Eliminating Topological Errors Using the STARS Toolbox

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Introduction

It is extremely critical that the edges are topologically correct to ensure that hydrologic distances and spatial relationships are calculated properly using the STARS toolset. The process of topologically correcting the data can easily be the most time-consuming aspect of the modeling process, especially for large datasets. There are a number of useful tools provided in the STARS toolset to help identify and remove errors and so the majority of the pre-processing occurs before the final Landscape Network (LSN) is generated. However, LSNs used to create .ssn objects must be dendritic (Figure 1). As such, there are three additional topological restrictions, which are not considered a true topological error in a GIS or within a LSN. First, diverging streams, which represent features such as braids in the network or canals, are not permitted. Second, converging streams are not allowed. These nodes occur at the downstream node of two edges that converge, but do not flow into another downstream edge. Third, only two edges may converge and flow into a single downstream edge at a confluence. When more than two segments converge, we refer to these as complex confluences. Note, only the topological relationships shown in Figure 1 are permitted in an LSN used to generate a spatial statistical model using the SSN package.

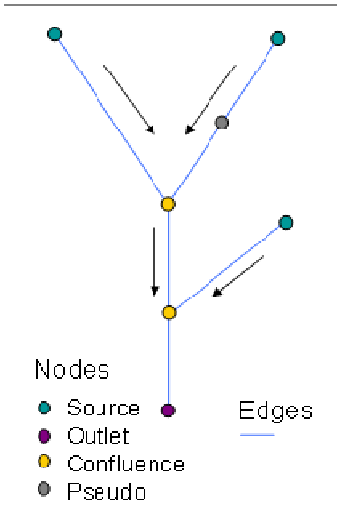


Figure 1. Topological relationships permitted in a .ssn object.

The purpose of this short tutorial is to familiarize users with the procedures used to eliminate topological errors from streams datasets using the STARS custom toolset and standard Editing tools provided in ArcGIS. These procedures are not exhaustive and assume that the user has a working knowledge of ArcGIS version ≥ 10.1 software. The shapefile **UpperSalmon.shp** has been provided to help users work through this tutorial.

General Procedures

The general procedures used to eliminate topological errors in a Landscape Network (LSN) are as follows:

1. Examine the streams shapefile and fix obvious errors using the ArcGIS Editing tools.
2. Run the script **Polyline to Landscape Network** to generate the LSN from the streams shapefile.
3. Run the script **Check Network Topology** to attribute each node type and identify potential node errors.
4. Run the script **Identify Complex Confluences** to identify nodes that require modification.
5. Examine potential errors in the LSN and use ArcGIS Editing tools to correct errors in the stream network shapefile.
6. Rerun steps 1-5 to generate a valid LSN and confirm that all errors have been corrected.

It often takes more than two iterations of this process to fix all topological errors in the network.

Specific Procedures

In this section, we provide step-by-step instructions to guide you through the general procedures described above. Note that, all of the STARS scripts/tools referred to reside in the STARS>Pre-processing toolbox.

Getting Started

1. Open ArcMap and add the STARS toolbox. In the ArcToolbox window, right click on 'ArcToolbox' and select Add Toolbox. Navigate to the STARS toolbox and click OK. Then, right click on ArcToolbox again, scroll down, select Save Settings, and click on To Default.

2. Change the Environment Settings. Click on the Geoprocessing menu and select Environments. Expand M Values and set Output has M Values to Disabled. Repeat these steps for Z Values and click OK.

3. Overwrite outputs by default. In the menu, select Geoprocessing and click on Geoprocessing Options. Check the box next to the Overwrite the outputs of geoprocessing operations and click OK.

4. Convert PolylineZM features to Polyline features.
    a. Add the UpperSalmon shapefile to the ArcMap Table of Contents (TOC) by clicking on the Add Data button,  .
    b. In ArcToolbox, go to Conversion Tools > To Shapefile and double click on the Feature Class To Shapefile (multiple) script.

c. Set the Input Features to UpperSalmon and navigate to the appropriate Output Folder on your computer. Click OK. This procedure will generate a new shapefile and remove ZM features using the Environment settings chosen in step 2 above.

5. In ArcCatalog, rename the new shapefile streams.shp.
    a. Click on the Catalog button,  , to open the Catalog window.
    b. Navigate to the directory that contains the new shapefile.
    c. Right click on the shapefile and scroll down to Rename.
    d. Rename the shapefile streams.shp.
    e. Close the Catalog window.
    f. Remove UpperSalmon. Select UpperSalmon in the TOC, right click, and select Remove.
    g. Add streams.shp to the ArcMap TOC.

Find Segments Digitized in the Wrong Direction

1. In the TOC, check the box next to streams.shp to make the streams visible.

2. Click on the line symbol in the TOC to open the Symbol Selector box. Scroll down and change the line symbol to "Arrow at End" →.

3. Briefly, examine the digitized direction of the stream segments. Are they all pointing downstream? It can be difficult to identify individual segments that may be digitized in the wrong direction, but this step allows you to quickly assess whether a large number of segments may be pointing in the wrong direction. Note that, other subsequent pre-processing steps can also be used to identify these errors.

4. In this example, most segments are digitized in the correct direction and so we will help you find one that isn't.
    a. Open the streams attribute table and select the stream segment with COMID = 23480151. To do this, click on the Table Options button,  , in the upper left hand corner, scroll down, and choose Select by Attributes. Type in "COMID" = 23480151. One feature should be selected.
    b. Close the attribute table and zoom in on the selected segment. Notice that the arrow points upstream, which means that this segment is digitized in the wrong direction. This will need to be fixed.

5. Click on the Editor toolbar and select Start Editing. Note that, you may have to make the Editor toolbar visible before you can use it. To do this, right click on the main menu, scroll down, and select Editor.

6. Set the Snapping options to ensure that new and modified polyline segments are snapped to the ends of other line segments (this is very important!)
    a. Click on the Editor toolbar, scroll down to Snapping, and makes sure that the Snapping toolbar is checked.
    b. In the Snapping toolbar, click on the End Snapping button, as shown below.

    c. Click on the Snapping toolbar, scroll down and select Options. Set the Tolerance to 10 pixels. Make sure that the Show tips, Layer name, and Snap type boxes are checked. Click OK.

7. Click on the Edit tool, , and select the segment that is digitized in the wrong direction.

8. Right click on the selected segment, scroll down, and select Edit Vertices, . Alternatively, you can simply double click on the segment to activate the Edit Vertices tool.

9. Right click on the selected segment again, and select Flip. Click somewhere else on the screen to unselect the segment. The arrow should now be pointing in the downstream direction.

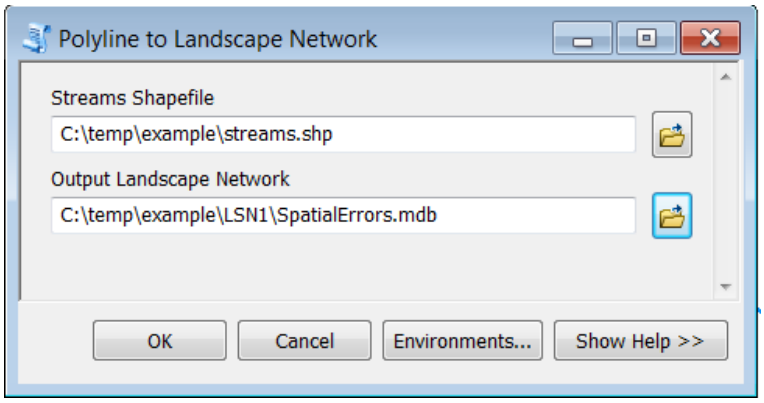
10. Click on the Editor toolbar and scroll down and select Save Edits.

11. In the TOC, click on the line symbol under streams to open the Symbol Selector window. Change the line symbology back to River.

Create the Landscape Network and Check for Errors

1. Create a folder called LSN1, where the new LSN will be stored.

2. In ArcToolbox, go to the STARS_v2.0.0 > Pre-processing and run the **Polyline to Landscape Network** script. Set the arguments and click OK.

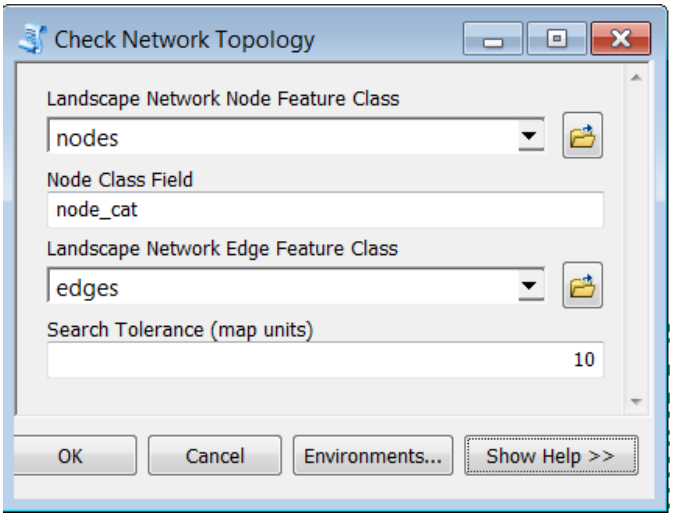


*Note that, you may need to navigate to the corresponding directories and select the files on your computer.

3. Click on the Add Data button, navigate to LSN1/SpatialErrors.mdb, and add the edges and nodes feature classes to the TOC.

4. Run the script **Check Network Topology**

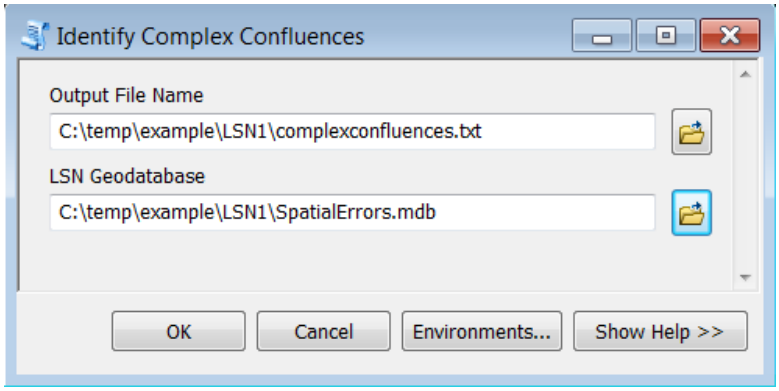
   *Note that, you must have a C:/temp directory to run this script. If you do not have one, open Windows Explorer, navigate to C: and create a new directory named temp.



   This script adds a new field to the nodes attribute table (node_cat) with a description of the node category (Confluence, Converging stream, Downstream Divergence, Outlet, Pseudo Node, Source). It will also create a shapefile of points, node_errors.shp, in the same directory as the LSN (in this case, LSN1), which can be used to identify potential topological errors.

   *Note, if you receive an error citing a “schema lock” it will be necessary to close and reopen ArcGIS before running the script again. Also make sure to delete any temporary files that were written to the C:/temp directory.

5. Run the script **Identify Complex Confluences**



The Identify Complex Confluences tool produces a comma delimited text file (.txt), which contains the pointid values for nodes where more than two edges converge and flow into a single downstream edge.

Examine Potential Errors and Edit If Necessary

The Check Network Topology tool creates a shapefile of points, node_errors.shp, which is used to identify potential topological errors in the LSN. These points do not necessarily represent true errors; each one must be examined and then edited if it is deemed a true topological error. Note that, topological errors must be manually edited in the streams shapefile and then a new LSN must be generated. It is not possible to 'fix' the old LSN.

Identify Downstream Divergences Such as Braids and Canals

Downstream divergences occur at nodes that have more than one segment downstream. These are not true topological errors, but instead represent features such as braided streams and canals. Nevertheless, downstream divergences are not permitted in the .ssn object and must be identified and removed.

1. Open the nodes attribute table from the LSN and select node_cat = 'Downstream Divergence'. Four nodes should now be highlighted. Close the attribute table.

2. Zoom into one of the selected nodes and examine the line segments downstream of it. Note that, it may help to change the symbology of the edges to 'Arrow at End'. These diverging stream segments must be edited.

3. The user must make a choice about which diverging channel to edit. In many cases it makes sense to leave the main channel untouched and to edit side channels. However, it can be difficult to identify which channel is the main channel without knowledge of the area. If the stream network has been attributed, then the decision can be based on variables such as catchment area, modelled flow, etc.

In this example, the streams were extracted from the US NHDPlusV2 streams dataset, which has been attributed. Diverging channels in NHDPlusV2 can be easily distinguished from the main channel by identifying segments where StreamOrde <> StreamCalc in attribute table.

a. Use the Identify tool, , to identify the downstream line segment where StreamOrde <> StreamCalc

4. Be sure that streams.shp is displayed in ArcGIS and that it is currently the feature class being edited.

5. Click on the Edit tool, select the line segment that you want to delete from the streams.shp (not edges), and delete it.

   *Note, if you have a large number of diverging streams the process could be automated by opening the streams attribute table, selecting segments where StreamOrde <> StreamCalc, and deleting those segments.

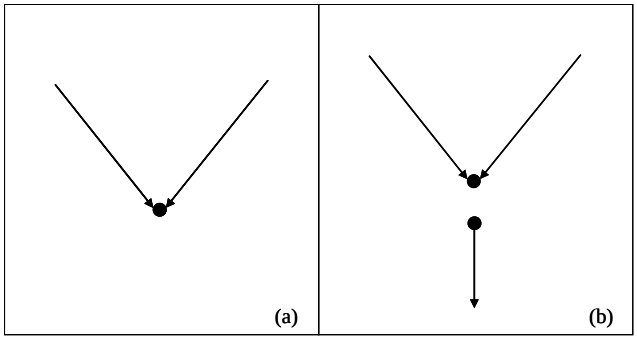
6. Repeat steps 1-5 for each of the downstream diverging nodes.

7. Click on the Editor toolbar, scroll down, and select Save Edits.

Identify Converging Streams

Converging streams are not permitted and must be edited before an .ssn object can be produced.

Figure 2. Converging stream nodes occur at the downstream node of two edges that converge (a,b), but do not flow into another downstream edge. This commonly occurs at the edge of the streams shapefile (a) or may be the result of topological errors within the stream network (b).



1. Open the nodes attribute table and select node_cat = 'Converging stream'. One node should now be highlighted. Close the attribute table.

2. Zoom into the selected node and examine the line segments up and downstream of it. You may have to zoom in quite a bit to see the error. In this case, the converging streams are the result of a true topological error, as shown in Figure 2b, and must be fixed.

3. Click on the Edit tool, and then double click on the line segment downstream of the converging node from the streams.shp (not edges) to activate the Edit Vertices tool.

4. Left click on the segment end node closest to the converging stream node, drag it to the converging stream node until you see the snap tip "streams: Endpoint", and release to move the end node. This is when it's very important to have the Snapping Options set, which we did above.

5. Click on the Editor menu, scroll down and select Save Edits. Unselect the segment.

Find and Correct Complex Confluences

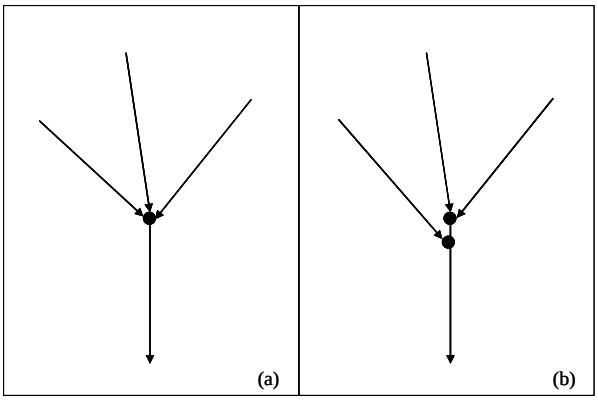


Figure 3. The stream network may contain confluences where three or more edges converge and flow into a single downstream edge (a).

Complex confluences are not permitted in an LSN (Figure 3a). When this occurs, they must be identified using the Identify Complex Confluences tool and the error manually corrected (Figure 3b) in the streams shapefile before the LSN is rebuilt.

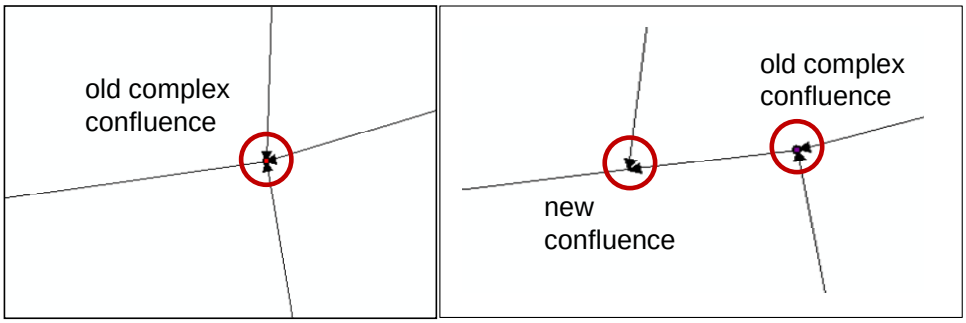
1. In the TOC, make sure that the streams shapefile and LSN nodes feature class are both visible.

2. Use Windows Explorer to navigate to the LSN1 directory and open complexconfluences.txt in a text editor. One complex confluence has been identified.

3. Open the nodes attribute table, select the pointid that was listed in complexconfluences.txt., close the attribute table, and zoom in to examine the node. Note that, the pointid assigned to this node may vary from computer to computer and LSN to LSN.

4. The complex confluence must be edited, as shown in Figure 3b. To do this:
    a. Click on the Edit Tool and select the segment downstream from the node. Again, it may be helpful to change the symbology to Arrow at End.
    b. In the Editor toolbar, click on the Split tool, 
    c. Move the cursor so that it lies slightly downstream from the node. You should see a circle appear over the segment. Left click to split the selected segment. There should now be two stream segments.
    d. Click on the Edit tool and double click on the segment that flows south into the node (COMID = 23484265) to activate the Edit Vertices tool.

e. Select the end node of the selected segment and drag it downstream so that it lies at the new pseudo node downstream. You should see the snap tip streams:Endpoint when you move the end node.



5. Save your edits and clear the selection.

Examine Potential Errors in node_errors.shp

The results of the Check Network Topology tool are used to identify true topological errors in the LSN. Note that the errors identified are only potential errors and must be visually examined before editing. Figure 4 shows a map of the streams and node errors.

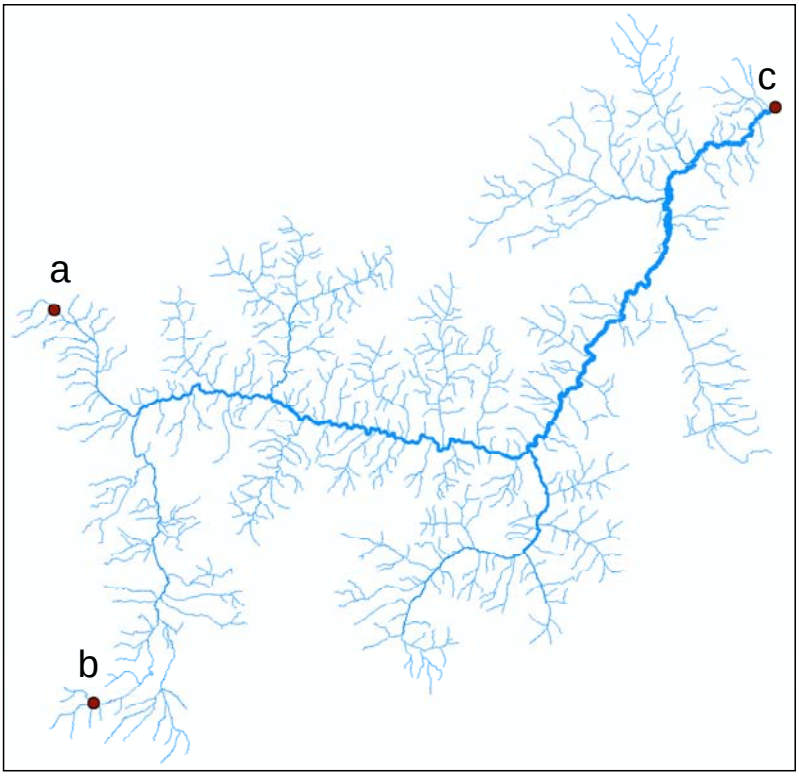
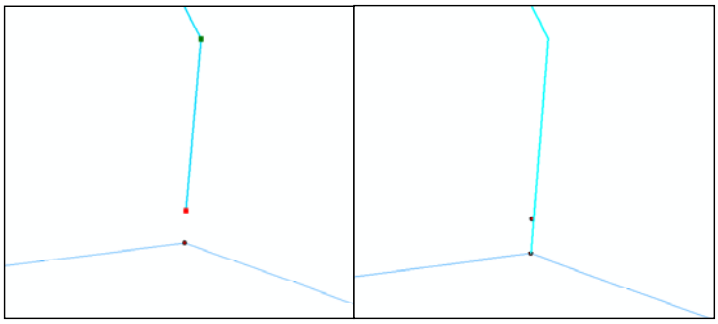


Figure 4. Node errors identified using the Check Network Topology too.

1. Navigate to the LSN1 directory and add the node_errors.shp to the TOC. If you get a message indicating that the Spatial Reference is unknown for node_errors, ignore it.

2. Open the attribute table for node_errors. Notice the pointid field; this corresponds to the pointid field in the nodes attribute table.

3. Zoom into the node error shown in Figure 4a and examine it. If it is unclear what type of topological error has been identified, you can also use the Identify tool to obtain the node_cat value for the node the error corresponds to. However, in this case it is fairly obvious if you zoom in close enough. This is a true topological error because there is a break in the stream network. The segment that flows south falls short instead of flowing into the adjacent stream segments. This must be fixed.
    a. Click on the Edit tool and double click the segment that flows south to activate the Edit Vertices tool.
    b. Move the end node of the segment to the correct node and make sure it snaps properly.
    c. Save your edits and clear the selection.



4. Zoom into the node error shown in Figure 4b and examine it. This is the converging stream node that we fixed in a previous section.

5. Zoom into the node errors shown in Figure 4c. Note that there are two potential errors here.
    a. Visually examine the potential topological errors. Notice that these appear to be Outlet nodes.
    b. In the TOC, make the nodes feature class visible. Use the Identify tool to look at the node_cat for each of the nodes corresponding to the node errors. This indicates that these are Outlet nodes.
    c. These are not true topological errors and no editing is needed.

6. Click on the Editor toolbar and select Save Edits. Then, click on the Editor toolbar again and select Stop Editing.

Re-run the Pre-Processing Tools and Check for Errors

1. Remove SpatialErrors.mdb files from the TOC (edges, nodes), as well as the node_errors.shp.

2. Create a new directory called LSN2 (only one LSN should be stored in each directory) and run the script **Polyline to Landscape Network** to generate a new LSN. Make sure and use the edited streams shapefile as the input to this script.

3. Run the script **Check Network Topology** to attribute each node type and find node errors.

4. Run the script **Identify Complex Confluences** to identify stream junctions that require modification.

5. Re-check for errors as described above.

6. Continue this process until there are no errors in the LSN and the only node types are those shown in Figure 1.