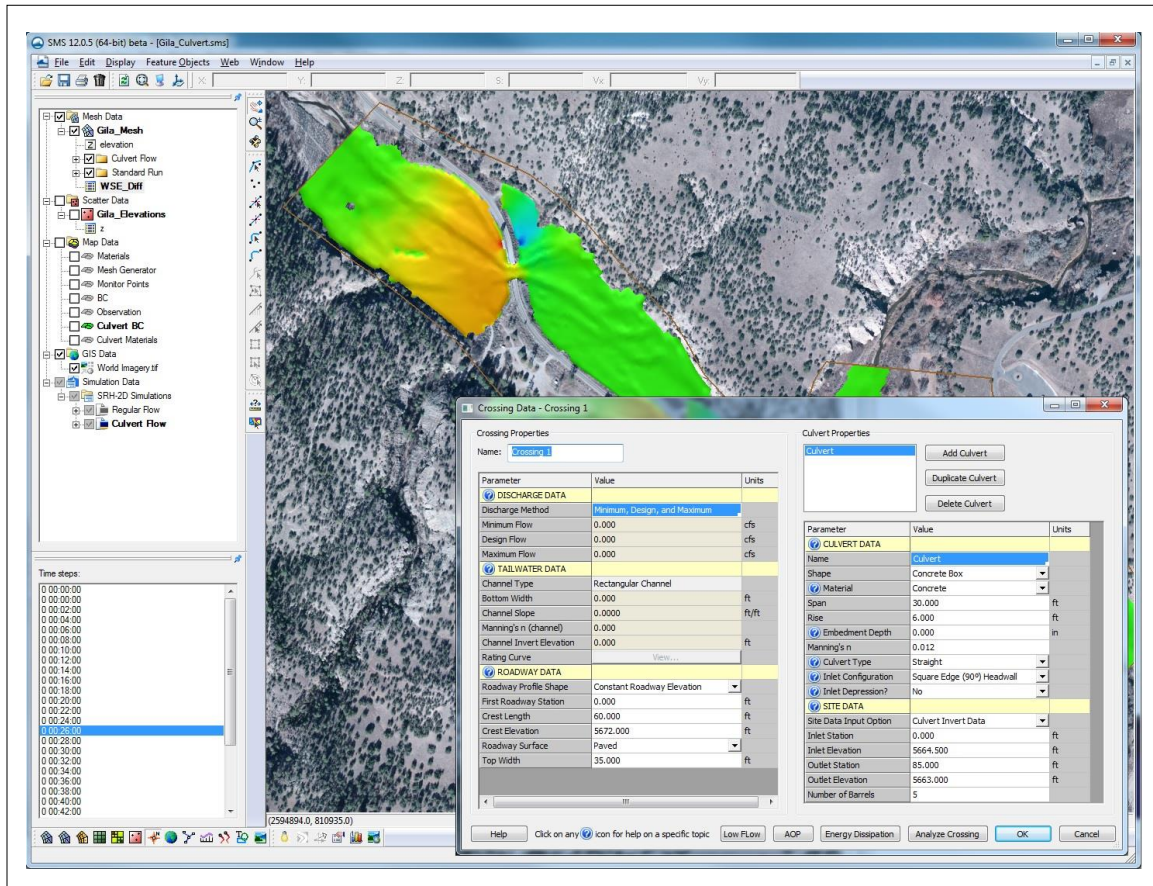




SRH-2D Tutorial Culvert Structures with HY-8



Objectives

This tutorial demonstrates the process of modeling culverts in SRH-2D coupled with the Federal Highway Administrations HY-8 culvert analysis application. The “SRH-2D Simulations” tutorial should have been completed before attempting this one. All files for this tutorial are found in the “Input” folder within the “SMS_SRH-2D_HY8_Culvert” tutorial folder.

Prerequisites

- SMS Overview
- SRH-2D
- SRH-2D – Simulations

Requirements

- SRH-2D
- Mesh Module
- Scatter Module
- Map Module

Time

- 15–20 minutes



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1 Model Overview

An existing SRH-2D model will be used to facilitate the setup for this tutorial. SRH-2D provides two different ways to define a culvert. One way couples the FHWA HY-8 culvert model with SRH-2D and the other way utilizes the culvert definition built into SRH-2D. This tutorial will demonstrate the first method.

The area being modeled is located at the confluence of the west and middle forks of the Gila River, located in New Mexico.

During high flows, a significant amount of water is backed up near one of the roadway bridges causing flooding upstream. The purpose of this tutorial is to simulate a culvert relief structure near the bridge to mitigate the flooding.







Although an HY-8 culvert structure is a capable option for modeling culverts, it is a 1D calculation and any momentum calculated in the 2D computations will not be transferred through the structure.

2 Getting Started

To begin, do the following:

1. Open a new instance of SMS.
2. Select *File* | **Open** to bring up the *Open* dialog.
3. Navigate to and select the “Gila_Structure.sms” project found in the / *SMS_SRH-2D_HY8_Culvert /Input* folder for this tutorial.
4. Click **Open** to import the data.

The existing project will open and appear similar to Figure 1.

In the Project Explorer, duplicates of the “ Regular Flow” simulation and “ BC” coverage have been made to expedite the model setup process. The duplicates have been renamed as “ Culvert Flow” and “ Culvert BC” respectively. The culvert structure will be created within the “ Culvert BC” coverage and simulated in the “ Culvert Flow” simulation.

The process of duplicating these items was demonstrated in the “SRH-2D Simulations” tutorial. Creating duplicates of simulations or coverages allows making modifications to a model while still preserving the original simulation or coverages. This also enables creating several modeling scenarios in the same project and compare the solutions.

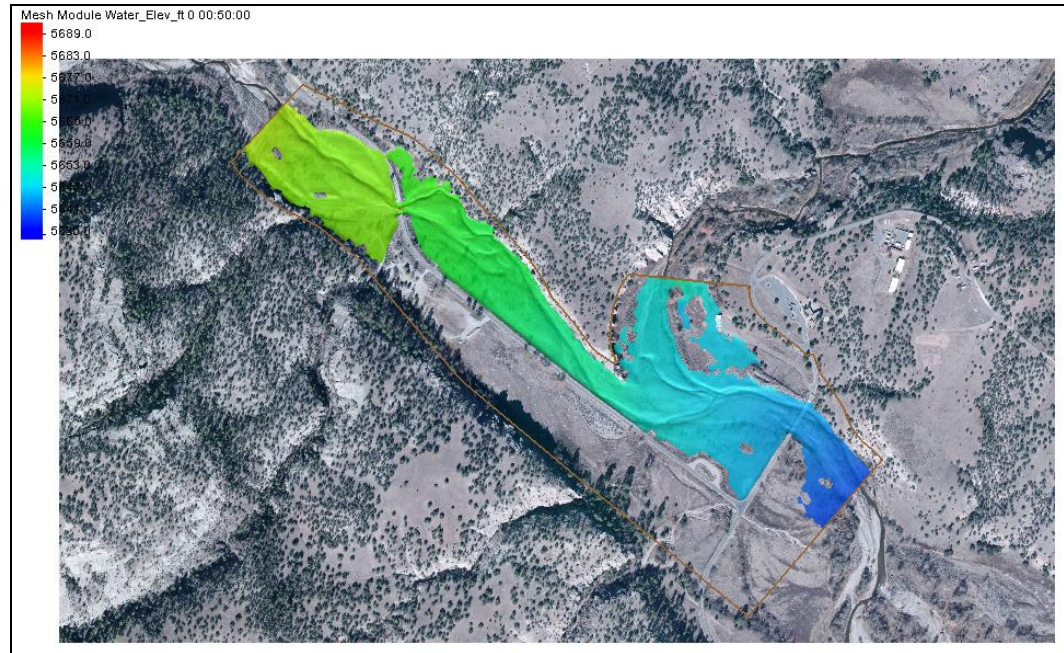


Figure 1 Gila_Structure.sms project

The mesh datasets located under the “Regular Flow” folder in the Project Explorer are from an SRH-2D solution of the existing flow conditions, without the culvert relief structure. The datasets can be used to make comparisons and visualize the effects the culvert structure boundary condition will have on the model.

1. In the *Time steps* window, scroll through the time steps and select the final time interval at “0 02:30:00”.

Notice that the flow is overtopping the roadway in the upper left part of the road.

3 Creating the Culvert Structure

The culvert structure will be created near the bridge location (as shown in Figure 2). Culvert structures are defined by creating two boundary condition arcs, one on the upstream face and one on the downstream face of the structure. The boundary condition arcs are then defined as a culvert structure and the attributes of the culvert are defined in the HY-8 culvert definition dialog.

3.1 Creating the Structure Arcs

The first step for creating a culvert structure for SRH-2D is to create arcs representing the structure within the SRH-2D boundary condition coverage.

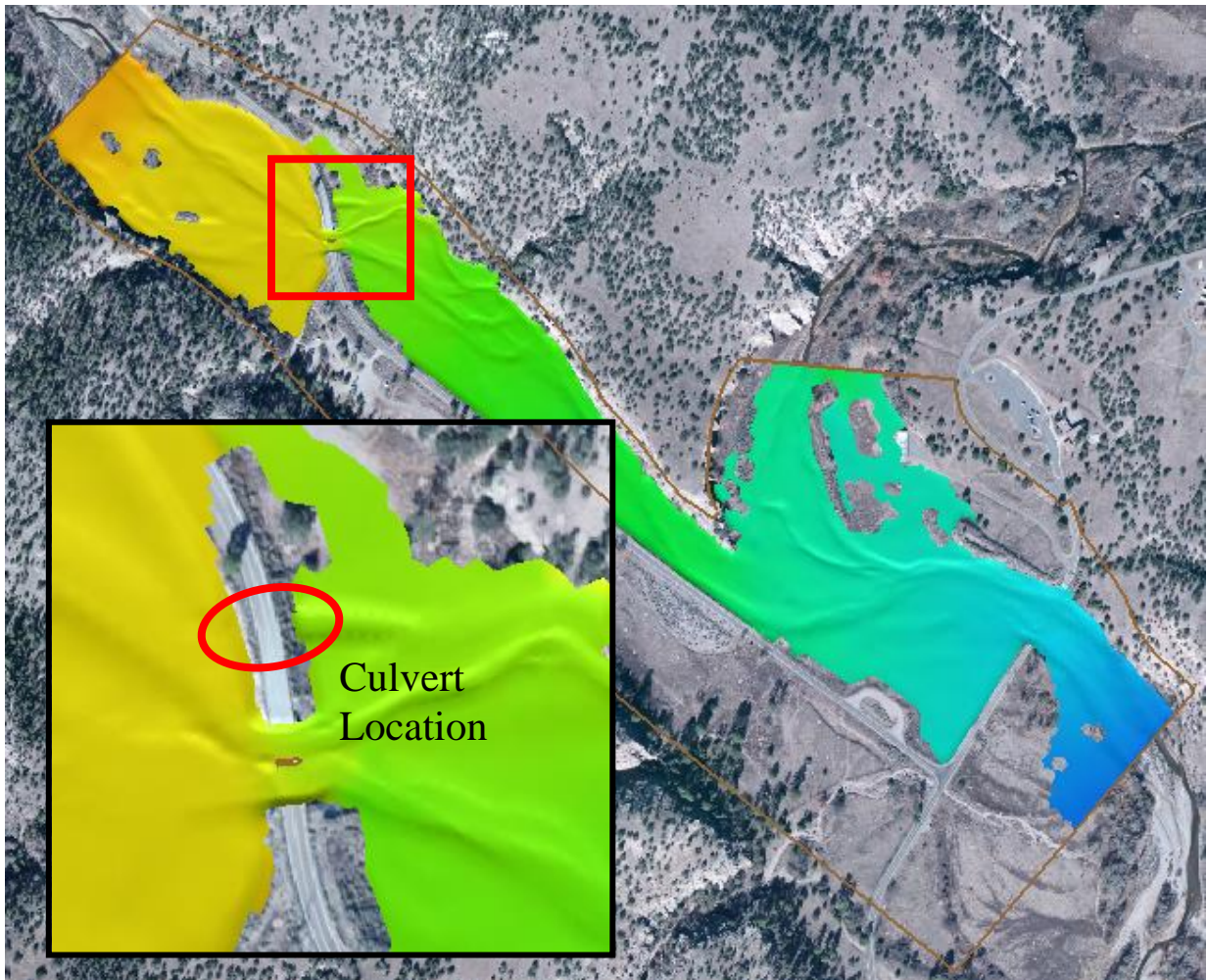







Figure 2 Culvert location

1. Use the **Zoom**  tool to zoom into the culvert location near the bridge.
2. Select the “ Z” dataset under “ Gila_Mesh” in the Project Explorer to display the mesh elevations.
3. Select *Display* | **Display Options...** to open the *Display Options* dialog.
4. In the *2D Mesh* section, check the box next to *Elements* to turn on the display of mesh elements.
5. Select **OK** to exit the *Display Options*.

6. In the Project Explorer, check the box next to the “ Culvert BC” coverage and select it to make it the active coverage.
7. Use the **Create Feature Arc**  tool to create two arcs, one on each side of the road. These arcs will define the upstream and downstream faces of the culvert structure. The created arcs should be placed in the locations shown in Figure 3.

It is recommended that the mesh be created to contain quadrilateral elements within the area between these two arcs which represent the culvert structure and that the structure arcs are aligned with a clean row of element edges.

Note: When drawing these arcs, they should be drawn in the same direction. After the first arc has been drawn, ensure that the second arc is drawn in the same direction (north to south or south to north). Drawing them in opposing directions may cause an error when running SRH-2D.

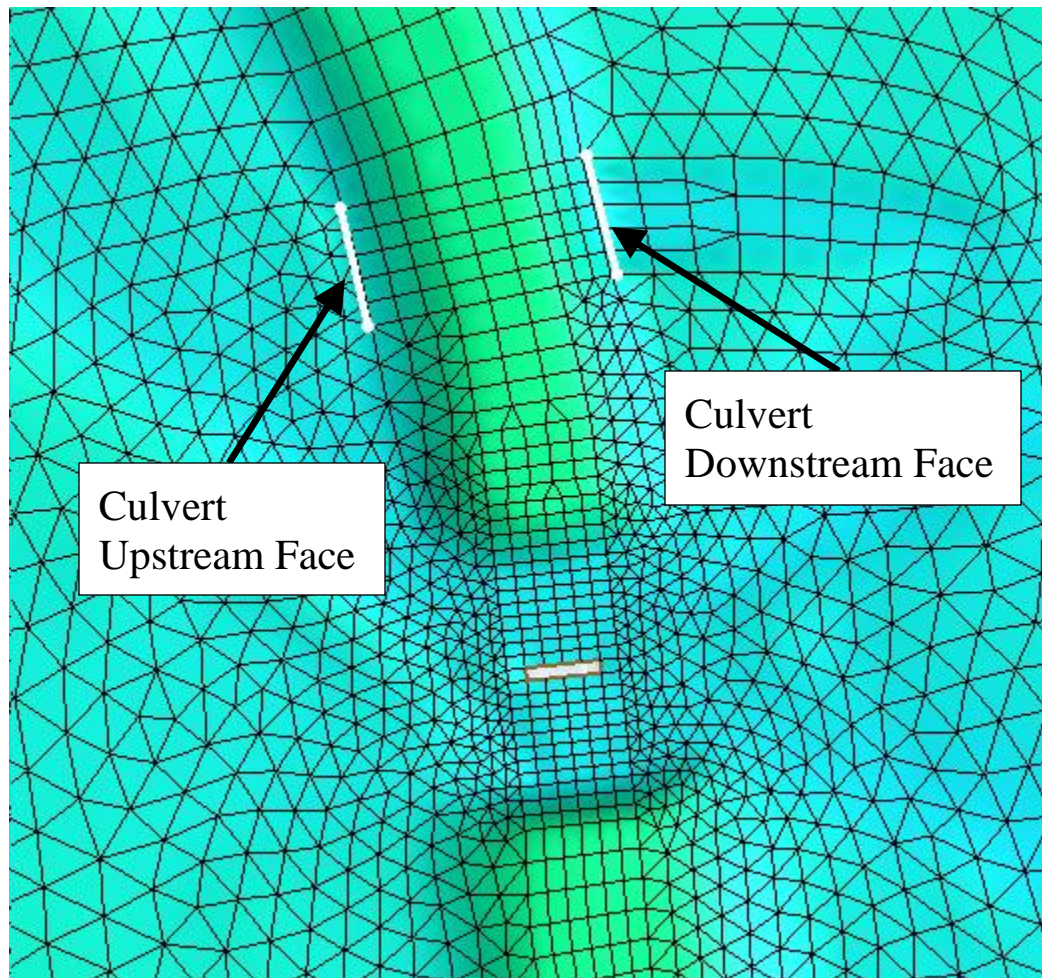



Figure 3 Upstream and Downstream BC Culvert Arcs


3.2 Creating the HY-8 Culvert Definition File

When running the model, SMS couples SRH-2D with HY-8. The HY-8 crossing definition file must be created.


1. Right-click on the “ Culvert BC” coverage and select **HY-8 Options...** to bring up the *HY-8 Options* dialog.
2. Click **Select** under *HY-8 File* to launch a file browser.
3. Navigate to the directory where the tutorial project file is stored (/ SMS_SRH-2D_HY8_Culvert /Input”).
4. Enter “Relief_Culvert.hy8” (be sure to include the “.hy8” extension) as the *File name*.
5. Select **Save** to create the file and close the file browser.
6. Select **OK** to close the *HY-8 Options* dialog.

3.3 Assigning Culvert Structure Attributes in HY-8

The next step in creating the culvert structure is to specify the boundary condition type and define the culvert attributes.

1. Using the **Select Feature Arc**  tool, select the upstream (leftmost) culvert arc and take note of the ID for this arc, which is displayed the *Status Bar* at the bottom of the SMS application.
2. Hold the *Shift* key and select the downstream (right) culvert arc so that both of the arcs are selected.
3. Right-click on either arc and select the **Assign Linear BC...** command. SMS will bring up the *SRH-2D Linear BC* dialog.
4. In the *Type* combo box, select “Culvert HY-8”. Be sure to select “Culvert HY-8” and not “Culvert”.
5. Note the assignment of “Culvert Upstream” and “Culvert Downstream” to the two arcs, associated with their ID values. If the ID displayed for culvert upstream is not the same as noted above in step 1, switch the associations using the combo box for *Role*.
6. The *Units* can be left as “U.S. Customary”.

The *Use total head* option will add the velocity head to the water surface elevations for the 1D culvert calculations. It will not be used for this application.

7. Select **Launch HY-8** under *HY-8 Culvert*. This will open the HY-8 software.
8. In HY-8, right-click on “ Project”, in the HY-8 Project Explorer and choose **Add Culvert Crossing**.
9. In the *Crossing Data* dialog, under *Crossing Properties*, change the *Name* to “Gila Crossing” and under *Culvert Data*, change the *Name* to “Relief Culvert”.



10. Define the culvert and crossing attributes as found in Table 1.

Note: When specifying the *Inlet Elevation* and *Outlet Elevation*, care must be taken such that the specified elevations are not lower than the underlying mesh node elevations. If the specified inlet and outlet elevations are lower, several approaches could be taken to remedy the issue such as specifying a higher elevation for the inlet and outlet elevations, relocating the BC arcs, refining the mesh around the culvert, or editing the mesh node elevations.

Parameter	Value	Parameter	Value
Discharge Method	Minimum, Design, and Maximum	Shape	Concrete Box
Minimum Flow	0.0	Material	Concrete
Design Flow	0.0	Span	8.0
Maximum Flow	0.0	Rise	6.0
Channel Type	Rectangular Channel	Embedment Depth	0.0
Bottom Width	0.0	Manning's n	0.012
Channel Slope	0.0	Culvert Type	Straight
Manning's n (channel)	0.0	Inlet Configuration	Square Edge (90°) Headwall
Channel Invert Elevation	5663.000	Inlet Depression	No
Roadway Profile Shape	Constant Roadway Elevation	Site Data Input Option	Culvert Invert Data
First Roadway Station	0.0	Inlet Station	0.0
Crest Length	40.0	Inlet Elevation	5664.5
Crest Elevation	5672.0	Outlet Station	85.0
Roadway Surface	Paved	Outlet Elevation	5663.0
Top Width	35.0	Number of Barrels	5

Table 1 Crossing data parameters

When done the dialog should resemble Figure 4.

11. Click **OK** to close the *Crossing Data* dialog.
12. In the main HY-8 window, select “ Gila Crossing” to make sure it is selected for use in the model.
13. Exit the main screen of HY-8 by pressing the exit button . All changes will be saved upon exiting.
14. In the HY-8 model wrapper, verify that “Gila Crossing” is listed next to *Crossing Name*. This is useful to verify, especially if a project contains more than one

crossing definition. A *Crossing GUID* will also be shown as a string of characters.

15. Select **Exit** to close the *HY-8* model wrapper in SMS.

It should say “(Executed)” next to the **Launch HY-8** button.

16. Click **OK** to close the *SRH-2D Linear BC* window.

Now would be a good time to save the project.

1. Select *File* | **Save as...** to bring up the **Save As** dialog.
2. Enter “Gila_Culvert.sms” as the *File name* and click **Save**.

Crossing Properties

Name:

Parameter	Value	Units
DISCHARGE DATA	Optional-Model will determine val...	Optional Info...
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	0.000	cfs
Design Flow	0.000	cfs
Maximum Flow	0.000	cfs
TAILWATER DATA	Optional-Model will determine val...	Optional Info...
Channel Type	Rectangular Channel	
Bottom Width	0.000	ft
Channel Slope	0.0000	ft/ft
Manning's n (channel)	0.000	
Channel Invert Eleva...	5663.000	ft
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	ft
Crest Length	40.000	ft
Crest Elevation	5672.000	ft
Roadway Surface	Paved	
Top Width	35.000	ft

Culvert Properties

Relief Culvert


Parameter	Value	Units
CULVERT DATA		
Name	Relief Culvert	
Shape	Concrete Box	
Material	Concrete	
Span	8.000	ft
Rise	6.000	ft
Embedment Depth	0.000	in
Manning's n	0.012	
Culvert Type	Straight	
Inlet Configuration	Square Edge (90°) Headwall	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	5664.500	ft
Outlet Station	85.000	ft
Outlet Elevation	5663.000	ft
Number of Barrels	5	

Help Click on any icon for help on a specific topic

Figure 4 HY-8 Crossing and Culvert Inputs

4 Saving, Exporting, and Launching the Simulation

Now that the culvert structure has been created and defined, the model is ready to run.

1. Right-click on the “ Culvert Flow” simulation and choose **Save, Export, and Launch SRH-2D**.
2. Select **OK** if a warning is displayed stating that the “Culvert Materials” coverage will be renumbered before exporting.
3. When the run completes, a message stating “Program Terminated with exit code 0, Exit Window?” will appear. Select **Yes**.
4. Make sure *Load Solution* is checked in the SMS model wrapper, as shown in Figure 5 and click **Exit**.

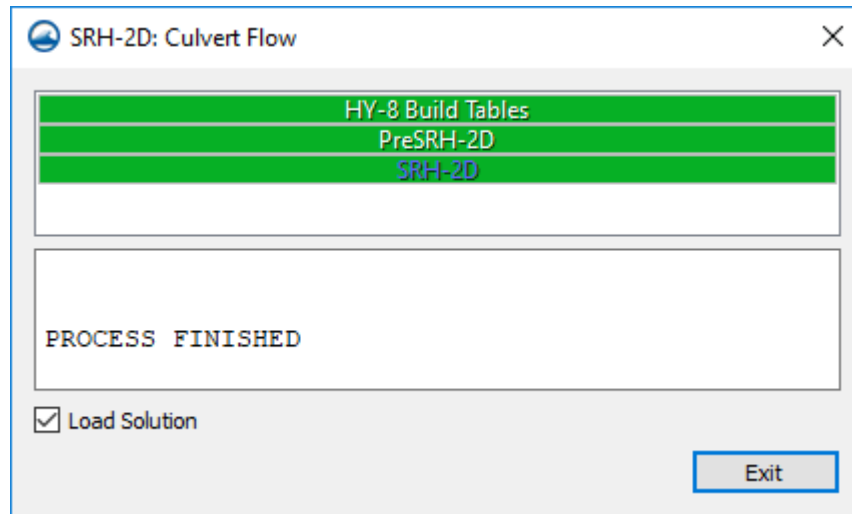











Figure 5 SMS Model Wrapper

The solution datasets will now be listed in the Project Explorer under “ Gila_Mesh”.

4.1 Organizing the Solution Datasets

For better dataset organization, a folder will be created in which the culvert solution datasets may be stored.

1. Right-click on “ Gila_Mesh” and select **New Folder**.
2. Rename the new folder as “Culvert Flow”.
3. Select the six mesh datasets that correspond to the culvert solution by holding down the *Shift* key and selecting the datasets. The datasets are labeled: “ Froude”, “ Strs_lb_p_ft2”, “ Vel_Mag_ft_p_s”, “ Velocity”, “ Water_Depth_ft”, and “ Water_Elev_ft”.
4. Drag the selected datasets below the “ Culvert Flow” folder that was created in steps 1 and 2. The datasets should be organized as shown in Figure 6.

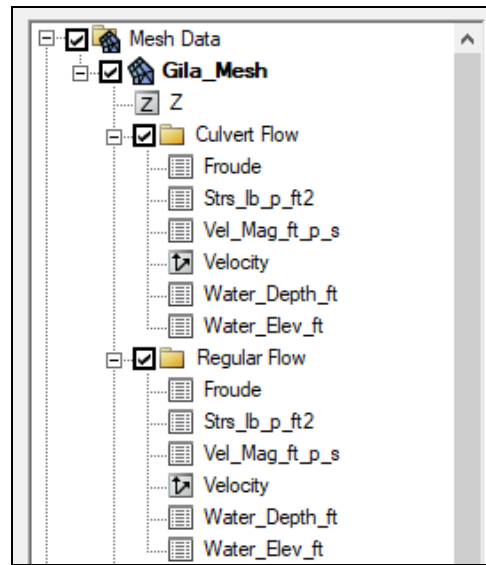








Figure 6 Mesh Dataset Organization

5. Select the “ Water_Elev_ft” mesh dataset within the “ Regular Flow” folder to make it the active dataset for viewing.

5 Visualizing the Results



SMS has several ways by which results can be visualized.


One method is to toggle through the datasets and time steps to see the results in the main graphics window.

1. View the final time step “0 02:30:00” of the “ Water_Elev_ft” solution dataset, below the “ Regular Flow” folder. Notice that water flows over a portion of the road to the north of the bridge.
2. View the final time step “0 02:30:00” of the “ Water_Elev_ft” solution dataset below the “ Culvert Flow” folder. With the current culvert design, the flooding across the road has been mitigated. Modifications of the current culvert design could be created to attempt to further mitigate flooding. However, for the purposes of this tutorial, this culvert design will be used.

Another useful way to compare the effects of the culvert on the channel is to create a new mesh dataset representing the differences in water surface elevations between the culvert solution and the existing condition solution. The difference dataset can be created using the *Data Calculator*.

1. Select *Data | Dataset Toolbox...* to bring up the *Dataset Toolbox* dialog.

An expression will be created in the calculator that uses the final time step of the results and takes the difference between both water surface elevation datasets, existing conditions “ Water_Elev_ft” and the proposed culvert conditions “ Water_Elev_ft”

2. Select “Data Calculator” in the *Tools* section.
3. Click on the “d6. Water_Elev_ft” dataset under the “Regular Flow” folder to select and make it active.
4. In the *Time Steps* section, scroll down and select the final time step “0 02:30:00”.
5. Select the **Add to Expression** button to add the final time step of the “d6. Water_Elev_ft” dataset to the expression.
6. Select the subtract  button.
7. Select the “d11. Water_Elev_ft” dataset under the “Culvert Flow” folder.
8. In the *Time Steps* section, scroll down and select the final time step “0 02:30:00”.
9. Select the **Add to Expression** button to add it to the expression. The expression should now look like the following expression: “d6:31-d11:31”.
10. Specify the name of the dataset as “WSE_Diff” in the *Output dataset name* box. The window should look like Figure 7.
11. Select **Compute** to create the new dataset.
12. Select **Done** to close the *Dataset Toolbox*.

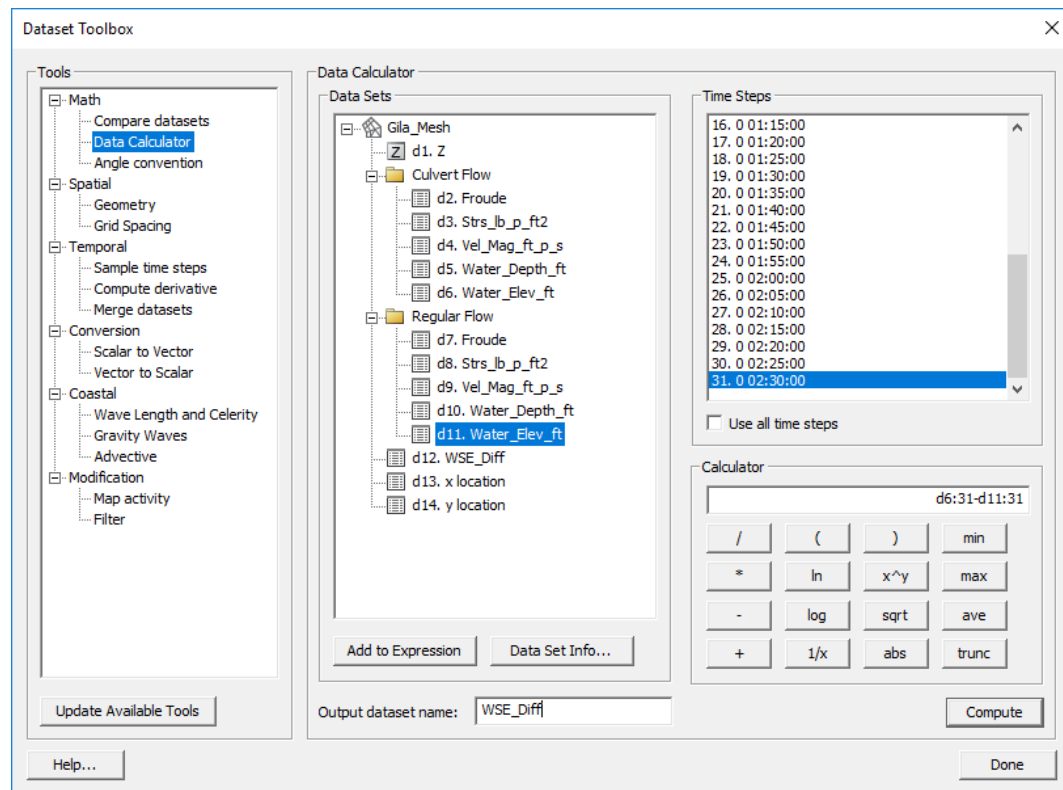



Figure 7 Data Calculator Expression

13. Select the “ WSE_Diff” dataset to view the differences.

The positive values represent water surface elevations that were higher in the existing condition solution and negative values represent water surface elevations that were higher in the culvert solution. Upstream of the bridge, the reduction in WSE is evident with the largest differences being located near the culvert structure.

When SRH-2D was run, an output file was created for the culvert structure that includes diagnostic information for the culvert. This file can be a useful way to understand what is happening within the culvert structure. It can be found within the output file directory and is called “Culvert_Run_HY1.dat”. It can be opened in a text editor for viewing the flows through the culvert and water surface elevations at the faces of the structure.

This concludes the “SRH-2D – Culvert Structures with HY-8” tutorial. If desired, further analysis could be performed on the solution to evaluate other possible effects of the culvert on the channel.

Conclusion

This concludes the “SRH-2D Culvert Structures with HY-8”¹ tutorial. Topics covered in this tutorial included:

- Opening an existing SRH-2D project
- Creating a culvert structure
- Saving and running SRH-2D
- Organizing mesh datasets into folders
- Visualizing and comparing solution results
- Using the data calculator

Continue to experiment with the SMS interface or quit the program.

¹ This tutorial was developed by Aquaveo, LLC under contract with the Federal Highway Administration.