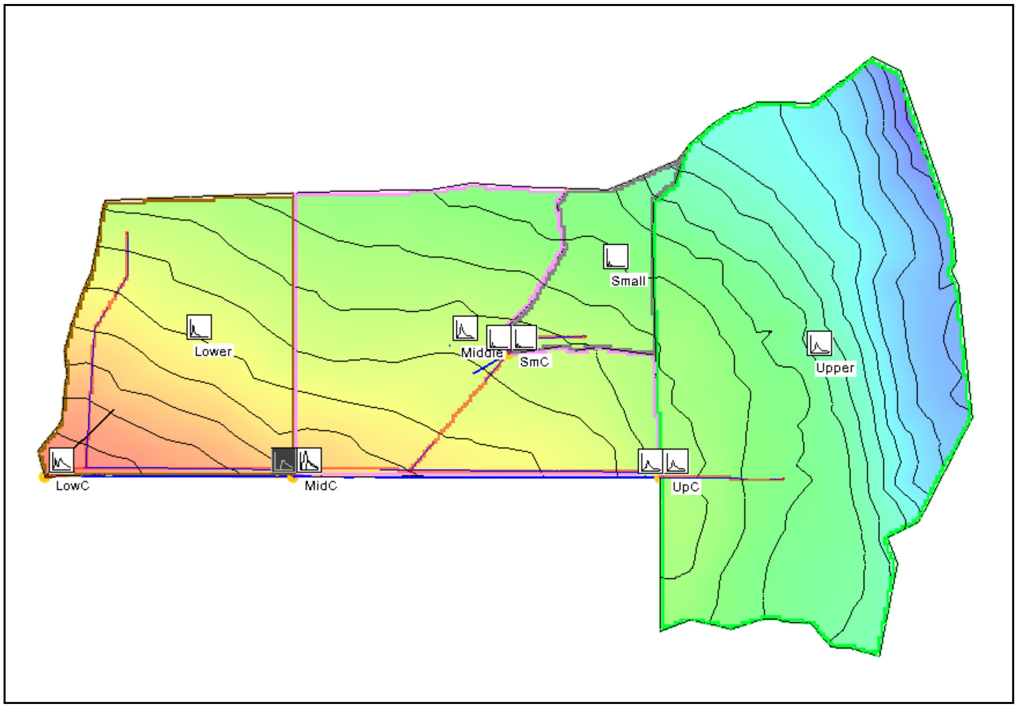
v. 11.0

WMS 11.0 Tutorial

Rational Method Interface

Model urban areas using the WMS rational method interface



Objectives

Learn how to model urban areas using the Rational method, including how to compute rainfall intensity, compute hydrographs, and combine and route hydrographs using the traditional method and by summing hydrographs.

Prerequisite Tutorials

- DEM Delineation
- DEM Delineation – Tc, Basin IDs, and Smoothing
- DEM Delineation – Stream Arcs

Required Components

- Drainage
- Map
- Hydrology

Time

- 15–45 minutes

1 Introduction

The Rational Method is one of the simplest and best known methods routinely applied in urban hydrology. Peak flows are computed from the simple equation:

Q = kCiA

where:

Q = Peak flow

k = Conversion factor

C = Runoff coefficient

i = Rainfall intensity

A = Area

This tutorial demonstrates and discusses how to solve problems using a digital terrain model and the Rational Method.

2 Getting Started

Starting WMS new at the beginning of each tutorial is recommended. This resets the data, display options, and other WMS settings to their defaults. To do this:

1. If necessary, launch WMS.
2. If WMS is already running, press *Ctrl-N* or select *File* | **New…** to ensure that the program settings are restored to their default state.
3. A dialog may appear asking to save changes. Click **No** to clear all data.

The graphics window of WMS should refresh to show an empty space.

3 Importing Terrain Data

The first step is to open the project file:

1. Click **Open** to bring up the *Open* dialog.
2. Select "WMS XMDF Project File (*.wms)" from the *Files of type* drop-down.

3. Browse to the *rational\rational* folder and select "afrational.wms".

A project will appear in the Main Graphics Window (Figure 1).

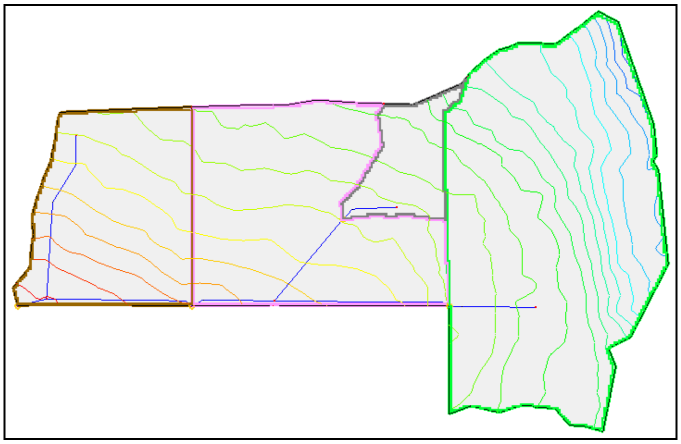


Figure 1 The initial project

4. Switch to the **Drainage** module.
5. Select *DEM* | **Compute Basin Data** to bring up the *Units* dialog.
6. Click **No** if asked to compute flow directions and accumulations.
7. In the *Model units* section, click **Current Projection…** to bring up the *Display Projection* dialog.
8. In the *Horizontal* section, select *No projection* and select "Feet (U.S. Survey)" from the *Units* drop-down.
9. In the *Vertical* section, select "Feet (U.S. Survey) from the *Units* drop-down and click **OK** to close the *Display Projection* dialog.
10. In the *Parameter units* section, select "Acres" from the *Basin Areas* drop-down and "Feet" from the *Distances* drop-down.
11. Click **OK** to close the *Units* dialog.
12. Click **Display Options** to open the *Display Options* dialog.
13. Select "Drainage Data" from the list on the left.
14. Click **All off** and then click **OK** to close the *Display Options* dialog.

4 Running a Rational Method Simulation

The areas computed with the DEM can now be used in setting up a Rational Method simulation of the urban development. Each of the outlet points represents an inlet to a storm drain.

1. Switch to the **Hydrologic Modeling** module.

Notice that the basin names and outlet names are now visible on the model (Figure 2).

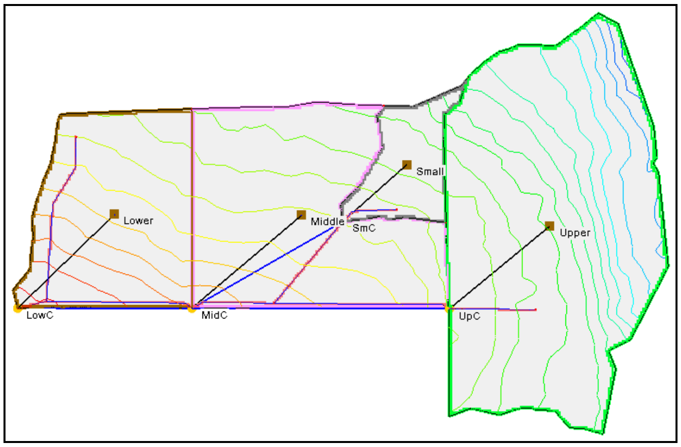


Figure 2 Basin and outlet names are visible

2. Select “Rational” from the *Model* drop-down (Figure 3).

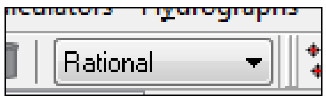


Figure 3 Model drop-down

4.1 Runoff Coefficients and Time of Concentration

The runoff coefficient, *C*, is used to account for losses between rainfall and runoff. The more developed a catchment is, the higher the *C* value it will have.

1. Using the **Select Basin**  tool, double-click the basin icon for the basin labeled “Upper” to bring up the *Rational Method* dialog.

The parameters shown in the dialog correspond to the basin that was selected.

2. In the *Parameters* section, enter “0.20” as the *Runoff Coefficient (C)*.
3. Enter “22.0” as the *Time of concentration (Tc)*.
4. Click **OK** to close the *Rational Method* dialog.
5. Repeat steps 1-3 using the values in the table below for the basins labeled “Small”, “Middle”, and “Lower”.

Basin Name	Runoff Coefficient (C)	Time of Concentration (Tc)
Small	0.35	6.0
Middle	0.40	18.0
Lower	0.40	11.0

A runoff coefficient coverage could be used to automatically map *C* values and basin data. A time computation coverage could also be employed to determine *Tc* values. For this tutorial, they were computed or estimated separately and entered manually.

4.2 Rainfall Intensity and Basin Peak Flows

As part of the WMS interface to the Rational Method, IDF curves can be computed using HYDRO-35, NOAA, or user-defined data. HYDRO-35 data will be used here, with a recurrence interval of 10 years.

1. Using the **Select Basin** tool, double-click the basin icon for the “Upper” catchment to bring up the *Rational Method* dialog.
2. On the *Compute I – IDF Curves* row, click **Compute…** to bring up the *Rational Method -- IDF Computation* dialog.
3. In the *IDF curve computation* section, select *HYDRO-35 Data (Eastern US)*.
4. Click **Define Storm Data…** to bring up the *Input variables for IDF curves* dialog.
5. Enter the following values in the *Variables for HYDRO-35 da*ta section:

Time (min)	Depth (in)
2 yr. 5 min.	0.47
2 yr. 15 min.	0.97
2 yr. 60 min	1.72
100 yr. 5 min.	0.81
100 yr. 15 min.	1.75
100 yr. 60 min.	3.60

6. Click **OK** to close the *Input variables for IDF curves* dialog.

The IDF curves for the 2, 5, 10, 25, 50, and 100 year recurrence intervals will be drawn, and values will be listed for selected times above the IDF curves (Figure 4).

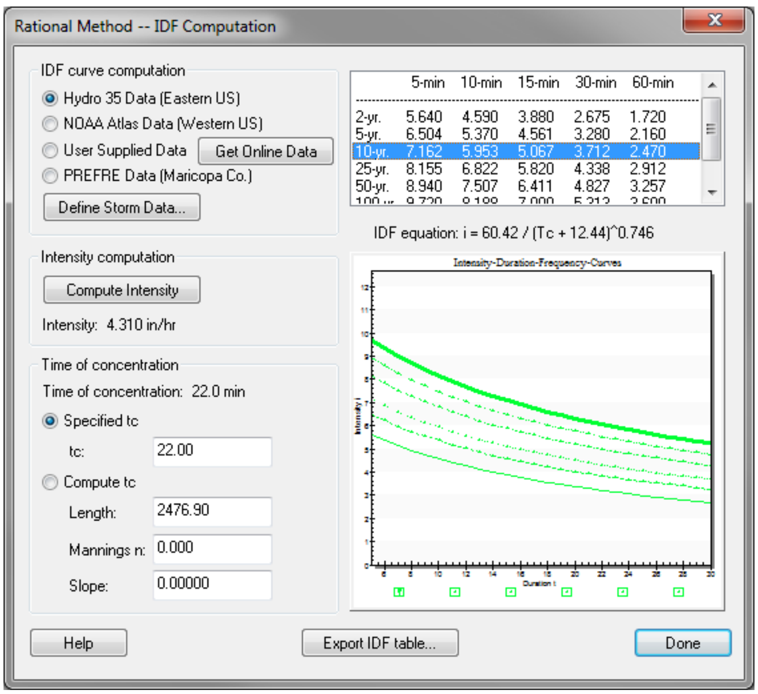


Figure 4 Dialog with 10-yr recurrence interval selected

7. Select the “10-yr.” line in the text window at the top right (Figure 4).

Notice the *IDF equation* below the text window. The rainfall intensity is determined using the selected interval according to the previously-entered value for time of concentration.

8. In the *Intensity computation* section, click **Compute Intensity** to compute *i* for the equation.
9. Click **Done** to close the *Rational Method -- IDF Computation* dialog.

Notice that the value of *i* as computed above is automatically entered for the *Rainfall Intensity (I)* in the *Parameters* section. The value for runoff *Q* is also automatically computed and displayed on the *Flowrate (Q)* row.

10. Click **OK** to close the *Rational Method* dialog.

The HYDRO-35 data only needs to be entered once (unless different data is to be used for different basins), so the rainfall intensity for the remaining basins can be defined using the following steps:

11. Using the **Select Basin** tool, double-click on the basin icon for “Small” to bring up the *Rational Method* dialog.
12. Click **Compute…** on the *Compute I – IDF Curves* row to bring up the *Rational Method -- IDF Computation* dialog.
13. Select the “10-yr.” line in the text window at the top right (see Figure 4).
14. In the *Intensity computation* section, click **Compute Intensity**.
15. Click **Done** to close the *Rational Method -- IDF Computation* dialog.
16. Click **OK** to close the *Rational Method*.
17. Repeat steps 11-16 for the “Middle” and “Lower” basins.

4.3 Basin Hydrographs

As the data entry for each basin is completed, a peak flow (Q) is computed and listed in the *Flowrate (Q)* row in the *Rational Method* dialog. The Rational Method equation does not produce a hydrograph. However, one of several unit-dimensionless hydrographs can be used to distribute the peak flow through time to create a runoff hydrograph.

1. Using the **Select Basin** tool, double-click the basin labeled “Upper” to bring up the *Rational Method* dialog.
2. On the *Compute Hydrographs* row in the *Parameters* section, click **Compute…** to bring up the *Rational Method Hydrographs* dialog.
3. In the first section, select *Traditional method*.
4. In the second section, select “Rational method hydrograph” from the *Hydrograph computation method* drop-down.
5. Click **Done** to compute the hydrograph and close the *Rational Method Hydrographs* dialog.
6. Click **OK** to close the *Rational Method* dialog.

A small hydrograph icon should appear next to the “Upper” basin icon (Figure 5).

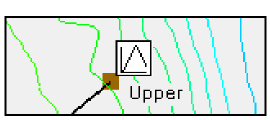


Figure 5 Hydrograph icon for the Upper basin

7. Using the **Select Hydrograph** tool, double-click on the small Upper basin hydrograph icon to bring up the *Hydrograph* dialog.

The hydrograph should appear similar to Figure 6.

8. When finished viewing the hydrograph, close the *Hydrograph* dialog by clicking the at the top right of the window.

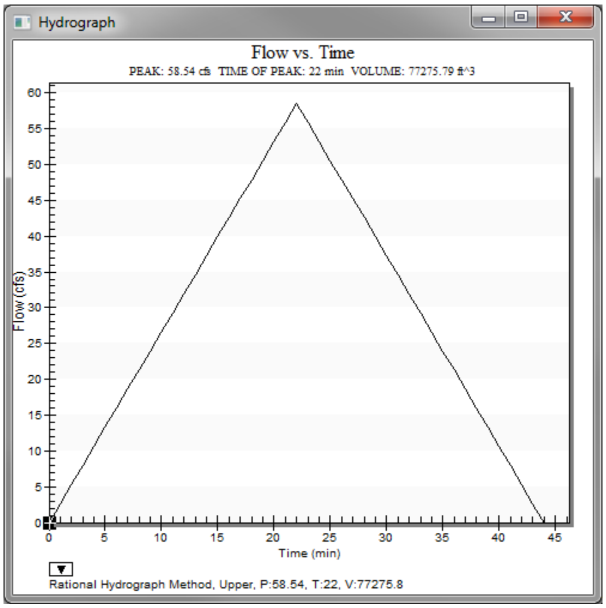


Figure 6 Rational method hydrograph for the Upper basin

4.4 Outlet Peak Flows and Hydrographs (Traditional Method)

At outlet points, WMS uses data from all upstream basins to calculate composite rational method parameters, which can be used to compute peak flows and generate hydrographs. The area is the cumulative upstream area, and the runoff coefficient is determined as an area-weighted value from the upstream basins. The time of concentration at an outlet point is defined as the longest flow time from contributing upstream basins (times of concentration) combined with any lag (travel) times from channels.

With the time of concentration at the outlet defined, now determine the appropriate rainfall intensity. In order for WMS to compute peak flows and hydrographs at outlets, the travel time needs to be defined between outlet points, and the rainfall intensity needs to be determined for the total time of concentration at each outlet.

1. Using the **Select Outlet** tool, double-click on “UpC”, the outlet icon for the “Upper” basin, to bring up the *Rational Method* dialog.

Notice the *Outlet* column in the *Parameters* section. The upstream information for this outlet has been aggregated into the *Runoff Coefficient (C)*, *Area (A)*, and *Time of concentration (Tc)* rows.

2. Click **Compute…** on the *Compute I -- IDF Curves* row in the *Outlet* column to bring up the *Rational Method -- IDF Computation* dialog.

3. Select the “10-yr” line in the text field at the top right and click **Compute Intensity** in the *Intensity computation* section.

4. Click **Done** to close the *Rational Method -- IDF Computation* dialog.

Notice that a composite peak flow is computed and displayed in the *Flowrate (Q)* row in the *Outlet* column (scroll down if necessary).

5. On the *Routing Lag Time (Tl)* row in the *Outlet* column, enter “5.0”.

This is the time that is takes for water to travel in the channel from outlet “UpC” downstream to outlet “MidC”. This number is used for total time of concentration calculations at downstream outlet points.

6. Click **OK** to close the *Rational Method* dialog.
7. Repeat steps 1-6 for the “SmC” and “MidC” outlets, entering “3.0” and “4.0” (respectively) in the *Routing Lag Time (Tl)* row in the *Outlet* column.

For these outlets, the upstream areas are summed, the *C* values weighted, and the longest travel path is determined based on the upstream basin *Tc* values and travel times between outlets.

The last (bottom-most) outlet does not need to have a routing lag time defined since the hydrograph accumulations will occur at this point, but the rainfall intensity still needs to be defined.

8. Using the **Select Outlet** tool, double-click the “LowC” outlet to bring up the *Rational Method* dialog.
9. Click **Compute…** on the *Compute I -- IDF Curves* row in the *Outlet* column to bring up the *Rational Method -- IDF Computation* dialog.
10. Select the “10-yr” line in the text field at the top right and click **Compute Intensity** in the *Intensity computation* section.
11. Click **Done** to close the *Rational Method -- IDF Computation* dialog.
12. Click **Compute…** on the *Compute Hydrographs* row in the *Outlet* column to bring up the *Rational Method Hydrographs* dialog.
13. In the top section, select *Traditional method*.
14. In the lower section, select “Rational Method hydrograph” from the *Hydrograph computation method* drop-down.
15. Click **Done** to close the *Rational Method Hydrographs* dialog.
16. Click **OK** to close the *Rational Method* dialog.
17. Using the **Select Hydrograph** tool, double-click on the hydrograph icon for the “LowC” outlet to bring up the *Hydrograph* dialog.

Notice that the peak value (about “160”) of the “LowC” outlet is considerably higher than that of the “Lower” basin hydrograph (about “65”). This shows that the flows from the upper basins have been routed to the “LowC” outlet.

18. When finished viewing the hydrograph, close the *Hydrograph* dialog by clicking the at the top right of the window.

4.5 Combine Hydrographs by Summing

WMS allows lagging of hydrographs computed for basins and add them using the principle of superposition at outlets in order to produce downstream peak flows and hydrographs.

1. Using the **Select Outlet** tool, double-click on the “LowC” outlet to bring up the *Rational Method* dialog.
2. In the *Outlet* column on the *Compute Hydrographs* row, click **Compute…** to bring up the *Rational Method Hydrograph* dialog.
3. In the top section, select *Route by summing*.
4. In the bottom section, select “Rational method hydrograph” from the *Hydrograph computation method* drop-down.
5. Click **Done** to close the *Rational Method Hydrographs* dialog.
6. Click **OK** to close the *Rational Method* dialog.
7. Using the **Select Hydrograph** tool, double-click the hydrograph icon for the bottom-most outlet.

Notice the difference between these two methods as both hydrographs are plotted in the window (Figure 7).

8. When finished viewing the hydrograph, close the *Hydrograph* dialog by clicking the at the top right of the window.

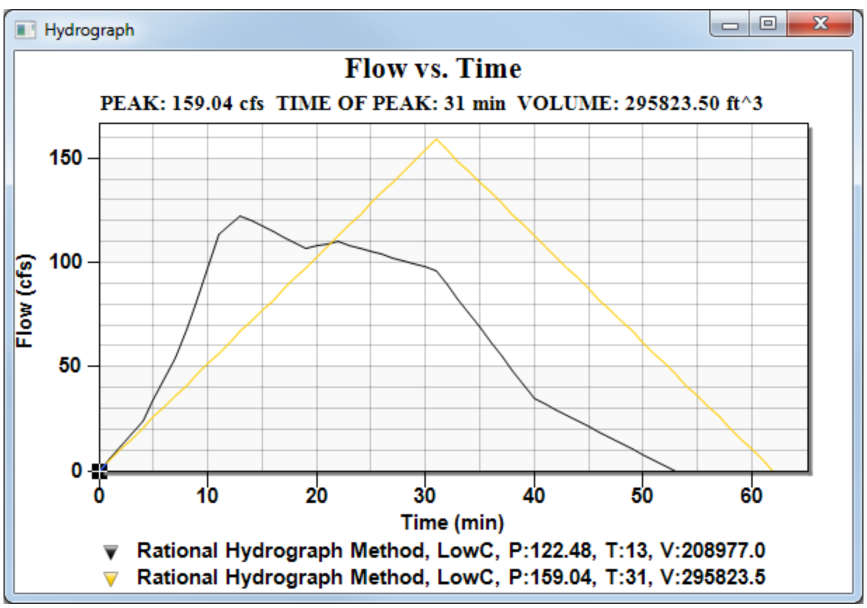


Figure 7 Both hydrographs

5 Adding a Detention Basin

If computing runoff using the route by summing method, hydrographs can be routed through detention basin structures defined at any of the outlet locations.

1. Using the **Select Outlet** tool, double-click the "MidC" outlet to bring up the *Rational Method* dialog.
2. In the *Outlet* column on the *Define Reservoir* row, click **Define…** to bring up the *Detention Basin Hydrograph Routing* dialog.
3. In the *Elevation - storage capacity - discharge* section, click **Define…** to bring up the *Storage Capacity Input* dialog.

A hypothetical detention basin will be defined for the "Small" catchment basin using approximate geometric parameters. WMS can compute a storage capacity curve for any rectangular basin. A pre-computed storage capacity curve can also be entered, or use elevation data to calculate the storage capacity data.

4. In the *Storage capacity* section, select *Known Geometry* and enter the following:

Length	150.0
Width	200.0
Depth	30.0
Side Slope	2.0

5. Leave *Base Elevation* at the existing value. It will be assumed on-grade at the outlet location.
6. Click **OK** to close the *Storage Capacity Input* dialog and bring up the *Detention Basin Analysis* dialog.

Now define a standpipe and spillway (weir) for outlet structures. WMS will compute the elevation-discharge relationship automatically. In addition to standpipes and weirs, low-level outlets or a pre-computed elevation-discharge relationship can be defined.

7. Click **Define Outflow Discharges…** to bring up the *Elevation Discharge Input* dialog.
8. Click **Add Standpipe** to add "Standpipe 1" to the *Discharges* list on the left. It should automatically be selected.
9. In the list of parameters below the list of *Discharges*, enter "4.0" on the *Pipe diameter* row in the *Value* column.
10. Enter "7.0" as the *Height above base elevation*.
11. Click **Add Weir** to add "Weir 2" to the *Discharges* list. It should automatically be selected.
12. Enter "20.0" as the *Weir length*.
13. Enter "25.0" as the *Height above Base Elev*.
14. Click **OK** to close the *Elevation Discharges Input* dialog.
15. Click **OK** to close the *Detention Basin Analysis* dialog.
16. Click **OK** to close the *Detention Basin Hydrograph Routing* dialog.
17. Click **OK** to close the *Rational Method* dialog.

A detention facility has been defined with a standpipe and a spillway for control structures. The incoming hydrograph to this outlet point is routed through the detention facility before routing downstream and combining with the hydrographs of other basins.

18. Select *Hydrographs* | **Delete All**.
19. Using the **Select Outlet** tool, double-click on the “LowC” outlet to bring up the *Rational Method* dialog.
20. In the *Outlet* column on the *Compute Hydrographs* row click on **Compute…** to bring up the *Rational Method Hydrographs* dialog.
21. In the top section, select *Route by summing*.
22. In the lower section, select “Universal hydrograph method” from the *Hydrograph computation method* drop-down.
23. Click **Done** to close the *Rational Method Hydrographs* dialog.
24. Click **OK** to close the *Rational Method* dialog.
25. Using the *Select Hydrograph* tool, double-click on the “MidC” hydrograph icon to view the incoming and routed hydrographs (Figure 8).
26. When finished viewing the hydrograph, close the *Hydrograph* dialog by clicking the at the top right of the window.

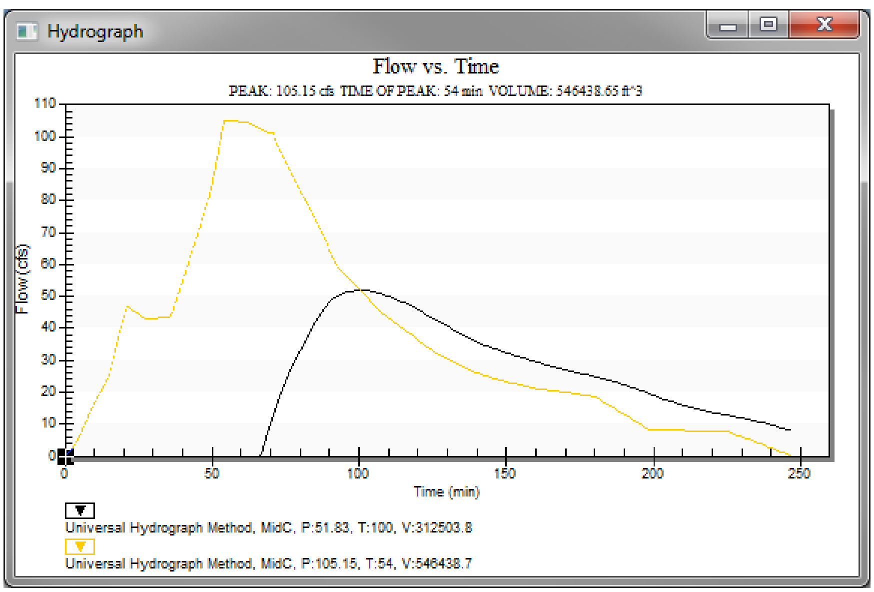


Figure 8 UHM hydrographs

6 Conclusion

This concludes the “Watershed Modeling – Rational Method Interface” tutorial. Some of the options available for using the Rational method in WMS were discussed and demonstrated. Feel free to continue experimenting with the different options in order to become familiar with all the capabilities in WMS for doing rational method simulations.