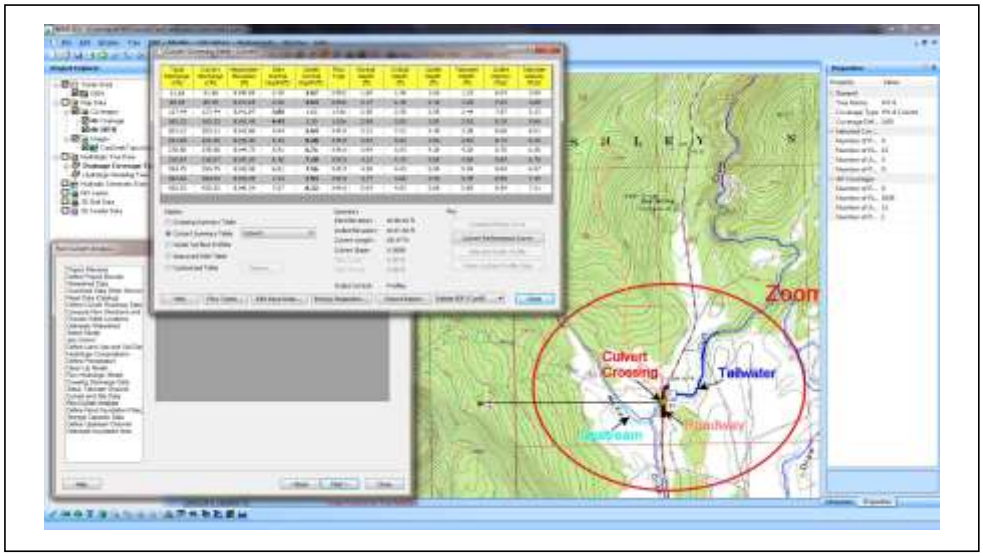
WMS

v. 11.1

WMS 11.1 Tutorial

HY-8 Modeling Wizard

Learn how to model a culvert using HY-8 and WMS



Objectives

Define a conceptual schematic of the roadway, invert, and downstream tailwater associated with a culvert. Delineate the watershed upstream from the culvert and compute a discharge. Compute a storage capacity curve and route a hydrograph through the culvert. Delineate the floodplain based on the culvert hydrograph.

Prerequisite Tutorials

- DEM Delineation

Required Components

- Data
- Drainage
- Map
- Hydrology

Time

- 20–40 minutes

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1 Introduction

The US Federal Highway Administration's (FHWA) culvert design model, HY-8, is a widely used culvert modeling program. Beginning with version 7.0, Aquaveo developed HY-8 in cooperation with the FHWA.

The HY-8 modeling wizard incorporates the HY-8 culvert design tools into the watershed modeling tools in WMS. The wizard automates the steps in the hydrologic modeling process.

This tutorial discusses and demonstrates how to use the WMS HY-8 wizard to simulate a culvert design in a rural area, including:

- Developing a hydrologic model to estimate the runoff of the watershed
- Use the hydrologic model and a digital elevation model as input for HY-8 culvert design
- Run an HY-8 culvert analysis to view the culvert performance curve, determine the routed hydrograph through the culvert, and determine floodplain depths upstream from the culvert.

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.

4. Click **Open** to bring up the *Open* dialog.

5. Browse to the *HY-8WizardTutorialFiles* folder and select "CartCreek.wms".
6. Click **Open** to import the project and exit the *Open* dialog.
7. **Zoom** in on the marked area on the map.

The project should appear similar to Figure 1.

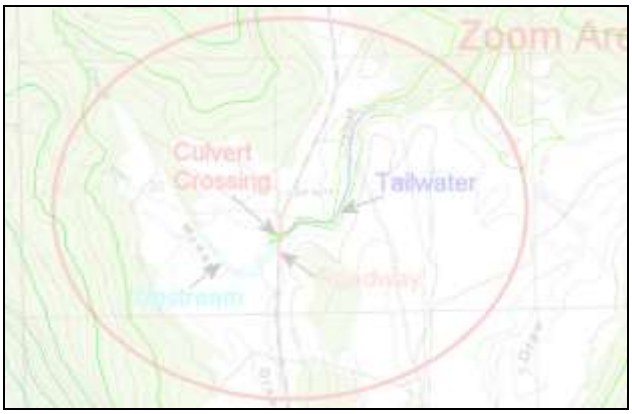

Figure 1 Zoom area

If desired, feel free to change the transparency of the "CartCreekTopo.tstopo.web.jpg" to make the arcs created in the next section easier to see. The transparency is set to 80% in Figure 1.

3 HY-8 Modeling Wizard

The HY-8 Modeling Wizard is similar to the Hydrologic Modeling Wizard. The main difference is the inclusion of HY-8 culvert tools. This tutorial shows how to set up the culvert arcs in a project where the watershed boundaries have already been defined.

The second part of the tutorial uses a new project with the HY-8 culvert inputs already entered. The tutorial will then show how HY-8 culverts change the results of an NSS model. For more detailed information on delineating a watershed, see the "DEM Delineation" tutorial.

3.1 Opening the HY-8 Modeling Wizard

1. Click **HY-8 Modeling Wizard** to bring up the *HY-8 Modeling Wizard* dialog.

Note that the name of this dialog changes based on which item is selected from the list on the left side of the dialog. The first item, "Project Filename", will be selected by default, and the dialog will have the name *Project Filename* (Figure 2).

The right side of the *HY-8 Modeling Wizard* dialog is used to perform specific tasks related to the item select from the list on the left. Clicking **Next** in the wizard moves to the next sequential item in the list on the left.

Most of the individual items do not have to be completed in any specific order, though some require a previous step be completed. Simple select any step by selecting it from list on the left.

Note that the *HY-8 Modeling Wizard* window is a non-modal window, meaning it allows interacting with the main menus and graphics window while it is open. Feel free to move it to a location which does not block the view of the graphics window.

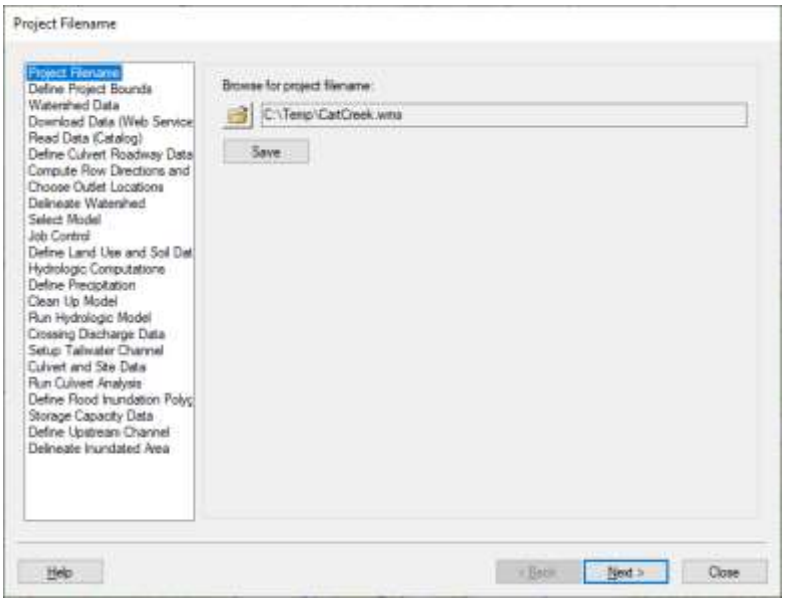

Figure 2 HY-8 Modeling Wizard

3.2 Define Roadway and Culvert Crossing Centerlines

The roadway centerline and culvert location must be defined before running TOPAZ and computing flow directions because the roadway embankment impacts the direction of flow. When defining a culvert crossing, a single arc represents either a single culvert or several culverts at the culvert crossing. Remember to draw the arcs from upstream to downstream.

1. In the *HY-8 Modeling Wizard*, select "Define Culvert Roadway Data" from the list on the left.

The arcs for the roadway centerline and culvert crossing centerline have already been defined. If wanting to see how they were defined, delete the arcs and recreate them using steps 2–5. Otherwise, proceed to step 6.

Comment [JC1]: Remove

2. Click the **Define roadway centerline** button.
3. In the graphics window, create an arc along the highlighted "Roadway" area (Figure 1) from south to north (upstream to downstream). Double-click to end the arc.

If needed, zoom in or out by using the mouse scroll wheel when defining the roadway centerline. The length of the arc will be mapped to the roadway length in the HY-8 model. This value is used to determine the weir length when overtopping occurs. For this tutorial, the length has been exaggerated and will be corrected later.

4. In the *HY-8 Modeling Wizard*, click the **Define culvert crossing centerline** button.
5. In the graphics window, create an arc for the culvert crossing as indicated in Figure 1 from left to right (upstream to downstream). Be sure to start and end the culvert far enough away from the roadway arc to prevent the culvert nodes snapping to the roadway centerline arc.

If needed, zoom in or out by using the mouse scroll wheel when defining the culvert crossing centerline. The length of this arc will define the length of the culvert which has been exaggerated for ease of working with the data. This will be corrected later.

6. In the *HY-8 Modeling Wizard*, click **Edit Crossing/Roadway Data** to bring up the *Properties* dialog.
7. Check the boxes on both rows *1* (Roadway centerline) and *2* (Culvert crossing centerline) in the *Define Crossing* column.
8. In the *Crossing Name* column, on both rows *1* and *2*, enter "Cart Creek".
9. In the *Roadway Top Width (ft)* column, enter "26.0" on row *1*.
10. In the *Elevation Profile* column on row *1*, click the button to bring up the *Edit DEM Elevations* dialog.
11. Click **Set to constant elevation** to open the *Constant elevation* dialog.
12. Enter "8152.06" in the *Enter a constant elevation value for all points* field and click **OK** to close the *Constant elevation* dialog.
13. Click **Snap roadway profile to culvert**.

The DEM elevation profile plot should appear similar to the one in Figure 3.

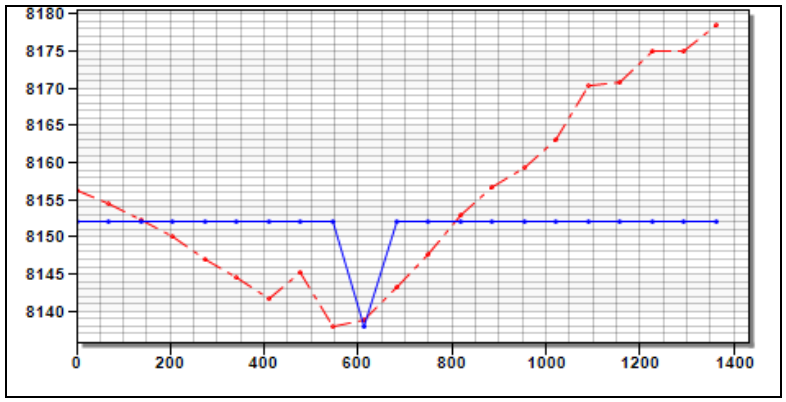

Figure 3 DEM elevation profile plot

The **Snap roadway profile to culvert** button adjusts the DEM elevations to create a flow path through the embankment. When WMS uses TOPAZ to determine flow directions, the flow will be routed to the culvert crossing.

However, the lowest point will not be transferred to the HY-8 model. It is important to leave one location at the elevation of the culvert invert elevation even if not using **Snap roadway profile to culvert**.

14. Click **OK** to close the *Edit DEM Elevations* dialog.
15. Click **OK** to close the *Properties* dialog.
16. Select "Compute Flow Directions and Accumulations" from the list on the left.

3.3 Computing TOPAZ

With the roadway defined and the DEM elevations adjusted to match the roadway elevations, run TOPAZ to compute flow directions and accumulations. The flow accumulations define where the stream is located.

1. In the *HY-8 Modeling Wizard*, select the option to *Compute sub-basin areas* in "Square Miles" and *Compute distances* in "Feet".
2. Click **Compute TOPAZ** to bring up the *Model Wrapper* dialog.
3. After TOPAZ finishes running., click **Close** on the *Model Wrapper* and the solution will be read.
4. Select "Choose Outlet Locations" from the list on the left.

3.4 Defining the Outlet Point

The next step is to define an outlet point that is used to delineate the watershed upstream from the culvert.

1. In the *HY-8 Modeling Wizard*, click **Define Outlets from Culvert Locations**. Clicking this button should define an outlet point at the upstream end of the culvert.
2. If an outlet point is not created, define an outlet point manually by selecting the **Create outlet point** tool and then clicking on the point where the outlet should be located.
3. Select "Delineate Watershed" from the list on the left.

3.5 Delineating the Watershed

With an outlet point defined and the flow accumulations computed, delineate the watershed.

1. In the *HY-8 Modeling Wizard*, make sure the *computed sub-basin areas* are set to "$mi^{2"}$ and the *computed distances* are set to "feet". If they are not, click **Units** and set the *parameter units* to "square miles" and "feet".
2. Enter "1.0" as the *Stream threshold value* and click **Apply to Display**.
3. Click **Delineate Watershed** to create the watershed boundaries (Figure 4).

4. Select “Clean Up Model” from the list on the left.

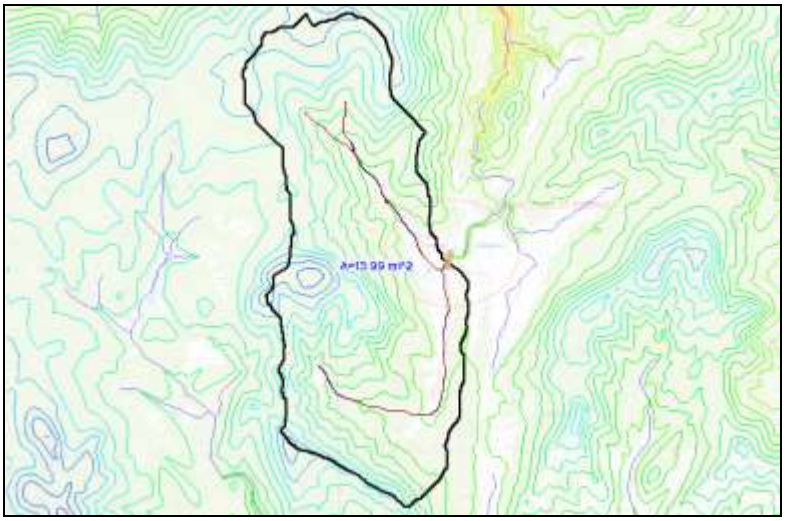

Figure 4 Delineated watershed with outlet at the culvert

3.6 Cleaning the Model and Running Hydrologic Computations

With the watershed delineated and the basin data computed, clean up and run the NSS model. All the data required to run the NSS model has already been computed when delineating the watershed.

1. Turn off the option to *Turn off the display of all non-drainage coverages*.
2. Turn off the option to *Run the model checker* and click **Clean up Model** to bring up the *Redistribute Vertices* dialog.
3. Select “Specified spacing” from the *Specify* drop-down.
4. Enter “100.0” as the *Average spacing* and click **OK** to close the *Redistribute Vertices* dialog.
5. Click **Save** to save the project files.
6. If asked, click **Yes** to save the image files to the project directory.
7. Select “Run Hydrologic Model” from the list on the left.
8. Switch to the **Hydrologic Modeling** module.
9. Select the watershed outlet point and click **Run Simulation** to bring up the *National Streamflow Statistics Method* dialog.
10. In the *Basin information* section, select “Utah” from the *State* drop-down.
11. In the *Regional regression equations* section, select “Region 4” from the list of *Available Equations*. Be sure to not accidentally select “Mean Flow SIR08 5230 Region 4”.
12. Click **Select** → to move it to the list of *Selected Equations*.

13. In the *Results* section, click **Compute Results** to populate the spreadsheet below the button.
14. Select "100" from the *Recurrence (years)* column in the spreadsheet, and click **Compute Hydrograph…** to bring up the *NSS Hydrograph Data* dialog.
15. In the *Compute lag time* section, click **Compute Lag Time – Basin Data…** to bring up the *Basin Time Computation* dialog.
16. Select "Denver method" from the *Computation type* drop-down and click **OK** to use the computed lag time.
17. Click **OK** to close the *NSS Hydrograph Data* dialog and compute the 100-year storm hydrograph.
18. Click **Done** to close the *National Streamflow Statistics Method* dialog.

Notice that a hydrograph icon appears at the outlet point. Use this hydrograph to run an HY-8 analysis. Then route the hydrograph through the culvert and determine the flood depths behind the culvert based on the culvert headwater elevations.

3.7 Defining Discharge Data

After running the hydrologic model, discharge data for use in the HY-8 model should be defined. This can be done by either transferring the computed hydrograph to the HY-8 model or by entering a design flow to use in the HY-8 model.

For convenience and consistency, a project with all the previous steps should be opened by doing the following:

1. Click **New** to restore program settings to their default state.
2. Click **Open** to bring up the *Open* dialog.
3. Browse to the *HY-8\HY-8* folder and select "CartCreek-delineated.wms".
4. Click **Open** to import the project and exit the *Open* dialog.
5. Switch to the **Hydrologic Modeling** module.
6. Select *Hydrographs* | **Open…** to bring up the *Open* dialog.
7. Select "All Files (*.*)" from the *Files of type* drop-down.
8. Select "CartCreek-delineated.dat" and click **Open** to exit the *Open* dialog.
9. Click **OK** if advised that the hydrograph file does not match the active hydrologic tree.

A hydrograph should appear at outlet 3C (lower left, Figure 5).

10. **Zoom** in on the marked area on the map.
11. Click **HY-8 Modeling Wizard** to bring up the *HY-8 Modeling Wizard* dialog.
12. Select "Crossing Discharge Data" from the list on the left.

Notice that the outlet point "3C" is assigned to the Cart Creek HY-8 culvert crossing.

13. In the *Define discharge data* section, select "Hydrograph" from the drop-down in the *Flow Source* column.

14. Click **Select…** in the *Hydrograph* column to open the *XY Series Editor* dialog.

Notice that the hydrograph gently rises from left to right. The flow values from this hydrograph are used to compute the headwater elevations in HY-8.

15. Click **OK** to close the *XY Series Editor* dialog.
16. Select "Setup Tailwater Channel" from the list on the left.

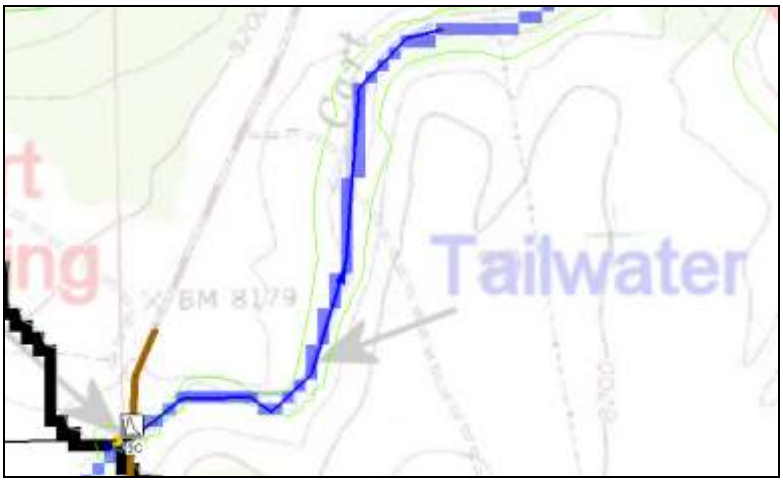

Figure 5 Hydrograph at outlet 3C, and tailwater centerline arc

3.8 Defining Tailwater Data

Now create the tailwater centerline.

1. In the Project Explorer, turn on "HY-8".
2. Select "HY-8" to make it active.

This makes the existing roadway and culvert crossing arcs visible.

3. **Zoom** into the area surrounding the culvert crossing and around the tailwater in the model.
4. Click **Define tailwater centerline**.
5. Using the GIS image as a guide, create an arc starting at the downstream culvert outlet point and proceeding downstream (Figure 5). Try to follow the flow accumulation cells on the DEM while drawing the tailwater arc. Double-click to end the arc.
6. Click **Edit Tailwater Data...** to bring up the *Properties* dialog.
7. Turn on *Define Crossing* on the *Tailwater centerline* row.
8. Select "Rectangular Channel" from the drop-down in the *Channel Type* column.
9. Enter "10.0" in the *Bottom width (ft)* column.
10. Enter "0.045" in the *Manning's n* column.

11. Click **OK** to close the *Properties* dialog.
12. Select "Culvert and Site Data" from the list on the left.

The direction of flow along the arcs created in the HY-8 coverage can be shown by turning on *HY8 Stream Arrows* after selecting "Map Data" from the list on the left in the *Display Options* dialog.

3.9 Culvert and Site Data and Running the Analysis

Most of the culvert, roadway, and tailwater data have been defined using the modeling wizard. However, there are a few more parameters that must be defined before running the culvert analysis. In some cases, the DEM may not contain enough resolution to capture the roadway, culvert, and tailwater geometric properties. Therefore, culvert survey data can be used to modify the HY-8 culvert parameters instead of using the WMS-computed data.

1. In the *Culvert and Site Data* section, click **Edit…** in the *Edit Culvert and Site Data* column to bring up the *Crossing Data – Cart Creek* dialog.

Notice all of the roadway, culvert, and tailwater data previously entered or computed in WMS. For more information on where WMS gathers this data, see the XMS Wiki[1].

Now edit some of these parameters based on existing culvert information.

2. In the *Crossing Properties* section, under *Roadway Data*, enter "100.0" as the *Crest Length*.
3. Enter "8152.06" as the *Crest Elevation*.
4. Enter "26.0" as the *Top Width*.

If the length of the roadway arc is correct, it is not necessary to change this value. In this tutorial, the roadway arc was made longer for ease in working with the data.

5. In the *Culvert Properties* section, under *Culvert Data*, select "Corrugated Steel" from the *Material* drop-down.
6. Enter "10.0" as the *Diameter*.
7. Under *Site Data*, enter "8138.02" as the *Inlet Elevation*.
8. Enter "69.5" as the *Outlet Station*.

If the length of the culvert arc is correct, it is not necessary to change the outlet station. In this tutorial, the culvert arc was made longer for ease in working with the data.

9. Click **OK** to close the *Crossing Data – Cart Creek* dialog.
10. Select "Run Culvert Analysis" from the list on the left.
11. In the *Run Culvert Analysis* section, click **Run…** in the *Analyze Crossing* column to bring up the *Summary of Flows at Crossing – Cart Creek* dialog.

This dialog allows various plots and charts to display. Feel free to explore the various options in the *Display* and *Plot* sections.

[1] See https://www.xmswiki.com/wiki/WMS:Culvert_and_Site_Data for more details.

12. When done exploring the plot and chart options, close any additional windows that were opened in order to return to the *Summary of Flows at Crossing – Cart Creek* dialog.
13. Click **Close** to exit the *Summary of Flows at Crossing – Cart Creek* dialog.
14. Select "Storage Capacity Data" from the list on the left.

3.10 Define Storage Capacity Data

The storage capacity data step can be used to route the hydrograph through the culvert to determine the effects of the culvert on the watershed hydrograph. WMS extracts storage information from the digital elevation model and uses the discharge and headwater elevations from the HY-8 model to get the data necessary to route the hydrograph.

1. In the *Define Storage Capacity Data* section, click **Define…** in the *Storage Capacity Data* column to bring up the *Storage Capacity Input* dialog.
2. In the *Storage capacity* section, make sure *Use DEM* is selected.

WMS computes the basin storage at the headwater elevations computed from HY-8 and transfers these volumes to the detention basin calculator to route the hydrograph.

3. Click **OK** to close the *Storage Capacity Input* dialog and bring up the *Detention Basin Analysis* dialog.

Notice that the elevations, volumes, and discharges computed by HY-8 and WMS are pre-defined in the *Detention Basin Analysis* window.

4. Click **Plot Hydrographs…** to bring up the *Routed Hydrographs* dialog (Figure 6).

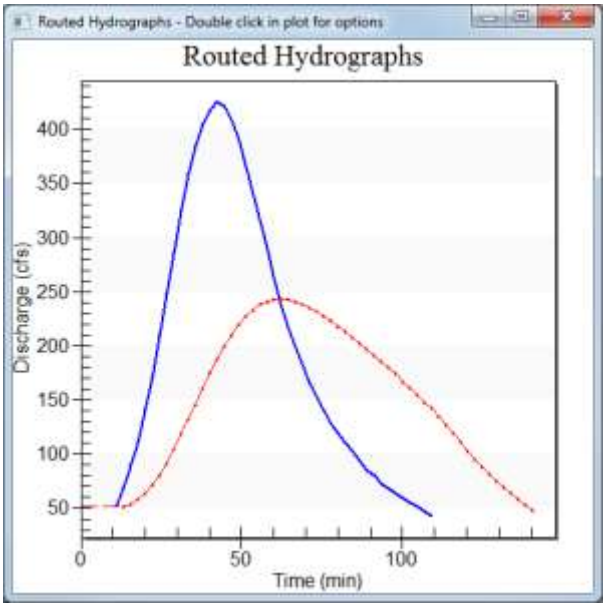

Figure 6 Routed Hydrographs dialog

5. When done reviewing the hydrograph, click  in the top right corner of the *Routed Hydrographs* dialog to close it.
6. Click **OK** to exit the *Detention Basin Analysis* dialog.
7. Switch to the **Hydrologic Modeling**  module.

Notice that the routed hydrograph is imported into WMS and assigned to the outlet point associated with the Cart Creek culvert crossing.

The "Floodplain Package" sections require the floodplain package.[2] If this package is not included on the WMS installation being used, please skip to the Conclusion.

4 Floodplain Package (optional)

This section requires the floodplain package, so this section is optional.

4.1 Define Upstream Data

The next step is to define a centerline representing the upstream channel. The purpose of this line is to define the upstream channel so water surface elevation points can be created along this upstream channel. These water surface elevations are then used to delineate the floodplain.

1. **Zoom**  in on the marked area on the map.
2. Click the **Define upstream channel centerline**  button.
3. In the graphics window, create an arc curving along the highlighted "Upstream" area from left to right and going upstream to downstream. Click on the outlet 3C to end the arc.

If *HY-8 Stream Arrows* are turned on in the *Display Options* dialog, the direction of flow is shown as arrows along the upstream channel centerline arc.

4. Select "Delineate Inundated Area" from the list on the left.

4.2 Delineate Inundated Area

The final step in the wizard is to delineate the floodplain. This step determines the inundated area inside the watershed caused by the roadway and culvert.

1. Click **Floodplain Delineation Options…** to open the *Floodplain Delineation* dialog.
2. In the *Delineation options* section, enter "1000.0" as the *Max search radius*.
3. Click **OK** to close the *Floodplain Delineation* dialog.
4. In the *Delineate Inundated Area* section, in the Delineate column, click **Delineate…** on the *Cart Creek* row.

[2] See https://www.aquaveo.com/software/wms-pricing for more details.

5. After the delineation is completed, click **Finish** to close the *HY-8 Modeling Wizard* dialog.

Feel free to turn off the TIN triangles and vertices if they are turned on.

6. Select "Cart Creek Flood Depth" under the "Cart Creek (FLOOD)" folder under "New tin" in the Project Explorer.
7. Scroll through the time steps in the Properties window and notice how the flood depths change over time as the storm hydrograph progresses.

Feel free to change from normal linear contours to contour fill in the *Contour Options* dialog if desired.

5 Conclusion

This concludes the WMS "HY-8 Modeling Wizard" tutorial. The following key concepts were discussed and demonstrated:

- Define roadway and culvert crossings in HY8
- Developing a Hydrologic model to estimate the runoff of the watershed
- Using the Hydrologic model and a digital elevation model as input for HY-8 culvert design
- Running an HY-8 culvert analysis to view the culvert performance curve, determine the routed hydrograph through the culvert, and determine floodplain depths upstream from the culvert.

Feel free to continue to experiment, or exit the program.