SRH-2D Tutorial
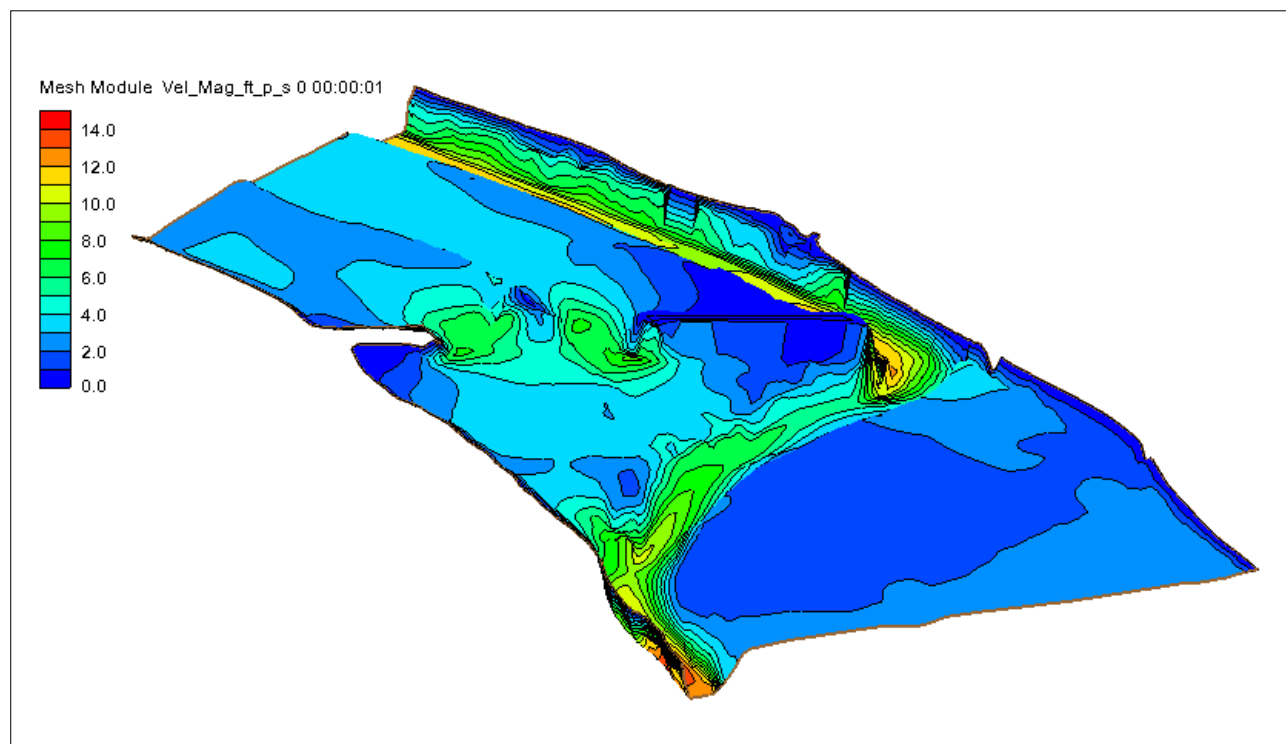# Sediment Transport Modeling

Objectives

This tutorial demonstrates how to perform sediment transport simulations in SRH-2D.

Prerequisites

- SMS Overview tutorial
- SRH-2D

Requirements

- SRH-2D Model
- Map Module
- Mesh Module
- Data files

Time

- 25–50 minutes model setup
- Up to an hour model run

1   Introduction

The Sedimentation and River Hydraulics – Two-Dimensional (SRH-2D) model is a hydraulic, sediment, temperature, and vegetation model for river systems developed by the United States Bureau of Reclamation (USBR) and sponsored by the United States Federal Highway Administration (FHWA).

Sediment Transport modeling is an advanced topic. This tutorial assumes that the user is knowledgeable and experienced with the SMS interface and the SRH-2D hydraulic model. Furthermore, this tutorial demonstrates how to set up and run a sediment transport simulation in SRH-2D with SMS but does not provide background on sediment transport theory or the analysis methodology.

Users should have proper training in sediment transport theory before performing and relying on sediment transport simulations. Some guidance is provided in the SRH-2D articles in the SMS documentation (http://www.xmswiki.com/wiki/SMS:SRH-2D), but this is not considered as comprehensive or sufficient for proper training. Refer to Hydraulic Series 6 [1] and other sediment transport texts for additional background.

For this tutorial, a previously developed SRH-2D hydraulic simulation is extended to include sediment transport simulations. The primary interest for FHWA is in relation to bridge scour, and SRH-2D sediment transport simulations can be very informative for estimating contraction scour, which is essentially an erosion and sediment transport problem. SRH-2D also provides detailed hydraulic output that can be used to estimate pier and abutment scour potential.

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[1] Richardson, E.V., Simons, D.B. and Lagasse, P.F., 2001. *River engineering for highway encroachments- highways in the river environment*, Federal Highway Administration, Hydraulic Series No. 6, Washington, DC. Publication NHI-01–004.

1.1 Background

The Cimarron River example from the SMS SRH-2D overview tutorial was modified for use in this tutorial. The modifications included converting the model to U.S. Customary units and adjusting the material types to provide additional detail in the overbank areas. Further modifications included adjusting the flow, the upstream and downstream boundary conditions, and the restart file to represent the 50-year peak flow event. The 50-year flood discharge was selected because it comes close to overtopping the road, although a road overtopping discharge could also have been selected.

The Cimarron River hydraulic model is well suited for sediment transport analysis because the level of detail in the channel and floodplains is good without being too refined. The number of elements (approximately 28,000) is well within the target for SRH-2D sediment transport simulations (targeting less than 30,000 elements and upper limit of generally less than 40,000 elements). Run times for sediment transport simulations can be extremely long, so limiting the number of elements is necessary and excessively large networks may not even run as sediment transport simulations. Hydraulic models with more than 40,000 elements may need to be reconfigured for fewer elements while still maintaining an adequate representation of the channel and floodplain.

This tutorial will cover defining sediment parameters and properties including sediment material types, boundary conditions, transport equation, and other input parameters. This tutorial is for instruction purposes and is not intended as an analysis of actual conditions at this bridge crossing.

2 Getting Started

To start this tutorial:

1. Launch the SMS application.

2. If SMS is already running, press *Ctrl-N* or select *File* | **New** to ensure that the program settings are restored to their default state.

3. Select *File* / **Open…** to bring up the *Open* dialog.

4. Browse to the file "Cimarron_Sed.sms" located in the *data files* folder for this tutorial.

5. Click **Open** to import the project file and close the *Open* dialog.

This file opens the existing hydraulic model as shown in Figure 1. The project includes results from a hydraulic run of the 50-year recurrence flood condition, which is used as a restart condition for the sediment transport run. This project will be modified to perform sediment transport simulations.
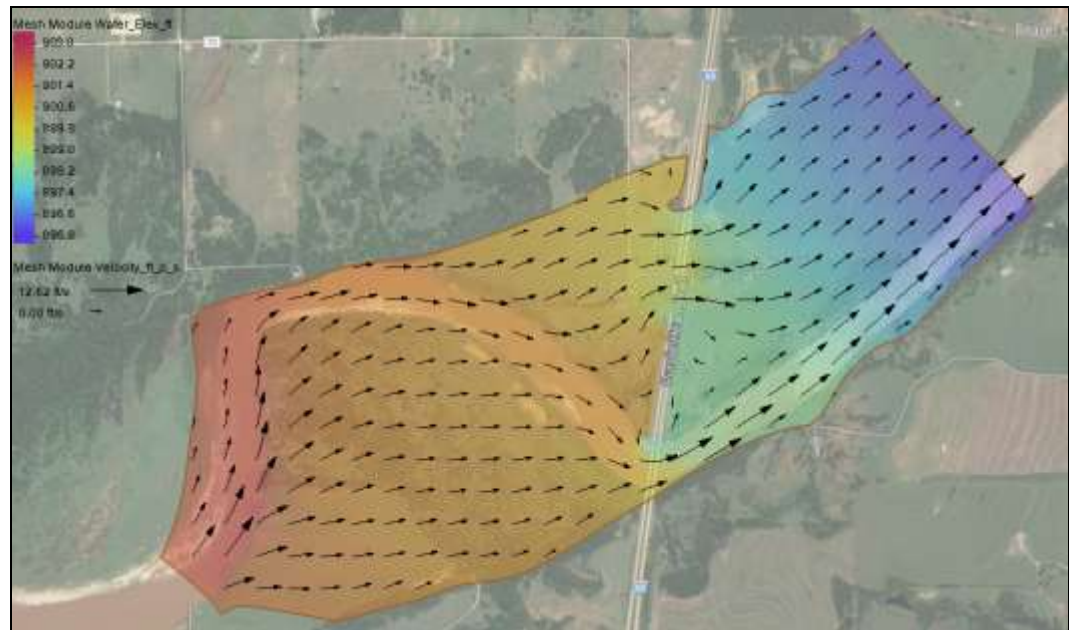
Figure 1   The hydraulic model of the Cimarron River

3   Boundary Conditions

Boundary conditions force certain hydrodynamic conditions and sediment transport rates onto the model. For this model, an inflow water condition will be specified at the upstream boundary and a water-surface elevation will be specified at the downstream boundary.

In SRH-2D, the boundary conditions are assigned to an SRH-2D boundary condition coverage. This tutorial uses a copy of the boundary condition coverage created in the SRH-2D hydraulic modeling tutorial. A steady-state water-surface elevation was applied at the downstream boundary with a steady-state flow at the upstream boundary. The sediment load coming into the model must be defined since this was not part of the hydraulic simulation. This tutorial will use the "Capacity" option to estimate the sediment load at the upstream boundary.

To assign boundary conditions at the upstream boundary:

1. Click on "🌐 50yr" under "🗺 Map Data" in the Project Explorer to make it active.

2. Using the **Select Feature Arc** 🖈 tool, double-click on the arc on the left (upstream) side. This will open the *SRH2D Assign BC* dialog. Since this boundary condition was copied from the hydraulic simulation, the hydraulic parameters should already be:

    a. *BC Type* set to "Inlet-Q (subcritical inflow)"

    b. *Discharge option* set to "Constant".

      c.   *Constant Q* set to "178208" (ft^3/s).

      d.   *Constant Q* flow unit set to "cfs".

      e.   *Distribution at Inlet* set to "Conveyance".

3. Under *Sediment discharge type*, leave the setting as "Capacity" which is the default option.

4. Click **OK** to exit the *SRH2D Assign BC* dialog.

To verify the boundary conditions at the downstream boundary:

1. Using the **Select Feature Arc** tool**,** double-click on the arc on the right (downstream) side to bring up the *SRH2D Assign BC* dialog. The values should be:

      a.   *BC Type* set to "Exit-H (subcritical outflow)".

      b.   *Water surface (WSE) option* set to "Constant".

      c.   *Constant WSE* unit set to "Feet".

      d.   *Constant WSE* set to "896" feet.

2. When done, click **OK** to exit the *SRH2D Assign BC* dialog.

3. Save (**Ctrl + S**) the project.

4   Defining Sediment Material Properties

The channel bed material and overbank soil characteristics are specified as a material type. Each material type can either be assigned a uniform soil profile where the representative soil gradation is the same over the entire depth of sediment, or the sediment gradation changes with depth. It is also possible to assign a non-erodible material type. Sediment can deposit on a non-erodible surface, and the deposited material can be eroded off the surface, but not below the original depth of the non-erodible surface. For this example, two material types are used; one to represent the main channel area and an area under the secondary bridge opening, and a non-erodible material to represent the remaining floodplain area.

To create the materials coverage for this simulation:

1. Click on the "🌐 Sed_Mat" coverage under "🗂 Map Data" in the Project Explorer to make it active and make sure it is turned on.

2. Right-click on the "🌐 Sed_Mat" coverage and select *Type | Models | SRH-2D |* **Sediment Materials** as the new type.

3. Right-click on the "🌐 Sed_Mat" coverage and select **Material List and Properties** to open the *Material List and Properties* dialog.

4. Click the **Add Material** ➕ button to create a "new material".

5. Double-click on "new material" and rename it "Channel".

6. On the right side of the dialog, click on the **Add Material Attribute Row** button.

7. Set the *Thickness* to "1" (ft), *Units* to "English" (double-click the drop-down).

8. Scroll to the right and click the **Edit Curve…** button under *Gradation Curve* to bring up the *Gradation Curve* dialog.

9. Change the *Number of rows* to "8" and enter the sediment gradation parameters as shown in Table 1. (Note: the sizes in the gradation curve do not have to match the particle sizes in the simulation.)

Table 1: Sediment Gradation Parameters

Particle size di (mm)	% finer
0.0625	0.0
0.125	4.7
0.25	11.7
0.5	38.6
1.0	76.9
2.0	96.0
4.0	98.9
8.0	100

10. Click **OK** to close the *Gradation Curve* dialog to return to the *Material List and Properties* dialog.

11. Now add a second layer to the "Channel" by clicking the **Add Material Attribute Row** button.

SRH-2D guidance indicates that a minimum of two layers is recommended even if the bed material is vertically uniform. The top layer interacts with the sediment in the water column and is part of the active layer used for computing sediment transport. A zero-thickness layer can also be specified to set the area as non-erodible.

12. In the new row, set *Thickness* to "20" (ft) and *Units* to "English" (double-click the drop-down).

13. Click on the **Edit Curve…** button under *Gradation Curve* for the new row to bring up the *Gradation Curve* dialog.

14. Enter the same sediment gradation parameters as shown in Table 1. (Note: the values can be copied to the clipboard using *Ctrl-C* when looking at the curve defined in step 9 above. They can then be pasted into this layer since they are the same.)

15. Click **OK** to close the *Gradation Curve* dialog.

Now add a material for the areas outside of the channel.

16. Click the **Add Material** button to create a "new material".

17. Double-click on "new material" and rename it "Non-Erodible".

18. Click **OK** to close the *Material List and Properties* dialog.

5   Assigning Materials

Now apply the material properties to the polygons on the "🟢 Sed_Mat" coverage. Use Figure 2 below for reference.

1. Using the **Select Feature Polygon** 📐 tool, double-click on the area representing the main channel to bring up the *Assign Material* dialog.

2. Select the "Channel" material to assign it to the polygon.

3. Click **OK** to close the *Assign Material* dialog.

4. Using the **Select Feature Polygon** 📐 tool, double-click on the area at the secondary bridge opening to bring up the *Assign Material* dialog.

5. Select the "Channel" material to assign it to the polygon.

6. Click **OK** to close the *Assign Material* dialog.

Now assign the remaining areas a non-erodible material type; these areas can be assigned individually or all at once. To assign individually:

7. Using the **Select Feature Polygon** 📐 tool, double-click on any polygon other than the main channel or the area near the secondary bridge to bring up the *Assign Material* dialog.

8. Select the "Non-Erodible" material to assign it to the polygon.

9. Click **OK** to close the *Assign Material* dialog. Notice only the selected polygon has assigned material properties as the "Non-Erodible".

To assign "Non-Erodible" to all the remaining polygons at once:

10. Using the **Select Feature Polygon** 📐 tool, select the channel polygon.

11. Hold the *Shift* key and select the other erodible area in the secondary opening.

12. Right-click and select **Invert Selection**. This selects all polygons except the two specified as erodible.

13. Right-click and select **Assign Material** to open the *Assign Material* dialog.

14. Select "Non-Erodible" as the material for all of the remaining polygons.

15. Click **OK** to close the *Assign Material* dialog.

Figure 2 shows the two assigned material zones in the sediment materials coverage. The blue color represents the channel areas, and the brown color represents the non-erodible areas.

> *Note:* Sediment gradation could be assigned to the non-erodible material with a very small thickness (such as 0.1 ft). The capacity upstream sediment load (see Section 3.2) would calculate a load for the overbank portion but would not be able to erode more than 0.1 ft from the floodplain.
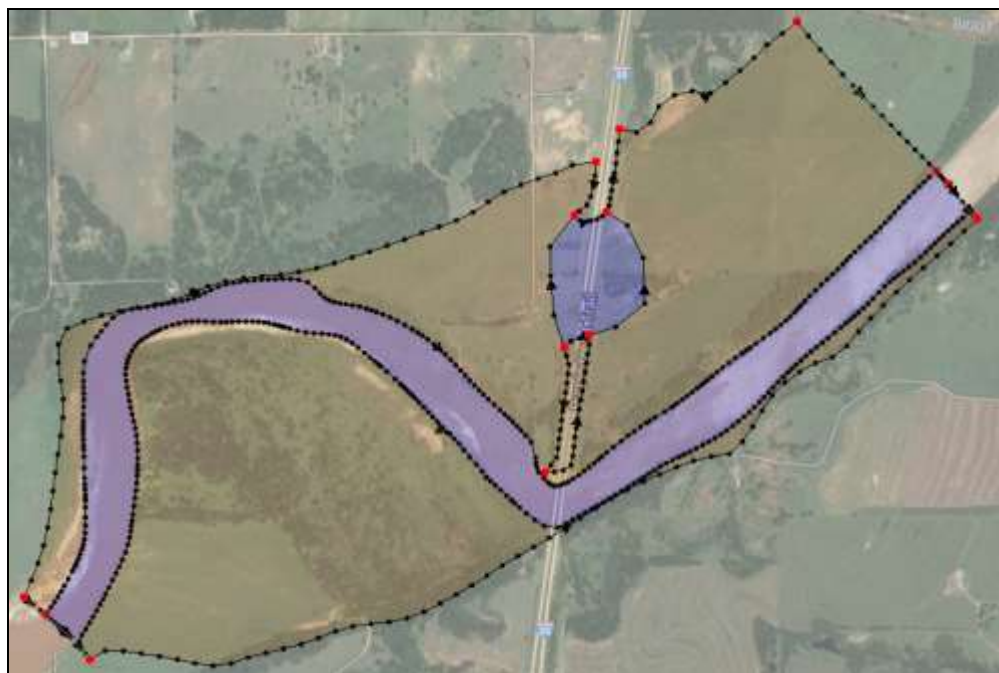
Figure 2   The two assigned material zones: the aqua color represents the channel areas, and the light brown color represents the non-erodible areas

6   Defining the SRH-2D Simulation

The SRH-2D simulation is created as a separate entity in the SMS project. Each project can contain multiple SRH-2D simulations. Individual components (such as coverages and meshes) are associated or linked to the simulation. Each simulation can have its own assigned parameters.

To create the simulation:

1.   Right-click in the white space at the bottom of the Project Explorer and select *New Simulation* | **SRH-2D**. This creates a new simulation, " Sim", in the Project Explorer tree.

2.   Right-click on the new simulation and select the **Rename** command.

3.   Enter "Sed_Steady" as the new name.

6.1   Applying Components

Components are added to the simulation by either right-clicking on the component and selecting the *Apply to →* command, or by dragging and dropping the component into the simulation.

To link the components for this simulation, do the following:

1.   Right-click on the " I-35" mesh and select the *Apply To* | **SRH-2D Simulations → Sed_Steady** command.

2. Repeat the previous step for the "⬤ 50yr", "⬤ Mat", "⬤ Monitor", and "⬤ Sed_Mat" coverages.

6.2   Assigning SRH-2D Parameters

Now it is also necessary to set up the SRH-2D control data and define the model parameters for the new simulation.

To do this:

1. Right-click on the "⬤ Sed_Steady" simulation and select **Model Control…** to bring up the *SRH2D Model Control* dialog.

2. Select the *General* tab and define the data as follows:

    a. Set *Simulation Description* to "Cimarron Sediment Transport".

    b. Set *Case name* to "Sed_Steady".[2]

    c. Set *Start time (hours)* to "0".

    d. Set *Time step (seconds)* to "2". [3]

    e. Set *End time (hours)* to "12".[4]

    f. Set *Initial condition* to "Restart File".

    g. Click the **Select File…** button to bring up a *Select File* browser.

    h. Navigate to the *data files* folder for this tutorial and select the "I35_RST1.dat" file.

    i. Click **Select** to close the *Select File* browser.

3. Select the *Output* tab and enter the following:

    a. Make sure the *Output format* is set to "XMDF".

    b. Set *Output units* to "English".

    c. Set *Output method* to "Specified Frequency".

    d. Set *Output frequency* to "1" and "Hours".

4. Leave all the parameters under *Advanced* tab at their default settings.

5. Leave the *SRH2D Model Control* dialog open and continue to the next section to enter sediment parameters.

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[2] To avoid confusion, it is a good practice to name the *Case name* the same as the simulation name.

[3] The time step should be selected to maintain hydraulic computational stability during the model run. Monitor Points can be used to track model stability.

[4] The simulation end time depends on the type of simulation and the characteristics of the channel and bed material. Steady flow simulations can be run for long periods to reach equilibrium transport and bed elevation conditions, or for a representative amount of time the flow could occur. Hydrograph simulations should include a sufficient amount of time before and after the peak to adequately represent the range of flows.

6.3 Assigning Sediment Parameters

Now change the simulation type from a hydrodynamic (flow) simulation to a mobile boundary simulation.

1. Select the *Sediment* tab in the *SRH2D Model Control* dialog.

2. Check on the *Enable sediment* option.

The sediment transport parameters are now available and can be modified to represent the site conditions.

3. Set *Sediment specific gravity* to "2.65" (the default value).

The values input into the *Particle diameter threshold* box represent the bin sizes of the bed material gradations and sediment inflow gradations. Nine representative bin sizes are specified (**Table 2**). Typically, the bins are defined using the Phi scale.

4. At the bottom of the *Particle diameter threshold* box, change the *Number of Rows* to be "9".

5. Enter "0.0025" mm into the first row. This value is the lower end of the first bin.

6. Enter "0.0625" mm into the second row. This value is the upper end of the first bin and the lower end of the second bin.

7. Continue adding the remaining values: "0.125", "0.25", "0.5", "1", "2", "4", and "8" in increasing sizes in **Table 2**. The nine values create nine bins.

Table 2: Representative Sediment Sizes

Bin	mm
1	0.0025
2	0.0625
3	0.125
4	0.25
5	0.5
6	1
7	2
8	4
9	8

Note: The maximum number of bin sizes in SRH-2D is nine; the more bin sizes, the longer the simulation time. The smallest bin size (0.0025 to 0.0625 mm in this case) can be used for cohesive sediment transport modeling. This will be demonstrated in another tutorial.

There are seven sediment transport equations available including Engelund-Hansen (1972), Meyer-Peter Müller (1948), Parker (1990), Wilcock-Crowe (2003), Wu-et-all (2000), Yang 1973 Sand w 1984 Gravel, and Yang 1979 Sand w 1984 Gravel. In addition, there is a mixed option, where the user can specify a *Sediment size class cutoff* and two sediment transport equations. One equation applies to sediment sizes less than the *Sediment size class cutoff*, and the other equation applies to sediment sizes greater.

8. For this example, leave the transport equation and parameters at the defaults:

    a.   *Sediment transport equation* set to "Engelund-Hansen".

    b.   *Water temperature* to "12" (degrees Celsius).

    c.   *Adaption Coefficients for Suspended Load*[5] to:

- *Deposition coefficient* to "0.25".

- *Erosion coefficient* to "1".

There are five methods available for setting the *Adaption Length for Bedload Transport,* including the "Constant Length", "Phillips-Sutherland Saltation Length Formula", "Van Rijn Sand Dune Formula", "Van Rijn Saltation Length Formula", and the "Seminar et al. (2002) Formula". The SRH-2D pre-processor provides the following guidelines: "Constant Length" is recommended for gravel bed rivers (Length = 1 to 5 channel widths), the "Phillips-Sutherland Saltation Length Formula" is recommended for sandy bed rivers.

9. Set *Mode,* under *Adaption Length for Bedload Transport,* to "Phillips-Sutherland Saltation Length Formula".

There are two methods to set the *Active Layer Thickness Specification* of the surface layer: "Constant Thickness" and "Thickness based on D90". The SRH-2D pre-processor provides the following guidelines for the "Thickness based on D90" method: Set the thickness scale from 1 to 3 times the D90 for gravels, 5 to 14 for sands.
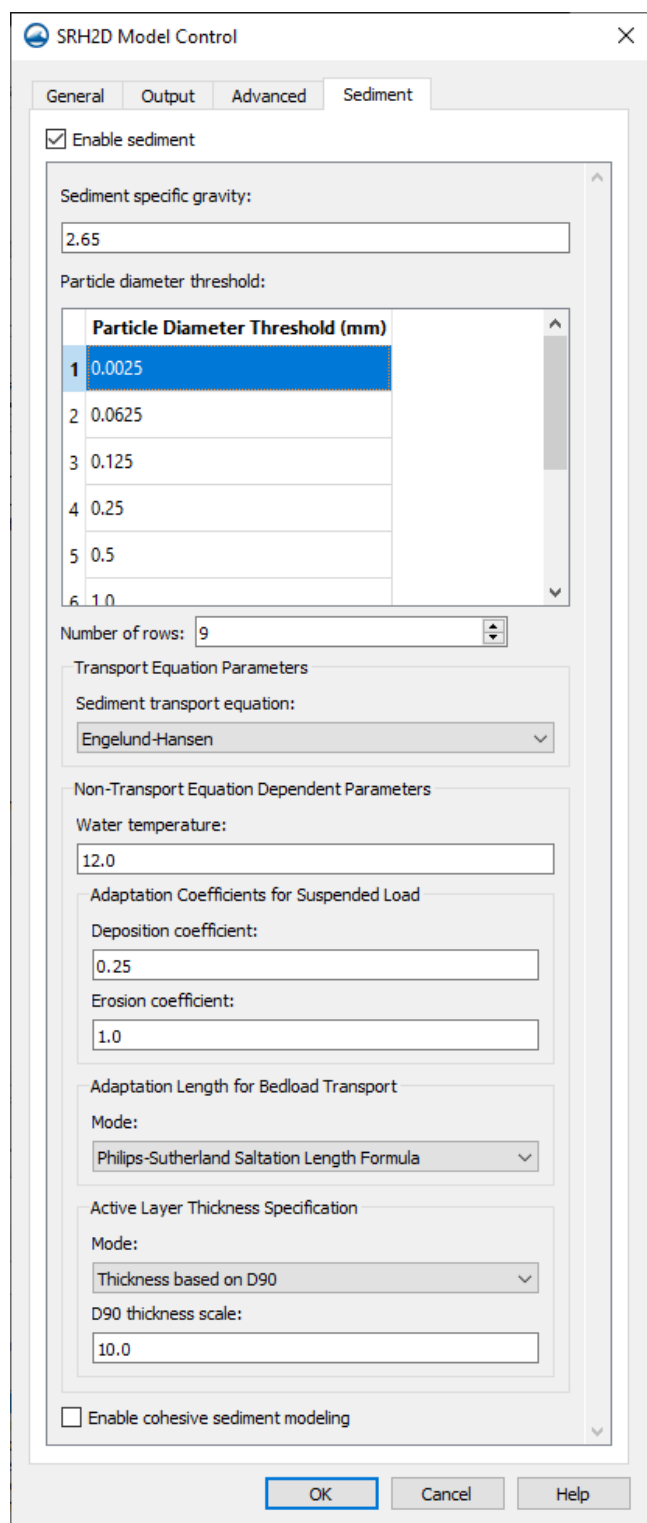
10. Set the *Mode* under *Active Layer Thickness Specification* to "Thickness based on D90" and set the *D90 thickness scale* to "10".

11. Leave the *Enable cohesive sediment modeling* option checked off.

The *Sediment* tab of the *SRH2D Model Control* dialog should look like Figure 3.

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[5] For more information on the adaption coefficients, see:

  Greimann, B., Lai, Y. and Huang, J., 2008. Two-dimensional total sediment load model equations. *Journal of Hydraulic Engineering*, *134*(8), pp.1142-1146.

Figure 3   Sediment options in the SRH2D Model Control dialog

6. Click **OK** to close the *Model Control* dialog.

7. Save (**Ctrl** + **S**) the project.

6.4   Model Check

Before assigning SRH-2D parameters, the **Model Check** should be run.

To do this:

1. Right-click on the "⭕ Sed_Steady" simulation and select **Model Check…**

   a. If everything is correct, a dialog comes up indicating "No model checks violated."

   b. If there are any errors, follow the instructions in the *Model Checker (Potential Issues Found)* dialog to correct them.

2. Once all of the errors are corrected, proceed to the next section.

6.5   Running SRH-2D

The simulation is now ready to run. The method of launching a sediment transport simulation is identical to that for a hydraulic simulation. However, it should be noted that sediment transport simulations do require much more computation power and time. If time is limited, a set of solution files are provided for the next section.

> *Note:* Sediment transport simulations require significant computation power. Any computer system with hardware less than the recommended system for running SMS will not be able to complete an SRH-2D sediment transport simulation.

To run SRH-2D:

1. Right-click on the "⭕ Sed_Steady" simulation and select **Save Project, Simulation and Run**.

This command will save the SMS project, export all necessary files for PreSRH-2D, run the preprocessor and then run SRH-2D.

SMS will renumber the boundary conditions as needed when exporting the files for SRH-2D. When this happens, SMS will display a message that this will occur.

2. Click **Yes** to continue from this message.

While executing the run command, SMS assumes that SRH-2D executables are stored into the SMS installation folder, if it cannot find those executables, a prompt will ask to manually locate those. This is a one-time process and SMS will remember the location of the executables after this.

Once the run is complete (it could take up to 1 or 2 hours depending on the CPU being used and hard drive speeds), SRH will display a completion message.

3. Click **Load Solution** to load the solution into the project.

4. Click **Close** to close the *Simulation Run Queue* dialog.

6.6   Viewing SRH-2D Output

Once an SRH-2D run completes, it will generate a XMDF file which will have a name "Sed_Steady_XMDF.h5". SMS loads this file in when **Load Solution** is clicked.

If the model run was skipped to save time, import the solution file by doing the following:

1. Select *File |* **Open…** to bring up the *Open* dialog.

2. Browse to *data files\Cimarron_Sed\SRH-2D\Sed_Steady* folder for this tutorial and select the "Sed_Steady_XMDF.h5" file.

3. Click **Open** to close the *Open* dialog and import the solutions file.

This file includes at least the following datasets:

- Point ID of the mesh element[6]

- X_ft, Y_ft: coordinates of the element[6]

- D50_mm: Median size of the bed material

- Froude: dimensionless Froude number (< 1 indicates sub-critical flow)

- CONC_T_ppm: Sediment concentration in parts per million.

- ERO_DEP_ft: Erosion depth in feet. Positive values represent degradation and negative values represent aggradation.

- Bed_Elev_ft: bed elevation. This may change over the duration of the simulation

- B_Stress_lb_p_ft: bottom stress at the ground in pounds per square foot

- Water_Elev_ft: water surface elevation in feet above the datum

- Vel_Mag_ft_p_s: velocity magnitude in feet per second

- Water_Depth_ft: depth of water in meters

- Velocity_ft_p_s: *x* and *y* components of velocity in feet per second

SRH-2D also supports options for additional dataset output in a variety of situations.

See the visualization tools in SMS as described in the "Data Visualization" tutorial, to evaluate the solution created by the SRH-2D model.

For example, the positive (erosion) values of the ERO_DEP_ft variable is shown for the end of the simulation in Figure 4.

Detailed output files are also created in the SRH-2D folder associated with this SMS project. These output files are created for the monitor lines found on the " Monitor"

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[6] These datasets are included in the output file and used for graphical representation, but do not appear in the SMS list of output.

coverage. The monitor line output summarizes the average hydraulics and sediment transport results through the duration of the simulation for each monitor line in the *_LN#.dat output files. Two files are created for each monitor point. The *_PT#.dat files contain detailed hydraulics, bed elevation and D50 bed material size output during the simulation and the *_PT#_SED.dat output files include detailed sediment transport results.

An observation coverage can also be used to view simulation results from an SRH-2D sediment transport simulation (see the SMS "Observation" tutorial for guidance on using observation coverages). Figure 5 shows an observation profile plot of the bed elevation using a feature arc through the main channel bridge at the beginning, midpoint, and end of the 12-hour simulation. Figure 6 shows a time series plot of erosion using feature points in the relief bridge and main channel bridge. Although significant scour has occurred, the ultimate scour has not been reached during the simulation.
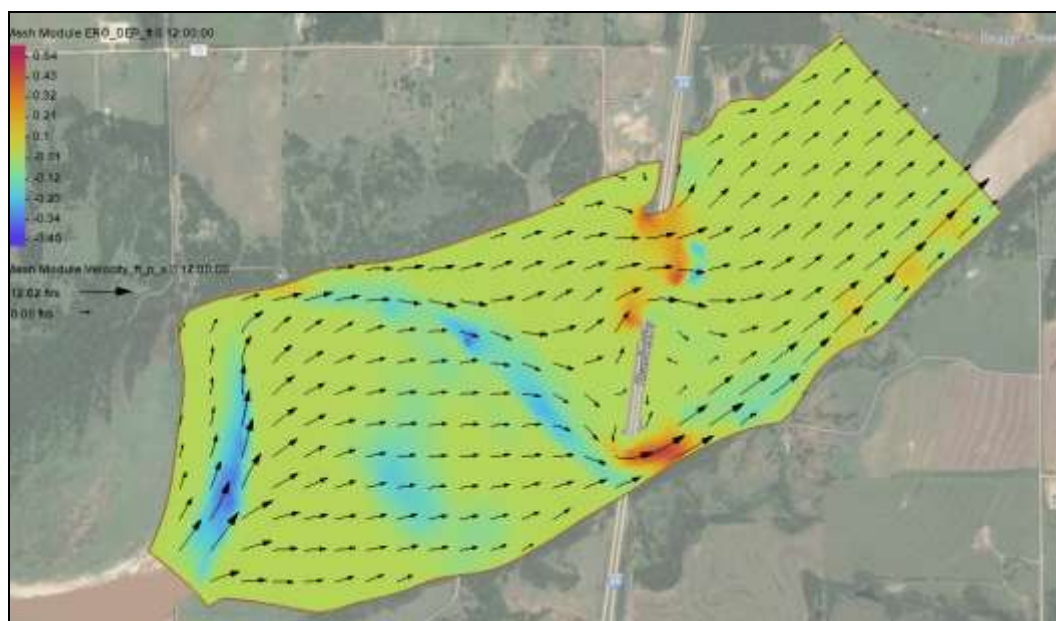

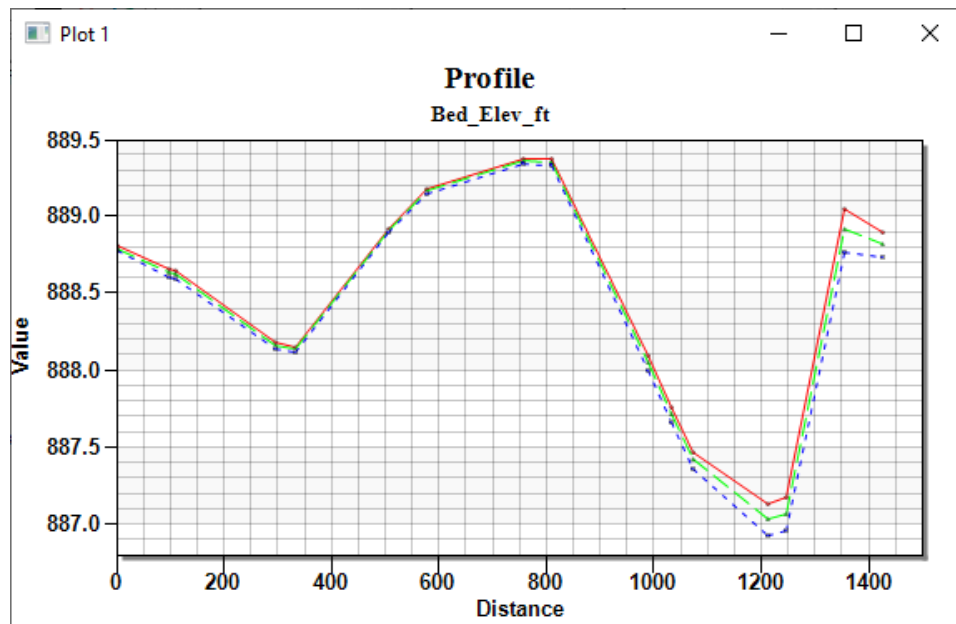*Figure 4   Erosion at the end of the sediment transport simulation*

Figure 5   Bed Elevation change in the Main Channel Bridge during the simulation
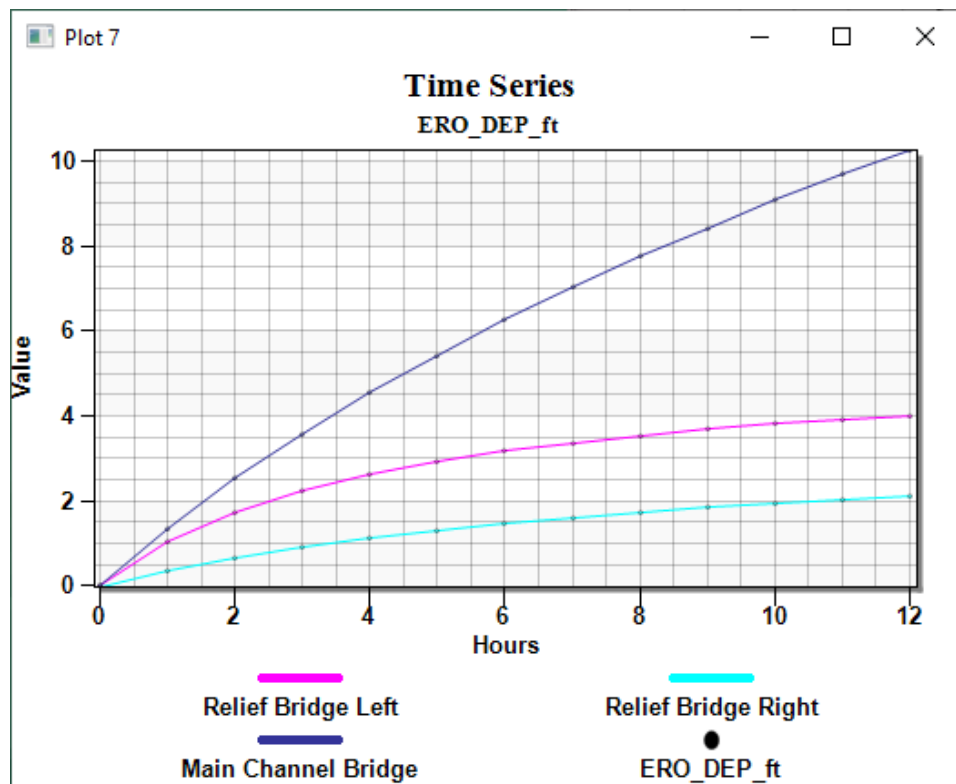

Figure 6   Scour occurring in the Main Channel and Relief Bridges during the simulation

7   Conclusion

This concludes the "SRH-2D Sediment Transport Modeling" tutorial[7]. This tutorial demonstrated:

- Setting up an SRH-2D boundary condition coverage for sediment transport

- Assigning monitor points

- Creating an SRH-2D sediment materials coverage.

- Defining an SRH-2D simulation for sediment transport

- Running an SRH-2D sediment transport simulation

- Viewing results from a sediment transport simulation

Additional tutorials cover using sediment transport with unsteady flow and cohesive materials. Continue to experiment with the sediment transport options for SRH-2D in SMS or exit the program.

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