloads.aspx

Overview

In order to prepare input parameters for the HEC-HMS model, the following data must be processed in the District's HEC-HMS Preprocessor:

- Watershed area (sq. mi)
- Basin factor, "n" (*Plate E-3)*
- Point precipitation (in)
- Areal adjustment factor (%) (*Plate E-5.8)*
- Length of main watercourse, L (ft)
- Length along main watercourse measured upstream to a point opposite the centroid, Lca (ft)
- Difference in elevation from the concentration point and the upstream end of the watercourse, H (ft)
- Areas identified by cover type, soil group and land use

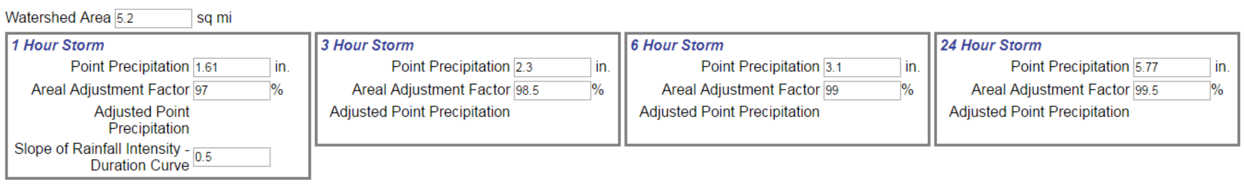


District's HEC-HMS Preprocessor

Precipitation

1-, 3-, 6-, 24-hour storm durations (*From NOAA Atlas 2 Isohyetal Maps in District's Hydrology Manual or other sources of data applicable to the study, such as NOAA Atlas 14 Volume 6 or District rain gage analysis*)

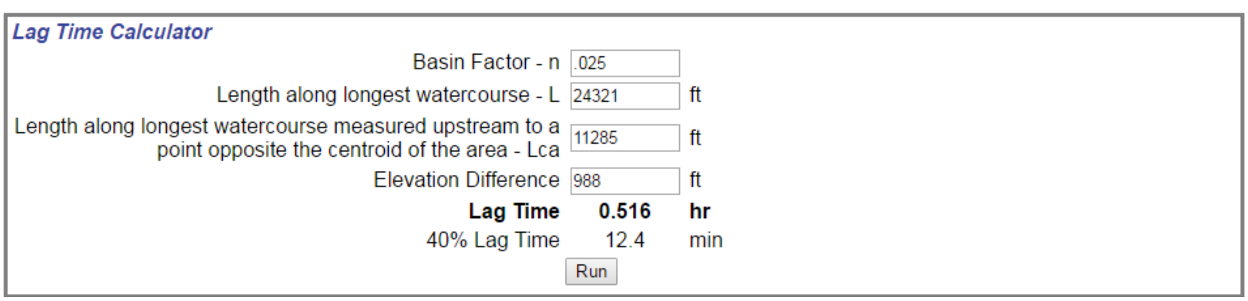
- Enter the "**Point Precipitation**" for the storm events being analyzed
- Enter the "**Areal Adjustment Factor**" (*Plate E-5.8*)
- If analyzing the 1-hour storm event, enter the "**Slope of Rainfall Intensity-Duration Curve**" (*Plate D-4.6)*



Lag Time

A calculator has been provided to determine the **Lag Time** of a watershed and selecting the **Unit Time** period for the analysis. (*Page E-4)*

- Enter the "**Basin Factor, n**" *(Plate E-3)*
- Enter the "**Length along main watercourse, L**"
- Enter the "**Length along main watercourse measured upstream to a point opposite the centroid, Lca**"
- Enter the "**Elevation Difference, H**" between the concentration point and point at the upstream end of the watercourse
- Click the **RUN** button to calculate the **Lag Time** and 40% of that value (t*he unit time period for the analysis must be less than 40% of the lag time)*



Loss Rate

The "**Average Adjusted Loss Rate**" is based on the soil-cover complex and land use impervious percentage. The user can either use the built in calculator to determine the loss rate or enter it manually (*Page E-8).*

Note: If the user chooses to enter the Average Adjusted Loss Rate manually, the backup calculation for this value will need to be attached to the Preprocessor printout.

- To use the Average Adjusted Loss Rate calculator provided:
  - Select the **AMC condition** (I, II, or III) (*Page C-3*)
  - Select the **Soil-Cover Complex** for pervious areas (*Plate E-6.1*)
  - Select the **Actual Impervious Cover Percentage** for developed areas (*Plate E-6.3*)
  - Enter the **AREA** and click the **ADD** button to record the entry

Loss Rate Data | Effective Rainfall | S-Graphs

◉ Average Adjusted Loss Rate Calculator (Plate E-2.1) ○ Average Adjusted Loss Rate (Manual Entry)

Add Loss Rate Values

AMC Condition: II

Soil Group / Cover Type View Chart	RI Number	Perv. Area Infiltrn Rate (in/hr)	Land Use	Imp. Area Decimal %	Adj.Infiltrn Rate (in/hr)	Area (acres)		
-							Add	

Soil Group / Cover Type	RI Number	Perv. Area Infiltrn Rate (in/hr)	Land Use	Imp. Area Decimal %	Adj.Infiltrn Rate (in/hr)	Area (acres)	Area/ Total Area	Ave. Adj. Rate (in/hr)
Grass Good B	61	0.4590	50	50	0.252	100	0.571	0.144 X
Grass Good C	74	0.3150	40	40	0.202	50	0.286	0.058 X
Grass Good D	80	0.2440	20	20	0.2	25	0.143	0.029 X
					Total area =	175		
							Average Soil Loss =	0.231

- OR Manual Entry

Loss Rate Data | Effective Rainfall | S-Graphs

○ Average Adjusted Loss Rate Calculator (Plate E-2.1) ◉ Average Adjusted Loss Rate (Manual Entry) .230 in/hr

Effective Rainfall

The **Effective Rainfall** (rainfall converted to runoff after infiltration) per unit time is required since HEC-HMS does not support the District's loss rate methods (*low loss, 24-hour storm variable loss rate*). Therefore, rainfall in HEC-HMS is entered as effective rainfall with no loss method specified.

- Select the **Unit Time Period** *(select a unit time period less than 40% of the calculated lag time)*
- Enter the **Low Loss Percentage** *(usually taken to be 80-90% of the rainfall for any unit time period where loss would otherwise exceed rainfall) (Page E-8)*
- If analyzing the 24-hour storm event, enter F_m *(minimum value on loss curve, typically 50-75% of the "Average Adjusted Loss Rate") (Page E-8)*
- Click the **RUN** button. The program will calculate the effective rainfall (inches) per unit time.

Shown below is an example of the calculated Effective Rainfall for the 1-, 3-, 6- and 24-hour storm durations.

Loss Rate Data | Effective Rainfall | S-Graphs

Unit Time Period [5 ▼] min (Use interval less than 40% of lag time)

Low Loss [90] %

Fm (Percentage of F) (24-hour Storm Only) [50] % (Typically 50-75%)

[Run]

1 Hour

Unit Time	Effective Rainfall
00:05	0.048
00:10	0.053
00:15	0.057
00:20	0.062
00:25	0.068
00:30	0.082
00:35	0.096
00:40	0.118
00:45	0.181
00:50	0.42
00:55	0.092
01:00	0.054

3 Hour

Unit Time	Effective Rainfall
00:05	0.01
00:10	0.01
00:15	0.006
00:20	0.015
00:25	0.015
00:30	0.022
00:35	0.015
00:40	0.022
00:45	0.022
00:50	0.015
00:55	0.017
01:00	0.022
01:05	0.031
01:10	0.031
01:15	0.031
01:20	0.026
01:25	0.04
01:30	0.042
01:35	0.035
01:40	0.042
01:45	0.056
01:50	0.051
01:55	0.047
02:00	0.049
02:05	0.051
02:10	0.076
02:15	0.094
02:20	0.06
02:25	0.135
02:30	0.146
02:35	0.167
02:40	0.114
02:45	0.026
02:50	0.022
02:55	0.022
03:00	0.001

6 Hour

Unit Time	Effective Rainfall
00:05	0.002
00:10	0.002
00:15	0.002
00:20	0.002
00:25	0.002
00:30	0.002
00:35	0.002
00:40	0.002
00:45	0.002
00:50	0.002
00:55	0.002
01:00	0.002
01:05	0.005
01:10	0.005
01:15	0.005
01:20	0.005
01:25	0.005
01:30	0.005
01:35	0.005
01:40	0.005
01:45	0.005
01:50	0.005
01:55	0.005
02:00	0.008
02:05	0.008
02:10	0.008
02:15	0.008
02:20	0.008
02:25	0.008
02:30	0.008
02:35	0.008
02:40	0.008
02:45	0.012
02:50	0.012
02:55	0.012
03:00	0.012

24 Hour

Unit Time	Effective Rainfall
00:05	0
00:10	0
00:15	0
00:20	0.001
00:25	0.001
00:30	0.001
00:35	0.001
00:40	0.001
00:45	0.001
00:50	0.001
00:55	0.001
01:00	0.001
01:05	0.001
01:10	0.001
01:15	0.001
01:20	0.001
01:25	0.001
01:30	0.001
01:35	0.001
01:40	0.001
01:45	0.001
01:50	0.001
01:55	0.001
02:00	0.001
02:05	0.001
02:10	0.001
02:15	0.001
02:20	0.001
02:25	0.001
02:30	0.001
02:35	0.001
02:40	0.001
02:45	0.001
02:50	0.001
02:55	0.001
03:00	0.001

S-Graph

An **S-graph**, summation hydrograph, is a hydrograph of runoff that would result from the continuous generation of unit storm effective rainfall over the area. An S-graph represents the basic time-runoff relationship for watershed type in a form suitable for application of ungaged basins. Per the District's Hydrology Manual, four (4) S-graphs are used to represent the runoff characteristics of watersheds in western Riverside County (*Page E-3*).

- The **Mountain** curve is suitable for major watersheds in the Santa Ana, western San Jacinto and San Bernardino Mountains *(Plate E-4.3)*
- The **Valley** curve is suitable for valley floor and alluvial cone areas *(Plate E-4.1)*
- The **Foothill** curve is suitable for small watersheds with extreme slopes, or for confined valley areas surrounded by steep foothills *(Plate E-4.2)*
- The **Desert** curve is suitable for the southeastern San Bernardino and eastern San Jacinto mountains *(Plate E-4.4)*

Shown below are the S-graph ordinates for a 100% Foothill S-graph.

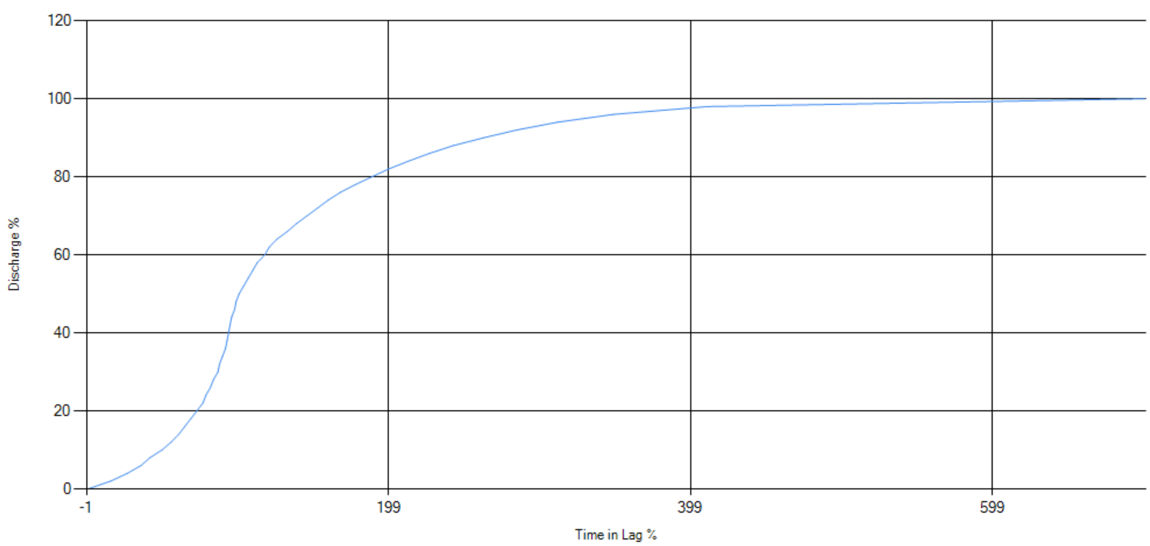
Loss Rate Data | Effective Rainfall | S-Graphs

Run S Graphs

S-Graph 1		S-Graph 2		S-Graph 3		S-Graph 4	
Type:	Mountain	Type:	Valley	Type:	Foothill	Type:	Desert
Weight %		Weight %		Weight %	100	Weight %	
Time in Percent of Lag	Discharge (percent)	Time in Percent of Lag	Discharge (percent)	Time in Percent of Lag	Discharge (percent)	Time in Percent of Lag	Discharge (percent)
0	0	0	0	0	0	0	0
0	2	0	2	15	2	0	2
0	4	0	4	26	4	0	4
0	6	0	6	35	6	0	6
0	8	0	8	41	8	0	8
0	10	0	10	49	10	0	10
0	12	0	12	55	12	0	12
0	14	0	14	60	14	0	14
0	16	0	16	64	16	0	16
0	18	0	18	68	18	0	18
0	20	0	20	72	20	0	20
0	22	0	22	76	22	0	22
0	24	0	24	78	24	0	24
0	26	0	26	81	26	0	26
0	28	0	28	83	28	0	28
0	30	0	30	86	30	0	30
0	32	0	32	87	32	0	32
0	34	0	34	89	34	0	34
0	36	0	36	91	36	0	36
0	38	0	38	92	38	0	38
0	40	0	40	93	40	0	40
0	42	0	42	94	42	0	42
0	44	0	44	95	44	0	44
0	46	0	46	97	46	0	46
0	48	0	48	98	48	0	48
0	50	0	50	100	50	0	50
0	52	0	52	103	52	0	52
0	54	0	54	106	54	0	54
0	56	0	56	109	56	0	56
0	58	0	58	112	58	0	58
0	60	0	60	117	60	0	60
0	62	0	62	120	62	0	62
0	64	0	64	125	64	0	64
0	66	0	66	132	66	0	66
0	68	0	68	138	68	0	68
0	70	0	70	145	70	0	70
0	72	0	72	152	72	0	72
0	74	0	74	159	74	0	74
0	76	0	76	167	76	0	76
0	78	0	78	177	78	0	78
0	80	0	80	188	80	0	80
0	82	0	82	199	82	0	82
0	84	0	84	212	84	0	84
0	86	0	86	226	86	0	86
0	88	0	88	242	88	0	88
0	90	0	90	262	90	0	90
0	92	0	92	284	92	0	92
0	94	0	94	311	94	0	94
0	96	0	96	348	96	0	96
0	98	0	98	410	98	0	98
0	100	0	100	700	100	0	100

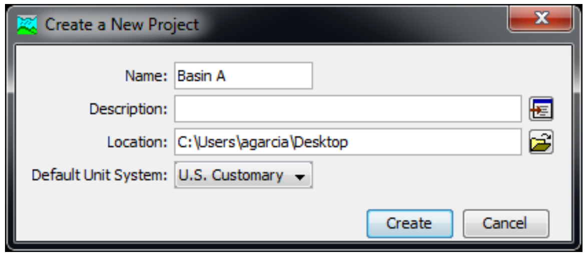
S-Graph Combined	
Type:	Combined
Weight %	
Time in Percent of Lag	Discharge (percent)
0	0
15	2
26	4
35	6
41	8
49	10
55	12
60	14
64	16
68	18
72	20
76	22
78	24
81	26
83	28
86	30
87	32
89	34
91	36
92	38
93	40
94	42
95	44
97	46
98	48
100	50
103	52
106	54
109	56
112	58
117	60
120	62
125	64
132	66
138	68
145	70
152	72
159	74
167	76
177	78
188	80
199	82
212	84
226	86
242	88
262	90
284	92
311	94
348	96
410	98
700	100

S-Graph Combined



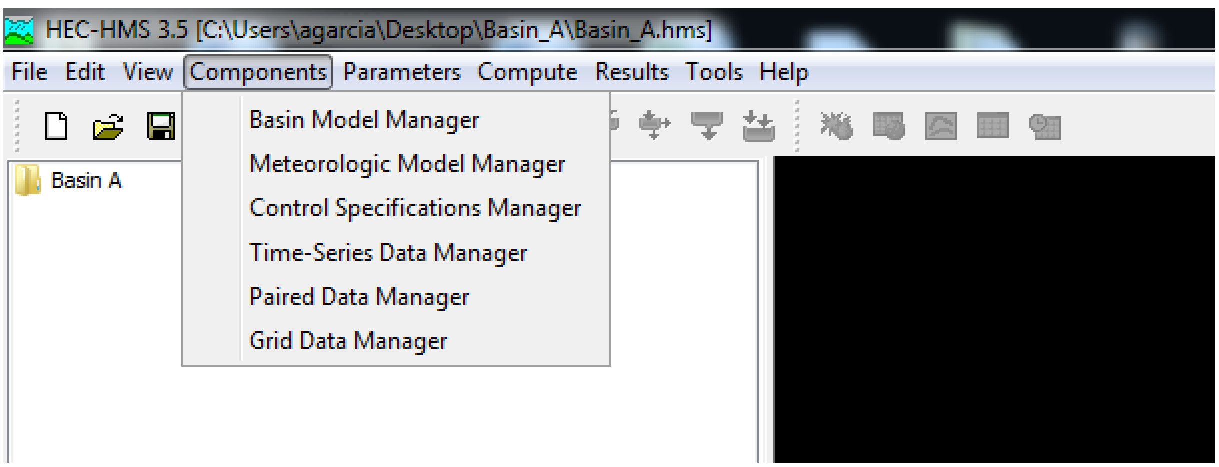
Preparing a HEC-HMS Model

Open **HEC-HMS** and create a new project.

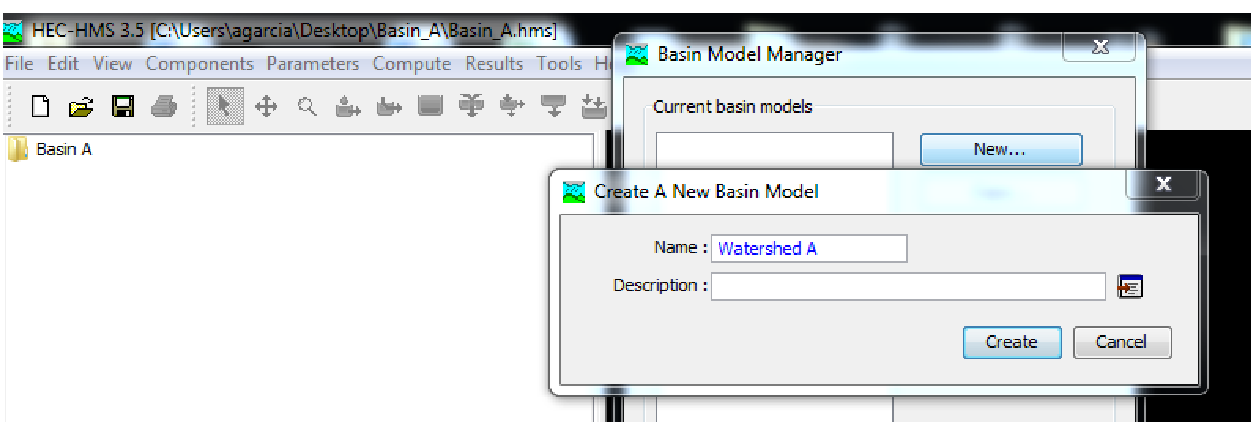


Basin Model Manager

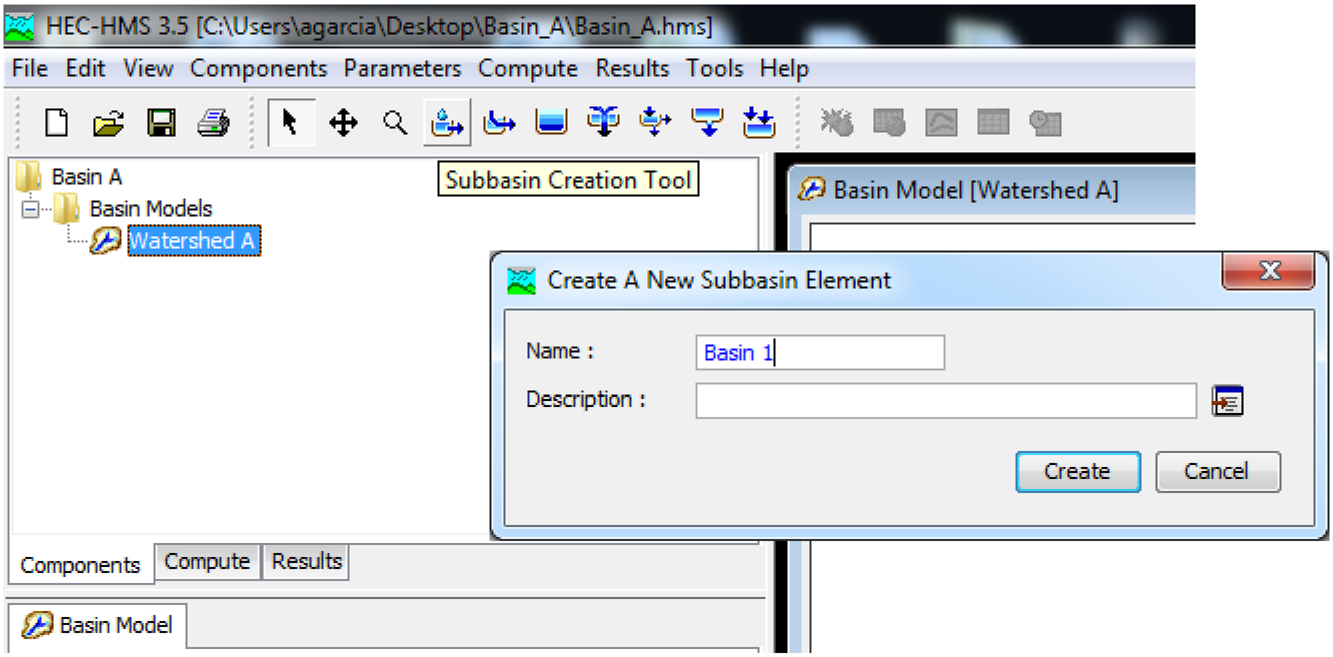
Navigate to the Components option on the menu bar and select "**Basin Model Manager**". The Basin Model Manager allows the user to create subbasins (watersheds) and other elements such as detention basins to the model. It can also be used to copy, rename or delete an existing basin model.



Create a new basin model and provide a name and description.

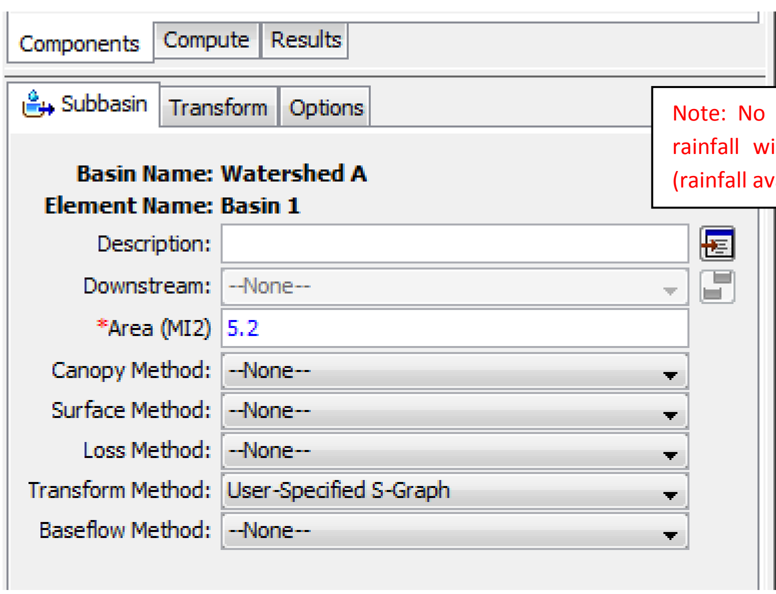


Select the **Subbasin Creation Tool**  and click anywhere in the model space to create a subbasin within the model.



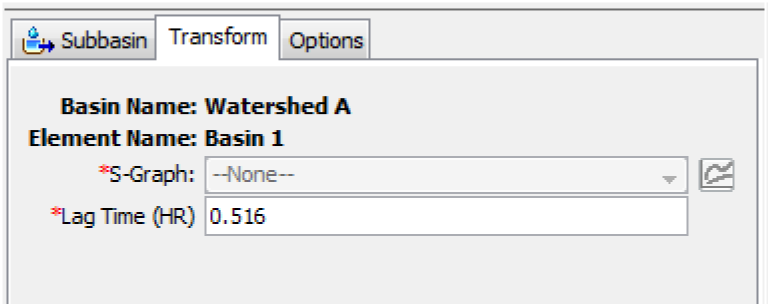
Select the subbasin previously created in the Watershed Explorer pane under the Components tab to begin entering parameters for the model.

Enter the **Area** and change the **Loss Method**, **Transform Method** and **Baseflow Method** to match the figure below.



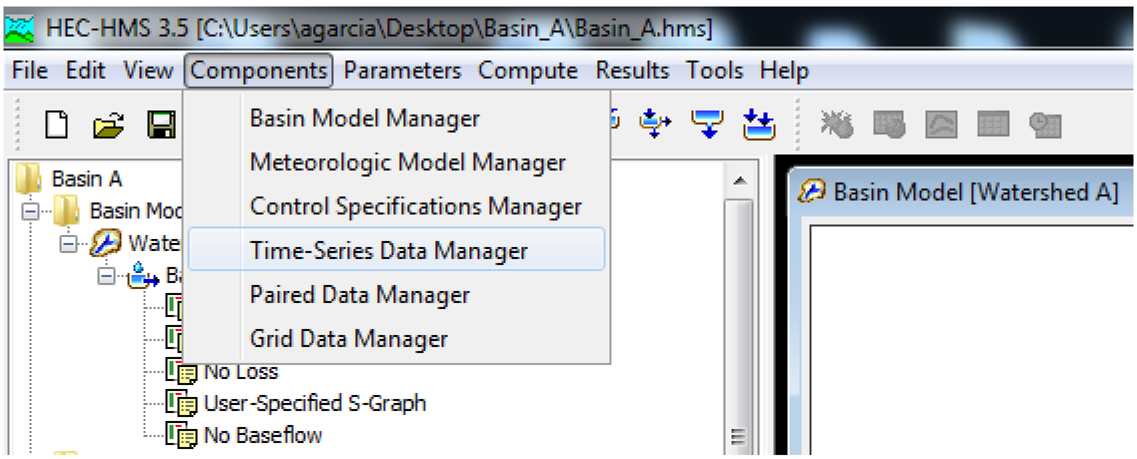
Note: No loss method is specified since the rainfall will be entered as effective rainfall (rainfall available for runoff after infiltration).

Enter the **Lag Time** calculated from the Preprocessor. An **S-graph** will be selectable once it is imported into the program. This will be discussed later in the manual.

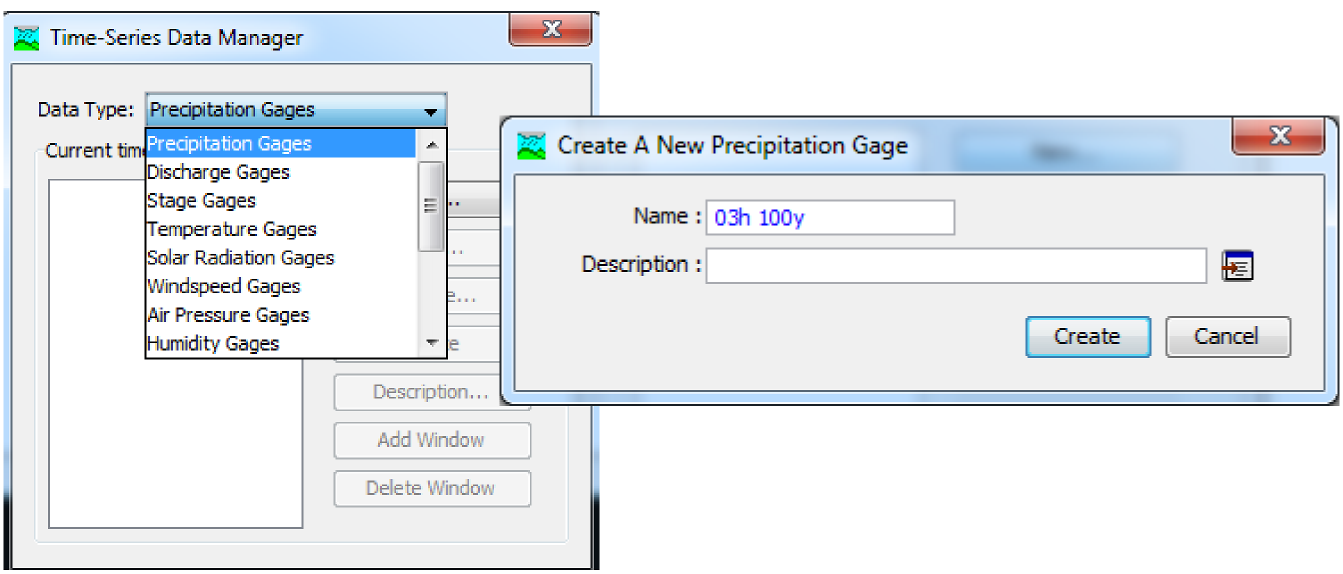


Time-Series Data Manager

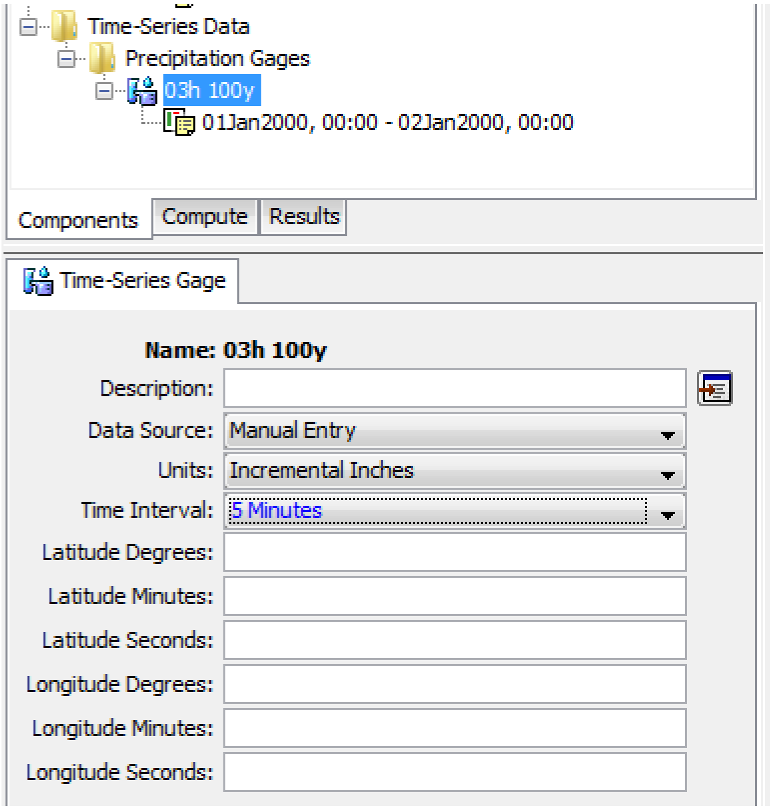
Navigate to the Components option on the menu bar and select “**Time-Series Data Manager**”. The Time-Series Data Manager allows the user to input the precipitation data calculated in the Preprocessor.



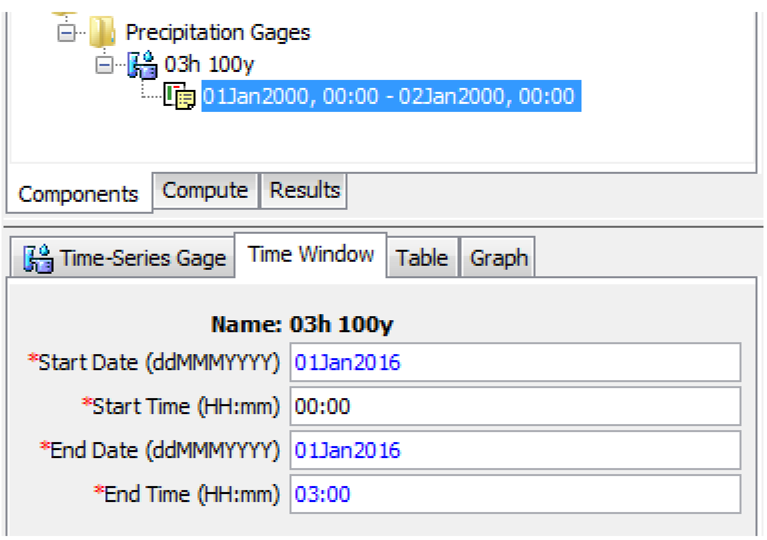
In the Data Type pull down menu, select “**Precipitation Gages**”. Create a new precipitation gage and provide a name and description (e.g., 03h 100y, 03h 010y, 24h 100y).



Select the precipitation gage in the Watershed Explorer pane under the Components tab. Set the **Time Interval** to the **Unit Time** used in the Preprocessor and the **Units** field as incremental inches.



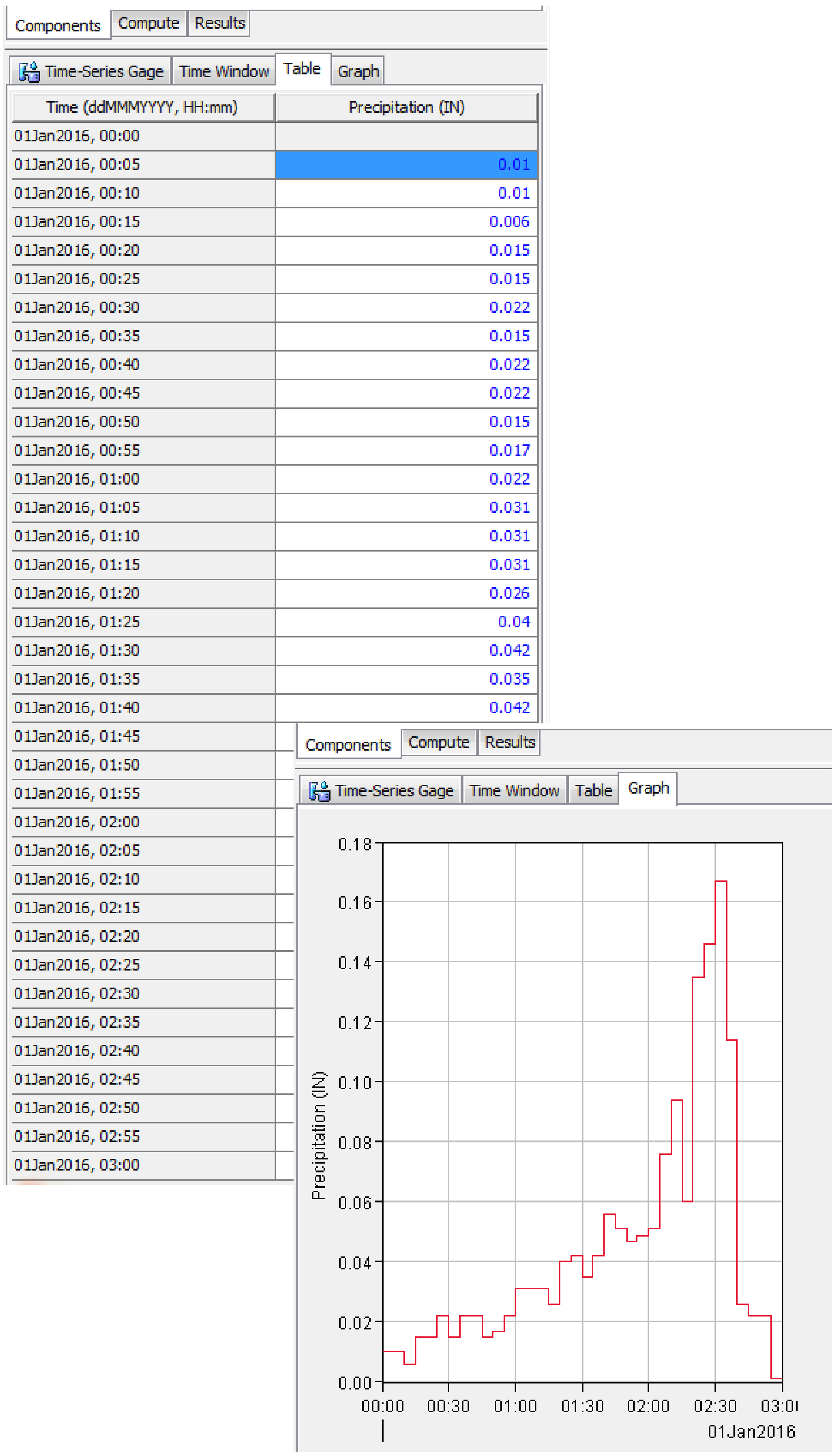
Under the Time Window tab, specify the **Start Date**, **End Date** and an **End Time** corresponding to the duration of the storm event being analyzed (e.g., for a 3-hour storm, enter the end time to as 03:00; 6-hour storm, enter the end time as 06:00; 24-hour storm, enter the end time as 00:00 and end date to the succeeding day).



Copy the **Effective Rainfall** column from the Preprocessor into the Table tab of the **Precipitation Gage**. The effective rainfall hyetograph can then be viewed in the Graph tab.

3 Hour

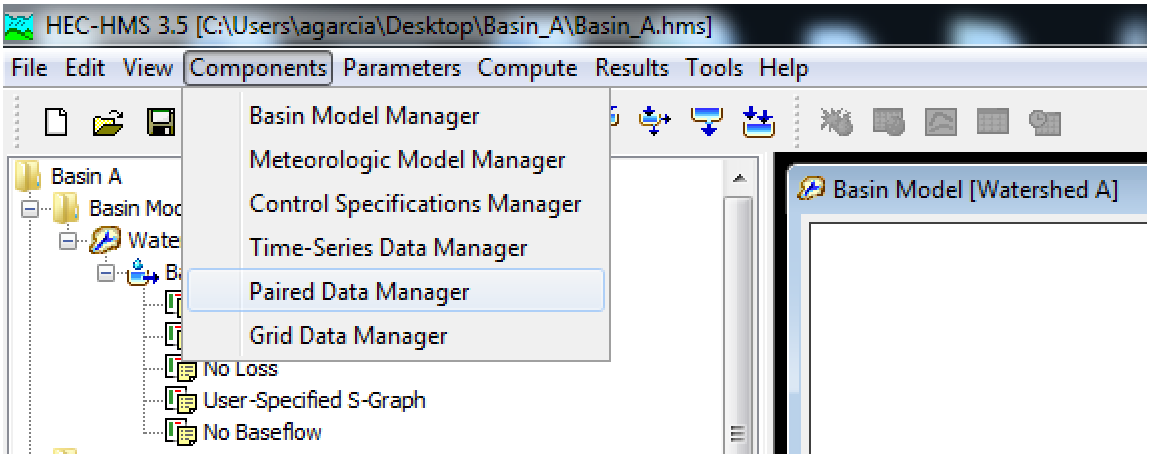
Unit Time	Effective Rainfall
00:05	0.01
00:10	0.01
00:15	0.006
00:20	0.015
00:25	0.015
00:30	0.022
00:35	0.015
00:40	0.022
00:45	0.022
00:50	0.015
00:55	0.017
01:00	0.022
01:05	0.031
01:10	0.031
01:15	0.031
01:20	0.026
01:25	0.04
01:30	0.042
01:35	0.035
01:40	0.042
01:45	0.056
01:50	0.051
01:55	0.047
02:00	0.049
02:05	0.051
02:10	0.076
02:15	0.094
02:20	0.06
02:25	0.135
02:30	0.146
02:35	0.167
02:40	0.114
02:45	0.026
02:50	0.022
02:55	0.022
03:00	0.001



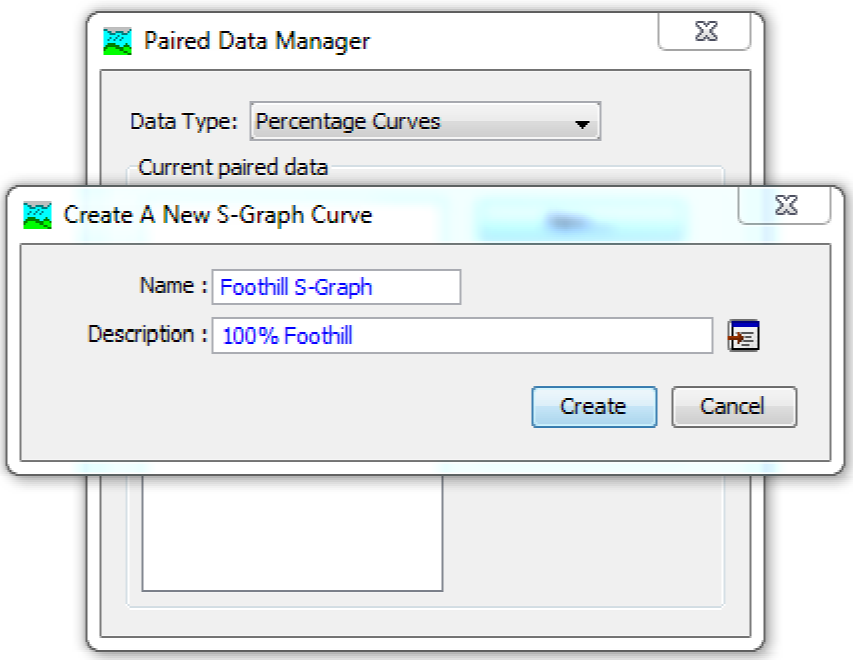
Time (ddMMMYYYY, HH:mm)	Precipitation (IN)
01Jan2016, 00:00	
01Jan2016, 00:05	0.01
01Jan2016, 00:10	0.01
01Jan2016, 00:15	0.006
01Jan2016, 00:20	0.015
01Jan2016, 00:25	0.015
01Jan2016, 00:30	0.022
01Jan2016, 00:35	0.015
01Jan2016, 00:40	0.022
01Jan2016, 00:45	0.022
01Jan2016, 00:50	0.015
01Jan2016, 00:55	0.017
01Jan2016, 01:00	0.022
01Jan2016, 01:05	0.031
01Jan2016, 01:10	0.031
01Jan2016, 01:15	0.031
01Jan2016, 01:20	0.026
01Jan2016, 01:25	0.04
01Jan2016, 01:30	0.042
01Jan2016, 01:35	0.035
01Jan2016, 01:40	0.042
01Jan2016, 01:45	
01Jan2016, 01:50	
01Jan2016, 01:55	
01Jan2016, 02:00	
01Jan2016, 02:05	
01Jan2016, 02:10	
01Jan2016, 02:15	
01Jan2016, 02:20	
01Jan2016, 02:25	
01Jan2016, 02:30	
01Jan2016, 02:35	
01Jan2016, 02:40	
01Jan2016, 02:45	
01Jan2016, 02:50	
01Jan2016, 02:55	
01Jan2016, 03:00	

Paired Data Manager

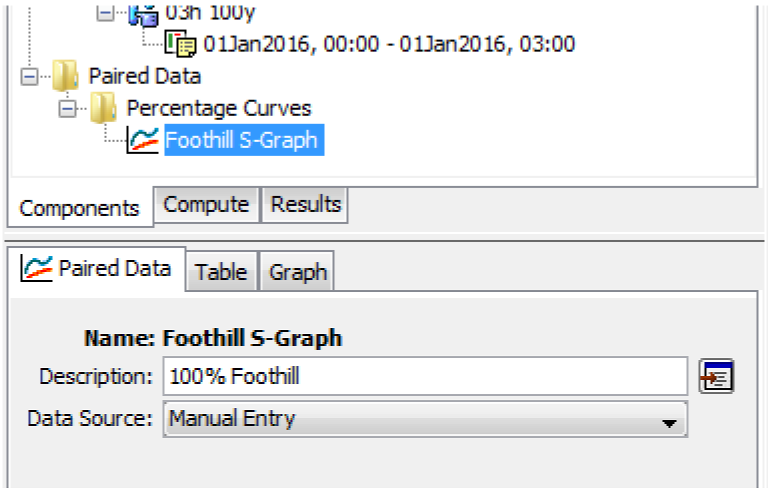
Navigate to the Components option on the menu bar and select "**Paired Data Manager**". The Paired Data Manager is where placeholders are created for stage-storage curves, stage-discharge curves, storage-discharge curves, etc. The S-graph will be imported using this manager.



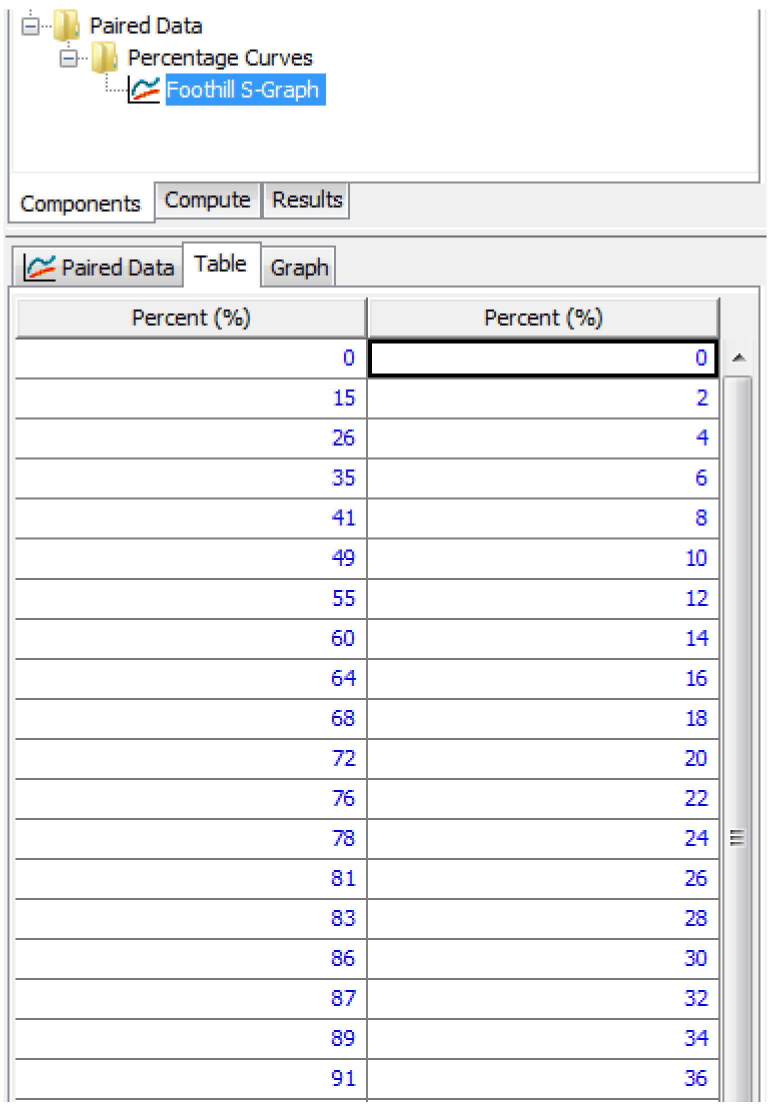
In the Data Type pull down menu, select "**Percentage Curves**". Create a new percentage curve and provide a name and description (e.g., Valley, Foothill, etc.).

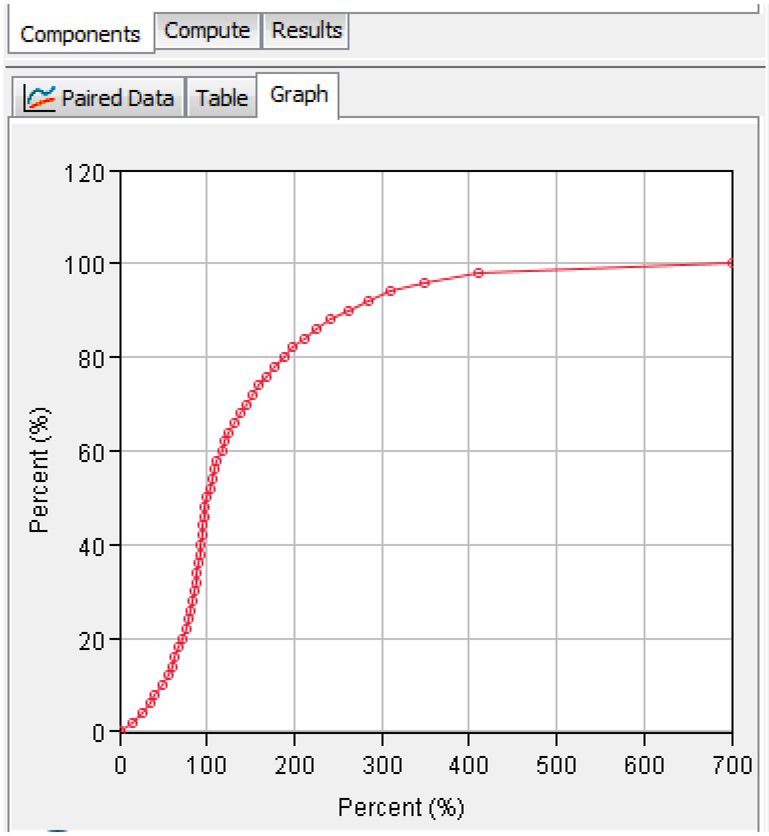


Select the S-graph in the Watershed Explorer under the Components tab. Set the **Data Source** to **Manual Entry** in the Paired Data tab. In the Table tab, copy and paste the S-graph ordinates from the **S-Graph Combined** table from the Preprocessor into HEC-HMS. The S-graph can then be viewed in the Graph tab.

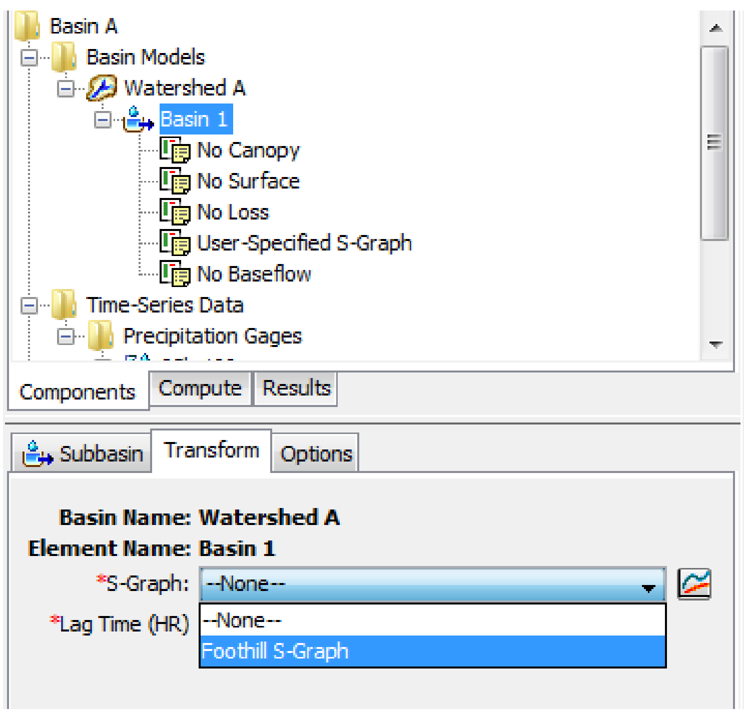


S-Graph Combined	
Type:	Combined
Weight %	
Time in Percent of Lag	Discharge (percent)
0	0
15	2
26	4
35	6
41	8
49	10
55	12
60	14
64	16
68	18
72	20
76	22
78	24
81	26
83	28
86	30
87	32
89	34
91	36
92	38
93	40
94	42
95	44
97	46
98	48
100	50
103	52
106	54
109	56
112	58





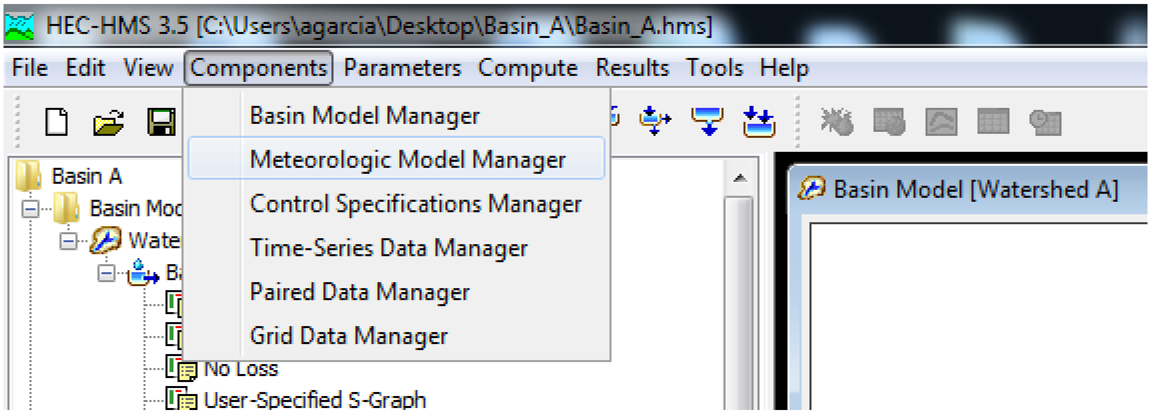
Now that the S-graph has been imported, the S-graph can be assigned to a subbasin. Select the Subbasin previously created in the Watershed Explorer pane under the Components tab. Navigate to the Transform tab and assign the **S-Graph** field to the S-graph imported in the previous step.

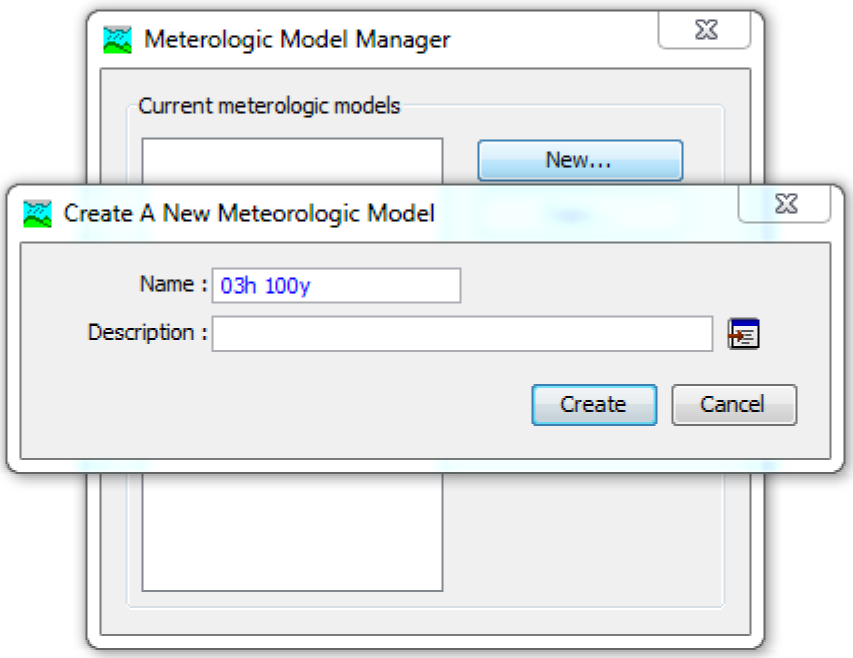


Meteorologic Model Manager

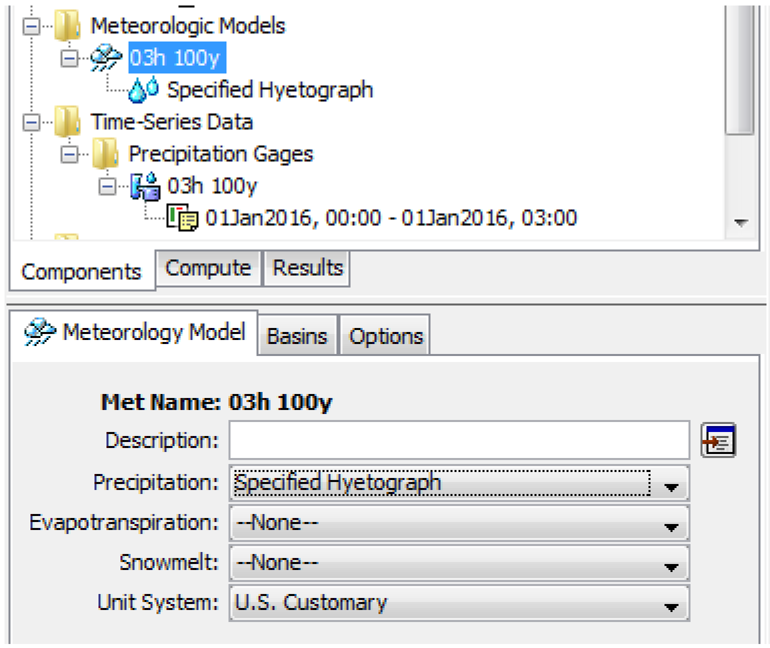
Navigate to the Components option on the menu bar and select "**Meteorologic Model Manager**". The Meteorologic Model Manager assigns the storm rainfall to the subbasins.

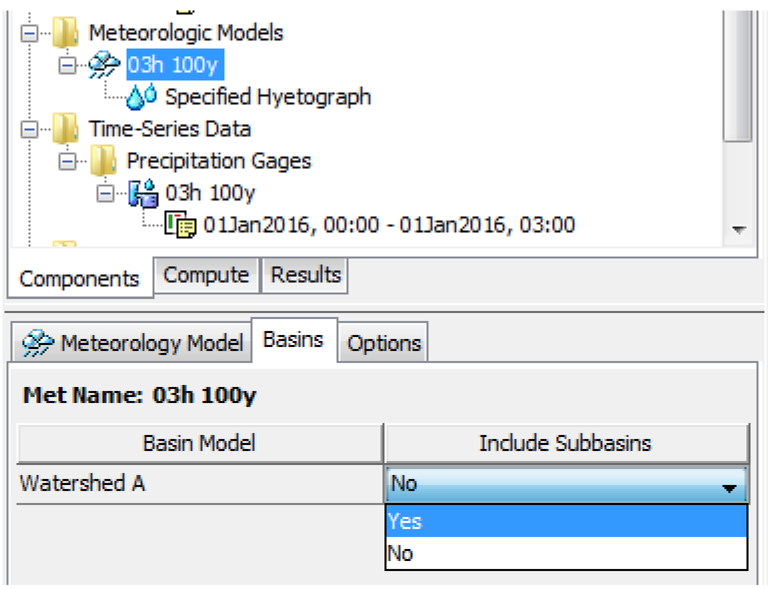
Create a new Meteorologic Model and provide a name and description.



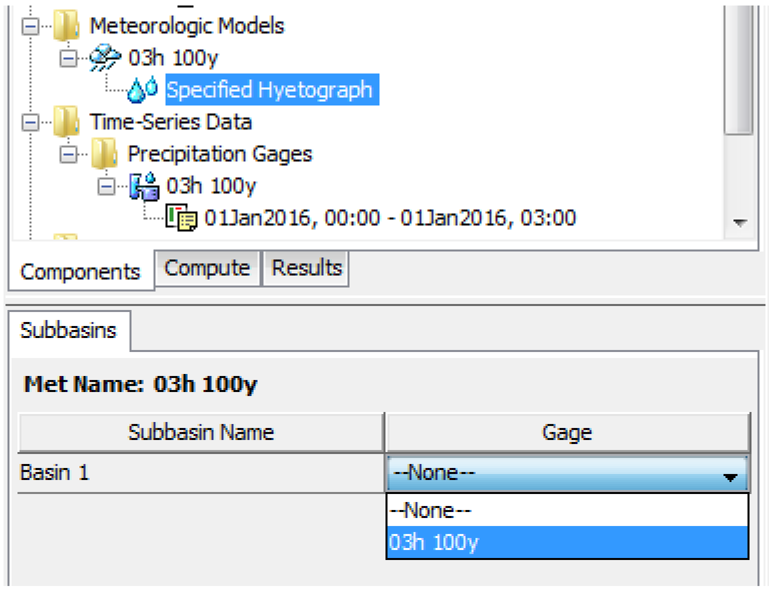


Select the Meteorologic Model in the Watershed Explorer under the Components tab. Set the **Precipitation** option in the Meteorology Model tab to "**Specified Hyetograph**". In the Basins tab, set the option to include Subbasins to "**Yes**".



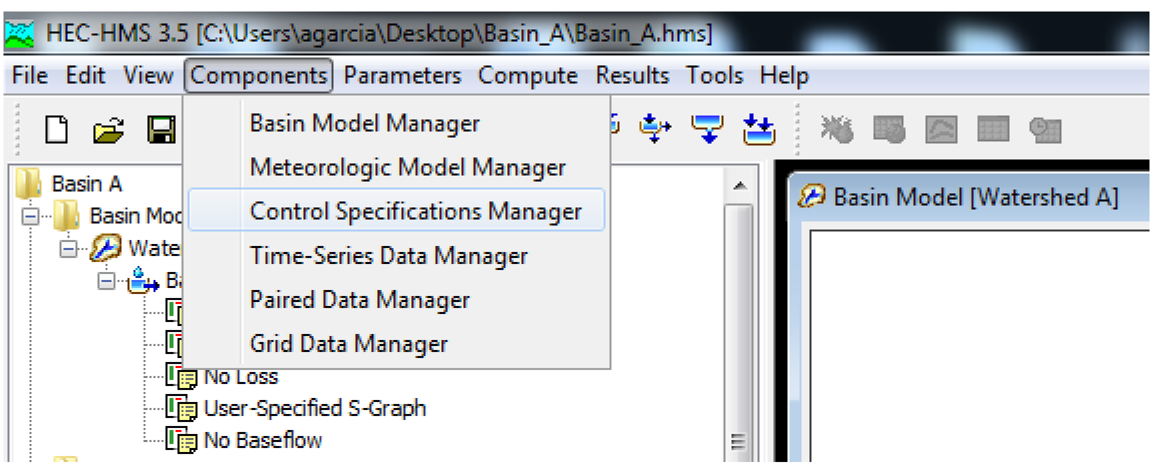


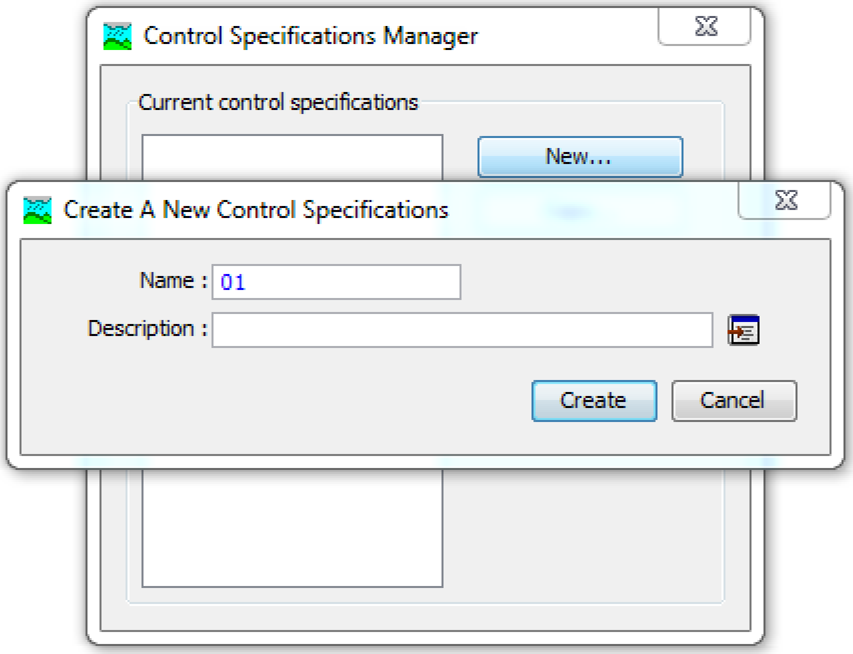
Expand the Meteorologic Model heading in the Watershed Explorer pane under the Components tab to display the "**Specified Hyetograph**" heading. Click on this heading to display the option to assign a Precipitation Gage to a subbasin.



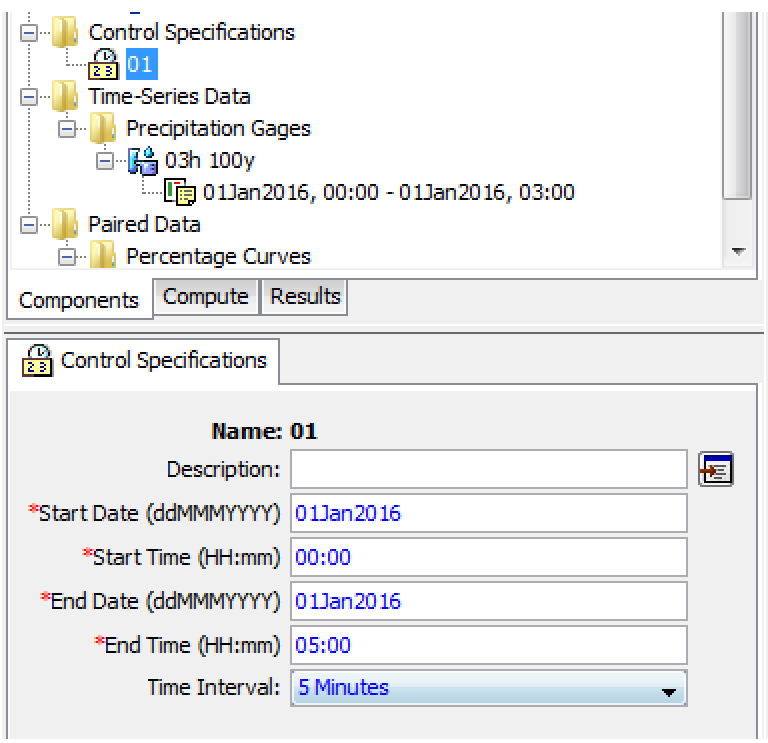
Control Specifications Manager

Navigate to the Components option on the menu bar and select "**Control Specifications Manager**". The Control-Specifications Manager allows the user to create a Control Specification to control when simulations start and stop, and the time interval used in the simulation. Create a new Control Specification and provide a name and description.



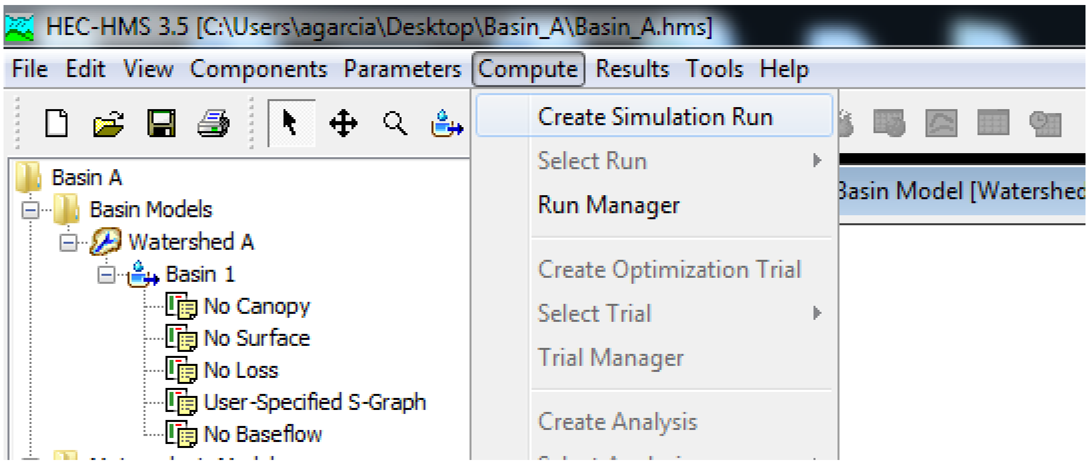


Select the control specification in the Watershed Explorer pan under the Components tab. The **Start Date**, **Start Time**, **End Date** and **Time Interval** should be consistent with what was specified for the **Precipitation Gage**. However, the End Time should be longer than the storm duration being analyzed to ensure that the entire hydrograph will plot in the results.

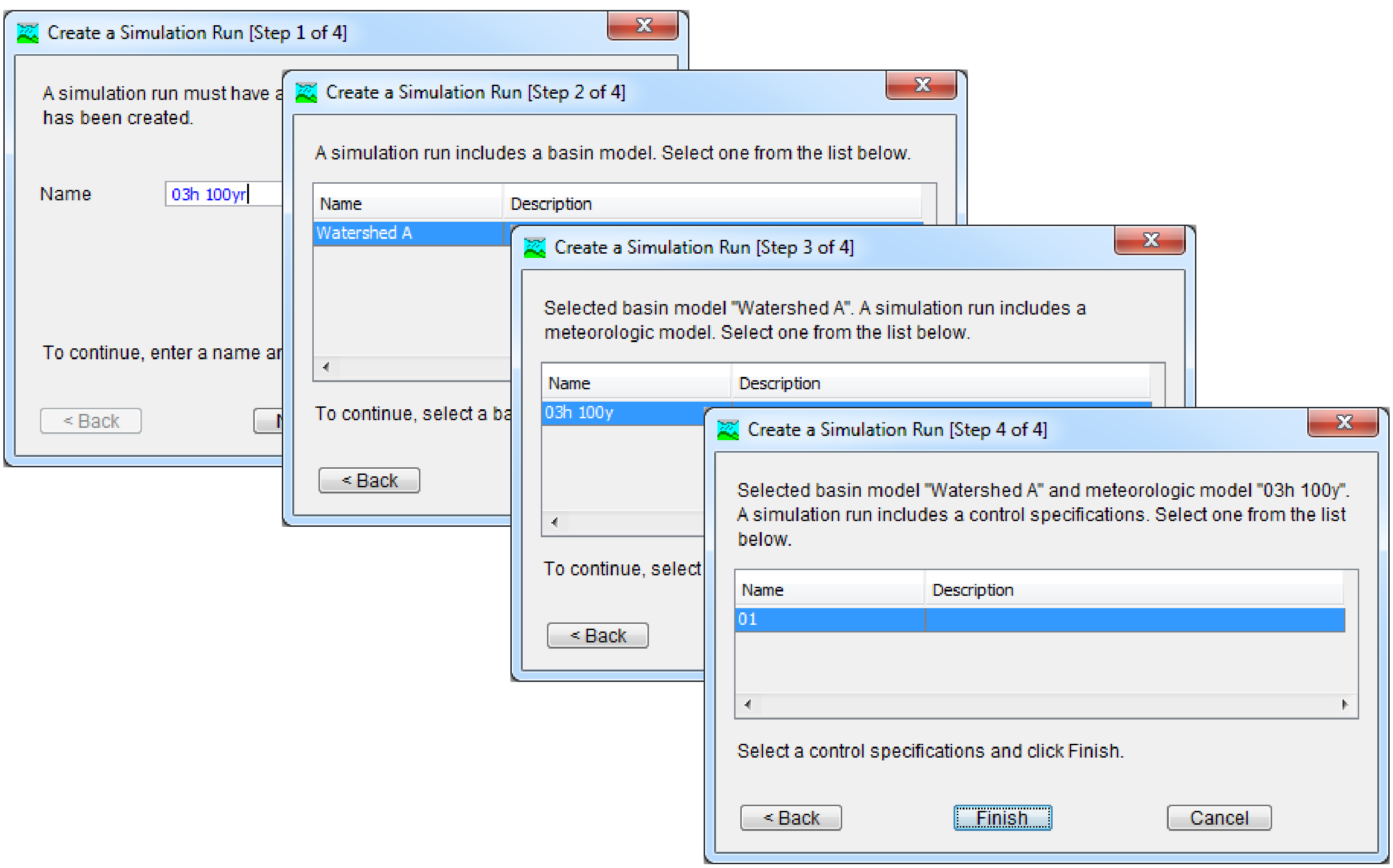


Simulating a HEC-HMS Model

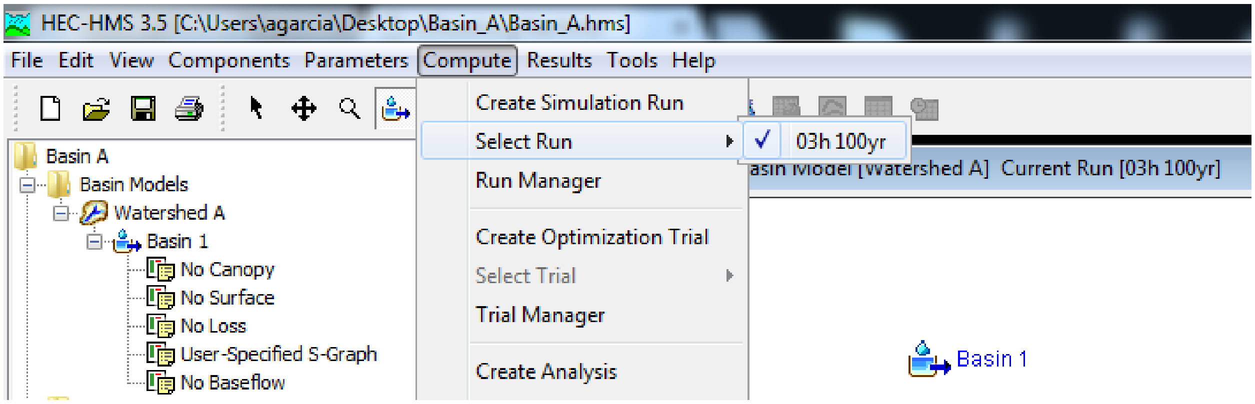
Navigate to the Compute option on the menu bar and select “**Create Simulation Run**”.



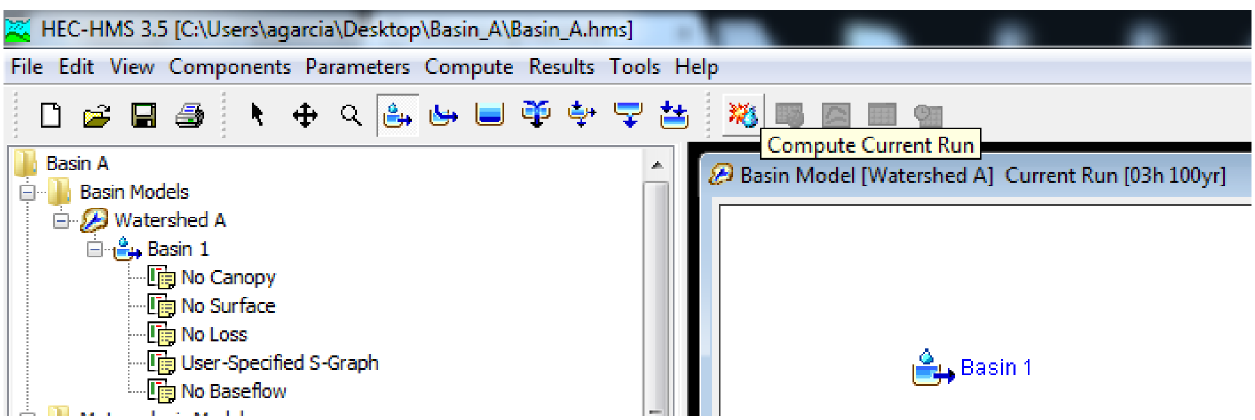
Assign a name to the simulation run in Step 1 (e.g., 03h 100yr), select the **basin model** in Step 2, select the **meteorologic model** in Step 3, and the **control specification** in Step 4.

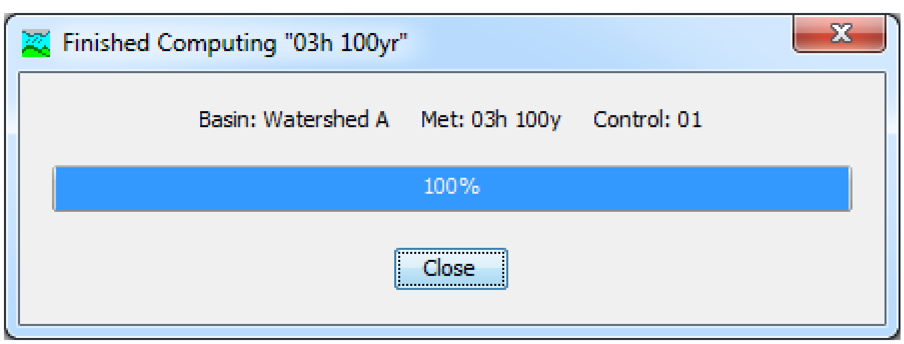


Once a run has been created, the user may navigate back to the Compute option on the menu bar to select a run. Runs can be added or deleted in the Run Manager.



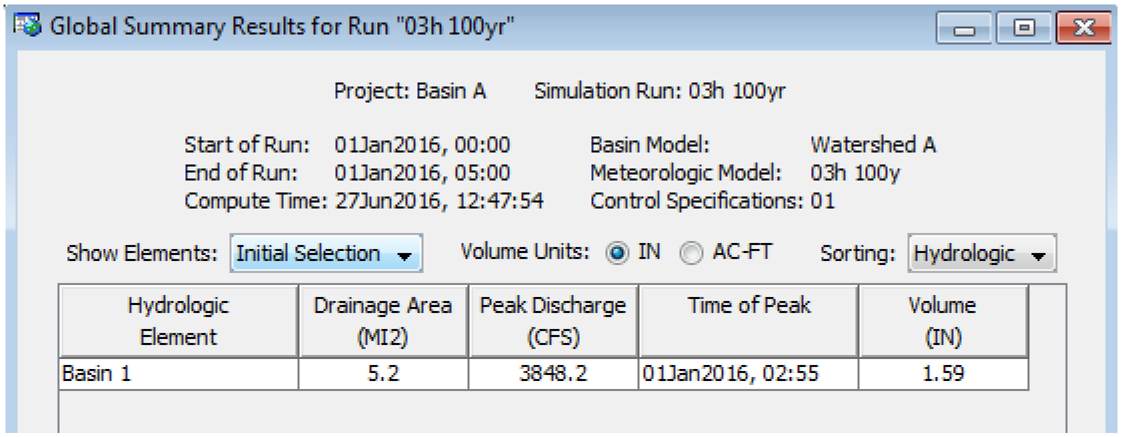
Once a Run is selected, select the **Compute Current Run**  to begin the simulation. A processing dialog box will appear showing the status of the simulation. Be sure to review the message log for any errors that may have been encountered.



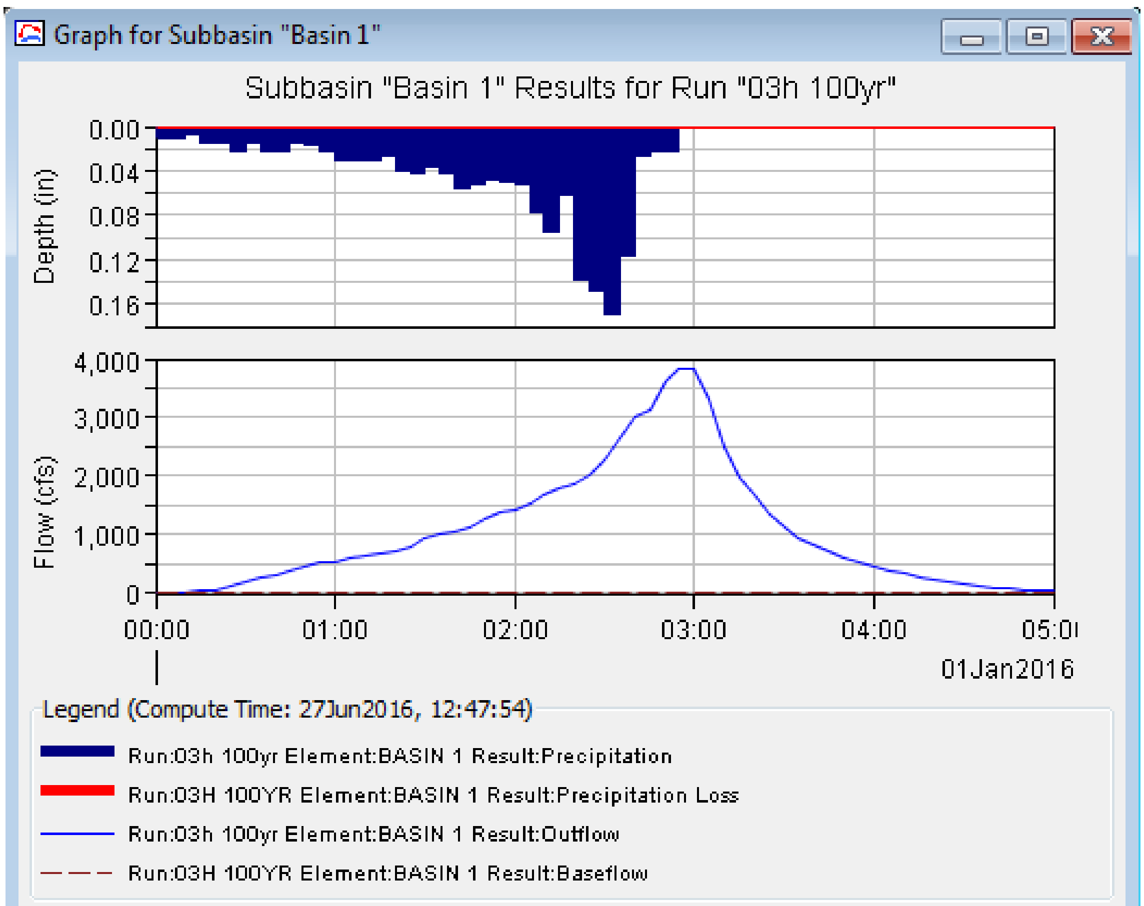


Viewing the HEC-HMS Results

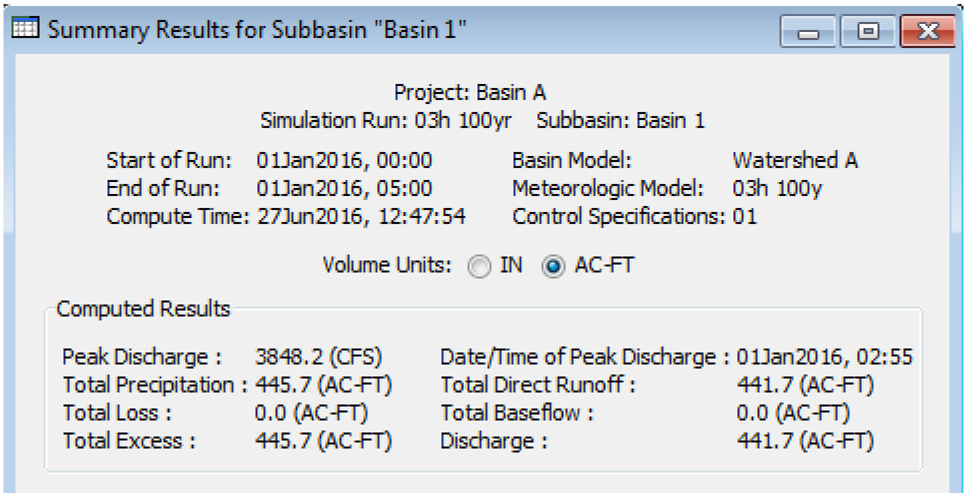
View Global Summary Table



View Graph for Selected Element(s)



View Summary Table for Selected Element(s)



Summary Results for Subbasin "Basin 1"

Project: Basin A
Simulation Run: 03h 100yr   Subbasin: Basin 1

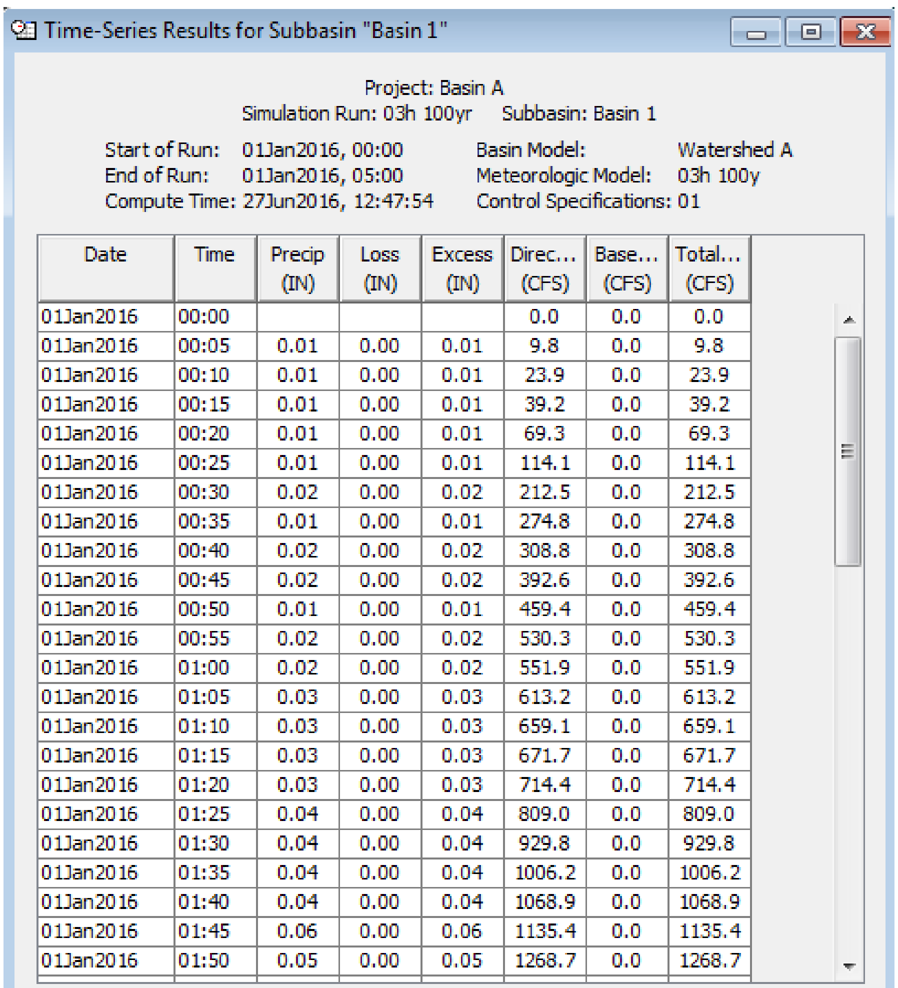
Start of Run: 01Jan2016, 00:00   Basin Model: Watershed A
End of Run: 01Jan2016, 05:00   Meteorologic Model: 03h 100y
Compute Time: 27Jun2016, 12:47:54   Control Specifications: 01

Volume Units: IN AC-FT

Computed Results

Peak Discharge : 3848.2 (CFS)   Date/Time of Peak Discharge : 01Jan2016, 02:55
Total Precipitation : 445.7 (AC-FT)   Total Direct Runoff : 441.7 (AC-FT)
Total Loss : 0.0 (AC-FT)   Total Baseflow : 0.0 (AC-FT)
Total Excess : 445.7 (AC-FT)   Discharge : 441.7 (AC-FT)

View Time-Series Table for Selected Element(s)



Time-Series Results for Subbasin "Basin 1"

Project: Basin A
Simulation Run: 03h 100yr   Subbasin: Basin 1

Start of Run: 01Jan2016, 00:00   Basin Model: Watershed A
End of Run: 01Jan2016, 05:00   Meteorologic Model: 03h 100y
Compute Time: 27Jun2016, 12:47:54   Control Specifications: 01

Date	Time	Precip (IN)	Loss (IN)	Excess (IN)	Direc... (CFS)	Base... (CFS)	Total... (CFS)
01Jan2016	00:00				0.0	0.0	0.0
01Jan2016	00:05	0.01	0.00	0.01	9.8	0.0	9.8
01Jan2016	00:10	0.01	0.00	0.01	23.9	0.0	23.9
01Jan2016	00:15	0.01	0.00	0.01	39.2	0.0	39.2
01Jan2016	00:20	0.01	0.00	0.01	69.3	0.0	69.3
01Jan2016	00:25	0.01	0.00	0.01	114.1	0.0	114.1
01Jan2016	00:30	0.02	0.00	0.02	212.5	0.0	212.5
01Jan2016	00:35	0.01	0.00	0.01	274.8	0.0	274.8
01Jan2016	00:40	0.02	0.00	0.02	308.8	0.0	308.8
01Jan2016	00:45	0.02	0.00	0.02	392.6	0.0	392.6
01Jan2016	00:50	0.01	0.00	0.01	459.4	0.0	459.4
01Jan2016	00:55	0.02	0.00	0.02	530.3	0.0	530.3
01Jan2016	01:00	0.02	0.00	0.02	551.9	0.0	551.9
01Jan2016	01:05	0.03	0.00	0.03	613.2	0.0	613.2
01Jan2016	01:10	0.03	0.00	0.03	659.1	0.0	659.1
01Jan2016	01:15	0.03	0.00	0.03	671.7	0.0	671.7
01Jan2016	01:20	0.03	0.00	0.03	714.4	0.0	714.4
01Jan2016	01:25	0.04	0.00	0.04	809.0	0.0	809.0
01Jan2016	01:30	0.04	0.00	0.04	929.8	0.0	929.8
01Jan2016	01:35	0.04	0.00	0.04	1006.2	0.0	1006.2
01Jan2016	01:40	0.04	0.00	0.04	1068.9	0.0	1068.9
01Jan2016	01:45	0.06	0.00	0.06	1135.4	0.0	1135.4
01Jan2016	01:50	0.05	0.00	0.05	1268.7	0.0	1268.7

Appendix A Rainfall Distributions

Tabulations of rainfall patterns published in the District's Hydrology Manual for the 3-, 6-, and 24-hour storms are for use with the Synthetic Unit Hydrograph method. As for the 1-hour storm, the District generally does not recommend the use of the Synthetic Unit Hydrograph method for smaller watersheds (less than 300 to 500 acres), however, when volume is a consideration, such as with a basin, rational tabling will not suffice. Consequently, the District has developed a method for generating the 1-hour rainfall distribution to assist with calculating the volume difference between the pre-project and post-project condition hydrology analysis.

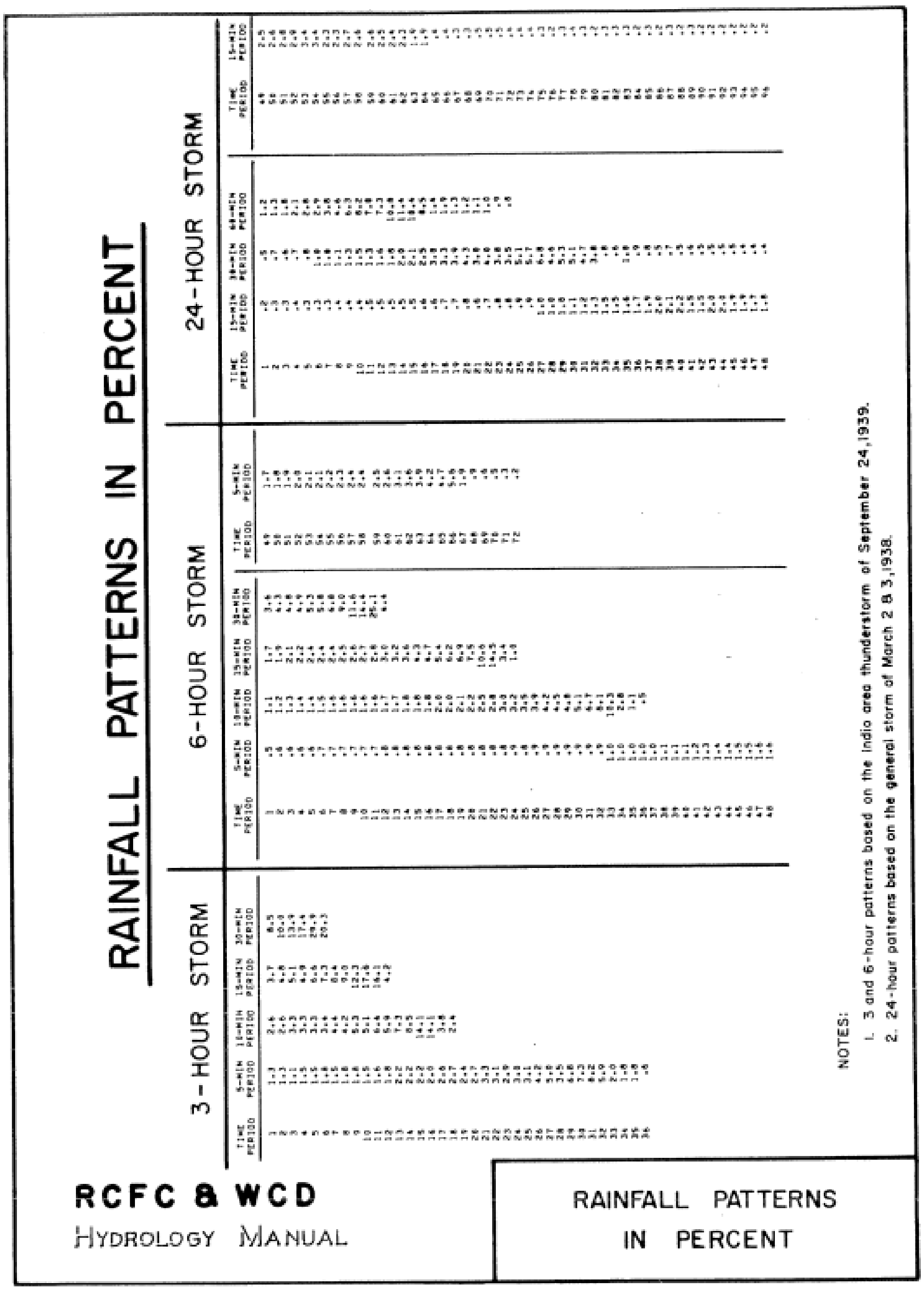
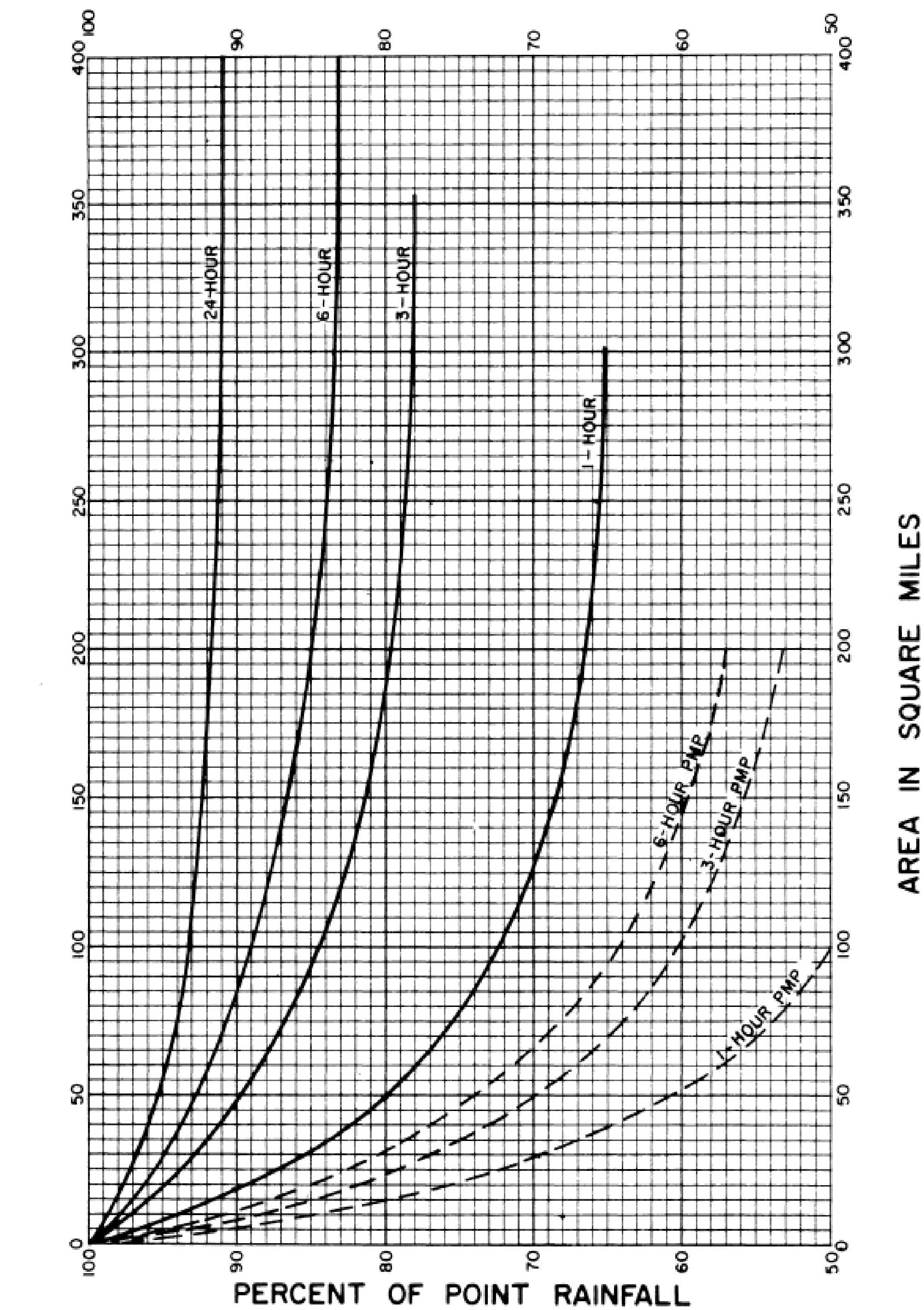


PLATE E-5.9



Reference: Bibliography items No. 27 & 29.

RCFC & WCD

HYDROLOGY MANUAL

DEPTH-AREA-DURATION RELATIONSHIPS

PLATE E-5.8

Appendix C Lag Time Equation

Lag for a drainage area is defined as the elapsed time in hours from the beginning of unit effective rainfall to the instant that the summation hydrograph for the concentration point of an area reaches 50 percent of ultimate discharge. Lag can be calculated from the physical characteristics of a drainage area by the empirical formula:

$$\text{Lag (hours)} = 24n\left[\frac{L * Lca}{S^{1/2}}\right]^{0.38}$$

where:

n = the visually estimated mean of the n (Manning's formula) values of all collection streams and channels within the watershed.

L = length of longest watercourse (miles)

Lca = length along longest watercourse, measured upstream to a point opposite the centroid of the area (miles)

S = overall slope of the longest watercourse between headwaters and the collection point (ft/mile)

TERMINOLOGY

L = LENGTH OF LONGEST WATERCOURSE.

L_{ca} = LENGTH ALONG LONGEST WATERCOURSE, MEASURED UPSTREAM TO POINT OPPOSITE CENTER OF AREA.

S = OVER-ALL SLOPE OF LONGEST WATERCOURSE BETWEEN HEADWATER AND COLLECTION POINT.

LAG = ELAPSED TIME FROM BEGINNING OF UNIT PRECIPITATION TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50% OF ULTIMATE DISCHARGE.

$\bar{n}$ = VISUALLY ESTIMATED MEAN OF THE n (MANNING'S FORMULA) VALUES OF ALL THE CHANNELS WITHIN AN AREA.

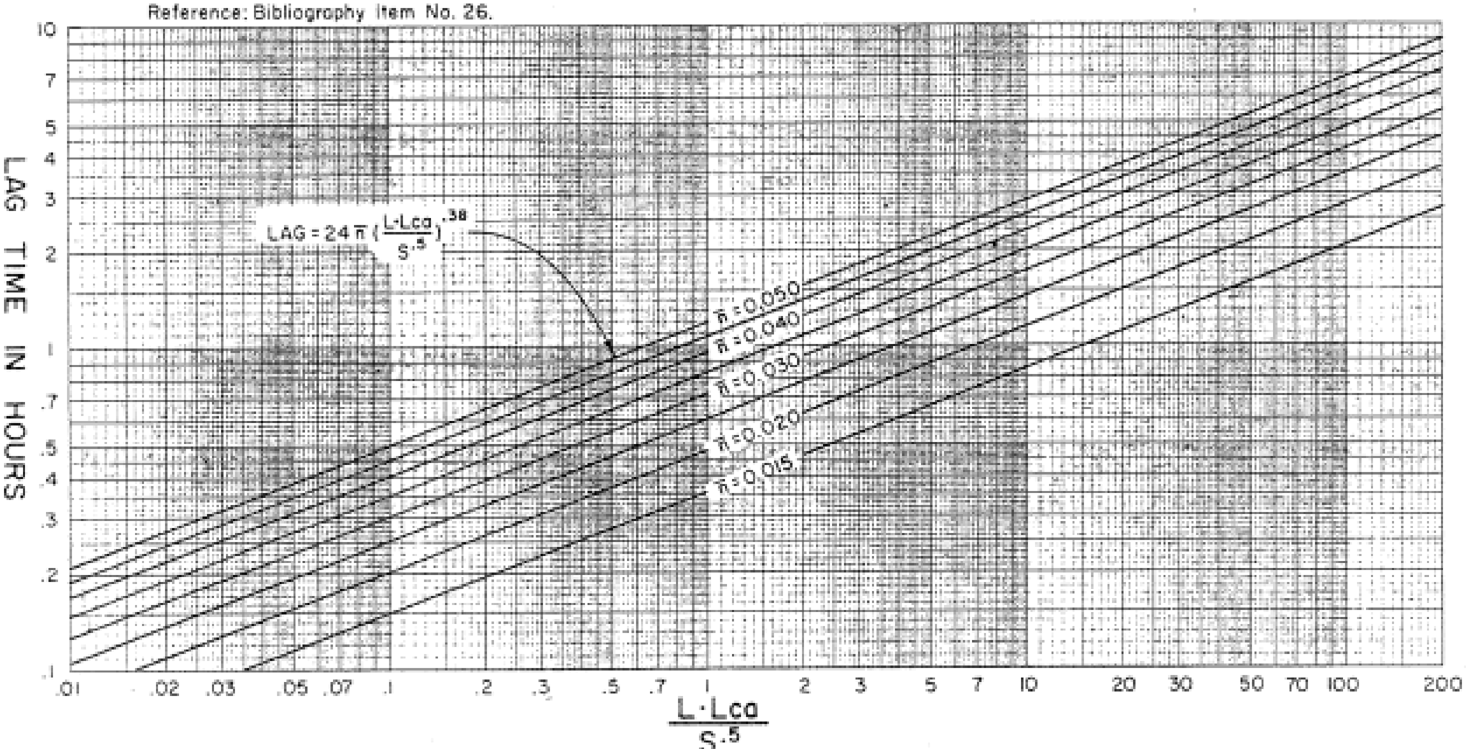
GUIDE FOR ESTIMATING BASIN FACTOR ($\bar{n}$)

$\bar{n}$=0.050: DRAINAGE AREA IS QUITE RUGGED, WITH SHARP RIDGES AND NARROW, STEEP CANYONS THROUGH WHICH WATERCOURSES MEANDER AROUND SHARP BENDS, OVER LARGE BOULDERS, AND CONSIDERABLE DEBRIS OBSTRUCTION. THE GROUND COVER, EXCLUDING SMALL AREAS OF ROCK OUTCROPS, INCLUDES MANY TREES AND CONSIDERABLE UNDERBRUSH. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$=0.030: DRAINAGE AREA IS GENERALLY ROLLING, WITH ROUNDED RIDGES AND MODERATE SIDE SLOPES. WATERCOURSES MEANDER IN FAIRLY STRAIGHT, UNIMPROVED CHANNELS WITH SOME BOULDERS AND LODGED DEBRIS. GROUND COVER INCLUDES SCATTERED BRUSH AND GRASSES. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$=0.015: DRAINAGE AREA HAS FAIRLY UNIFORM, GENTLE SLOPES WITH MOST WATERCOURSES EITHER IMPROVED OR ALONG PAVED STREETS. GROUND COVER CONSISTS OF SOME GRASSES WITH APPRECIABLE AREAS DEVELOPED TO THE EXTENT THAT A LARGE PERCENTAGE OF THE AREA IS IMPERVIOUS.

Reference: Bibliography Item No. 26.



RCFC & WCD

HYDROLOGY MANUAL

LAG RELATIONSHIPS FOR SOUTHERN CALIFORNIA

PLATE E-3

Appendix D Loss Rates

Loss rates for pervious areas can be estimated using Plates E-6.1 and E-6.2.

Loss rates for pervious areas can be adjusted to account for developed area using the relationship:

$$F = F_p\,(1.00 - 0.9A_i)$$

Where:

F = Adjusted loss rate – inches/hour

F_p = Loss rate for pervious areas – inches/hour (*Plate E-6.2*)

A_i = Impervious area (actual) – decimal percent (*Plate E6.3*)

Adjusted loss rates for watersheds within the District are generally between 0.10 to 0.40 inches/hour.

Constant Loss Rate

For short storm durations (1-, 3-, 6-hour) the adjusted loss rate may be taken as constant.

Variable Loss Rate

For longer storm durations (24-hour) the loss rate should normally be varied to decrease with time to yield a mean equal to the adjusted loss rate.

This can be expressed as a function of time:

$$F_T = C(D - T)^{1.55} + F_m$$

Where:

F_T = Adjusted loss rate at time "T" – inches/hour

C = $(F-F_m)/54$

F = Adjusted loss rate – inches/hour (*as previously defined*)

D = Storm duration – hours = 24-hours

T = Time from beginning of storm - hours

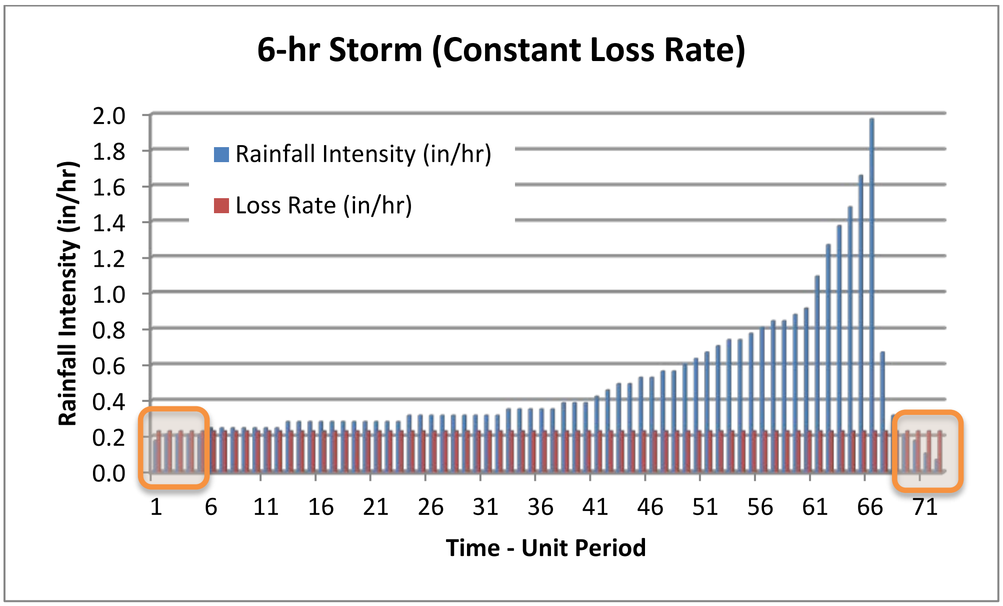
F_m = Minimum value on loss curve – inches/hour (*typically 50-75% of F*)

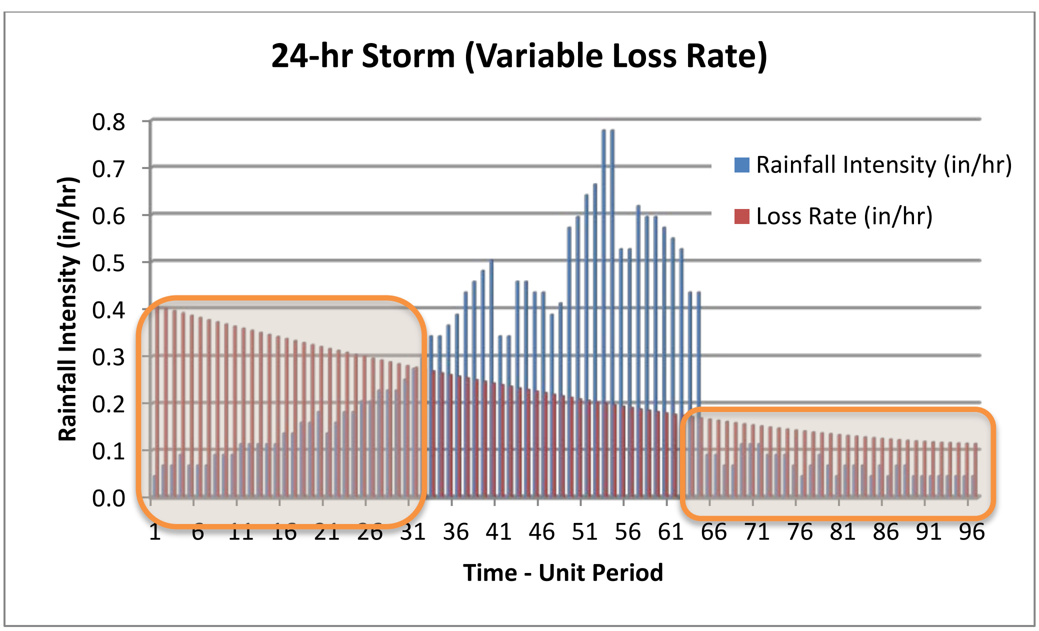
Low Loss

In the early and late stages of a design storm, the adjusted loss rate (constant or variable) will generally exceed the rainfall intensity on a unit time basis, indicating a zero runoff condition. This is considered unrealistic and therefore, to account for runoff occurring during such periods, a low loss rate is used.

The low loss rate is usually taken to be 80 to 90-percent of the rainfall for any unit time period where loss would otherwise exceed rainfall. This is equivalent to an effective rain of 10 to 20-percent of the storm rainfall for a particular time period.

Example:





Appendix E HEC-HMS vs CIVILDESIGN

CivilDesign, created by Joseph E. Bonadiman & Associates, has been used by the District for many years to generate flood hydrographs using the Synthetic Unit Hydrograph method. A sample project was used to compare the peak flow rates and volumes between CivilDesign and HEC-HMS. The results showed that peak flow rates and volumes were nearly identical between the two programs.