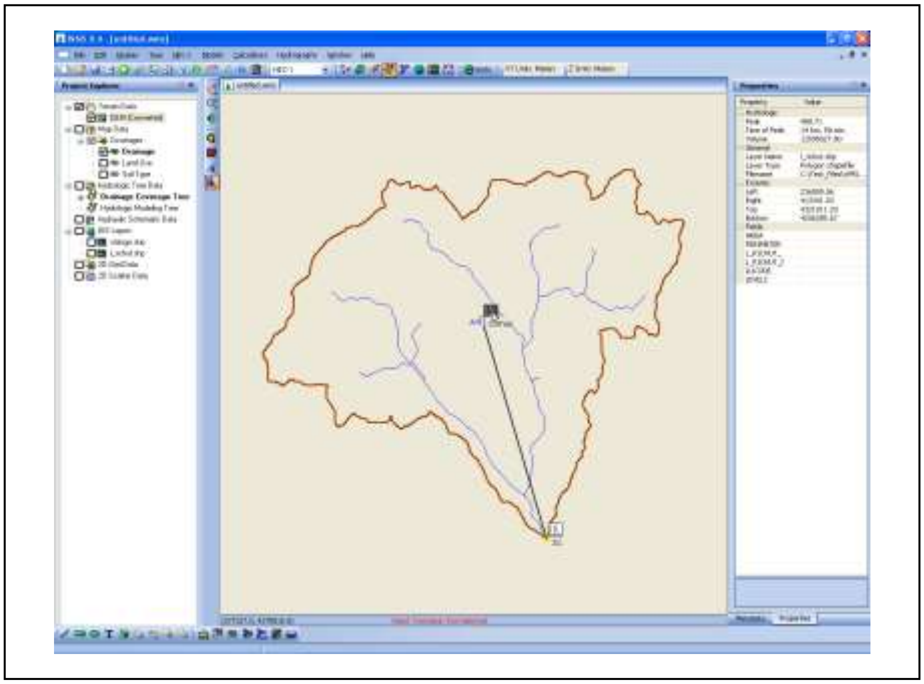
WMS

v. 10.0

WMS 10.0 Tutorial

Watershed Modeling – HEC-1 Interface

Learn how to setup a basic HEC-1 model using WMS



Objectives

Build a basic HEC-1 model from scratch using a DEM, land use, and soil data. Compute the geometric and hydrologic parameters required to run a HEC-1 model. Divide a single watershed into multiple sub-basins and define reach and reservoir routing between sub-basins.

Prerequisite Tutorials

- Watershed Modeling – DEM Delineation

Required Components

- Data
- Drainage
- Map
- Hydrology
- Hydrologic Models

Time

- 30-60 minutes

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1 Introduction

WMS includes a graphical interface to HEC-1. Geometric attributes such as areas, lengths, and slopes are computed automatically from the digital watershed. Parameters such as loss rates, base flow, unit hydrograph method, and routing data are entered through a series of interactive dialog boxes. Once the parameters needed to define an HEC-1 model have been entered, an input file with the proper format for HEC-1 can be written automatically. Since only parts of the HEC-1 input file are defined in this chapter, users are encouraged to explore the different available options of each dialog, being sure to select the given method and values before exiting the dialog.

The US Army Corps of Engineers now supports HMS rather than HEC-1, but the hydrologic calculations for the options within HEC-1 have not changed. Results of the two models will be identical.

2 Objectives

As a review, users will delineate a watershed from a DEM. Users will then develop a simple, single basin model using the delineated watershed to derive many of the parameters. Land use and soil shapefiles (downloaded from the Internet) will be used to develop a SCS curve number (CN) value. After establishing the initial HEC-1 model, other variations will be developed, including defining multiple basins with reach routing and including a reservoir with storage routing.

3 Single Basin Analysis

The first simulation will be defined for a single basin. Users will need to enter the global, or Job Control parameters as well as the rainfall event, loss method, and unit hydrograph method.

3.1 Setting up the Job Control

Most of the parameters required for a HEC-1 model are defined for basins, outlets, and reaches. However, there are many "global" parameters that control the overall simulation and are not specific to any basin or reach in the model. These parameters are defined in the WMS interface using the Job Control dialog.

1. Select *File* **| Open**. In the *Open* dialog, select "hec-1_SingleWatershed.wms" (*.wms) and click **Open**. An image will appear in the Main Graphics Window.
2. Switch to the **Hydrologic Modeling** module.
3. HEC-1 should be the default model, but if it is not select it from the drop down list of models found in the Edit Window.
4. Select *HEC-1* **| Job Control**. The *Hec-1 Job Control* dialog should open.
5. The first three lines are for comments/identification at the top of the HEC-1 input file. The first line already has information indicating that the input file is generated by WMS (users can change this if they want). Enter "Clear Creek Tributary Watershed" for the second ID line. Enter the user's name and the current date in the third line.
6. Leave the Day, Month, and Year fields alone

HEC-1 allows users to enter a date, but almost always they are simulating some kind of hypothetical or design storm and not an actual storm. If users change the simulation date they will need to be careful to make sure the storm date is in synch, but if users leave it alone, there will not be a problem.

7. Enter "5" (minutes) for the *Computational time interval*, and "300" for the *Number of hydrograph ordinates*. Leave the *Beginning time* at "0".

An HEC-1 simulation will run for a length of time equal to the time step multiplied by the number of ordinates. If users are simulating a 24-hr storm but only run the simulation for 12 hours users will not capture the full hydrograph. Conversely, if users run a 24-hr simulation for 96-hrs they are probably going to have a lot of runoff ordinates equal to 0 at the end. In this case users are running the simulation for 1500 minutes (slightly more than 24 hours) with an ordinate on the hydrograph being computed for every 5 minutes.

8. Set the *computation units* to *English units* (this should be the default).

Setting the computation units DOES NOT cause any units conversion to take place. Users are simply telling HEC-1 that users will provide input units in English units (sq. miles for area, inches for rain, feet/miles for length) and expect results of computation to be in English units (cfs). If users specify Metric then they must ensure that input units are metric (sq. kilometers, mm for rain, meters/kilometers for length) and results will be in metric (cms).

9. Select **OK.**

For now, leave the other Job Control settings at their default values.

3.2 Setting up the Basin Data Parameters

In the first simulation users will treat the entire watershed as a single basin.

1. Use the **Zoom** tool to zoom in on the colored portion of the graphic, to make the basin icon easier to see.

2. Select the **Select Basin** tool.
3. Double-click on the brown basin icon labeled 1B. Double-clicking on a basin or outlet icon always brings up the parameter editor dialog for the current model (in this case HEC-1). This dialog will be labeled *Edit HEC-1 Parameters*.
4. Select the **Basin Data** button.
5. The *HEC-1 Basin Data* dialog will appear. Notice that the area has been calculated (in this case in sq. miles because users are performing calculations in English units).
6. Change the name to "CCTrib". HEC-1 will only use the first six characters, so do not use names longer than six characters for basins or outlets.
7. Select **OK**.
8. Select the **Precipitation** button.
9. In the *HEC-1 Precipitation* dialog, select the *Basin Average* option.
10. Enter "1.8" (inches) for the *Average precipitation* depth.
11. Select the **Define Series** button.

In order to simulate a rainfall event users must enter both a rainfall depth and a temporal distribution. The SCS uses standard time distributions for different areas of the U.S. These are stored in WMS. Users could also define their own series according to an actual storm, or a design storm from a regulating agency.

12. Users will now be looking at the *XY Series Editor* dialog. In the *Selected Curve* drop down list select the "typeII-24hour" curve.
13. Select **OK**.
14. Select **OK**.
15. Select the **Loss Method** button.
16. In the *HEC-1 Loss Methods* dialog, enter a *Curve Number* (CRVNBR field) of "70". Users will compute a CN value from actual land use and soil files later.
17. Select **OK**.
18. Select the **Unit Hydrograph Method** button.
19. In the *HEC-! Unit Hydrograph Methods* dialog, make sure the *SCS dimensionless* option is chosen (it is the default).
20. Select the **Compute Parameters - Basin Data** button.
21. In the *Basin Time Computation* dialog, set the *Computation Type* to "Compute Lag Time" (the default).
22. Set the *Method* drop down list to "SCS Method" (near the bottom of the list).
23. Select **OK** to update the computed lag time for the SCS dimensionless method.
24. Select **OK**.
25. Select **Done**.

Users now have all of the parameters set to run a single basin analysis.

3.3 Running HEC-1

Whenever users run a HEC-1 simulation, WMS will first save a standard HEC-1 input file. Users will also be prompted for the name of an output file and a solutions file. The output file is the standard text output file generated by HEC-1 and the solution file is a plot file that contains the hydrographs formatted in a way that makes it easy for WMS to read and plot (it is actually the HEC-1 TAPE22 file).

1. Select *HEC-1* **| Run Simulation**.
2. The *HEC-1 Run Options* dialog will appear. Click the **browse** button next to the Input File.
3. For the file name enter *"*CCTrib*"* and click **Save** (this specifies the file name but does not actually save it).
4. Verify that the *Save file before run* option is toggled on.
5. Select **OK**.
6. A window will open while HEC-1 runs. Select **Close** once HEC-1 finishes running (wait a few seconds to a minute or so).

The solutions will automatically be read in and users should see a small hydrograph plot to the upper right of the Basin icon (now labeled as CCTrib).

7. Double-click on the hydrograph icon.

A plot window will appear with the hydrograph. Users will see that the hydrograph suddenly stops at 1500 minutes (the duration of the simulation as established in the Job Control dialog), but the simulation obviously has not run to completion.

8. Close the plot window by selecting the X in the upper right corner of the window
9. Select *Hydrographs* **| Delete All**.
10. Select *HEC-1* **| Job Control**.
11. The *HEC-1 Job Control* dialog will reappear. Set the *Number of hydrograph ordinates* to be "400".
12. Select **OK**.
13. Select *HEC-1* **| Run Simulation**.
14. Select **OK** (let it overwrite the other files).
15. Select **Close** once HEC-1 finishes running (wait a few seconds to a minute or so).
16. Double-click on the hydrograph icon.

Users now have a completed HEC-1 simulation for a single basin and the resulting hydrograph should look something like the solution shown in **Error! Reference source not found.**.

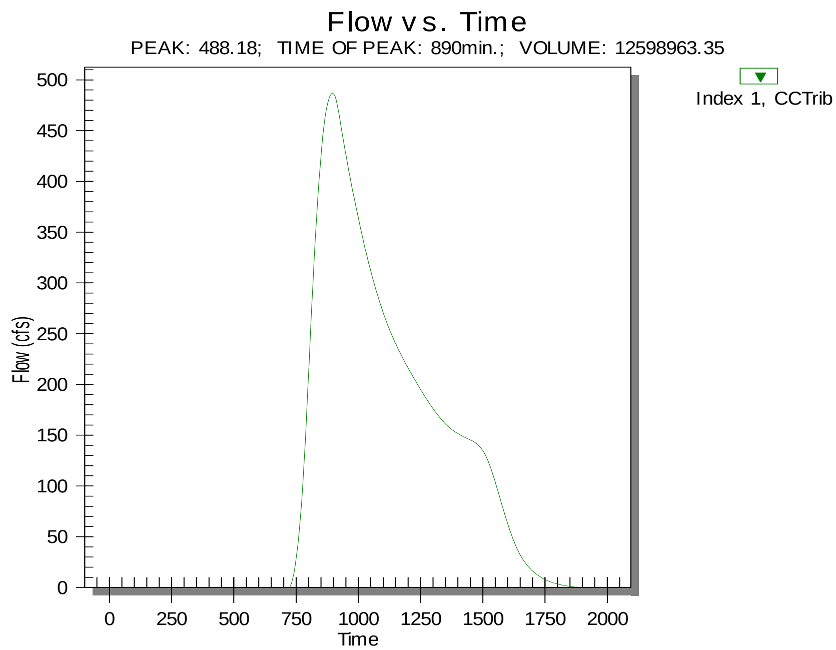


Figure 1 Solution hydrograph for HEC-1 Simulation

17. Close the hydrograph window by selecting the X in the upper right of the window.

4 Computing the CN Using Land Use and Soils Data

In the initial simulation users estimated a CN, but with access to the Internet it is simple to compute a composite CN based on digital land use and soils files. This was demonstrated in more detail in the Advanced Feature Objects exercise (Volume 1, chapter 6), but users will go through the steps here as a review.

4.1 Computing a Composite CN

In addition to the digital land use and soils file that overlap the watershed, users must have a table defined that identifies CN values for each of the four different hydrologic soil groups (A, B, C, D). This is described in detail at the gsda website (http://www.xmswiki.com/wiki/GSDA:GSDA), and in the Advanced Feature Objects exercise (Volume 1, chapter 6). For this exercise users will read in an existing file (users can examine it in a text editor if they wish) and compute the CN numbers.

1. Select the **Hydrologic Modeling** module.
2. Select *Calculators* **| Compute GIS Attributes**.
3. The *Compute GIS Attributes* dialog will appear. Select the **Import** button to load the mapping table.
4. Select **OK** to overwrite the current definition.
5. In the *Open* dialog, find and open the file named “scsland.tbl”.
6. Select **OK** to compute the CN from the land use and soils layers.
7. Select **OK** when prompted to open the file using Notebook.

Users should find that CN computed from the land use and soils digital data is about 72 or 73. While there is still some "judgment" required in setting up the mapping table, there is a lot more justification for this value than the one previously estimated.

8. Close the *Curve Number Report*.

4.2 Running HEC-1

Users can now run another simulation to compare the results with the modified CN value.

1. Select *HEC-1* **| Run Simulation**.
2. The *HEC-1 Run Options* dialog will reappear. Select **OK** (it is fine to overwrite the existing files, but users can change the file names if they want).
3. Select **Close** once HEC-1 finishes running (wait a few seconds to a minute or so).
4. Double-click on the hydrograph icon to plot both the old and the new hydrograph in a plot window.

With the increased CN value users should see that the resulting hydrograph peaks higher (more runoff). The peak should be about 600 cfs rather than the 500 cfs that was generated with a CN value of 70.

5. Close the hydrograph window by selecting the X in the upper right corner of the window.
6. Select *Hydrographs* **| Delete All**.

5 Adding Sub-basins and Routing

Users will now subdivide the watershed into two upper basins and one lower basin and define routing for the reaches that connect the upper basins to the watershed outlet.

5.1 Delineating the Sub-basin

1. Select the **Drainage**  module.
2. Select the **Zoom**  tool.
3. Create a zoom box around the region identified by a box in **Error! Reference source not found.**

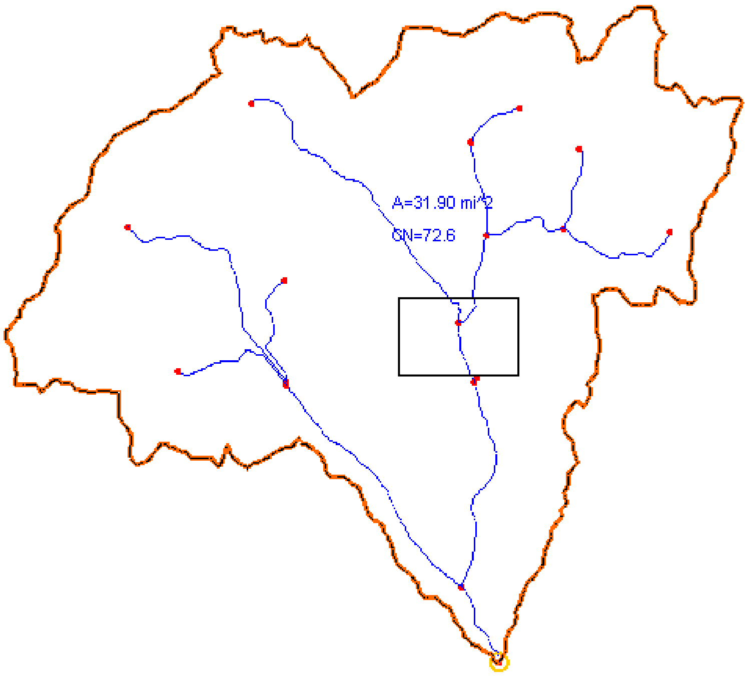
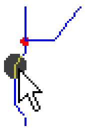


Figure 2 Zoom area

4. Select *Display* | **Display Options** to open the *Display Options* dialog.
5. On the *Map* tab toggle on *Vertices*. If there is no noticeable difference, users can make the size of the vertices larger, by clicking the icon next to the checkbox, and adjusting the size using the arrows, then clicking **OK** to close the *Point Properties* dialog.
6. Select **OK**.



7. Select the **Select Feature Vertex** tool.
8. Select the vertex that is just below the main branching point users just zoomed in around.
9. Select *DEM* | **Node ↔ Outlet**.

Users created the outlet point just below the branch in order to have a single upstream basin. If users wanted a separate basin for each upstream branch they could define the branching node to be an outlet. Thus, WMS would automatically assume that users want separate basins for each branch, so users have created a node just downstream of the branch and defined it as the outlet for the upper basin.

10. Select the **Frame** macro.
11. Select the **Zoom** tool.
12. Create a zoom box around the region identified by a box in **Error! Reference source not found.**.

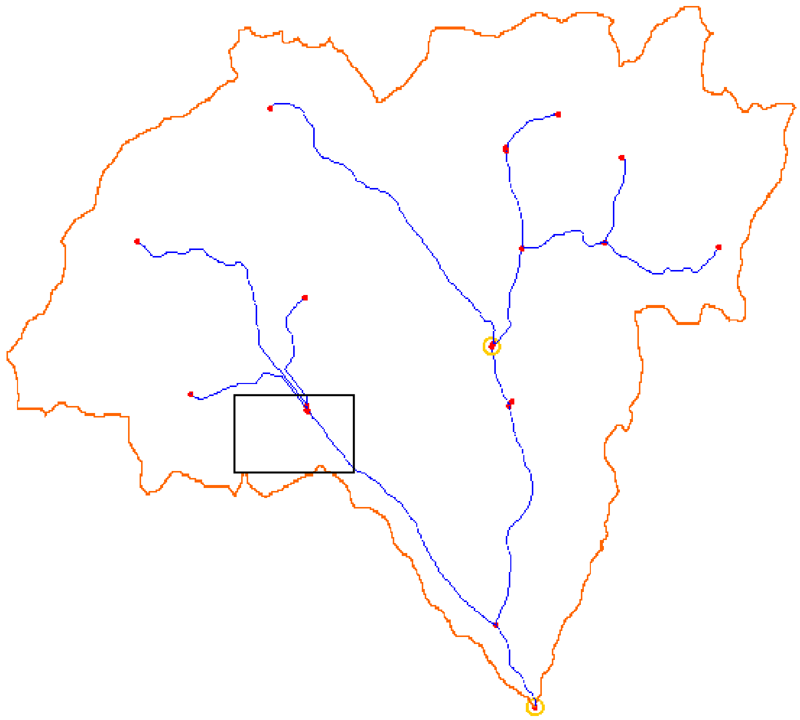


Figure 3 Zoom area

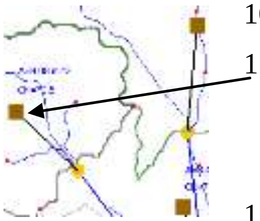
13. Select the **Select Feature Vertex** tool.
14. Select the vertex that is just below the feature node where the streams branch.
15. Select *DEM* | **Node ↔ Outlet**.
16. Select the **Frame** macro.
17. Select *DEM* | **Delineate Basins Wizard**.
18. Select **OK** when prompted to delete all feature data.
19. Select **OK** twice (when prompted) to delineate the watershed and compute the basin data.

5.2 Updating the Basin Parameters

Users will have to recompute the CN values and define precipitation and lag time for the basins.

1. Select the **Hydrologic Modeling** module.
2. Select *Calculators* | **Compute GIS Attributes**.
3. In the *Compute GIS Attributes* dialog, select **OK** and the CN values will be updated for all basins (they are actually very similar in this case because of the dominant soil polygon that covers the watershed).
4. A *View Data File* dialog will appear, prompting users to open the data in Notepad. Click **OK**.
5. Close the Curve Number Report in Notepad by clicking the X in the top right corner.

6. Select the **Select Basin** tool.
7. Double-click on the upper right basin icon to bring up the *Edit HEC-1 Parameters* dialog.
8. Select the **Basin Data** button.
9. In the *HEC-1 Basin Data* dialog, change the *Basin name* to “Right”.



10. Select **OK**.
11. Move the *Edit HEC-1 Parameters* dialog out of the way, if necessary, and click on the upper left basin icon to edit parameters for the upper left basin. Alternatively, users could select **Done** and then double-click the upper left basin to obtain the *Edit HEC-1 Parameters* dialog.
12. Select the **Basin Data** button.
13. In the *HEC-1 Basin Data* dialog, change the *Basin name* to “Left”.
14. Select **OK**.
15. Move the *Edit HEC-1 Parameters* dialog out of the way, if necessary, and click on the lower basin icon to edit parameters for the lower basin.
16. Select the **Basin Data** button.
17. In the *HEC-1 Basin Data* dialog, change the *Basin name* to “CCTrib”.
18. Select **OK**.
19. Select **Done**.
20. Select *Edit* **| Select All** to select all basins.
21. Select *HEC-1* **| Edit Parameters** to edit parameters for all basins at once. The *Edit HEC-1 Parameters* dialog will reappear.
22. Select the **Precipitation** button.
23. In the *HEC-1 Precipitation* dialog, select the *Basin Average* option.
24. Set the *Average Precipitation* to be “1.8” in.
25. Select the **Define Series** button.
26. The *XY Series Editor* will appear. Choose the “typeII-24hour curve” in the *Selected Curve* drop down list.
27. Select **OK**.
28. Back in the *HEC-1 Precipitation* dialog, select **OK**.
29. Select the **Unit Hydrograph Method** button.
30. In the *HEC-1 Unit Hydrograph Methods* dialog, make sure the *SCS dimensionless* option is chosen (it is the default).
31. Select the **Compute Parameters - Basin Data** button.
32. In the *Basin Time Computation* dialog, select “CCTrib” in the *Basin* window so that it is highlighted.
33. Select the *Method* to be “SCS Method” (near the bottom of the list).
34. Select “Right” in the *Basin* window so that it is highlighted.
35. Select the *Method* to be “SCS Method” (near the bottom of the list).

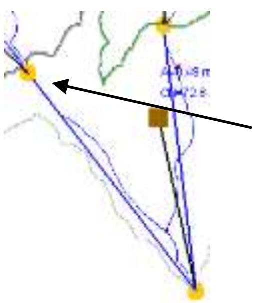
36. Select "Left" in the *Basin* window so that it is highlighted.
37. Select the *Method* to be "SCS Method" (near the bottom of the list).
38. Select **OK**.
39. Select **OK**.
40. Select **Done**.

5.3 Setting up the Routing Parameters

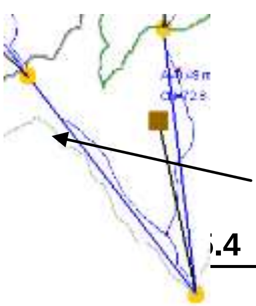
If users were to run HEC-1 now, they would see that the hydrographs from the upper basins would be combined with the lower basin hydrograph at the watershed outlet without any lag or attenuation because users have not yet set the routing parameters. Users will now define a routing method, which will instruct HEC-1 to compute lag and attenuation on the upper basin hydrographs before adding them to the lower hydrograph.

Routing for a reach is always defined at the upstream outlet of the reach in WMS.

1. Select the **Select Outlet** tool.
2. Double-click on the outlet (the yellow circle icon) of the upper right basin.
3. The *Edit HEC-1 Parameters* dialog will reappear. Select the **Routing Data** button.
4. In the *HEC-1 Routing Data* dialog, select the "Muskingum-Cunge" method as the *Routing type*.
5. Set the *width (WD)* field to be "5" (five feet wide).
6. Set the *side slope value (Z)* to be "1" (1:1 side slope).
7. Set the *Manning's roughness (N)* to be "0.05" (this is fairly rough, but users want to exaggerate the routing effects for this exercise).



8. Select **OK**.
9. Select **Done**.
10. Double-click on the outlet of the upper left basin. The *Edit HEC-1 Parameters* dialog will reappear.
11. Select the **Routing Data** button.
12. In the *HEC-1 Routing Data* dialog, select the "Muskingum-Cunge" method as the *Routing type*.
13. Set the *width (WD)* field to be "5" (five feet wide).
14. Set the *side slope value (Z)* to be "1" (1:1 side slope).
15. Set the *Manning's roughness (N)* to be "0.05" .
16. Select **OK**.
17. Select **Done**.



5.4 Running HEC-1

Users now have everything defined to run a three basin HEC-1 analysis that includes routing the upper basins through the reaches connecting them to the watershed outlet.

1. Select *HEC-1* **| Run Simulation**.

2. In the *HEC-1 Run Options* dialog, click the **browse** button next to the Input File.
3. The *Select HEC-1 Input File* will appear. For the *file name* enter *“*Routing*”* and click **Save** (this specifies the file name but does not actually save it).
4. Verify that the *Save file before run* option is toggled on.
5. Select **OK**.
6. Select **Close** in the *Model Wrapper* dialog once HEC-1 finishes running (wait a few seconds to a minute or so).
7. While holding the **SHIFT** key down, select all of the hydrograph icons, double-clicking on the last one so that all hydrographs are drawn in the same plot window.
8. Close the *Hydrograph* plot window by selecting the X in the upper right corner.

6 Modeling a Reservoir in HEC-1

There is an existing small reservoir at the outlet of the upper left basin. It has a storage capacity of 1000 ac-ft at the spillway level and 1540 ac-ft at the dam crest.

6.1 Defining a Reservoir in Combination with Routing

One of the routing methods available in HEC-1 is Storage routing, which can be used to define reservoir routing. However, in this case users are already using Muskingum-Cunge routing to move the hydrograph through the reach connecting the upper left basin to the watershed outlet so users must define the outlet as a reservoir so that users can route the hydrograph through the reservoir before routing it downstream.

1. Select the **Select Outlet** tool.
2. Select the outlet of the upper left basin.
3. Right-click on the outlet which was just selected and select *Add* **| Reservoir**.

6.2 Setting up the Reservoir Routing Parameters

In order to define reservoir routing with HEC-1 users must define elevation vs. storage (storage capacity curve) and elevation vs. discharge rating curves. Users can enter values directly, or enter hydraulic structures and compute the values, but in this exercise users will enter the values directly. Users will use the same elevation values for both curves (this is common, but not a requirement in HEC-1).

For this example users want to have no outflow until the elevation in the reservoir reaches the spillway. Since HEC-1 linearly interpolates between consecutive points on the elevation-discharge and elevation-volume curves users will “trick” it by entering two points on the curves at essentially the same elevation (6821.99 ft and 6822 ft) with the first having no outflow and the second having the discharge over the spillway (640 cfs) as defined for this dam.

1. Double-click on the reservoir outlet point (it is now represented as a triangle since users have defined a reservoir at this location).
2. In the *Edit HEC-1 Parameters* dialog, select the **Reservoir Data** button.
3. In the *Reservoir Routing Data* dialog, change the *Reservoir name* to “Tcreek”.

4. Set the *Type of storage routing* to *Reservoir*.
5. Select the **Define** button to the right of the reservoir option.
6. The *HEC-1 Reservoir Routing Options* dialog will open. On the right side of this dialog users will define the *Volume* or storage capacity data. Choose the *Known Volume* option.
7. Toggle on the check boxes for *SV* (Volumes) and *SE* (Elevations).
8. Select the **Define** button to the right of the *SV* option. An *XY Series Editor* will appear.

Users will define separate XY series for Volumes, Elevations, and Discharges using the *XY Series editor*.

9. Select **New**.
10. Change the *Curve name* of the new curve to "Volume".
11. In the first seven edit fields enter the values "0", "200", "410", "650", "1000", "1000", "1540" (acre-ft of volume), as shown in **Error! Reference source not found.**.
12. Select the 8th through 20th edit fields and select the **DELETE** key so that the values are blank rather than zero. Users can select them all at once (the same way this would be done in a spreadsheet since this dialog behaves like a spreadsheet) by clicking in the top and while holding the mouse button down dragging to the last, or users can select one at a time.

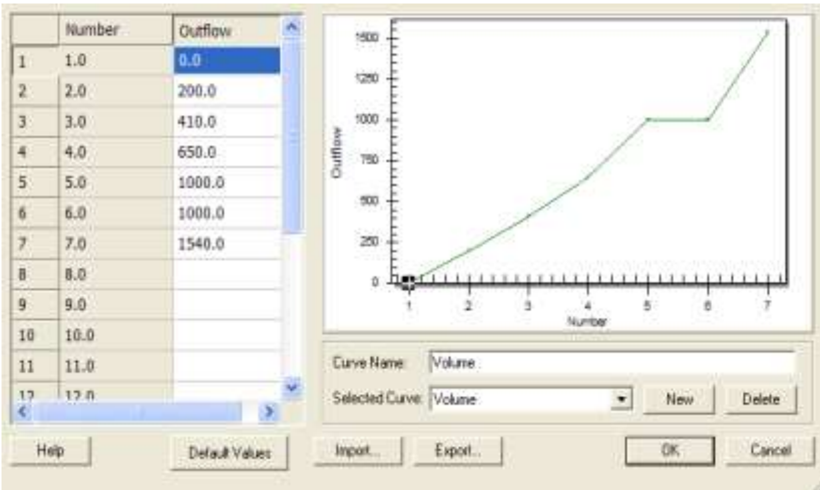


Figure 4 XY Series Editor for inputting volumes

13. Select **OK**.
14. Select the **Define** button to the right of the *SE* option.
15. An *XY Series Editor* window will appear. Select **New**
16. Change the *Curve name* of the new curve to "Elevation".
17. In the first seven entry fields enter the following values: "6803", "6808", "6813", "6818", "6821.99", "6822", "6825" (feet of elevation).
18. Set the 8th through 20th fields blank instead of zero as with the volume series.
19. Select **OK**.

20. On the left side of the *HEC-1 Reservoir Routing Options* dialog users will define the *Outflow* or elevation - discharge data. Choose the *Known Outflow* option.
21. Toggle on the check boxes for *SQ* (Discharges) and *SE* (Elevations).
22. Select the **Define** button to the right of the *SQ* option.
23. In the *XY Series Editor*, Select **New**.
24. Change the *Curve name* of the new curve to “Discharge”.
25. In the first seven entry fields enter the following values: “0”, “0”, “0”, “0”, “640”, “640”, “7000” (cubic feet per second of flow). There is no outflow until the water reaches the spillway.
26. Set the 8th through 20th fields blank instead of zero as with the volume series.
27. Select **OK**.
28. Select the **Define** button to the right of the *SE* option.

This time rather than creating a new curve users will select the elevation curve previously defined for the storage capacity curve.

29. Select the “Elevation” curve from the *Selected Curve* drop down list.
30. Select **OK**.

If users would like they may plot either the elevation-discharge or the elevation-volume curves by selecting the *Plot SQ-SE* or *Plot SV-SE* buttons. This will bring the curve into a plot window that users can export, print, or control the same way they can a hydrograph or any other plot in a plot window.

31. Select **OK**.

The last thing users need to input to define reservoir routing is the initial conditions of the reservoir. The initial condition can be defined as an elevation, a discharge, or a volume (with the data users just entered HEC-1 can determine the initial condition of the other two based on the one users enter). For this example users will set the initial condition to an elevation four feet below the top of the spillway (the spillway corresponds to elevation 6822).

32. Under the *Initial Condition Type* select the *ELEV* option.
33. Set the *RSVRIC* (reservoir initial condition) to be “6818”.
34. Select **OK**.
35. Select **Done**.

6.3 Running HEC-1

Users are now ready to save and run the HEC-1 file with the defined reservoir.

1. Select *HEC-1* **| Run Simulation**.
2. In the *HEC-1 Run Options* dialog, click the **browse** button next to the Input File.
3. The *Select HEC-1 Input File* will appear. For the *file name* enter “Reservoir” and click **Save** (this specifies the file name but does not actually save it).
4. Verify that the *Save file before run* option is toggled on.
5. Select **OK**.

6. In the *Model Wrapper* window, ensure that *Read solution on exit* option is selected and select **Close** once HEC-1 finishes running (wait a few seconds to a minute or so).
7. After HEC-1 runs users can open any (or multiple within the same plot window by holding down the **SHIFT** key to multi-select) of the hydrographs by double-clicking on the corresponding icon.
8. Close all plot windows before moving on.

7 Reviewing Output

It should be emphasized here that while WMS makes it easy to set up a HEC-1 model and compute a result, it is not a substitute for understanding the basic theory and equations used in HEC-1. Users are encouraged to read the HEC-1 manual found in the documents directory distributed with WMS and other texts on hydrologic modeling. Users are also encouraged to review the HEC-1 output file that is generated with each simulation in order to glean more understanding about how their model is working.

1. Select *File* **| Edit File**.
2. In the *Open* dialog, find and open the file named “reservoir.out”.
3. Select **OK** to open the file with Notepad.
4. Scroll through this file and examine what information HEC-1 saves to the output file. If users have errors running HEC-1 simulations they may often find the answer to the problem within the *.out output file. Close the window when finished.

8 Conclusion

This concludes the exercise defining HEC-1 files and displaying hydrographs. The concepts learned include the following:

- Entering job control parameters
- Defining basin parameters such as loss rates, precipitation, and hydrograph methodology a watershed analysis
- Defining routing parameters
- Routing a hydrograph through a reservoir
- Saving HEC-1 input files
- Reading hydrograph results