Workshop: Build a Basic HEC-HMS Model from Scratch

This workshop is designed to help new users of HEC-HMS learn how to apply the software. Not all the capabilities in HEC-HMS are demonstrated in the workshop as the focus is on creating a working model and calibrating the model to an observed flood event. This workshop presents HEC-HMS model development, calibration, and uncertainty assessment. You will start with an existing shapefiles that can be imported and used to create the HEC-HMS basin model network. You will parameterize the Basin Model, create a Meteorologic Model, and simulate a historic event. You will calibrate the model to the historic event by manually adjusting model parameters to improve model performance. Then you will evaluate the effects of parameter uncertainty in computed flow by running an HEC-HMS Uncertainty Analysis.

Overview

In this workshop you will:

- Create a basin model from existing shapefiles
- Review determining precipitation gage weights with HEC-GeoHMS
- Parameterize an HEC-HMS Basin Model
- Add streamflow and precipitation gage information to the project
- Create an HEC-HMS Meteorologic Model
- Create and compute an HEC-HMS Simulation Run
- Calibrate the model and evaluate model performance
- Create an uncertainty analysis and evaluate results

Background

The Punxsutawney Watershed (400 km^2) is part of the Allegheny River Basin located in western Pennsylvania, USA. Primary conveyance streams include: Stump Creek, East Branch Mahoning Creek, and Mahoning Creek. The confluence of Stump Creek and East Branch Mahoning Creek is located east of the enclave of Big Run. Mahoning Creek is downstream of the confluence. A map of the watershed is shown in Figure 1.

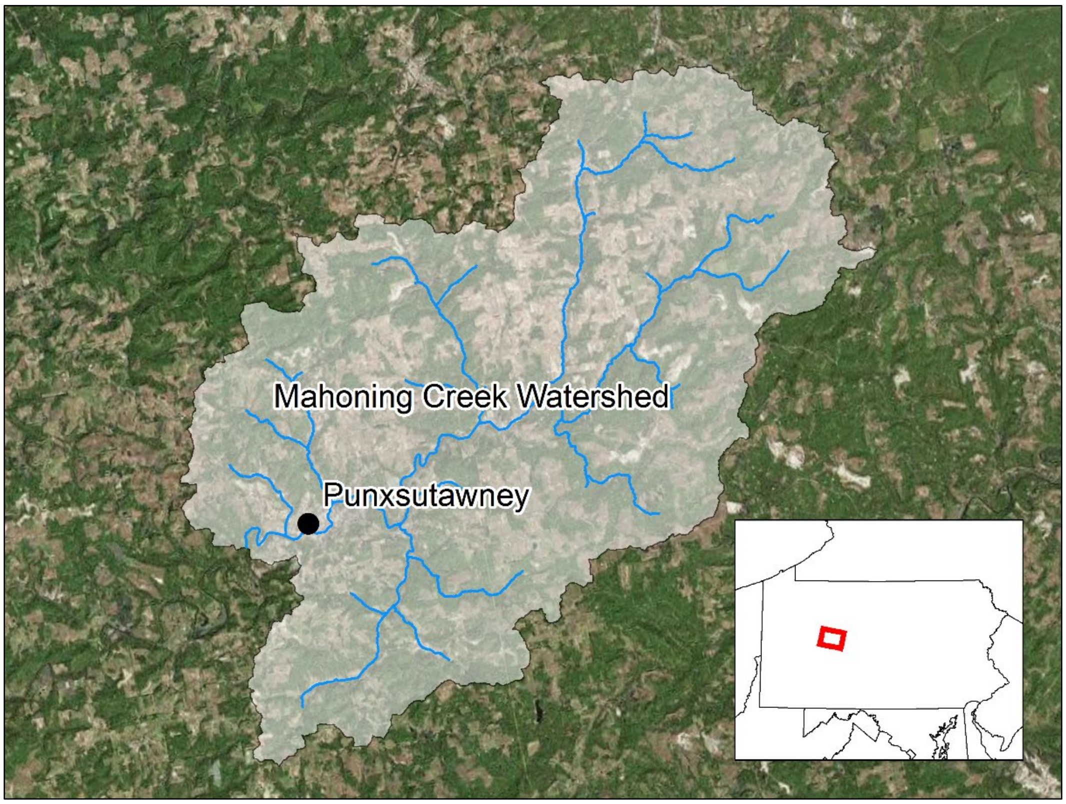


Figure 1. Study Area: Mahoning Creek upstream of Punxsutawney, PA

A storm event in April 1994 produced high-runoff in the town of Punxsutawney. Several regional precipitation gages and a discharge gage in Punxsutawney captured the event. These gages will be used to create a calibrated model of the event. The watershed will be modeled as 3 subbasins with incremental precipitation from recording rainfall gages; user-specified gage weighting will be used. Figure 2 shows the subdivided basin and nearby gages.

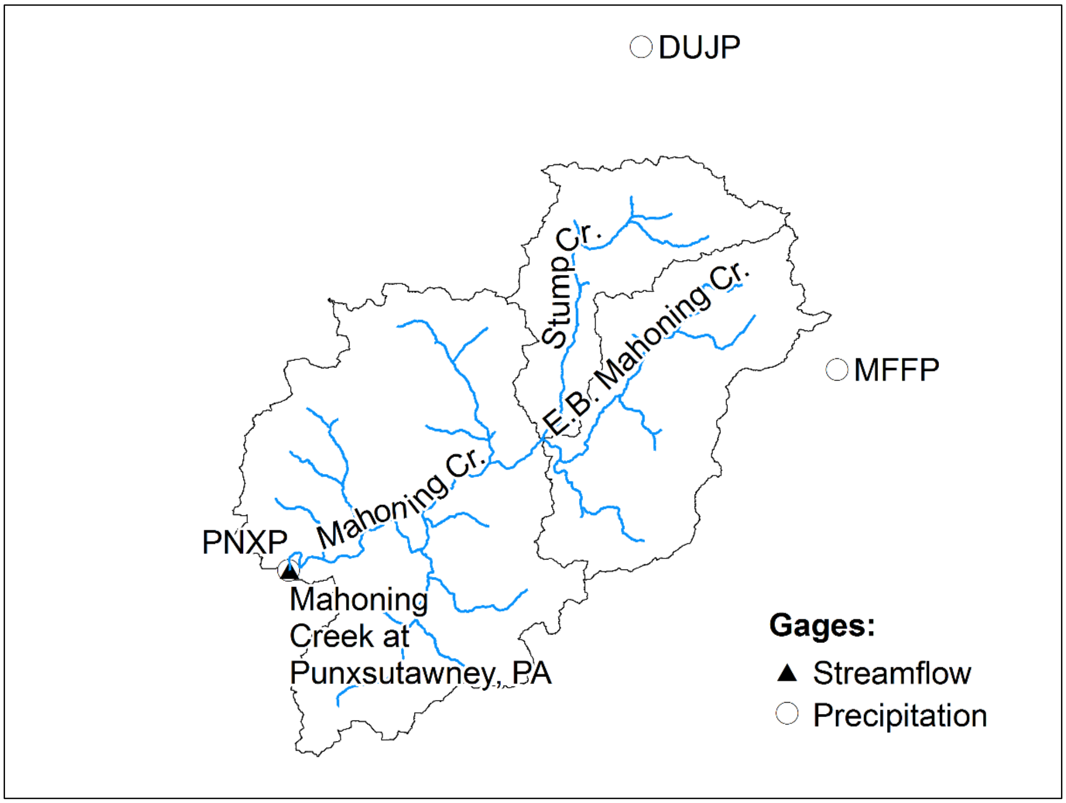


Figure 2. Precipitation and streamflow gages near Punxsutawney, PA

Tasks

1. Create a Basin Model from Existing Shapefiles

Basin geometry is defined by delineating subbasins and river reaches. HEC-GeoHMS, an add-in to ArcGIS, can be used to create the initial Basin Model from terrain information. Another option is to import GIS features from shapefiles and then link the elements using junctions. This task shows how to import shapefiles, which can be used to define HEC-HMS subbasin and reach elements.

The subbasin delineation is shown in Figure 3.

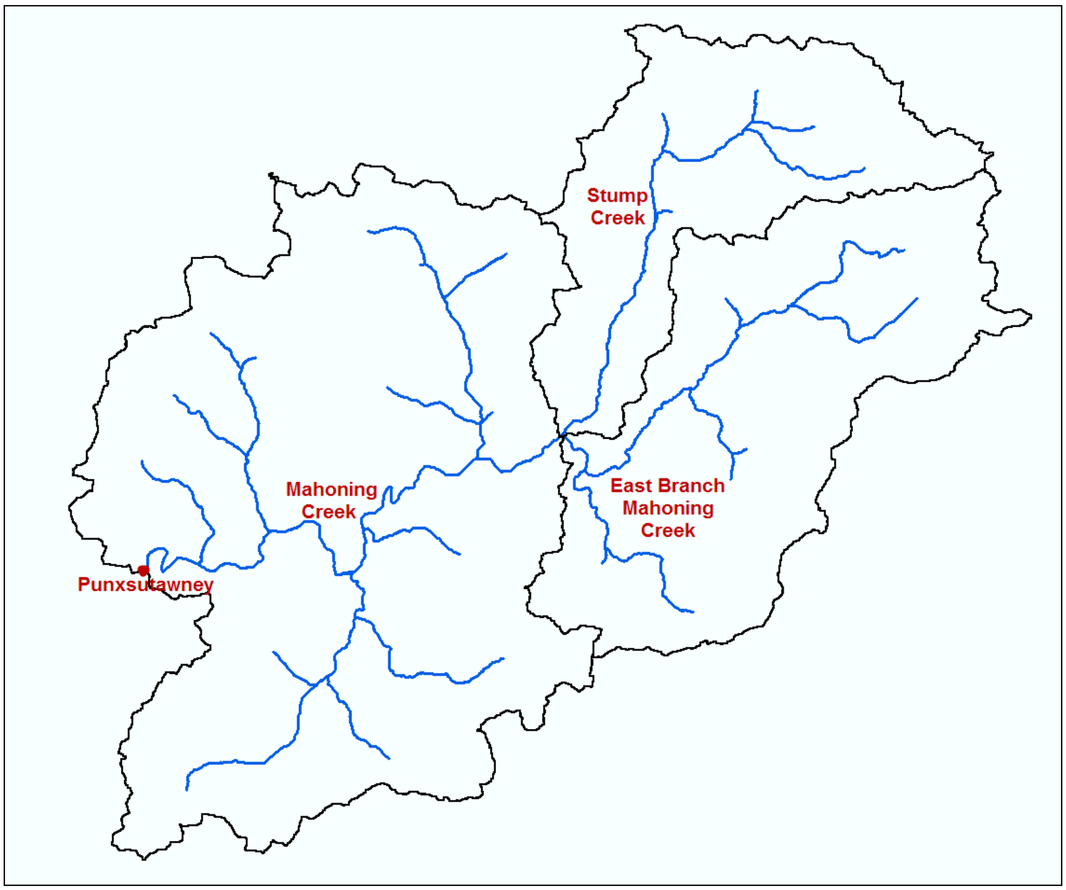


Figure 3. Final subbasin delineation of Mahoning Creek

1.1. **Double click the HEC-HMS icon** to start the program.

1.2. The main program window will appear; notice the menu bar across the top of the window with menus beginning with File and ending with Help. Also part of the window are the tool bars directly beneath the menu bar, the Watershed Explorer, the Component Editor, Message Log, and the Desktop. To open an existing project, **click File and select Open…**.

1.3. The Open an Existing Project window will open; click **Browse** to open the **Select Project File** window. Navigate to the project directory and select the **"HMS_Example.hms"** file. Click the **Select** button and the existing project will open.

1.4. Create a new Basin Model using the Basin Model Manager (select the **Components→Basin Model Manager** menu option). Name the basin model "MahoningatPunx". Open the basin model by selecting it in the Watershed Explorer. The basin model map will be empty.

1.5. Go to the **GIS** menu and choose the **Coordinate System** menu option. Within the **Coordinate System** editor, choose the browse button and navigate to the **… \HMS_Example\maps** directory on your computer. Select the **Subbasin.prj** file. The coordinate system information should populate as shown in Figure 4.

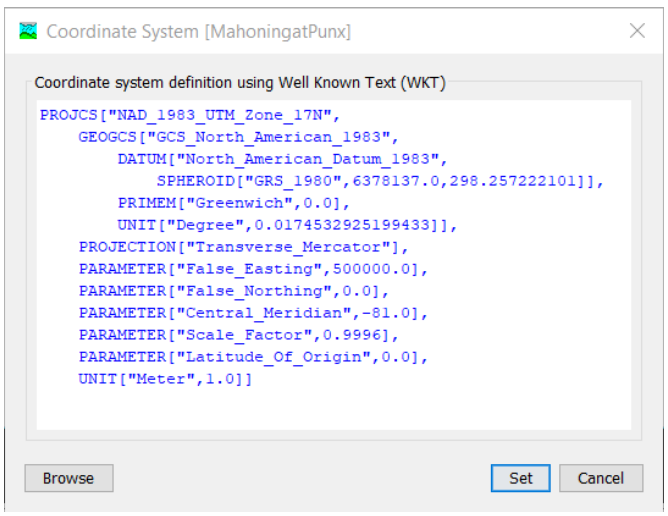


Figure 4. Coordinate system defined for the MahoningatPunx basin model

1.6. Import GIS element by selecting the **GIS→Import Georeferenced Elements** menu options. Choose the **Subbasins** element type and click the **Next** button. Navigate to the **… \HMS_Example\maps** directory and select the **Subbasins.shp** file. Click next. Choose the "**Name**" attribute field to set the subbasin element names. Click the finish button. You will see three subbasin elements in the basin model map. You can interact with the elements by clicking on the subbasin polygons or element icons.

1.7. Follow the previous steps and import the reach feature in the **Reach.shp** file. Figure 5 shows the three subbasin elements and the one reach element that were imported from the two shapefiles. These elements are not connected to one another.

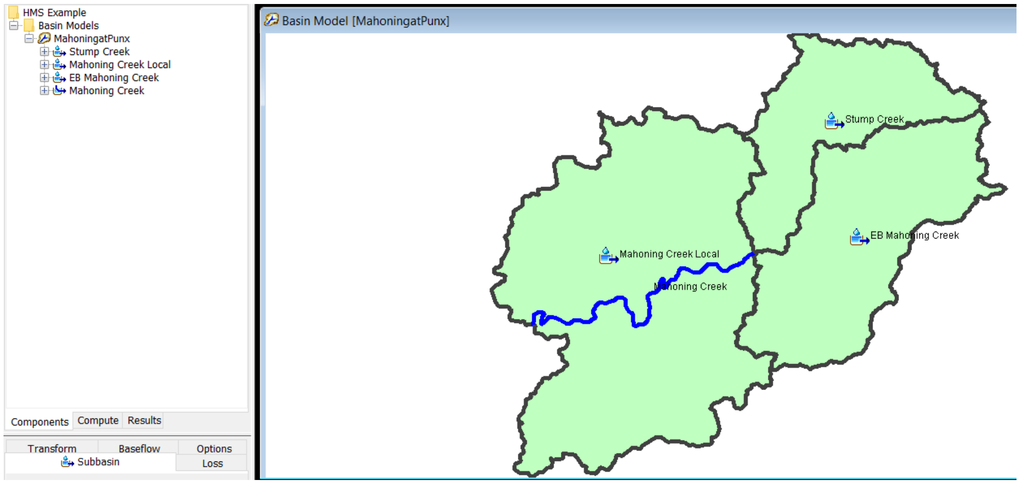


Figure 5. Subbasin and reach elements imported into the basin model

1.8. Add a junction element to the basin model map. Click on the **Junction Creation Tool** toolbar button and then click in the map around the upstream end of the Mahoning Creek reach element. Name the junction "**Big Run**".

1.9. **Connect** both Stump Creek and the EB Mahoning Creek subbasin elements to the Big Run junction element. Then, connect the Big Run junction element to the Mahoning Creek reach element. Elements can be connected by right clicking on the element icon in the map, selecting the **Connect Downstream** menu option, and then clicking on the downstream element. A simple connection should be shown in the map when elements are connected to one another. The exception is when elements are connected to a reach created by GIS features. You will not see the simple connection from the Big Run junction to the Mahoning Creek reach element, but the Big Junction component editor will show the connection.

1.10. Add a sink element and name it **Punxsutawney**. Connect the Mahoning Creek Local subbasin element and the Mahoning Creek reach element to the new sink element. Now, the elements should be linked to one another in the basin model map. Right click on the MahoningatPunx basin model name in the Watershed Explorer and choose the **Resort Elements Hydrologically** menu option. The elements in the Watershed Explorer should be ordered from upstream to downstream, as shown in Figure 6.

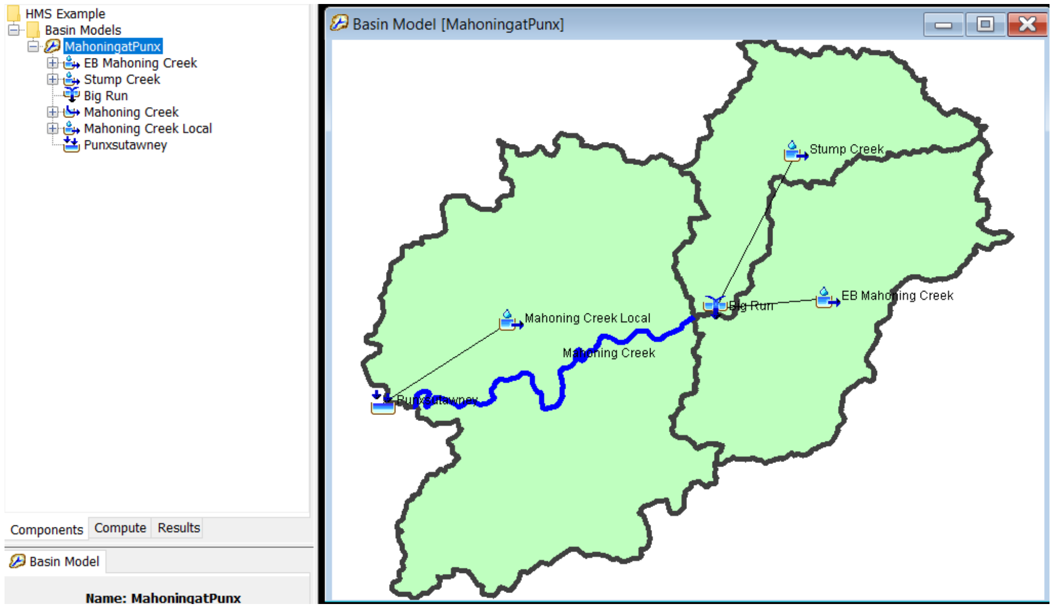


Figure 6. Basin model with georeferenced elements that are connected and displayed in hydrologic order

2. Review: Determine Precipitation Gage Weights with HEC-GeoHMS

Note: This task has been already been performed for you and is presented for your information.

A GIS was used to estimate precipitation gage weights for computing basin average precipitation. Figure 7 shows three precipitation gages in the region and their location with respect to the watershed. Thiessen polygons were created and then area weights computed based on intersecting the Thiessen polygons with the subbasin polygons.

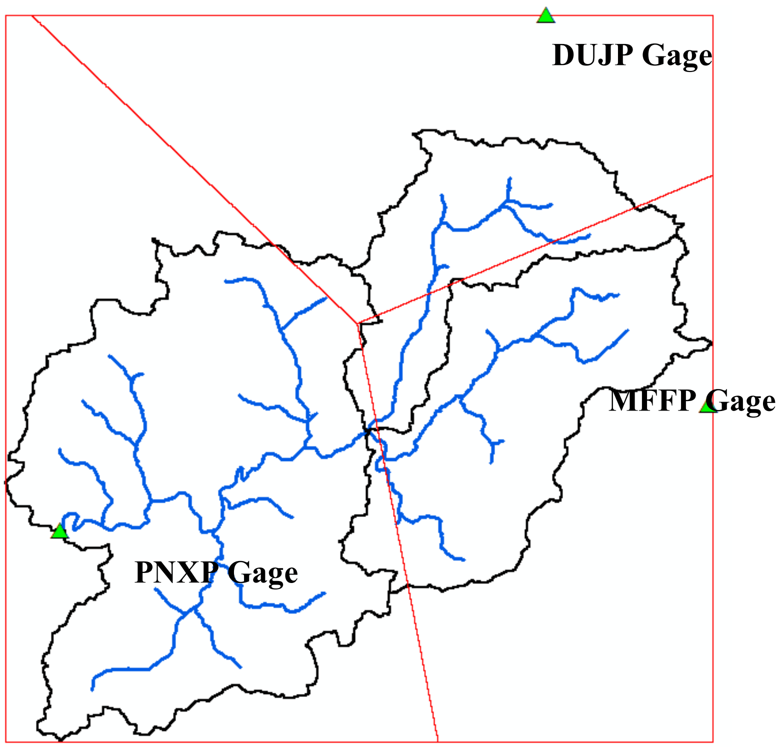


Figure 7. Thiessen polygons for Mahoning Creek gages

Results from the gage weight analysis are shown in Table 1.

Table 1. Precipitation gage weights using Thiessen polygons

Subbasin	DUJP	MFFP	PNXP
EB Mahoning Creek	0.00	0.93	0.07
Mahoning Creek Local	0.02	0.00	0.98
Stump Creek	0.64	0.33	0.03

3. *Parameterize the Basin Model*

3.1. **Expand the Basin Models node and select the Basin Model “MahoningatPunx”.** A map of the Basin Model should open as shown in Figure 8. Notice the subbasin area has been populated for each subbasin element, and modeling methods have been selected – Loss Method: Initial and Constant, Transform Method: Clark Unit Hydrograph, Baseflow Method: Recession, and Routing Method: Lag.

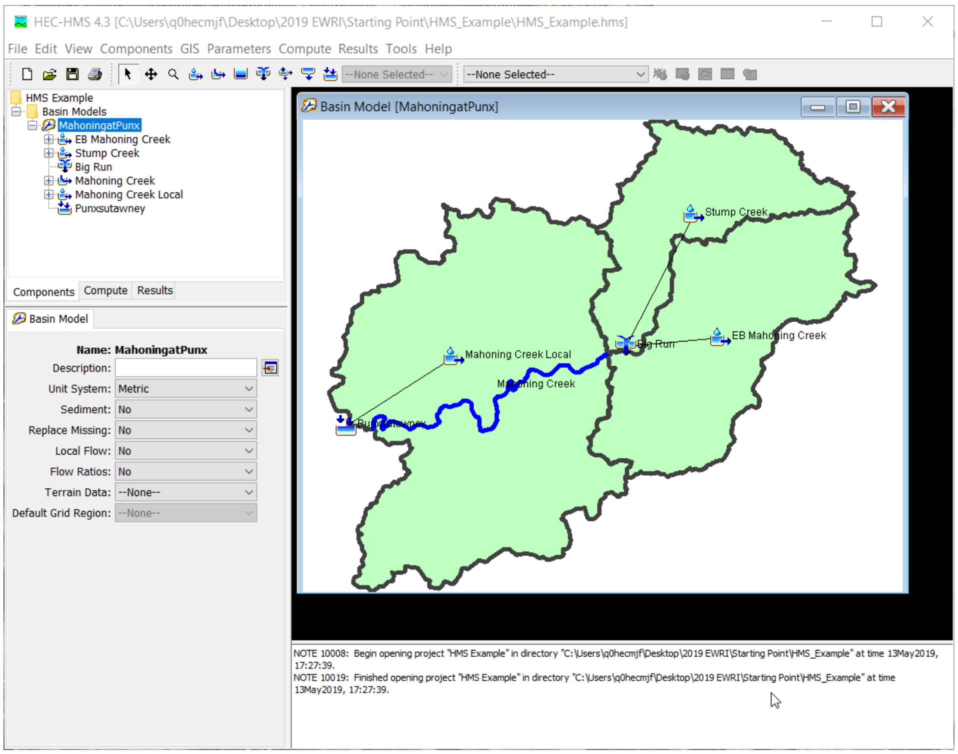


Figure 8. MahoningatPunx Basin Model map

3.2. The initial baseflow was determined by evaluating the observed baseflow at the beginning of the simulation and dividing by the total watershed area. The recession constant and ratio to peak values were determined from other regional models.

From the **Parameters** menu, select **Baseflow → Recession to** open the **Recession Baseflow gl**obal editor. Set Initial Type to **Discharge Per Area**. Recession baseflow parameters are shown in Table 2. Click the Apply and Close buttons when finished entering the baseflow parameters.

Table 2. Recession baseflow parameters

Subbasin	Initial Q ($m^3/s/km^2$)	Recession Constant	Ratio to Peak
E B Mahoning Creek	0.05	0.80	0.3
Stump Creek	0.05	0.80	0.3
Mahoning Creek Local	0.05	0.80	0.3

3.3. A table relating the Hydrologic Soil Group and landuse type to the constant loss rate was used to estimate the constant loss rate for each of the subbasins. The dominant soil types are Soil Group B and C and the dominant landuse in the watershed is Pasture/Dryland and Woodland/Grass. The initial loss was estimated based on the number of dry days prior to the storm event. The impervious area parameter was estimated based on GIS datasets.

Enter initial and constant loss parameters for each subbasin. From the **Parameters** menu select **Loss → Initial Constant Loss** to open the **Initial Constant Loss** global editor. Initial and constant loss rate parameters are shown in Table 3.

Table 3. Initial and constant loss rate parameters

Subbasin	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Impervious Area (%)
E B Mahoning Creek	8	2.5	3.0
Stump Creek	8	3	3.0
Mahoning Creek Local	8	2.8	5.0

3.4. The time of concentration was estimated using the TR-55 method where the travel time along the longest flowpath was estimated using slope, land use characteristics, and channel geometry. The storage coefficient was estimated using regional regression information between the time of concentration and the storage coefficient. The simple relationship is storage coefficient = 1.6 X time of concentration.

Enter Clark unit hydrograph parameters for each subbasin. From the **Parameters** menu select **Transform → Clark Unit**

Hydrograph to open the Clark Transform global editor. Clark transform parameters are shown in Table 4.

Table 4. Clark unit hydrograph parameters

Subbasin	Time of Concentration (hr)	Storage Coefficient (hr)
E B Mahoning Creek	3.7	5.9
Stump Creek	5.3	8.5
Mahoning Creek Local	6.0	9.6

3.5. The routing reach, Mahoning Creek, is used to route flow from the Big Run junction to the Punxsutawney junction. The Lag routing method was selected by default. Change the routing method to the **Muskingum** routing method. Select the Mahoning Creek reach element in the basin model map to open the reach's **Component Editor**. Change the **Routing Method** from **Lag** to **Muskingum**. The Muskingum K was estimated by computing a typical velocity for bank full flow and then using the reach length. The Muskingum K was determined to be **4 hours**. The Muskingum X and number of Subreaches are parameters best determined during model calibration. Set the Muskingum X to **0.25** and number of Subreaches to **4**.

Within the reach element's Component Editor, select the Routing tab. Enter a Muskingum K of **4 hours**, a Muskingum X of **0.25**, and number of Subreaches of **4**.

You have now completed the basin model for this project. The next step is to add observed flow and precipitation gage information.

4. Add Streamflow and Precipitation Gage Information

4.1. Create a new precipitation gage. From the **Components** menu select **Time-Series Data Manager**. In the manager window, press the **New…** button to create a gage (make sure the Precipitation Gages data type is selected); the window for creating a gage will open.

4.2. In the new gage window, change the default name to DUJP. Press the Create button to create the new gage; it will automatically be added to the Watershed Explorer. You can leave the manager window open since it will be used again shortly.

4.3. In the Watershed Explorer, browse to the gage you just created. In the **Component Editor** set the Data Source to **Single Record HEC-DSS**.

4.4. Select the correct external data source. You can click on the select button next to the filename field to navigate to the file. Browse to **…\HMS_Example\data\observe.dss**. It is good practice to store all external DSS data within the project directory. That way, the information is contained in the project and will be included whenever the model is handed off to others for application or review.

4.5. To select the correct pathname, click the Select DSS Pathname button, . You can use the Search by Parts filters near the top of the screen to find pathnames. Select the pathname with B-Part “**DUJP**” and C-Part “**PRECIP-INC**” (Figure 9). Click Set Pathname.

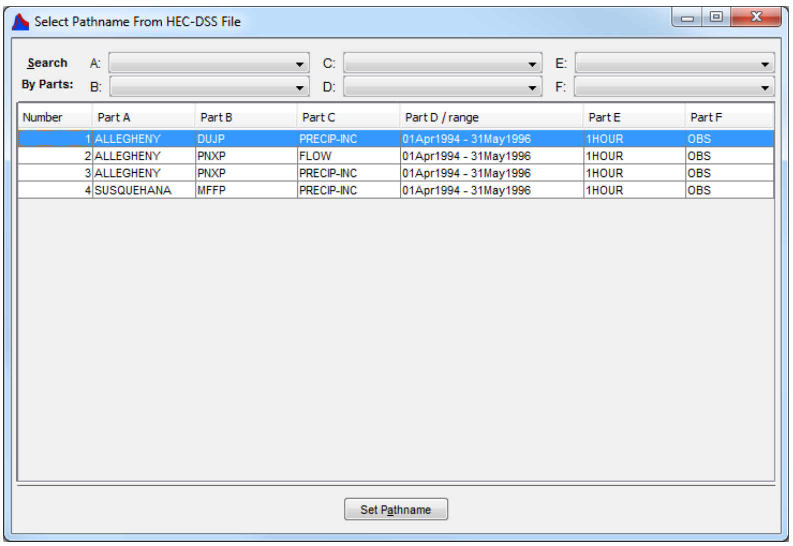


Figure 9. Selecting a the "DUJP" precipitation record

4.6. Change the default time window to inspect some of the data. In the Watershed Explorer, click on the time window under the "DUJP" gage icon. In the Component Editor, change start date to **10Apr1994**, the start time to 00:00, the end date to **15Apr1994**, and the end time to 00:00. Click on the Table and Graph tabs in the Component Editor to see the data, as shown in Figure 10.

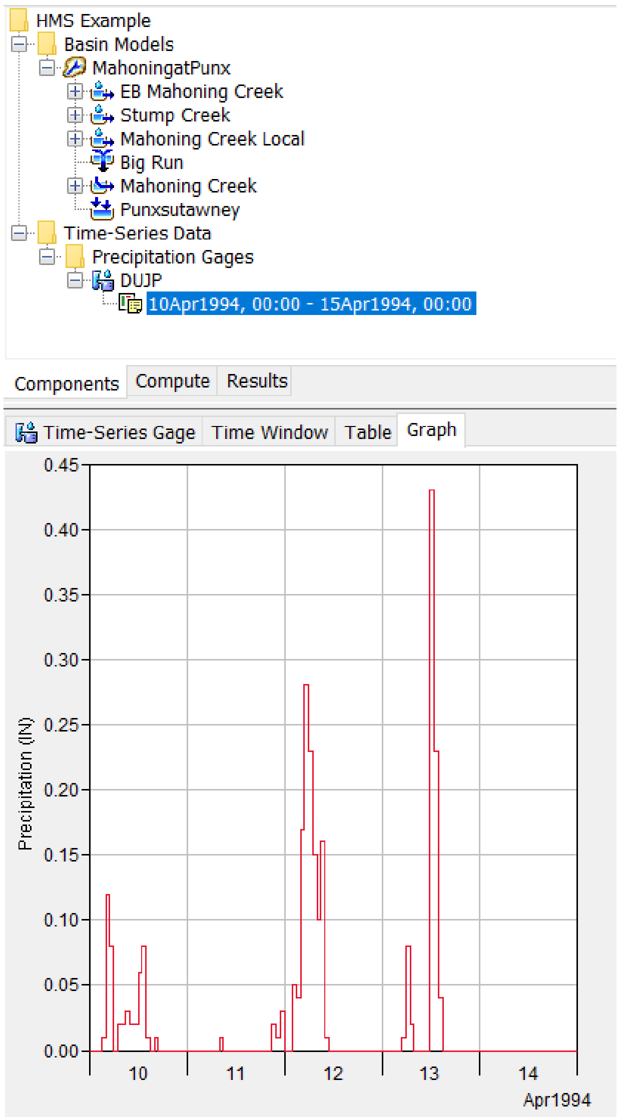


Figure 10. Viewing data in the component editor

You have finished setting up the "DUJP" time-series precipitation gage. We will use the gage later by referring to it by name.

Repeat steps 4.1 to 4.6 to create the "PNXP" and "MFFP" precipitation gages.

All of the precipitation data is now ready to use.

4.7. Add observed flow gage data. In the Time-Series Data Manager, change the data type to **Discharge Gage** and add a new gage. Name the gage **Punxsutawney Observed Flow** and link it to the flow record at Punxsutawney in the observe.dss file (B-Part = PNXP, C-Part=FLOW). Change the time window for the discharge gage and view the flood hydrograph for the April 1994 event, as shown in Figure 11.

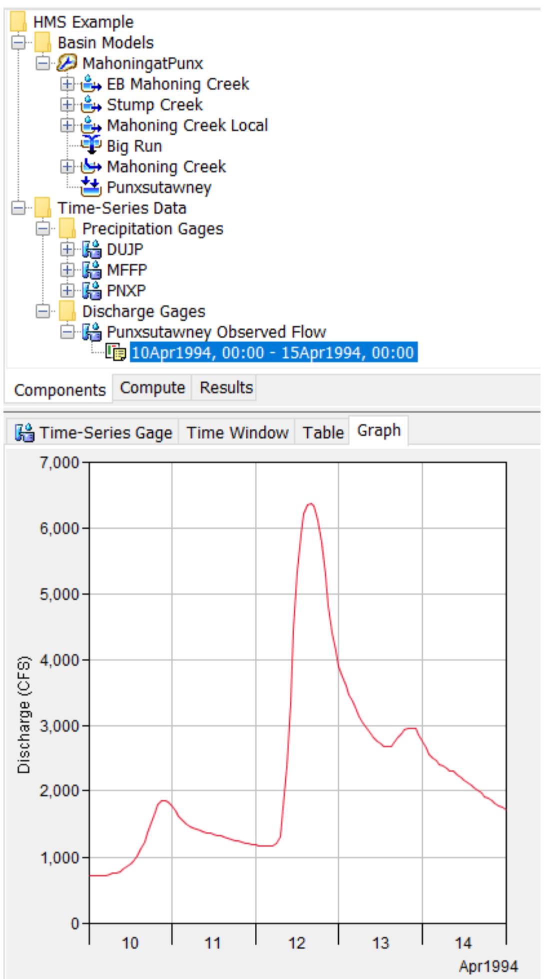


Figure 11. Flood hydrograph for April 1994 event

4.8. Reference the observed flow gage in the basin model to compare computed and observed results for the April 1994 simulation. In the Basin Model map, click on the junction element "Punxsutawney" to open the Component Editor. Select the Options tab, click the dropdown for Observed Flow, and select “Punxsutawney Observed Flow.”

5. Create a Meteorologic Model

5.1. From the Components menu, select the **Meteorologic Model Manager**; the Meteorologic Model Manager will open. Press the New… button to create a new meteorologic model.

5.2. Change the default name to **GageWeights** and press the Create button to create the new meteorologic model.

5.3. In the Watershed Explorer, browse to the new meteorologic model. Click on the model “GageWeights”. In the Component Editor, set the Precipitation method to Gage Weights. The evapotranspiration and snowmelt methods should be turned off, the unit system should be set to metric, and the Replace Missing option should be **Set to Default**.

5.4. Connect the meteorologic model to subbasins in the basin model. In the Component Editor, open the **Basins** tab. For basin model “MahoningatPunx,” set Include Subbasins to Yes.

The Gage Weights precipitation method requires parameters for each subbasin element in the basin model. The gage weights presented in Table 1 will be used in the Meteorologic Model for computing the total subbasin average precipitation. Only one gage will be used to define the time pattern.

5.5. In the Meteorologic Model, expand the node for “EB Mahoning Creek.” A Gage Weights node will display (Figure 12).

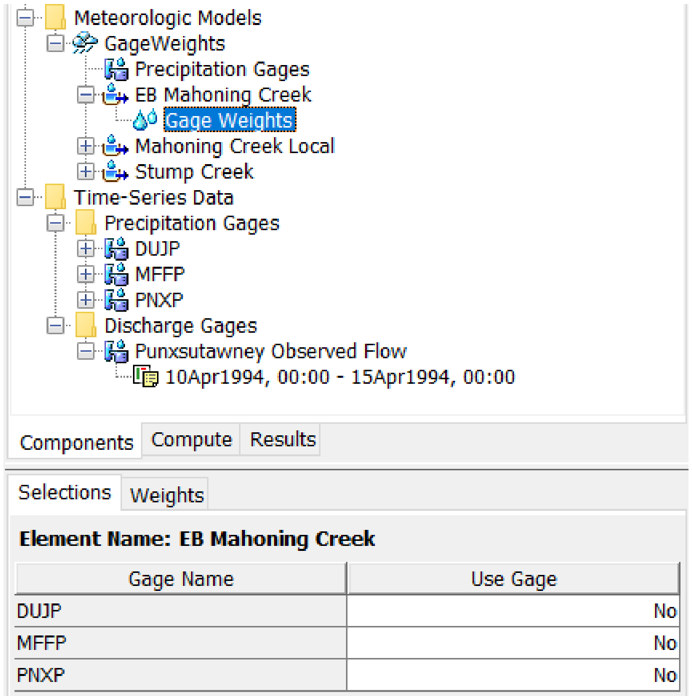


Figure 12. Gage Weights node selected

5.6. Select the **Gage Weights** node. The Component Editor will have two tabs: **Selections** and **Weights**. On the Selections tab, for each gage "DUJP," "MFFP," and "PNXP" change the Use Gage option to Yes.

5.7. Select the Weights tab. Enter the Depth Weight for each precipitation gage calculated using Thiessen polygons, shown in Table 1. The depth weight can be entered as either percentage in decimal format (Figure 13) or as an area.

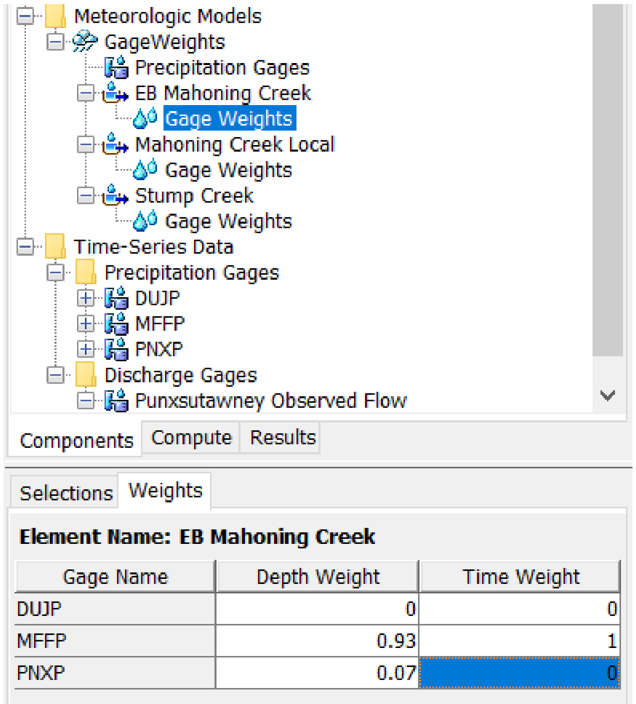


Figure 13. Depth and time weights specified for the EB Mahoning Creek subbasin

5.8. For subbasin "EB Mahoning Creek," enter a **Time Weight of 1.0** for the "MFFP" gage and 0.0 for the "PNXP" and "MFFP" gages. Here, the temporal distribution of the resulting hyetograph is solely governed by the temporal precipitation distribution of the "MFFP" gage.

Repeat steps 5.5-5.8 for subbasins "Mahoning Creek Local" and "Stump Creek." For "Mahoning Creek Local," set the Time Weight to 1 for the "PNXP" gage and to 0.0 for the "MFFP" and "DUJP" gages. For "Stump Creek," set the Time Weight to 1 for the "DUJP" gage and 0.0 for the "PNXP" and "MFFP" gages.

You have now completed the User-Specified Gage Weights Meteorologic Model.

6. Create and Run a Simulation

In order to create a Simulation Run, a Basin Model, a Meteorologic Model, and Control Specifications need to be defined in the project.

6.1. Create a new Control Specifications. From the Components menu select **Control Specifications Manager**; the manager window will open. Press the New… button to create a new control specifications.

6.2. Change the default name to **1994 Event**. Press the Create button to create the new Control Specifications.

6.3. In the Watershed Explorer, browse to the new Control Specifications. Enter a start date and time as 10Apr1994 at 00:00. Enter end date and time as 15Apr1994 at 00:00. Select 1 Hour for the time interval, as shown in Figure 14.

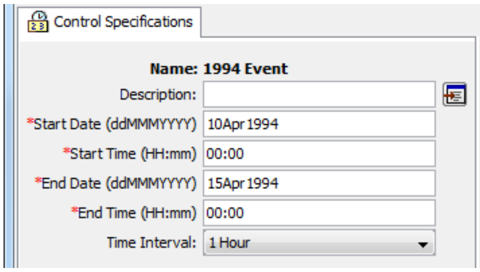


Figure 14. Control Specifications entered

The Basin Model, Meteorologic Model, and Control Specifications are complete. Now you will create and compute a Simulation Run.

6.4. From the Compute menu, select **Create Compute → Simulation Run**. A wizard window will open for creating a new simulation run. In Step 1, enter Simulation Run name: Run 1994 Flood Event. In Step 2, choose the "MahoningatPunx" Basin Model. In Step 3, choose the "GageWeights" Meteorologic Model. In Step 4, choose the "1994 Event" Control Specifications. Press the Finish button to complete the process of creating a Simulation Run.

6.5. Compute the Simulation Run. A Simulation Run must be selected before it can be computed. The Compute toolbar includes a selection list that shows all of the simulation runs that have been created in the project. Click on the selection list and choose "**Run: Run 1994 Flood Event.**" Once a Simulation Run has been selected, click the Compute button  immediately to the right of the selection list to perform the compute, as shown in Figure 15. The Compute button is available on the tool bar when a Simulation Run is selected. Alternately, from the Compute menu select the Compute Run (the name of the selected run will be shown within brackets next to the Compute Run menu option).

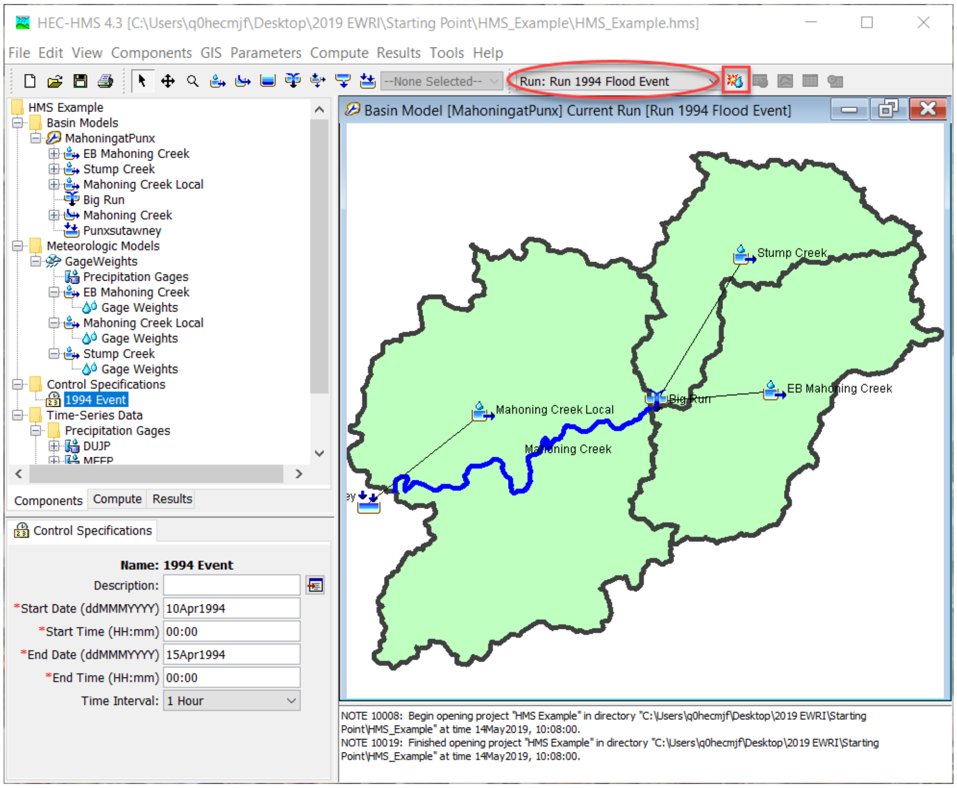
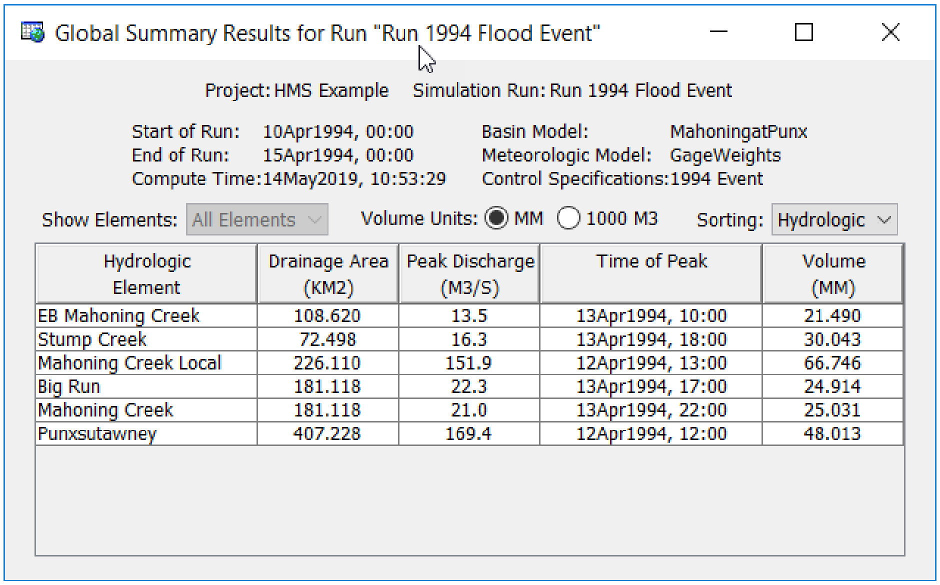


Figure 15. Select simulation and compute from the HEC-HMS tool bar

6.6. A Compute Progress window will open to show the advancement of the simulation. The simulation may abort if errors are encountered. If this happens, read the messages and fix any problems; then compute the Simulation Run again. Close the progress window when the run computes successfully.

Results are now available from the completed Simulation Run.

6.7. From the Results menu select the Global Summary Table. This Global Summary Table will display as shown in Figure 16. Alternately you can click the Global Summary Table button on the Compute tool bar.



Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
EB Mahoning Creek	108.620	13.5	13Apr1994, 10:00	21.490
Stump Creek	72.498	16.3	13Apr1994, 18:00	30.043
Mahoning Creek Local	226.110	151.9	12Apr1994, 13:00	66.746
Big Run	181.118	22.3	13Apr1994, 17:00	24.914
Mahoning Creek	181.118	21.0	13Apr1994, 22:00	25.031
Punxsutawney	407.228	169.4	12Apr1994, 12:00	48.013

Figure 16. Global summary results for Run 1994 Flood Event simulation

6.8. View results for each Basin Model element. Right-click on an element in the Basin Map; a context menu is displayed with several choices including View Results. From the View Results menu there are options to view graph, summary table or time-series table. The same results are available from the Results tab of the Watershed Explorer.

6.9. View the observed vs. computed hydrograph by selecting the **Graph** option for the junction “Punxsutawney” (Figure 17). The computed hydrograph shape is similar to the observed hydrograph shape; however, the peak flow and runoff volume are low and the timing of the peak flows do not coincide. At this point, model parameters have only been estimated using GIS datasets and regional information. The model must be calibrated for computed results to approximate observed flow.

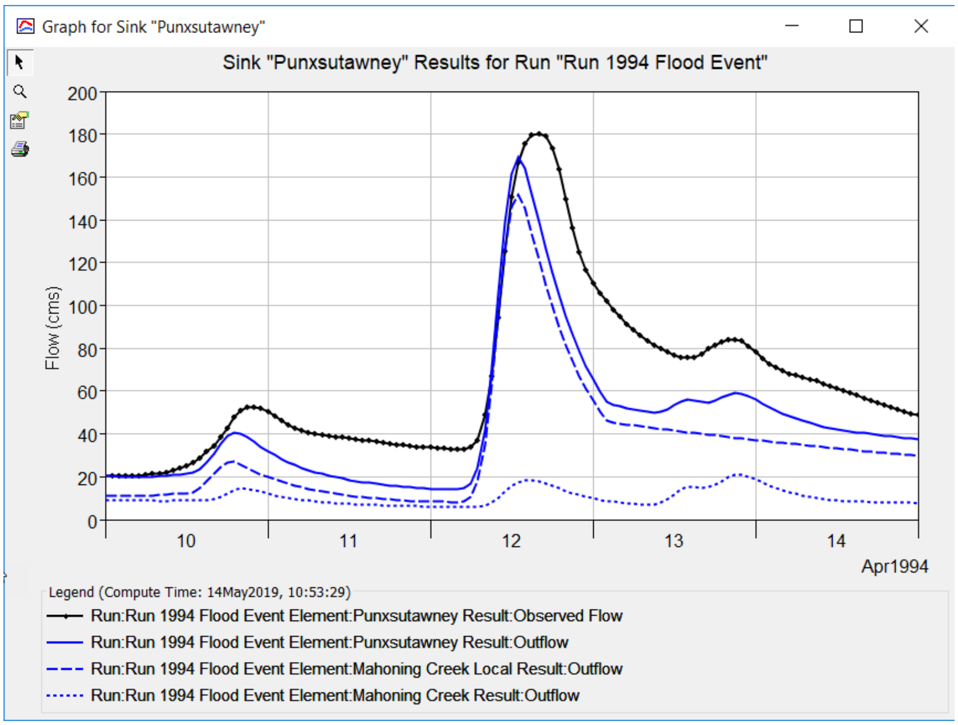


Figure 17. Observed vs. computed hydrograph at the Punxsutawney junction

7. Calibrate the Model and Evaluate Model Performance

Initial parameter values will be refined through several calibration runs.

7.1. First, loss parameters can be adjusted to increase the runoff volume. The summary results for the junction "Punxsutawney" show the observed runoff volume is 68.42 mm and the computed runoff volume is 48.01 mm. Decreasing the initial loss rate might improve the results on April 10 and 11. Select the **Parameters → Loss → Initial and Constant Loss** menu options to open the Initial and Constant Loss global parameter table. Reduce the Initial Loss and re-run the simulation. You will notice the computed flow hydrograph is not sensitive to the initial loss rate, even when setting the initial loss to 0 mm. This is likely due to the precipitation intensity and the constant loss rate values.

7.2. In addition to Initial Loss reduce the Constant Loss Rate to increase the computed runoff volume and increase the computed peak flows. The Initial Constant Loss global parameter table contains special editors to adjust all selected cells. Highlight all three Constant Rate values, right click and choose **Fill…**. In the Table Fill Options editor, choose the **Multiply** by constant: option and enter **0.75**, as shown in Figure 18. Re-compute the simulation.

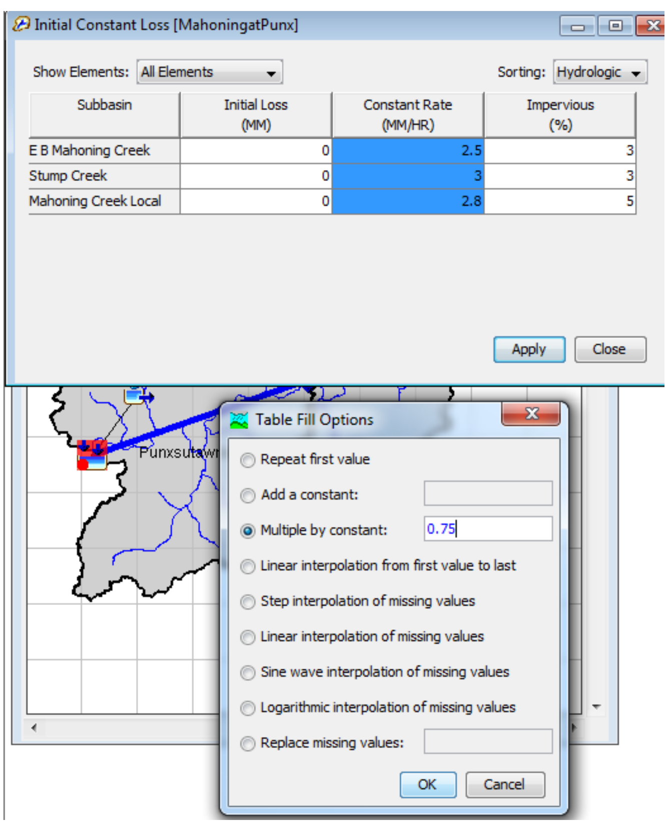


Figure 18. Editing initial and constant loss rate values

Notice the computed peak flow exceeds the observed, but the timing of the computed peak flow is early when compared to the observed hydrograph, as shown in Figure 19.

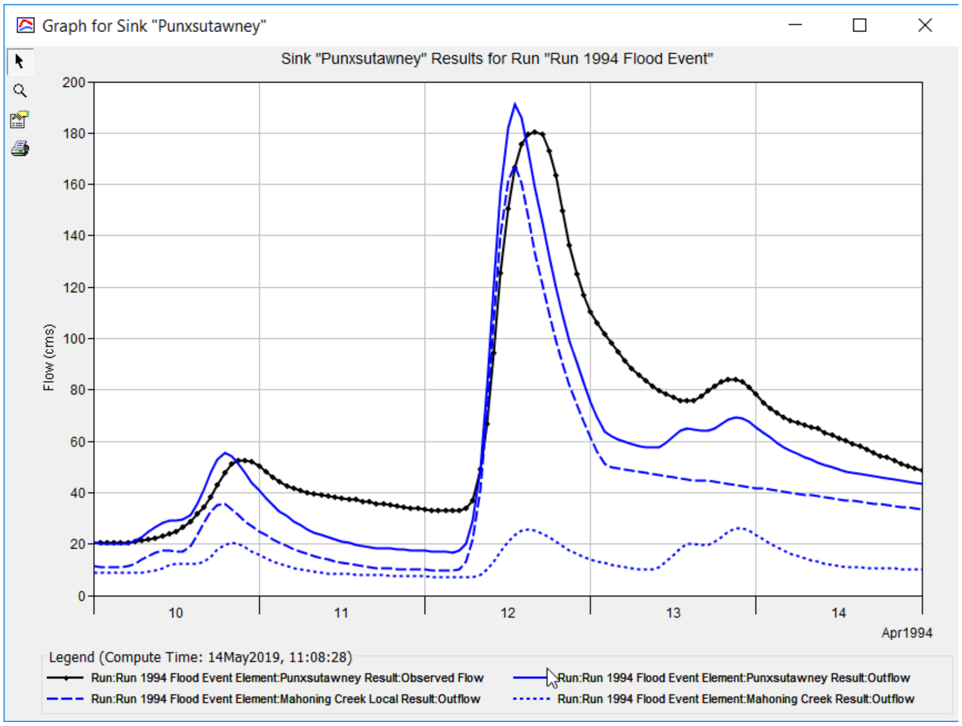


Figure 19. Comparison of simulated and observed hydrographs after editing initial and constant loss rates

7.3. The Clark unit hydrograph parameters control the timing and attenuation of runoff from subbasin elements. Notice in Figure 19 that a majority of the runoff at the junction “Punxsutawney” is due to runoff from the subbasin “Mahoning Creek Local” (the plot at this junctions shows all upstream contributions plus the total inflow). Before adjusting the UH parameters for the subbasins “Stump Creek” and “EB Mahoning Creek,” adjust the Clark unit hydrograph parameters for the subbasin “Mahoning Creek Local” only. Select this subbasin in the Basin Map to open the Component Editor. Go to the Transform tab and change the Time of Concentration from 6 hours to **9 hours** and the Storage Coefficient from 9.6 to **14.4 hours** (maintaining the relationship R = 1.6 * Tc). Re-compute the simulation and compare results at the junction “Punxsutawney.”

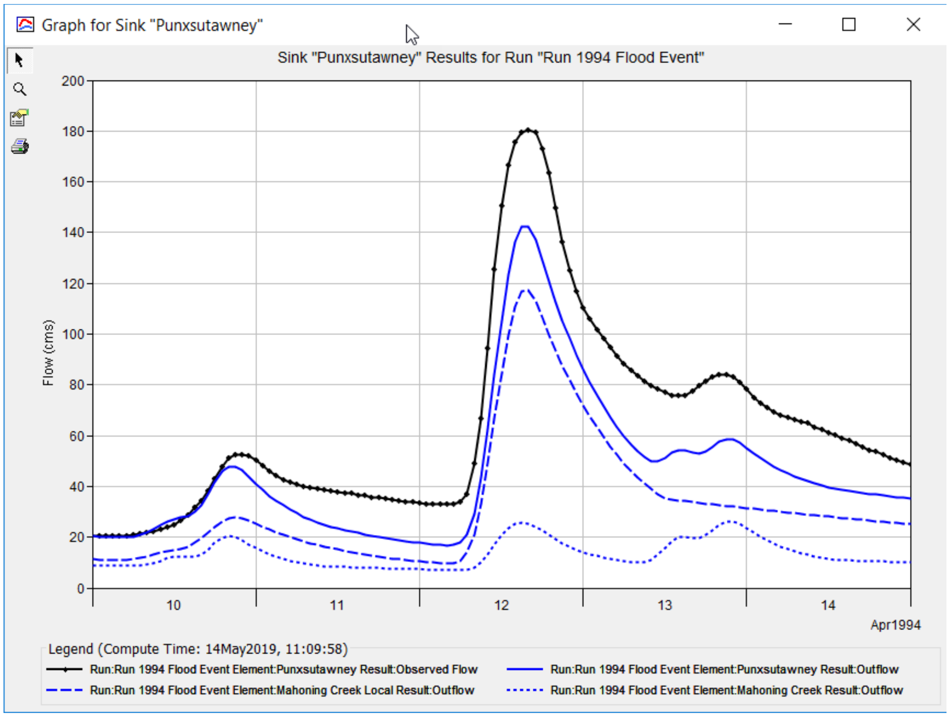


Figure 20. Comparison of simulated and observed hydrographs after editing the Clark unit hydrograph parameters for the subbasin "Mahoning Creek Local"

7.4 As show in Figure 20, the timing of the runoff hydrograph is greatly improved; however, the peak flow and volume need some additional adjustment. Within the Initial Constant Loss Global Parameter Table, reduce the constant loss parameters by multiplying values by **0.4** and set the initial loss to 6 mm for all subbasins. Re-compute the simulation and compare results at the junction "Punxsutawney." Figure 21 shows the computed results and observed flow after the above changes were made to the model. The computed volume, 62.13 mm, is much closer to the observed volume, 68.42 mm, and the timing and magnitude of the peak flow is much closer as well. The Nash-Sutcliffe metric is 0.949 for this simulation. The summary table for the junction "Punxsutawney" is shown in Figure 22.

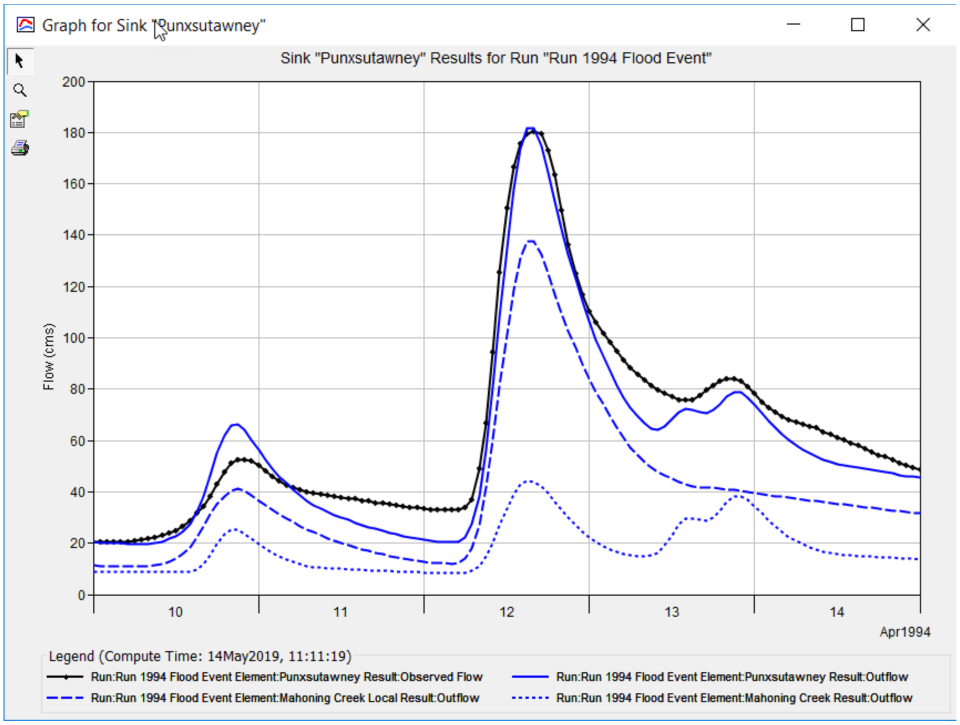


Figure 21. Comparison of simulated and observed hydrographs after editing the initial and constant loss parameters a second time

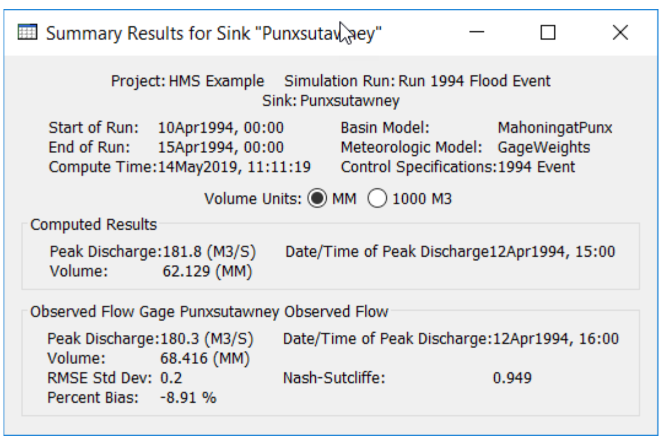


Figure 22. Summary table after model calibration is complete

The final loss and transform parameter values are presented in Table 5 and Table 6. Slight adjustments were required from the initial parameter estimates. Additional modification could be made to the recession baseflow parameters to improve the model fit to the baseflow portion of the runoff hydrograph. For example, increasing the **Recession Constant** to **0.9** increases the computed runoff volume to 65.50 mm and increases the Nash-Sutcliffe metric to 0.971. The model should be calibrated to additional flood events and then a final set of parameter values determined. Additionally the model should be validated against multiple flood events.

One thing to note is that boundary condition information should be evaluated when attempting to calibrate a model. The loss rates required for the April 1994 event that resulted in the best fit of modeled results are extremely low. Comparison of precipitation gage information from the DUJP, PNXP, and MFFP gages showed 64.77 mm, 83.82 mm, and 27.43 mm, respectively. This variability in measured precipitation shows the precipitation was not homogeneously distributed over the gages and watershed. It's likely that the low constant loss rates are due to inadequately modeling precipitation over the entire watershed. The meteorologic model could be updated and more depth weight applied to the PNXP precipitation gage. Applying a larger depth weight would result in higher basin average precipitation, which would result in loss rates that are more reasonable.

Table 5. Final initial and constant loss rate parameters

Subbasin	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Impervious Area (%)
E B Mahoning Creek	6	0.75	3.0
Stump Creek	6	0.90	3.0
Mahoning Creek Local	6	0.84	5.0

Table 6. Final Clark unit hydrograph parameters

Subbasin	Time of Concentration (hr)	Storage Coefficient (hr)
E B Mahoning Creek	3.7	5.9
Stump Creek	5.3	8.5
Mahoning Creek Local	9.0	14.4

8. *Create an Uncertainty Analysis and Evaluate Results*

The Uncertainty Analysis compute option can be used to evaluate uncertainty in model parameters on the computed results. The uncertainty analysis compute option allows the user to enter uncertainty distributions for basin model parameters, and then define the number of samples to perform. The uncertainty analysis does not vary the boundary conditions, only the selected basin model parameters. In this workshop, we will only explore the uncertainty in the loss rate parameters. Once the simulation is complete, we will review the range of output results available from the uncertainty analysis.

8.1. Create an uncertainty analysis. From the Compute menu select **Uncertainty Analysis Manager**. Name the analysis “Analysis April 1994”. Select Basin Model “MahoningatPunx” and the Meteorologic Model “GageWeights”.

8.2. On the **Compute** tab in the Watershed Explorer, browse to and select the new Uncertainty Analysis. Finish entering the configuration information with the following time specification data. See Figure 23.

Start Date: 10Apr1994
Start Time: 00:00
End Date: 15Apr1994
End Time: 00:00
Time Interval: 1 Hour
Total Samples: 100

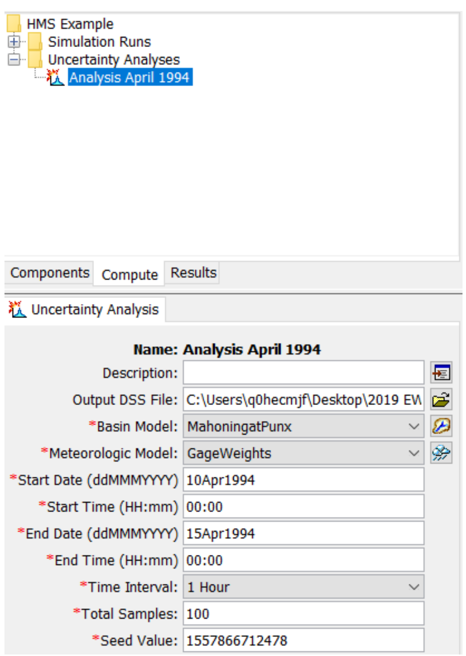


Figure 23. Completed Uncertainty Analysis Component Editor

8.3. Next you will add parameters to the Uncertainty Analysis. Right-click on the Uncertainty Analysis and select **Add Parameter**. Next, under the Uncertainty Analysis, select "Parameter 1" to edit the parameter in the Component Editor. In the Component Editor select Element: "EB Mahoning Creek" and Parameter: "Initial and Constant – Constant Rate," as shown in Figure 24. Select a **Triangular** distribution, and enter a minimum value of **0.5 mm/hr**, and a maximum value of **4.5 mm/hr**. Distribution parameters should be **0.5 mm/hr for the lower, 2.5 mm/hr for the mode, and 4.5 mm/hr for the upper**.

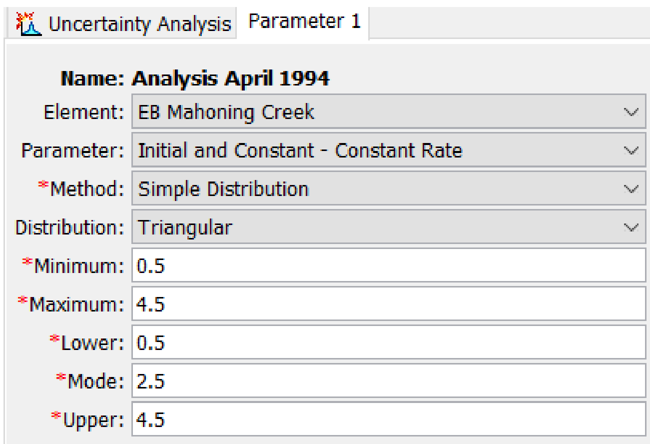


Figure 24. Configuring the first uncertainty parameter

8.4. Add two additional parameters to the Uncertainty Analysis (Right-click "Analysis April 1994" and select Add Parameter). In the Component Editor set the uncertainty parameters to **Constant Rate** for the subbasins "Stump Creek" and "Mahoning Creek Local." These two locations will be linked to the subbasin "E B Mahoning Creek" so that constant loss rates are adjusted in a similar manner; all values increase or decrease within a sample. In the Component Editor, set the sampling **Method to Regression With Additive Error**. Then set the Regression Element to "EB Mahoning Creek," and set the Regression Parameter to **Initial and Constant – Constant Rate**. A simple linear regression can be defined where the slope is 1 and the intercept is 0; effectively setting the parameter value to be equal to the related parameter value. The error term is represented by an uncertainty distribution. As shown in Figure 25, select the **Normal** uncertainty distribution and enter a mean of 0 mm/hr, and a standard deviation of 0.2 mm/hr (do this for both subbasins Stump Creek and Mahoning Creek Local). These parameter values should result in constant loss rate parameters that are within 0.2 mm/hr for about 68 percent of the sampled values.

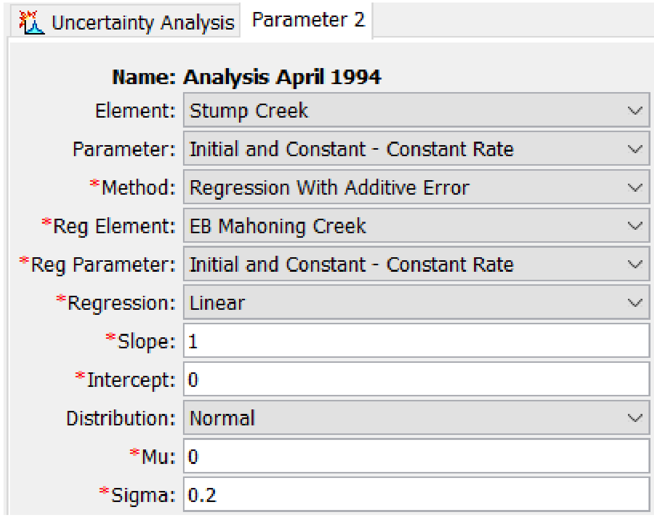


Figure 25. Configuring the Stump Creek constant loss rate parameter distribution

When complete, there should be 3 parameters selected in the uncertainty analysis.

8.5. The final step to preparing the Uncertainty Analysis for simulation is to configure the output results. In the Watershed Explorer to right-click on the Uncertainty Analysis “Analysis April 1994” and select **Results….** Next, press **Select….** Select the element “Punxsutawney” and time-series Outflow as shown in Figure 26. Close all of the results configuration windows.

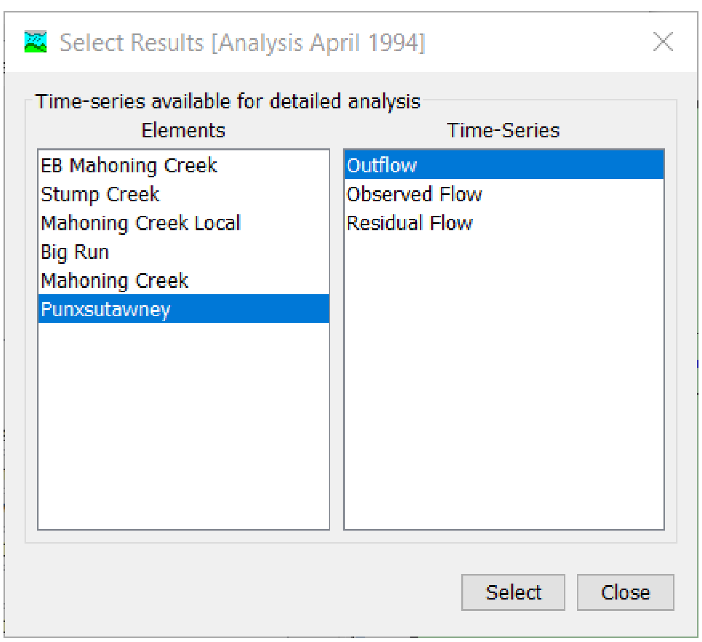
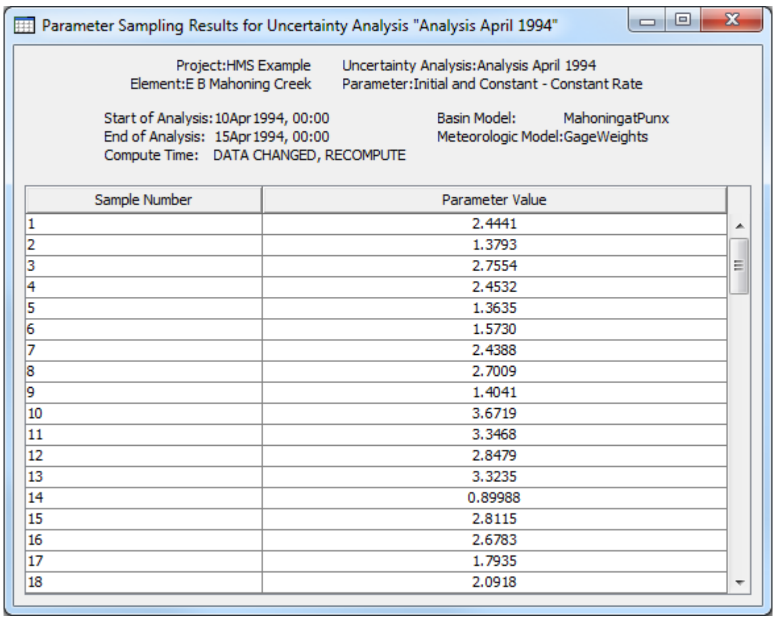


Figure 26. Choosing the Outflow time-series for the Punxsutawney element

8.6. Compute the Uncertainty Analysis - in the Watershed Explorer right-click “Analysis April 1994” and select Compute. You will notice the compute dialog and message window shows progress for the 100 sample simulation. After the simulation is completed, switch to the Results tab of the Watershed Explorer and review the available results. You should see three Parameter tables that show the samples of constant loss rate values for each subbasin element. Figure 27 shows the sampled constant loss rate values for the “EB Mahoning Creek” subbasin. The sampled values can be copied to another program to create a histogram of values as shown in Figure 28.



Sample Number	Parameter Value
1	2.4441
2	1.3793
3	2.7554
4	2.4532
5	1.3635
6	1.5730
7	2.4388
8	2.7009
9	1.4041
10	3.6719
11	3.3468
12	2.8479
13	3.3235
14	0.89988
15	2.8115
16	2.6783
17	1.7935
18	2.0918

Figure 27. Sampled constant loss rate values for the subbasin “EB Mahoning Creek”

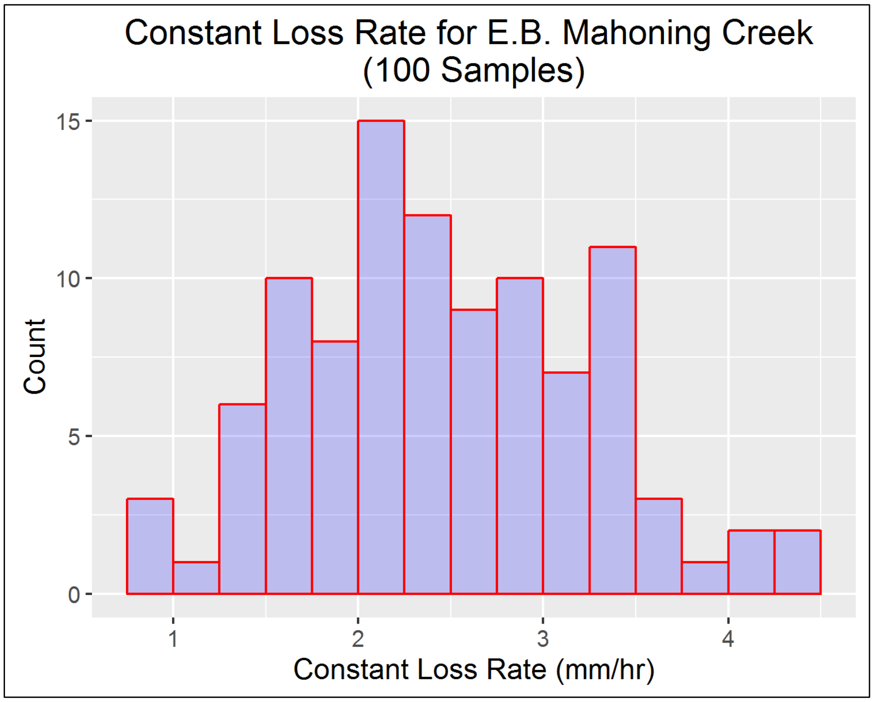


Figure 28. Histogram of constant loss rate values

There is a node for Outflow results at the junction “Punxsutawney.” Results include hydrographs (Figure 29), and tables of the Maximum Outflow and Outflow Volume. Open the tables to view results.

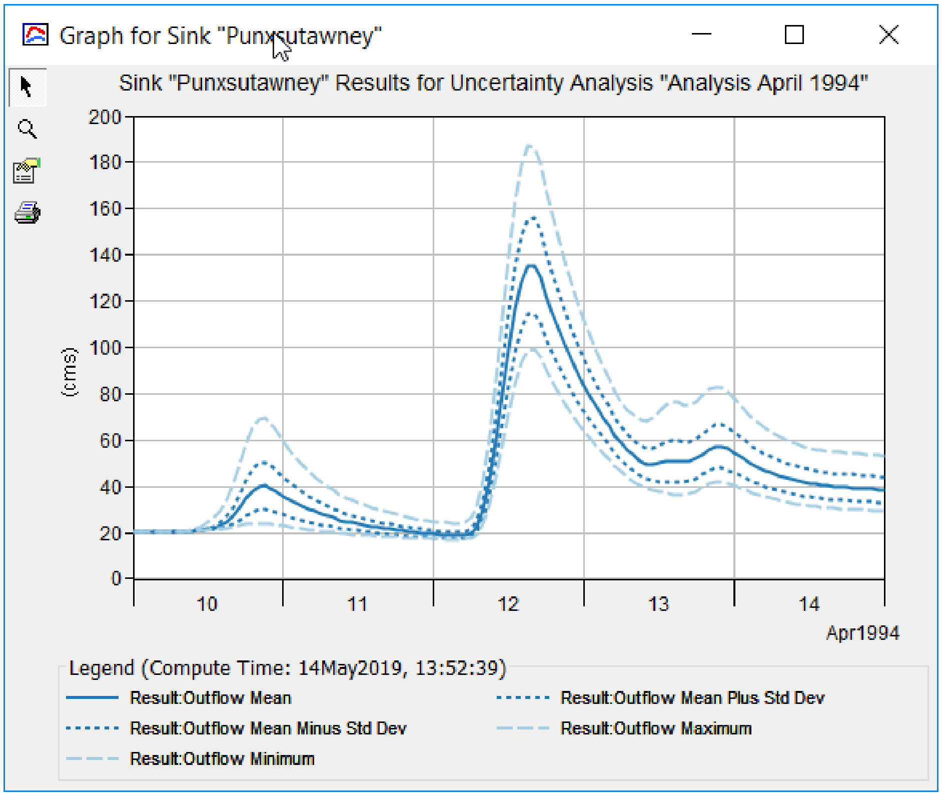


Figure 29. Hydrograph results for the Punxsutawney junction element