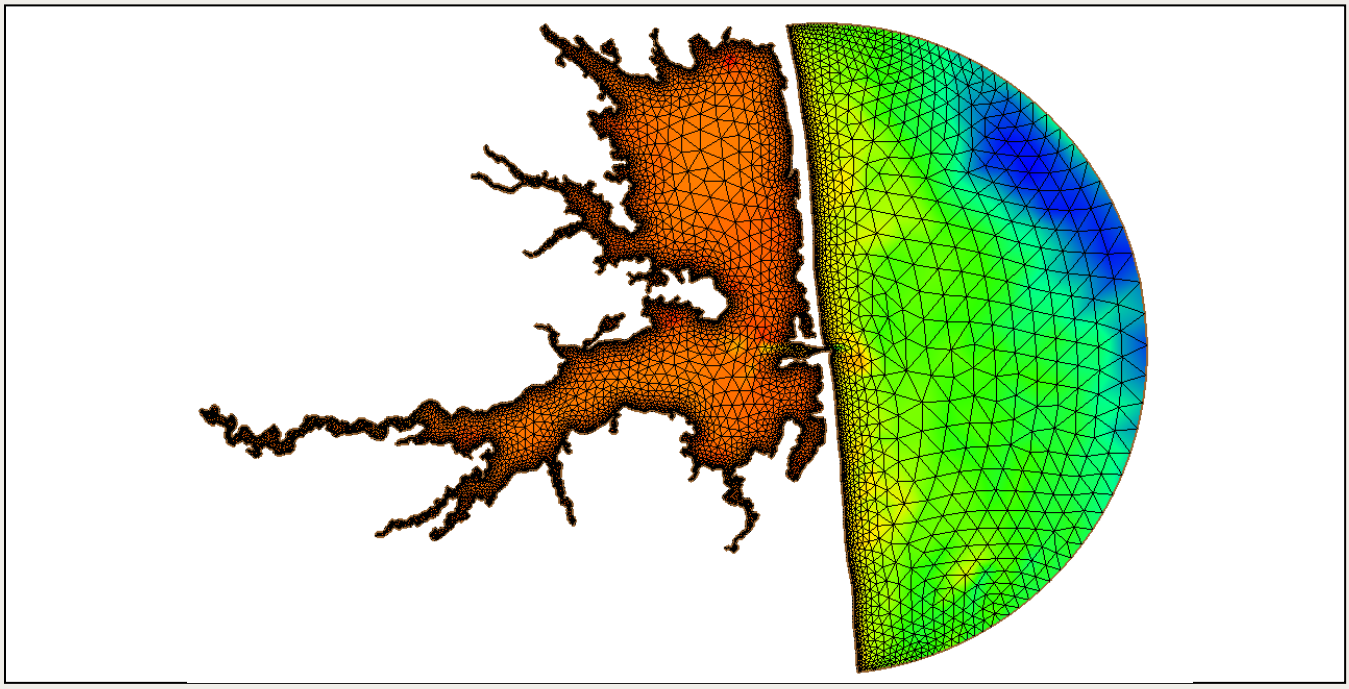
SMS 14.0 Tutorial

Mesh Quality



Objectives

This tutorial demonstrates multiple approaches for reviewing the quality of a mesh.

Prerequisite Tutorials

- Overview
- Map Module
- Raster
- Background Data
- Simulation Domain
- Mesh Generation

Required Components

- SMS Core

Time

- 15–20 minutes

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1 Introduction

This exercise illustrates tools in SMS for reviewing the quality of a mesh. This includes:

- Displaying element quality.
- Review the Angle Representation Region (ARR) plot.
- Computing the error between a terrain model (DEM) and the mesh.

This exercise utilizes data from the region around Indian River Inlet located on Delmarva Peninsula along the Maryland coast between Delaware Bay and Chesapeake Bay.

2 Getting Started

Start by importing a project file containing an existing mesh:

1. Launch the SMS application
2. From the *Menu* bar, select the *File* | **Open…** menu item.
3. From the *Files of type* drop-down menu, select “Project Files (*.sms)”.
4. Navigate to the *Extra Exercises/Indian River* folder
5. Select the “IR_mesh.sms” file.
6. Click the **Open** button to import the project and exit the *Open* dialog.

The initial project should appear similar to Figure 1.

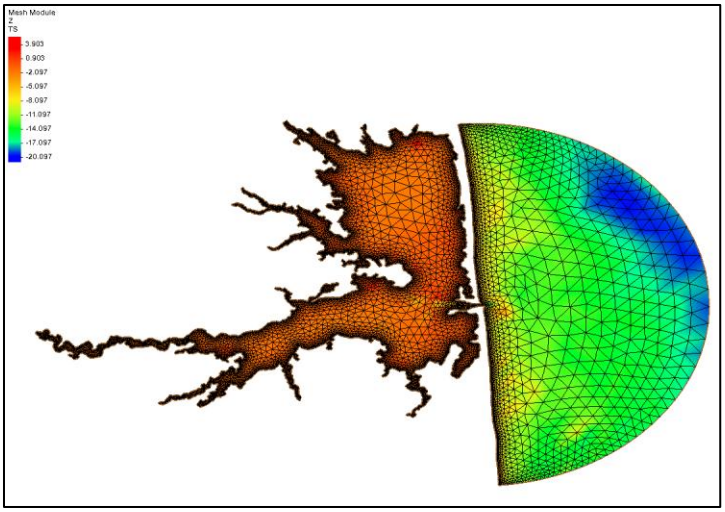

Figure 1: Initial Project

3 Display of Element Quality

SMS provides a tool to perform geometric quality checks on the elements in the grid. To view the checks that apply to ADCIRC:

1. In the *Project Explorer*, right-click on the "*Mesh Data*" folder and select the **Display Options…** context menu item.
2. From the list on the left select the *2D Mesh* item
3. On the section on the right, in the *2D Mesh* tab:
   a. Turn off the *Contours* checkbox.
   b. Turn on the *Mesh quality* checkbox
   c. To the right of *Mesh quality* checkbox, click on the **Options…** button. The *Element Quality Checks* dialog will appear.
4. Turn on the checks that apply to ADCIRC as shown in the following table.

Check	Value	Comment
Minimum interior angle	On	Detects long skinny triangles
Maximum interior angle	On	Detects potentially long triangles
Concave quadrilaterals	Off	ADCIRC uses only triangles
Maximum slope	Off	Not important to ADCIRC
Element area change	On	Large changes in area are numerically dangerous
Connecting Elements	On	Detects potentially unstable areas (wagon wheels)
Ambiguous gradient	Off	Applies to quadrilateral elements – not ADCIRC
Display Legend	On	

5. Click the **OK** button to exit the *Element Quality Checks* dialog.
6. Click the **OK** button to exit the *Display Options* dialog.

The display will update showing that SMS detects a few minor problems with this mesh. You may need to turn off the display of elements or zoom into the area of the inlet (as shown in Figure 2) to see this.

Blue lines (near the inlet) indicate that adjacent elements have an area ratio less than 0.5. The purple dot in the back of the inlet indicates that more than 8 elements come together at a single location.

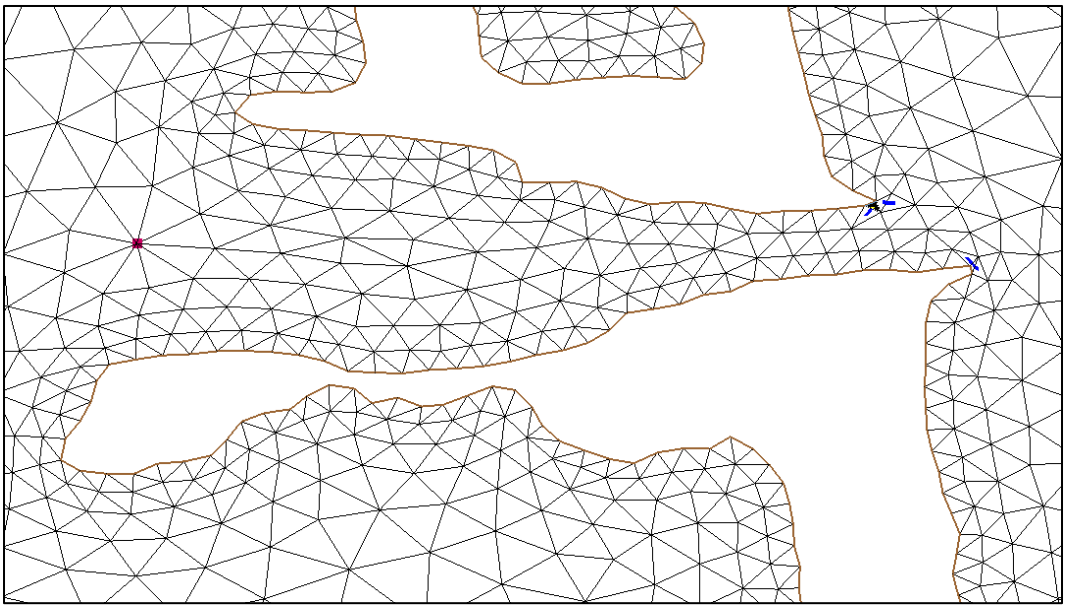

Figure 2: Mesh Quality Concern Display

Other possible concerns could include skinny triangles (small interior angles highlighted in red), and triangles with large interior angles (highlighted in purple). Overall, the lack of colored markings indicates a well-formed finite element mesh.

If serious problems exist in element quality, several methods may be employed to resolve them. Generally, regeneration of the mesh with a modified size bias transition is recommended.

Serious element problems along the domain boundary may indicate that the boundary contains too much detail for the target resolution. Smoothing of the boundary in this area followed by regenerating the mesh can resolve this problem.

SMS will redistribute the vertices to attempt to match the specified goal. It may not be able to do this precisely because of the curvature and overall length of the arc. Repeating the command can slightly improve the distribution as areas of high curvature or where arcs bend back on themselves are smoothed out. You can also reissue the command to review the spacing after each operation.

4 Resolving Isolated Issues

As mentioned above, the general solution to mesh quality issues involves regeneration of the mesh with modified parameters. This is because the individual editing steps to edit individual nodes or elements can be tedious and does not result in a consistent solution. However, there are situations where minor edits are desired.

4.1 Resolving Elements Connectivity Issues

In this case, there are a few nodes connected to more than seven (7) elements (wagon wheels). To correct these cases:

1. In the *Project Explorer*, click on the "*Mesh Data"* folder to make it active.
2. From the *Menu* bar, select the *Nodes* | **Reduce Nodal Connectivity** menu item.

A warning may appear to match the object projection to the display projection. Click the display projection. Click the **Yes** button to dismiss and then run the Reduce Nodal Connectivity command again.

SMS checks all nodes and inserts additional nodes to reduce the connectivity. A report dialog appears indicating how many nodes were reduced. When the report is complete:

3. Click the **Close** button to exit the report.

4.2 Resolving Local Area Transition

In some situations, the mesh generation process may insert extra nodes in the interior of a mesh. To check for and correct this:

1. In the *Project Explorer*, click on the "*Mesh Data"* folder to make it active.
2. From the *Menu* bar, select the *Elements* | **Fix Bad Size Transitions** menu item.

SMS checks all element pairs for bad transitions. If a transition can be fixed by removing a node, the node is removed. A report appears indicating how many nodes were removed and how many size transition issues remain. When the report appears:

3. Click the **Close** button to exit the report. (TK no fixable transitions, no report)

5 Using the ARR Plot

SMS includes a tool to review each element in a mesh. To do this:

1. From the *Macro* bar, click on the *Plot Wizard* macro to open the *Plot Wizard* dialog.
2. In the *Plot Type* section, from the list on the left, select the *ARR Mesh Quality* item.
3. Click the **Finish** button. A new window opens with a plot similar to Figure 3.

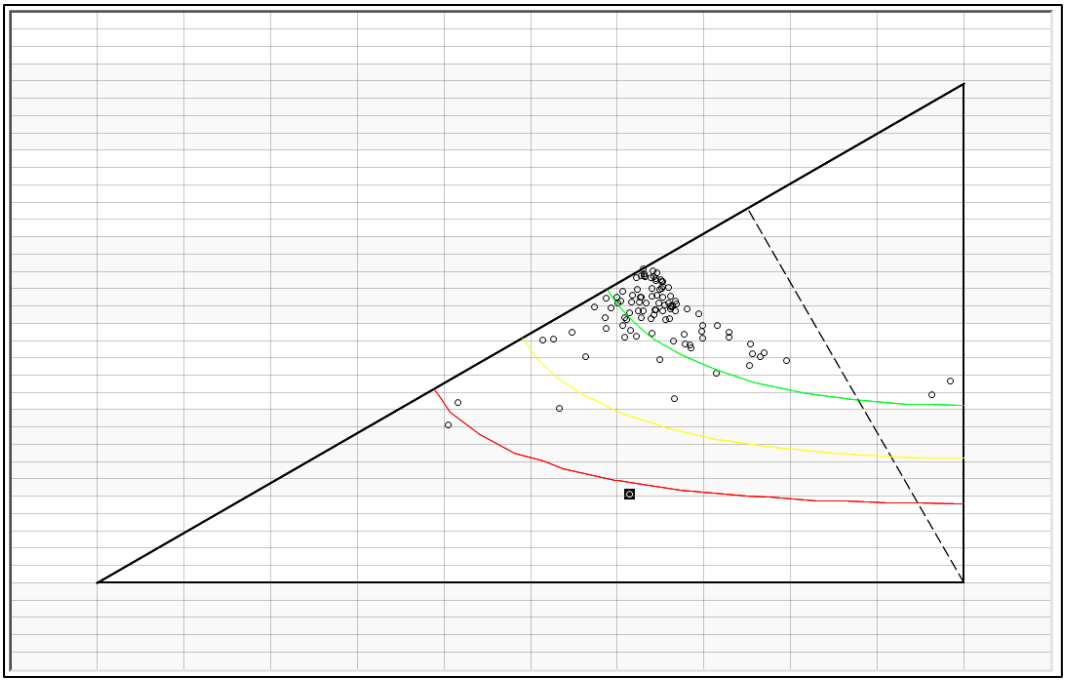

Figure 3: The ARR Plot

SMS generates a plot with points representing element quality. Since only the poor-quality elements are of concern, only the worst 200 are shown.

Generally, the lower and/or further left a point is on the plot, the worse the quality of the associated element.

1. Click on the lowest point in the plot.

SMS selects the associated elements and zooms to that element in the graphics window. The most common causes of issues include bad vertex spacing and arcs that are too close together and over constrain the element positioning.

These can be corrected by deleting or moving a vertex and regenerating the mesh.

2. Click on several of the points closest to the red line in the ARR plot.

If they correspond to a boundary element, they could be corrected by changing the vertex spacing in the coverage. Interior elements can be adjusted by changing the bias. A bias that allows elements to change size too rapidly (over a short geographic space) can result in a poorly oriented element edge.

The process of resolving mesh quality issues may be iterative since the meshing process has many parameters that influence the shape of the elements. The elements identified in the ARR can guide adjustments to resolve the problem.

We will not correct issues in this mesh because they are quite minor.

3. Click on the × **Close** button in the upper right corner of the ARR plot to close the plot.

6 Editing Individual Elements

SMS does include tools to manually edit nodes and elements. As mentioned above, these processes are tedious and not automatically reproducible, therefore, their use should be extremely limited.

Possible operations include:

- Inserting a new node into the mesh in a large element.
- Dragging a node to make a small element larger and a large element smaller.
- Swapping the edges between two elements.

Refer to xmswiki.com for instructions on manually editing a mesh.

We edited the mesh in the previous section, so we need to renumber it to be consistent. To do this:

1. In the *Project Explorer*, click on the "*Mesh Data"* folder to make it active.
2. From the *Menu* bar, select the *Nodes* | **Renumber** menu item to renumber the mesh.
3. Click the **OK** button to close the information dialog.

7 Mesh Error

It can be useful to know how well a mesh represents the original elevation data. This can be accomplished by converting the mesh to a raster, and then comparing the mesh raster to the original elevation raster using the *Python Toolbox* in SMS.

7.1 Converting the Mesh to a Raster

The first step in determining the error between a mesh and a DEM is to convert the mesh to a raster. To do this:

1. In the *Project Explorer,* right-click on the "IR_Inlet_DEM_2015.tif" raster and select the *Projection* | **Set as Display Projection** context menu item.
2. From the *Macro* bar, click on the *Toolbox* macro to open the *Toolbox (beta)* dialog.
3. Under the Tools tab, expand the *Rasters* section of the toolbox.
4. Select the *Raster from Dataset* tool.
5. Click the **Run Tool…** button. The *Raster from Dataset* tool dialog will appear.
6. For the *Dataset* to convert to a raster, select the "Mesh Data/constant pave 50-1000m/Z" drop-down menu item.
7. For the *Optional template* raster, select the "GIS Data/IR_Inlet_DEM_2015.tif" drop-down menu item.
8. For the *Raster template resolution option*, select the "Use template raster native resolution" drop-down menu item.
9. For the *Output raster* name, enter "Mesh Elevation DEM".

10. Click the **OK** button to execute the tool. A dialog will appear reporting progress. It may take 20-40 seconds to complete this process.
11. Click the **OK** button to close the status dialog when the tool execution is complete.

There will now be a raster representing the elevation of the mesh with pixels matching the original terrain raster. The pixel size can be any size you wish, but it is convenient and intuitive to use the original raster size for comparison.

7.2 Generating the Error Raster

To compare the mesh elevation to the original terrain:

1. In the *Toolbox (beta)* dialog, select the *Raster Difference* tool.
2. Click the **Run Tool…** button. The *Raster Difference* tool dialog will appear.
3. For the *Input base raster,* select ”GIS Data/IR_Inlet_DEM_2015.tif” from the drop-down menu.
4. For the *Input secondary raster,* select “GIS Data/Mesh Elevation DEM.tif” from the drop-down menu.
5. For the *Output raster* name, enter “Mesh Error”.
6. Click the **OK** button to execute the tool.
7. Click the **OK** button to close the status dialog when the tool execution is complete.
8. Click the **Close** button to close the *Toolbox (beta)* dialog box.
9. The in *Project Explorer,* turn on the “Mesh Error.tif” raster to make it visible and turn off everything else in the *Project Explorer* tree.

There will now be a raster representing the error between the mesh and the terrain at the resolution of the terrain similar to as shown in Figure 4:

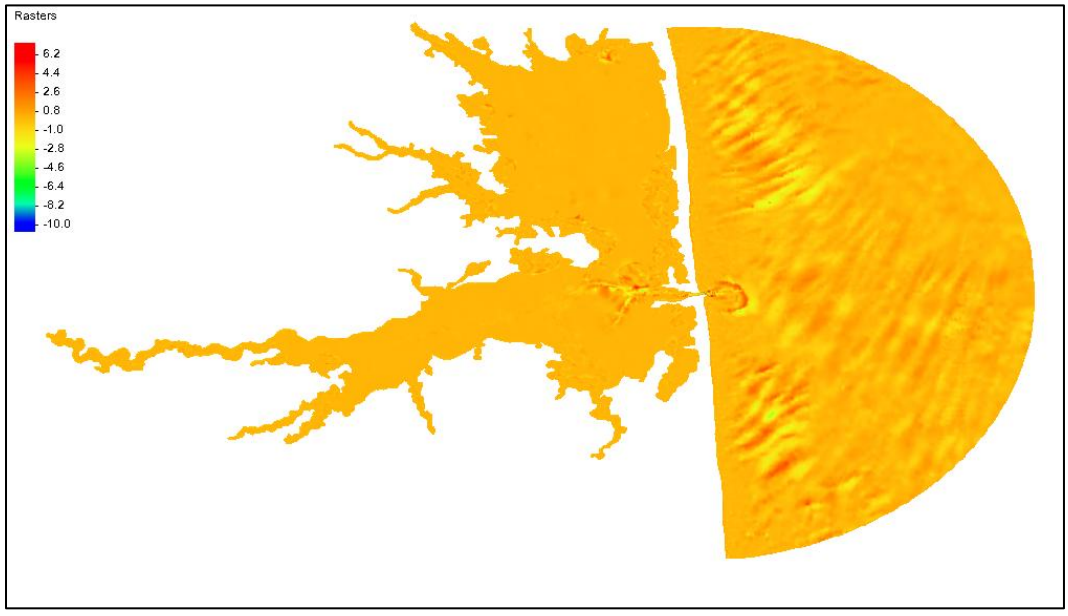

Figure 4: The Mesh Error Raster

With the raster active (click on it) you can pan over the raster and view the data in the *Status* bar at the bottom of the graphics window. Note that the error is generally in the range of +/- 0.05 meters. If you zoom into the inlet, you will see the extreme errors at individual pixels.

The fidelity of the mesh is limited by its resolution. If the error is too high, a higher resolution mesh is required.

8 Saving the Project

To save the project:

1. From the Menu bar, select the *File* | **Save As...** menu item to open the *Save As* dialog.
2. Navigate to the *Extra Exercises/Indian River/work* folder.
3. For the *File name,* enter "IR_checked_mesh".
4. Click the **Save** button to exit the *Save As* dialog.
5. Click the **OK** button when SMS gives you a message informing you that the mesh needs to be renumbered. This is because nodes were inserted and deleted in the local editing performed in the earlier sections. These edits leave gaps in the element numbering that must be cleaned up.

9 Conclusion

This concludes the “Mesh Quality” exercise. Several features have been demonstrated including:

- Mesh quality display.
- Local edit tools.
- ARR plots.
- Mesh error visualization.

If time permits, you may wish to try experimenting with:

- Experiment with the multiple element quality metrics in the ARR plot. This is accessed by bringing up an ARR plot and right clicking on the plot.
- Adjust the display parameters in the mesh quality options.
- Review the *Engineering With* Nature tutorials available at Aquaveo.com.
- Manually editing a mesh. This could include:
- Select indivisual nodes and moving or deleting them.
- Insert a node.
- Swap edges between two elements.