

Introduction to Topology

Session Objectives: At the conclusion of this session, you will be able to:

- Understand the basics of Topology and why Topology is important
- Review the Topology rules; know where to learn more about them and how to evaluate which are applicable to a project.
- Build a topology and examine data for errors and clean those errors using Topology tools.

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Revision: Gabriel DeAlessio (May 2010)

Revision: Eric Kelchlin (May 2013)

Revision: Gabriel DeAlessio (Feb 2016)

Software: ArcGIS 10.3.1

Directory Path: D:\GISWorkshop_Topology

GDB: GISWorkshop_Topology.gdb

Imagery: Aerial_2009

MXD:

All data are located in D:\GISWorkshop_Topology, unless otherwise stated.

TASK 1 - Establish Topology Rules

For this exercise, we will use the LC_Premade feature class, one that has common errors that sometimes occur when editing. Some polygons overlap their neighbors, while others don't come close enough and leave gaps. We're going to apply the following topological rules (i.e., relationships) in the geodatabase to clean-up the mess:

- Rule 1** A polygon cannot exist in the space as another polygon or overlap;
- Rule 2** All polygon boundaries are contiguous and there are no gaps between polygons; and
- Rule 3** **LC_Premade** feature class must cover the **Boundary** feature class.

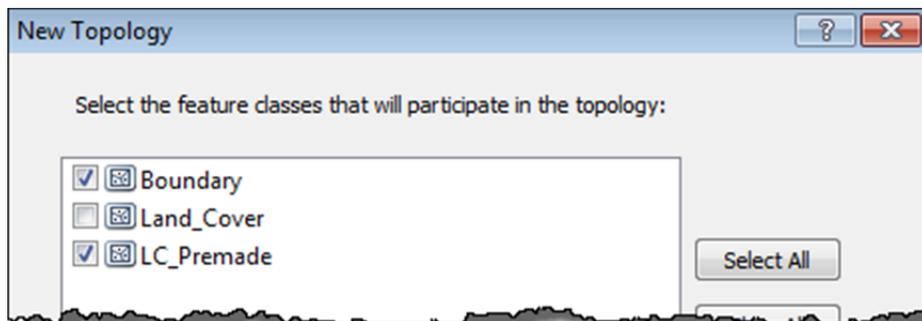
Online Topology Poster link:

http://help.arcgis.com/en/arcgisdesktop/10.0/help/001t/pdf/topology_rules_poster.pdf

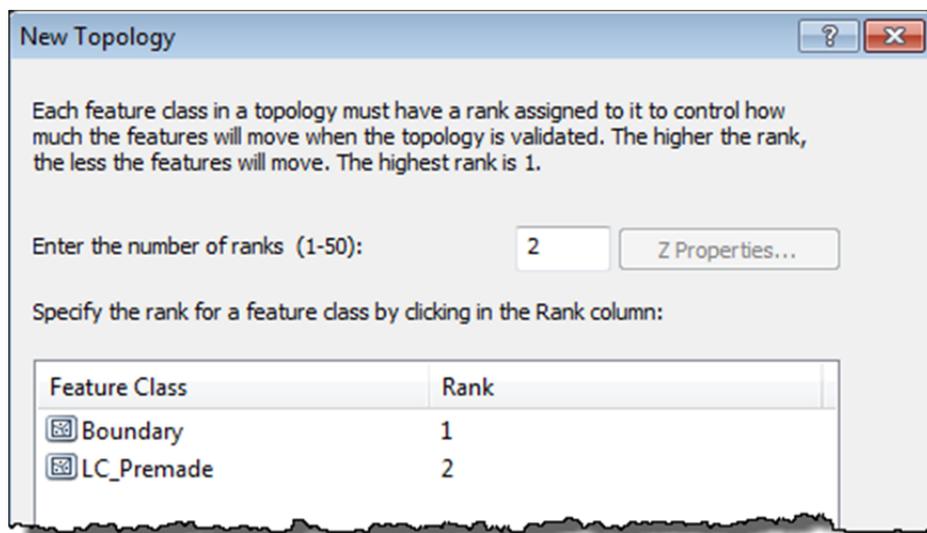
Online Topology Rule reference that includes possible fixes:

<http://help.arcgis.com/EN/ARCGISDESKTOP/10.0/HELP/index.html###/001t000000sp000000.htm>

1. Open ArcCatalog.
2. To make a new topology browse to the **GISWorkshop_Topology.gdb**. Right-click on the **NCTC** feature dataset, select **New** and choose  **Topology**.
3. A **New Topology** dialog appears. Read the overview information. Click Next.
4. Name the new topology **Landcover_Topology**. Accept the default tolerances. Click Next.
5. Select **Boundary** and **LC_Premade** to participate in the topology. Click Next.

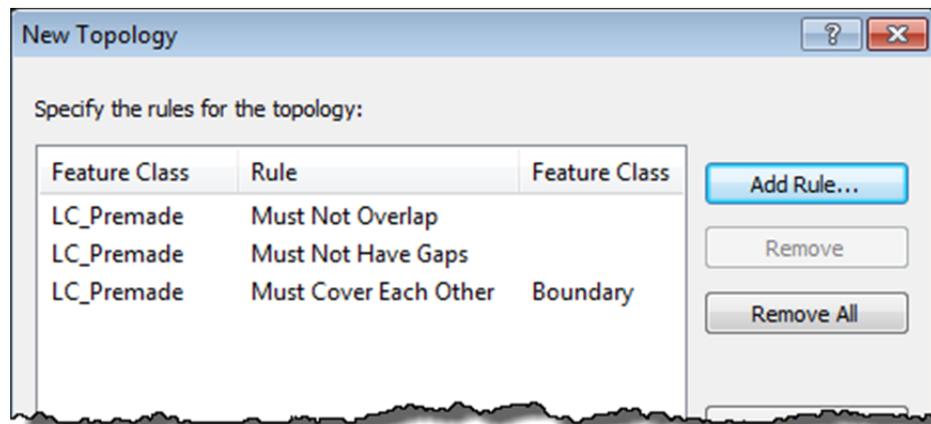


6. Enter the number of ranks to be **2**. Then, change the rank values as shown below. Click Next.



What does this ranking mean? Feature classes of a lower rank will be snapped to feature classes of a higher rank. So, in this example, the landcover layer will be adjusted to the boundary layer. The boundary is ranked the highest because we want to minimize any adjustment of this feature.

7. Use the  button to add the following 3 rules:



8. Click OK when finished adding the topology rules. A summary appears in the New Topology dialog. Click Finish.
9. Choose **NO** when asked to validate the topology. We will validate the topology and fix any errors using ArcMap in the next section.

Why did we select these topology rules?

Must Not Overlap – Requires that the interior of polygons in the feature class not overlap. The polygons can share edges or vertices. This rule is used when an area cannot belong to two or more polygons. It is useful for modeling administrative boundaries, such as ZIP Codes or voting districts, and mutually exclusive area classifications, such as land cover or landform type.

Must not have gaps – This rule requires that there are no voids within a single polygon or between adjacent polygons. All polygons must form a continuous surface. An error will always exist on the perimeter of the surface. You can either ignore this error or mark it as an exception. Use this rule on data that must completely cover an area. For example, soil polygons cannot include gaps or form voids—they must cover an entire area.

Must Cover Each Other – Requires that the polygons of one feature class must share all of their area with the polygons of another feature class. Polygons may share edges or vertices. Any area defined in either feature class that is not shared with the other is an error. This rule is used when two systems of classification are used for the same geographic area, and any given point defined in one system must also be defined in the other. One such case occurs with nested hierarchical datasets, such as census blocks and block groups or small watersheds and large drainage basins. The rule can also be applied to nonhierarchically related polygon feature classes, such as soil type and slope class.

For complete listing of rules and fixes, open the ArcGIS help and look up topology rules.

TASK 2 – Validate Topology & Must Cover Each Other Errors

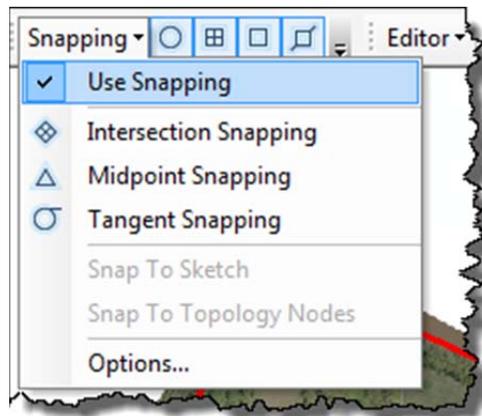
1. Close ArcCatalog and Open an ArcMap session.
2. Choose settings. From the **Editor** Toolbar, select Snapping > Snapping Toolbar. Dock the new toolbar.

3. From the Snapping Toolbar **select Options** and ensure the Snapping Tolerance is **set to 10 units**.

Also, make sure to **enable Use Snapping** by selecting it.

4. From the Editor Toolbar, **select Options** and ensure that the Sticky move tolerance is set to 15-20 pixels to avoid accidental polygon moves.

- Also, uncheck the Show mini toolbar box to hide a really annoying tool.



While not specific to topology rule, the settings in steps 2-4 are a useful to enable anytime you're editing data you want to keep "clean".

5. Add the topology to the map. Click **Add Data** and browse to the topology.
 - When prompted, click **Yes** to add all associated feature classes. You should see Topology, LC_Premade and Boundary files in your Table of Contents.
6. Use **Add Data** and add the Aerial_2009.sid file to the Map.
7. Zoom to Full Extent  if the entire boundary is not visible. It's time to validate to see to see if and where errors exist within the feature classes.
8. Go to Customize/Toolbars (or right-click in the top menu section of ArcMap) and check the box next to Topology to load the toolbar.
9. Start an editing session.
10. Click the **Validate Entire Topology**  button.



11. Click **Yes** when asked if you are really sure you want to validate the full extent. Yikes, look at all that red!
12. Click the **Error Inspector**  tool. This tool allows you to manage and interact with the topology errors on your map. You can search for violations of specific topology rules or for exceptions (errors that you mark as acceptable). You can also choose whether to inspect the currently visible extent or the entire topology.



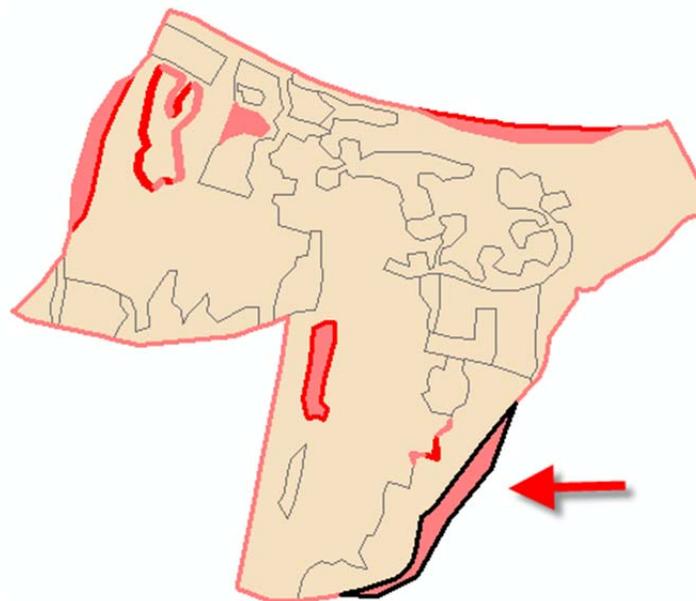
13. Click the **Search Now** button. You should find 21 errors total.

 A screenshot of the Error Inspector window. The window title is 'Error Inspector'. It shows a dropdown menu set to '<Errors from all rules>' and a count of '21 errors'. There is a 'Search Now' button and checkboxes for 'Errors' (checked) and 'Exceptions'. Below this is a table with the following columns: Rule Type, Class 1, Class 2, Shape, Feature 1, Feature 2, and Exception.

Rule Type	Class 1	Class 2	Shape	Feature 1	Feature 2	Exception
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False
Must Not Have Gaps	LC_Premade		Polyline	0	0	False

14. Click on Down Arrow and Select **Must Cover Each Other**. Click **Search Now**.
15. Click on the first error in the Error Inspector. Notice how the identified error turns black on the map.

Rule Type	Class 1	Class 2	Shape	Feature 1	Feature 2	Exception
Must Cover Each Other	LC_Premade	Boundary	Polygon	4	0	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	0	1	False
Must Cover Each Other	LC_Premade	Boundary	Polygon	13	0	False



16. Close inspection reveals that the polygon lies outside the NCTC Boundary.

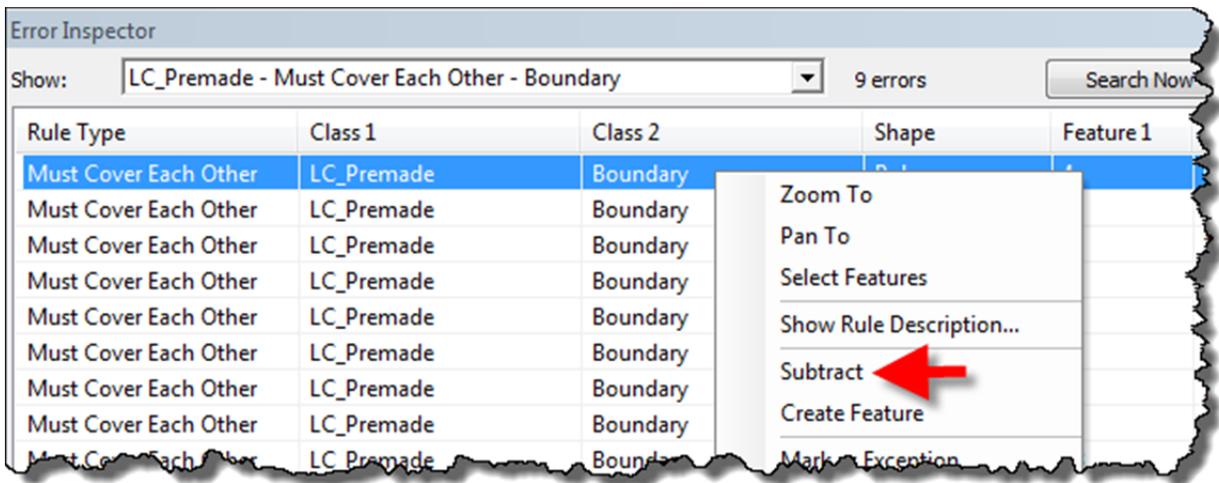
To fix errors identified by the **Must Be Covered By Feature Class Of** rule we two options:

Subtract: removes the overlapping portion of each feature that is causing the error so the boundary of each feature from both feature classes is the same.

Create Feature: creates a new polygon feature out of the portion of the overlap from the existing polygon so the boundary of each feature from both feature classes is the same.

With this error selected, **Right click** on the selected line inside the dialog and select **Subtract**. This will remove this area completely from the **LC_Premade**

layer (reshaping the layer's boundary). **Do not use Create Feature** as this fix will modify the NCTC Boundary, which we know is correct and don't want to change.

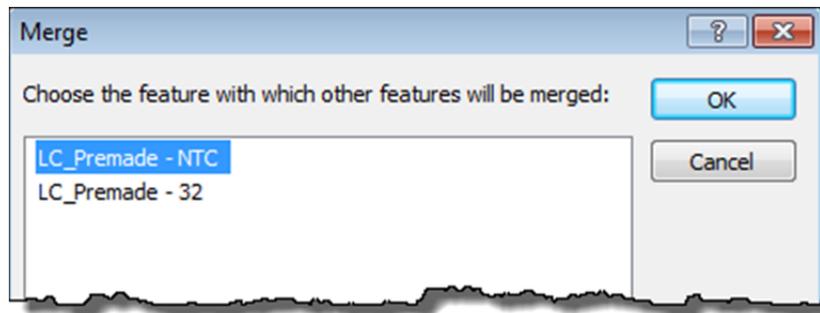


- Now let's **Validate Entire Topology**  again to make sure we fixed the problem.
17. Another way to correct topology is to use the **Fix Topology Error Tool** . Activate the tool on the toolbar by **left clicking** on it.
- With the tool active, select the error in the northeast.



18. Looking closely will reveal that there is a gap in the landcover between the NCTC Boundary and the existing landcover polygons. To correct, we need to **right click** and select **Create Feature** to add in a polygon.

- Once the feature is added, open the **Attribute** tool. You will notice that it lacks any attribute data. You can code it individually or choose to merge it to an adjacent feature.
- **Select**  both the new polygon and the Forest polygon to the south. Then in the **Editor Menu**, select **Merge**. Be sure to select the feature with attributes to Merge to rather than the new one to retain those attributes!



- Now let's **Validate Entire Topology**  again to make sure we fixed the problem.
- Notice this error is gone now. Leave the remaining errors for now, we'll fix them later.

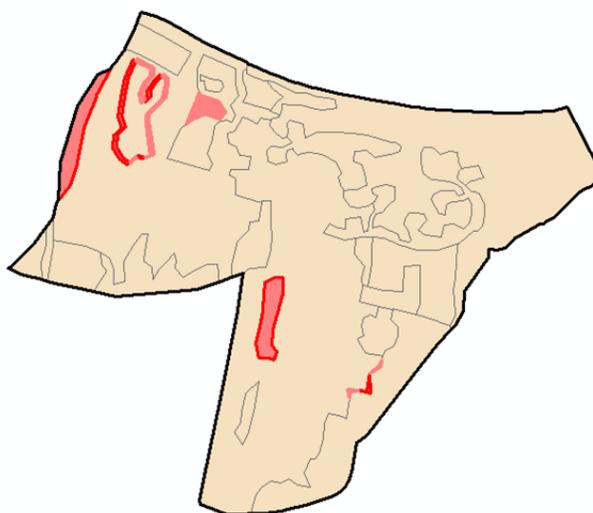
TASK 3 – Must Not Have Gaps

In this section we'll examine the MUST NOT HAVE GAPS errors. This is one of the few rules that will ALWAYS generate an error. This is because you will always have an 'end' to your polygons extents, and therefore a 'gap' where they do not touch another. We will start by marking this error as an exception

Must Not Have Gaps

This rule requires that there are no voids within a single polygon or between adjacent polygons. All polygons must form a continuous surface. **An error will always exist on the perimeter of the surface.** You can either ignore this error or mark it as an exception. Use this rule on data that must completely cover an area. For example, soil polygons cannot include gaps or form voids—they must cover an entire area.

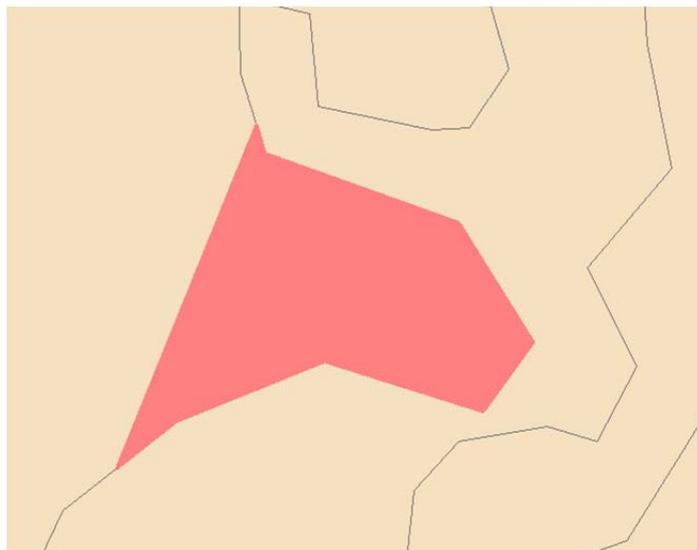
1. Click on the **Fix Topology Error Tool**  and click on the boundary so that it has a black outline.



- Click the **Error Inspector**  button. Notice there is only one error shown. Since this one error will always show up when we inspect, let's make it an exception so it won't appear again. That way, only the errors we are concerned with will be displayed.
- Right click on the error in the Error Inspector dialog and choose **Mark as Exception**.
- **Validate the Entire Topology** again to make sure we fixed the problem.
- Close the **Error Inspector** dialog.

Tip: If you need to go back to the error you marked as an exception, in the Error Inspector check Exceptions and click Search Now. Notice if you Right click on the Exception you can choose Mark as Error.

2. Let's look at actual errors now. Zoom into the error as shown below.



- Click the **Error Inspector**  button.
- Click the **Search Now** button to quickly find this error.
- Select the error in the Error inspector dialog. The polygon should have a black outline.
- To fix this error – Right click and select **Create Feature**, which will create a new polygon feature within **LC_Premade** (getting rid of the gap). If you had multiple errors and use selected them all and used the Create Feature fix, the result will be one polygon feature per gap. So, be careful.

3. Open the Attribute table and Attribute the new polygon to Developed.

OBJECTID	35
NWRNAME	<Null>
Classification	Developed
Acreage	
Shape_Length	459.507047
Shape_Area	8962.922456

4. **Validate the Entire Topology** again to make sure we have fixed the problem. TIP: After any polygon editing session; including the subtracting and creating and merging we just did, remember your Acreages are no longer accurate! ALWAYS recalculate your Acreages after editing shapes.

TASK 4 – Must Not Have Overlap

In this section, we will zoom-in to an area where polygons are overlapping. Since a land cover can only have 1 attribute per location, these are errors that need to be corrected. Overlapping polygons also lead to double counting of acreages.

1. Zoom to full extents .
2. Click the **Error Inspector**  button. Click **Search Now**.
3. Select the “**Must Not Have Overlap**” error to identify the error on the map.

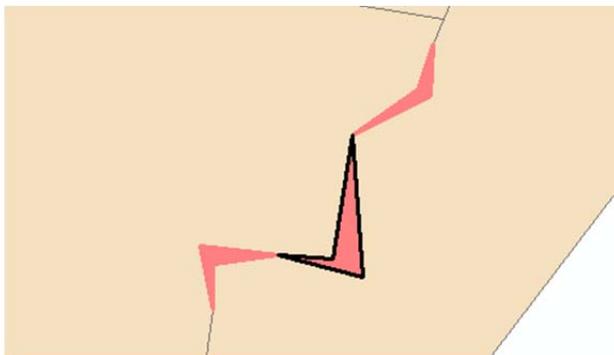
To fix errors identified by the **Must Not Have Overlap** rule we have **3** options within the error inspector:

Subtract: removes the overlapping portion from each feature and leaves a gap or void in its place. This fix can be applied to one or more selected Must Be Covered By Feature Class Of errors.

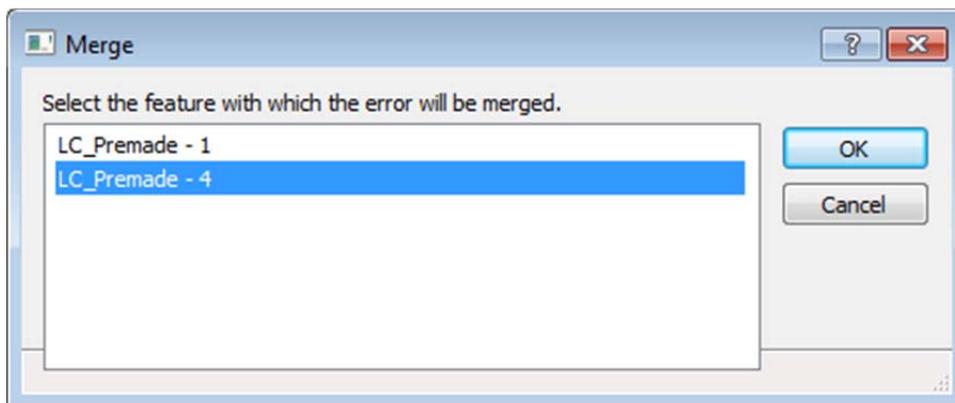
Merge: adds the portion of overlap from one feature and subtracts it from the others that are violating the rule. You need to pick the feature that receives the portion of overlap in the Merge dialog box that pops up. This fix can be applied to one Must Not Overlap error only.

Create Feature: creates a new polygon feature out of the error shape and removes the portion of overlap from each of the features. The fix can be applied to one or more selected Must Be Covered By Feature Class Of errors.

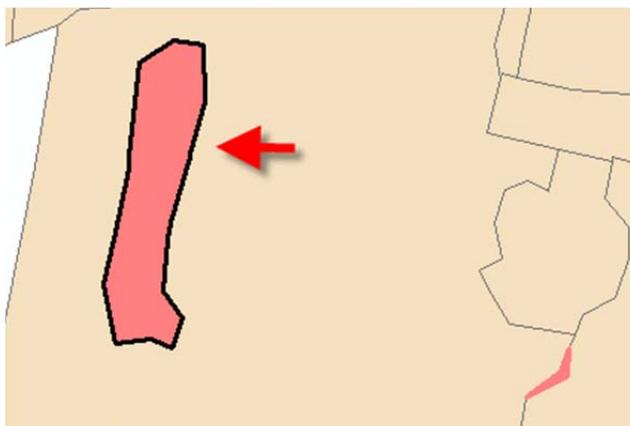
4. Select the error highlighted below using the **Fix Topology Error Tool** 



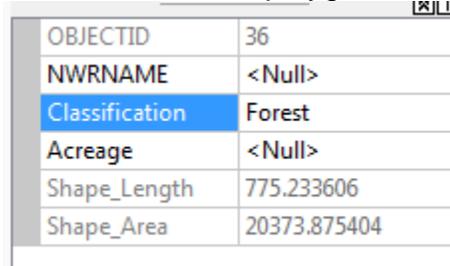
- Right click on the topology and select **Merge**. **Do Not** use Create Feature (which will make new polygons) or Subtract (which will create slivers in the LC_Premade feature class).
- Based on the underlying land cover, select the second feature on the list and click **OK**.



- **Validate the Entire Topology** again to make sure we fixed the problem.
5. Next, select the large overlapping error as shown below. We need to make sure only 1 polygon exists.

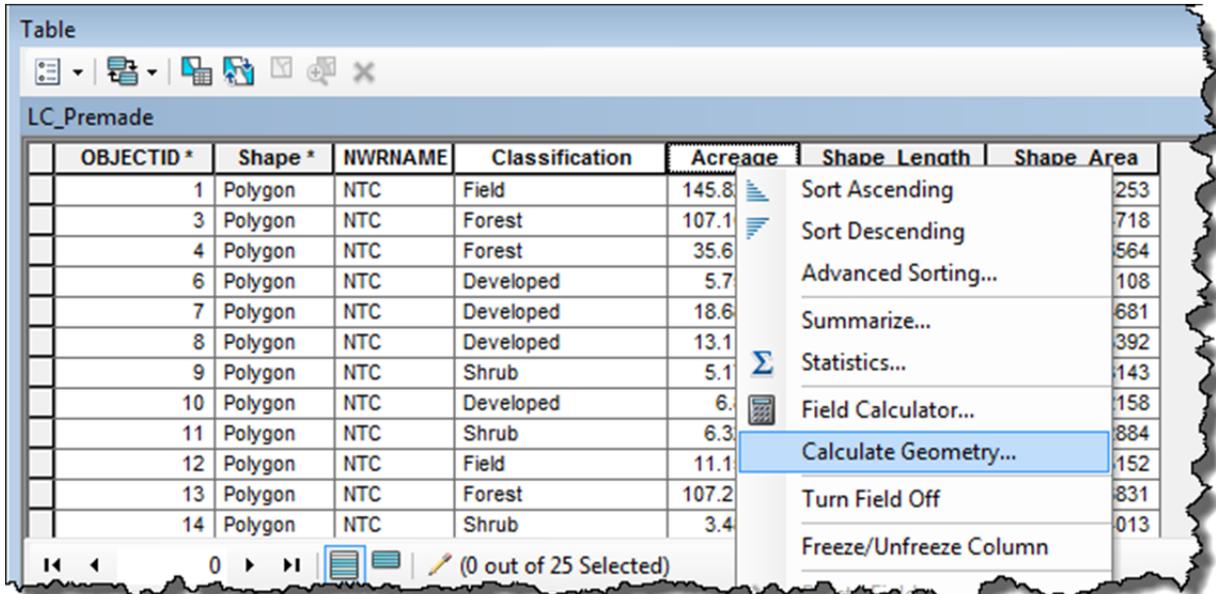


- **Right click** and choose **Create Feature**. This forces 2 simultaneous actions: 1) it subtracts the shape from the underlying polygon and 2) it creates a new feature in the same location.
- Identify on the new feature. You will notice the attribute has been lost since the Create Feature removes the existing and replaces it with a new polygon. You can attribute the new polygon to Forest.



OBJECTID	36
NWRNAME	<Null>
Classification	Forest
Acreage	<Null>
Shape_Length	775.233606
Shape_Area	20373.875404

- **Validate the Entire Topology** again to make sure we fixed the problem.
 - **Stop editing and save edits.**
6. Using the skills learned in this exercise; restart editing and continue fixing any remaining topological errors.
 7. When complete, be sure to **right-click** on the Acreage field and **Calculate the Geometry** to generate the correct acres. Remember - it's not automatic.



The screenshot shows a GIS software interface with a table titled "LC_Premade". The table has columns for OBJECTID, Shape, NWRNAME, Classification, Acreage, Shape Length, and Shape Area. A context menu is open over the Acreage column, listing options such as Sort Ascending, Sort Descending, Statistics..., and Calculate Geometry... The Calculate Geometry... option is highlighted. The status bar at the bottom indicates "(0 out of 25 Selected)".

OBJECTID *	Shape *	NWRNAME	Classification	Acreage	Shape Length	Shape Area
1	Polygon	NTC	Field	145.8	Sort Ascending	253
3	Polygon	NTC	Forest	107.1	Sort Descending	718
4	Polygon	NTC	Forest	35.6	Advanced Sorting...	564
6	Polygon	NTC	Developed	5.7	Summarize...	108
7	Polygon	NTC	Developed	18.6	Statistics...	681
8	Polygon	NTC	Developed	13.1	Field Calculator...	392
9	Polygon	NTC	Shrub	5.1	Calculate Geometry...	143
10	Polygon	NTC	Developed	6.1	Turn Field Off	158
11	Polygon	NTC	Shrub	6.3	Freeze/Unfreeze Column	884
12	Polygon	NTC	Field	11.1		152
13	Polygon	NTC	Forest	107.2		831
14	Polygon	NTC	Shrub	3.4		013

TASK 5 – Add Linear Topology Rules and Error Check

In this section we'll add a few more topology rules focusing on a stream network with some gages and perform error checks and corrections. The rules that will be applied:

(Line) Must Not Have Dangles	Requires that a line feature must touch lines from the same feature class (or subtype) at both endpoints. An endpoint that is not connected to another line is called a dangle. This rule is used when line features must form closed loops, such as when they are defining the boundaries of polygon features. It may also be used in cases where lines typically connect to other lines, as with streets. In this case, exceptions can be used where the rule is occasionally violated, as with cul-de-sac or dead-end street segments.
(Line) Must Be Single Part	Requires that lines have only one part. This rule is useful where line features, such as highways, may not have multiple parts.
(Line) Must Not Intersect	Requires that line features from the same feature class (or subtype) not cross or overlap each other. Lines can share endpoints. This rule is used for contour lines that should never cross each other or in cases where the intersection of lines should only occur at endpoints, such as street segments and intersections.
(Point) Must be Covered by Line	Requires that points in one feature class be covered by lines in another feature class. It does not constrain the covering portion of the line to be an endpoint. This rule is useful for points that fall along a set of lines, such as highway signs along highways.

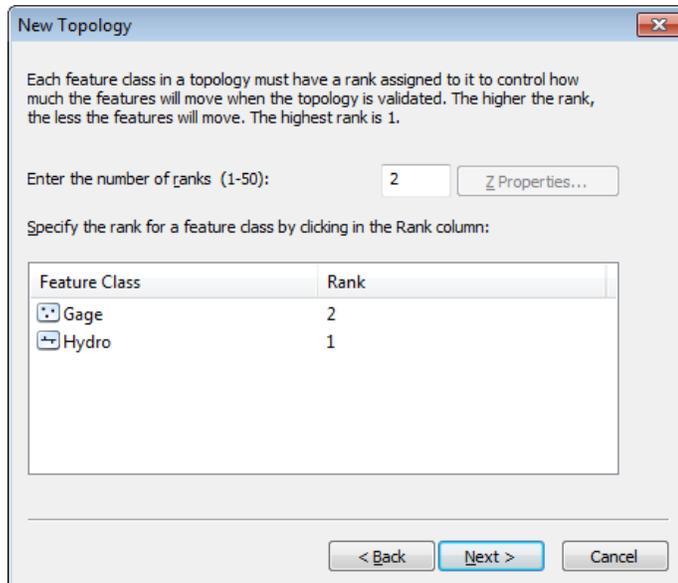
1. Open a new ArcMap project. In the ArcCatalog View, browse to the **GISWorkshop_Topology.gdb**.

This Feature Dataset contains a line feature class, "Hydro" and a point feature class, "Gage".

2. Right-click on the **Hydrology** feature dataset, select **New** and choose  **Topology**.
3. **Accept** the default name as "Hydrology_Topology", and the Cluster tolerance of 0.001 meters. **Click Next**.
4. **Check both feature classes** to participate in the topology. Click Next.
5. **Set the Number of Ranks to 2**. (Since we only have 2 layers, we only need 2 ranks.)

Make Hydro Rank 1 and Gage Rank 2.

This ensures that the rivers take priority over the gages when it comes to autocorrections that you may use. (Another way to think of it is that when editing... the gage needs to move to the river, not the other way around.)



Click Next.

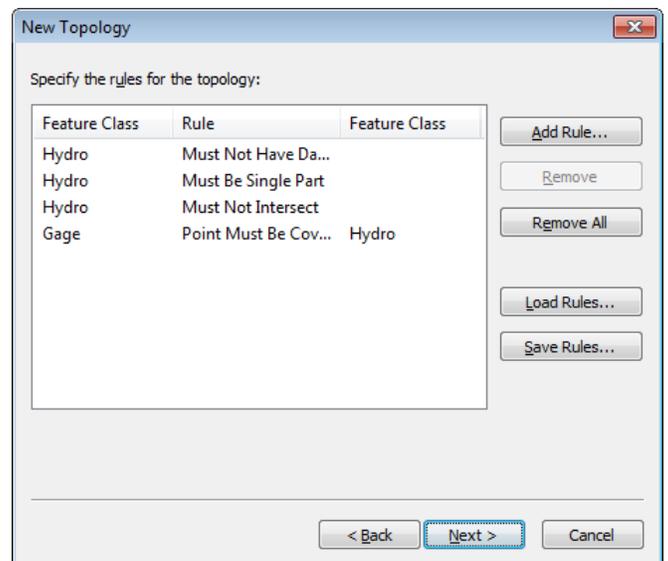
6. **Now add the 4 rules** noted on the previous page.

Make sure to read the notes about each one to better understand what each does (and what it doesn't do)!

Your Rule list should look like this when completed.

Click Next.

7. Review the summary and **Click Next.**
8. When asked, **Click Yes** to Validate now.



9. **Drag the Hydro_Topology** from the ArcCatalog View into ArcMap. **Click Yes** when asked to add participating feature classes.

Set Symbology as desired for the feature classes, but it's recommended to leave the topology to its default for now.

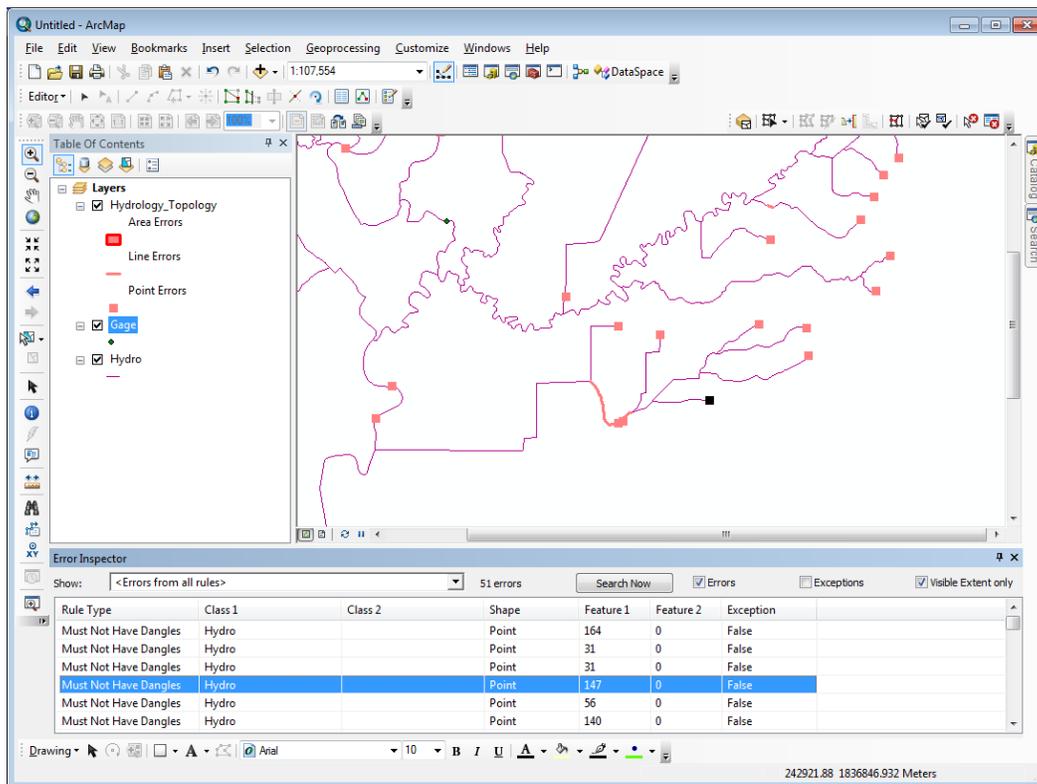
10. Make sure the Topology toolbar is on. **Start editing.**
11. Open the **Error Inspector** on the Topology toolbar.



12. **Click Search Now** to see all the errors.
13. Isolate the "Must Not Have Dangles" in the Error Inspector.

Many of the "errors" are actually not errors, but simply the furthestmost linear point in a headwater stream. Those will be marked as exceptions.

Highlight errors one at a time until you find an obvious headwater exception. (Dangles in the middle of stream runs or where 2 streams meet are actual errors.)

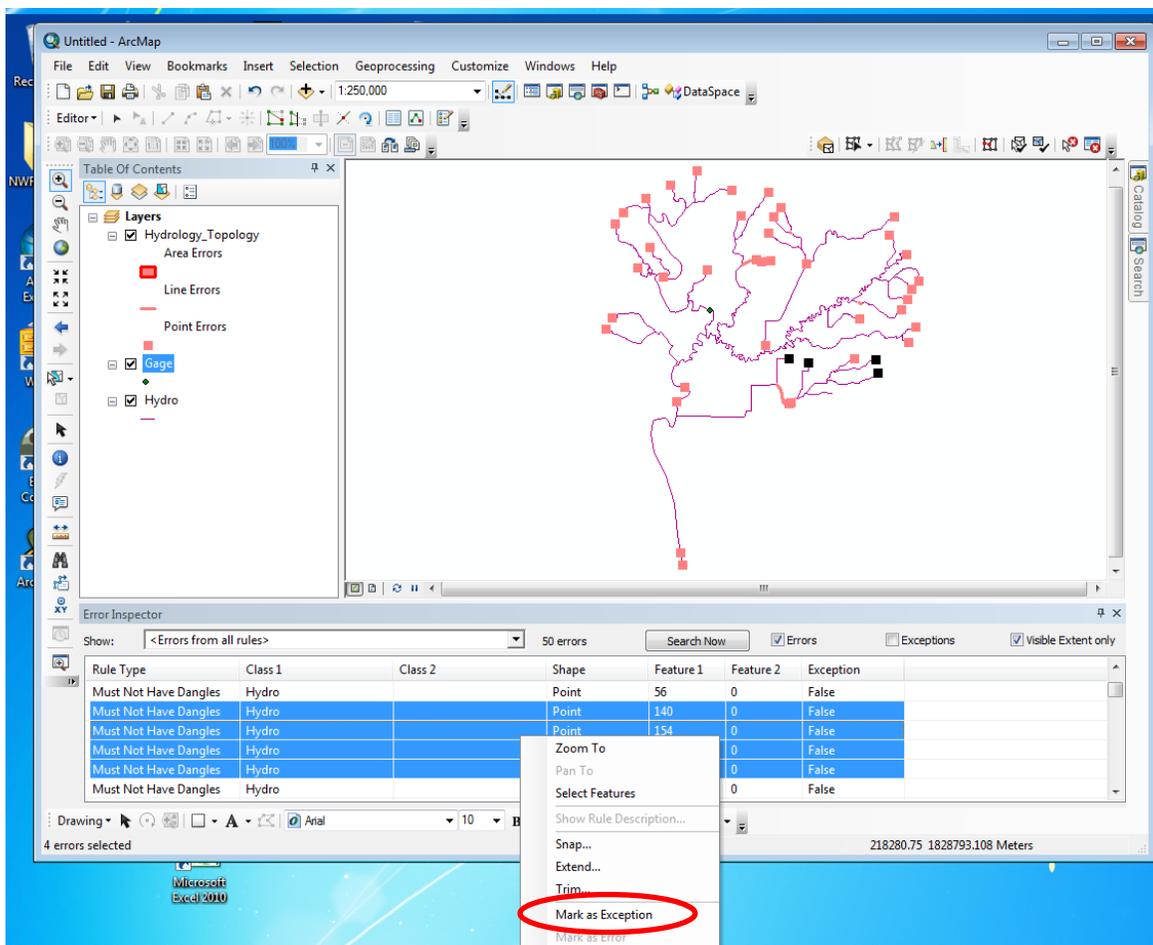


14. **Right Click** on the error. You will see the possible auto-fixes (Snap, Extend, Trim) along with other options.

Choose Mark as Exception.

15. Repeat for other Dangles.

Hint: You can choose multiple errors using Ctrl or Shift key + Click.



16. Now, focus on the actual errors. **Select** a remaining error, **Right Click** and use the **Zoom To**. Decide whether it's an exception or an error that needs fixing.

Use the auto-fix solutions or edit by head to clean the data. *In the real world we would use imagery, collateral data or firsthand knowledge to make adjustments, for this training use your best judgment!*

Be sure to refer to the Rule Description and/or to the online help that explains each fix.

<http://help.arcgis.com/EN/ARCGISDESKTOP/10.0/HELP/index.html#//001t000000sp000000.htm>

17. Work through the errors for the Must be Single Part and Must not Intersect next.
18. When the other rules have been addressed, finish by reviewing the errors of Point Must be Covered by Line.

These are gages that were added via heads up digitizing, but may not have been snapped to the lines. This will create problems should these layers participate in a geometric network later... the gage features will not be influence network routes if they don't intersect the linear rivers!

19. **Right Click** and **Zoom To** the first. Magnify further as needed.
20. **Right Click** on the Feature again. You will notice there is not an autofix option, so you'll have fix by hand. **Select the feature** (not the error marker) and **drag it** onto the line making sure it snaps into place.
21. **Rerun Topology** and be sure that error has disappeared.
22. Finish cleaning the remainder of errors.
23. **Save edits.**

Reminder: if this was real data, you would want to recalculate geometry of your linear distances and XY values if you included those in the attribute table!

TASK 6 – Topology Edit Tool (aka Shared Edit Tool)

In this final section, you'll experience the Topology Edit Tool. This tool allows you to select Nodes and Lines to edit. When you move one feature, it automatically moves features already associated by your topology rules. This is a very powerful tool that can save a lot of time when editing complex geometries.

1. ArcMap should be open with the Hydro topology and feature classes from the previous exercise. If not, reopen and add those layers.

2. **Zoom To** the southernmost gage and river stretch.

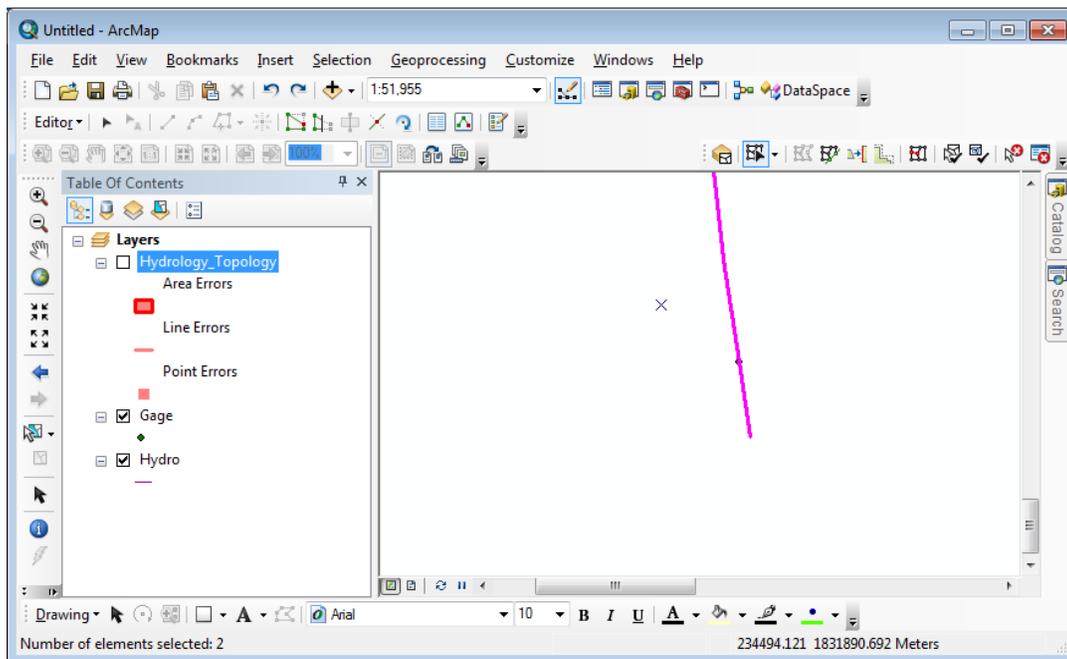
Due to a recent major earthquake that shifted the tectonic plate 100 meters, it's been determined that the river and gage has moved significantly to the east.

3. On the topology toolbar, **Select the Edit Topology Tool**.

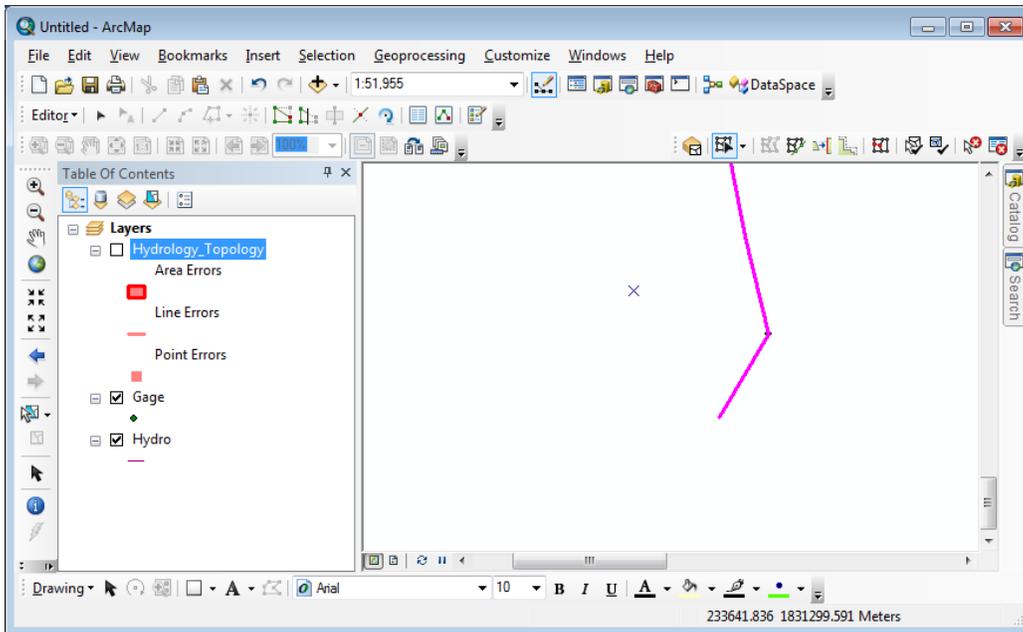


4. Using a **Hold Left Click**, drag a selection box around the gage point and intersecting both the up and downstream lines.

You should see a purple highlight on the lines when you have them selected.

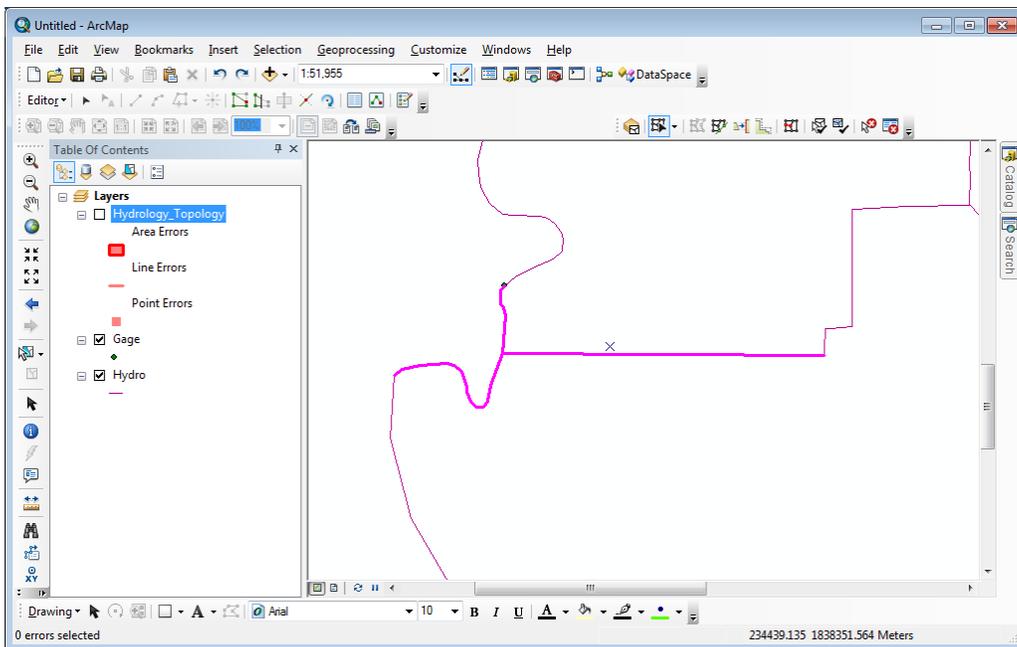


5. With the Topology Edit Tool still active, **Click** on the Gage point and **drag** it to the east.



When done correctly, you will see the gage as well as the line move together editing the data while keep topology intact.

6. Next, move upstream to the first convergence. Using the Topology Edit Tool, **Select** the three intersecting lines.

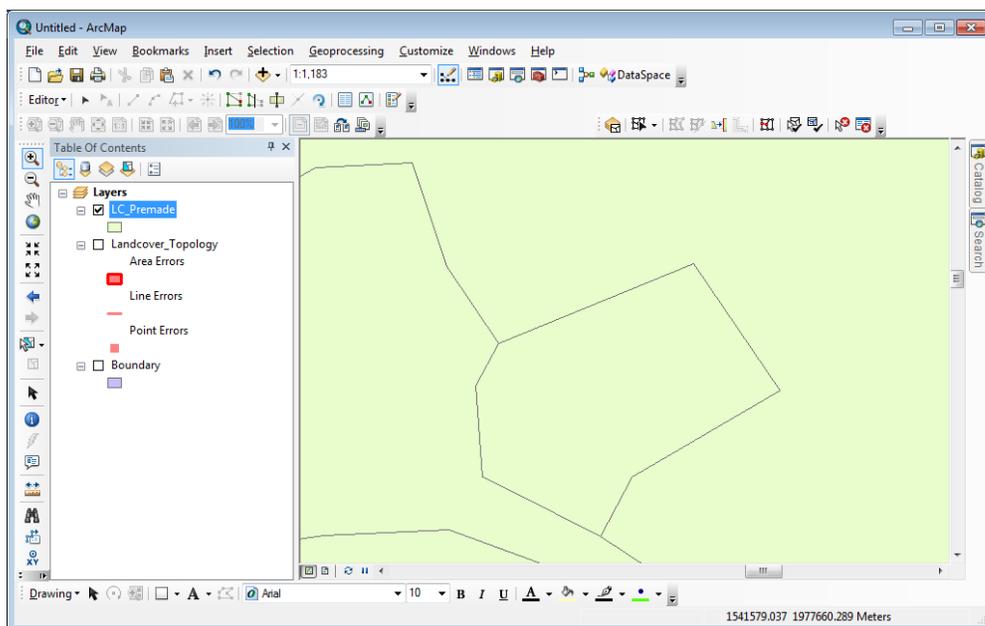


7. With the lines selected, **hover** over the intersection until you see the 4-arrow symbol.

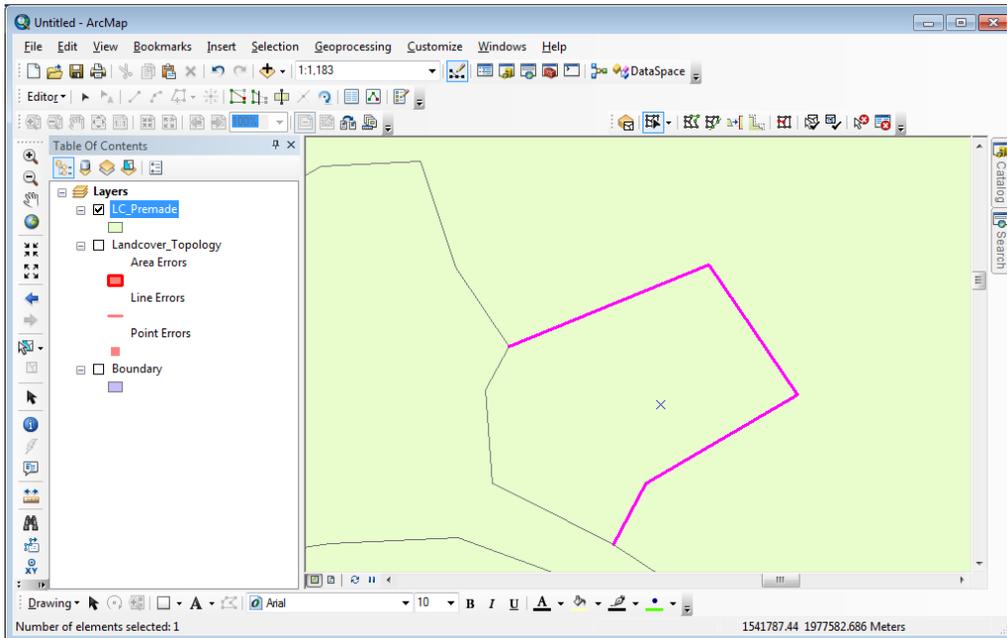
Drag the intersection point in a direction and the 3 lines will automatically adjust their shapes while maintaining their connection.

What's a better real world example where this would be commonly found?

8. **Save and Stop Editing.**
9. **Remove** the Hydro Topology and Feature Classes.
10. **Add** the Landcover_Topology and associated data layers you saved from the earlier exercise.
11. **Start editing.**
12. **Turn Off** the Landcover_Topology and Boundary for now.
13. **Zoom to** an interior set of features that are adjacent to one another.

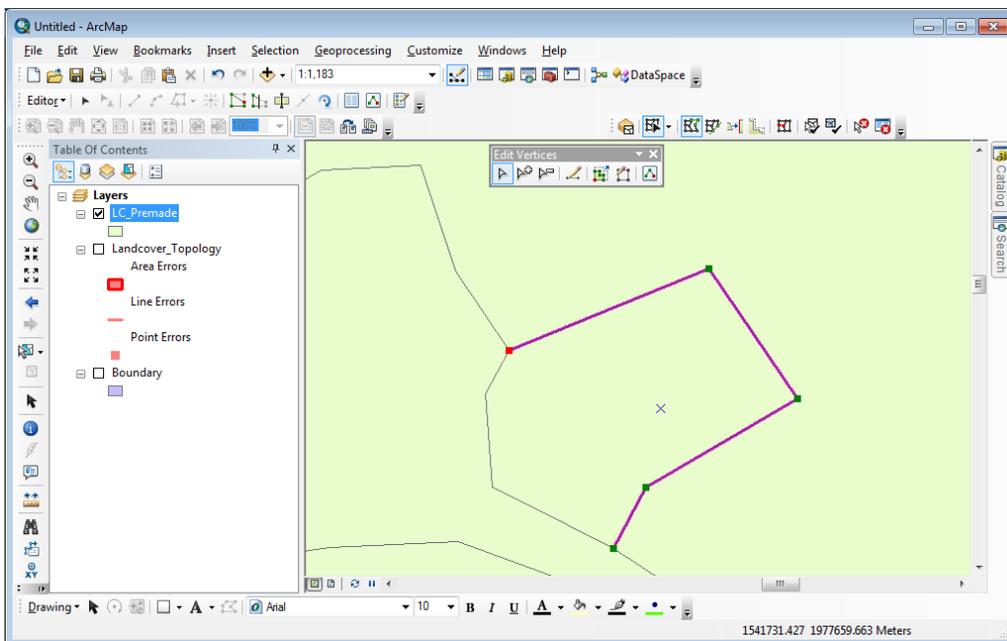


14. **Activate the Edit Topology Tool** and **Select** the boundary of two features.



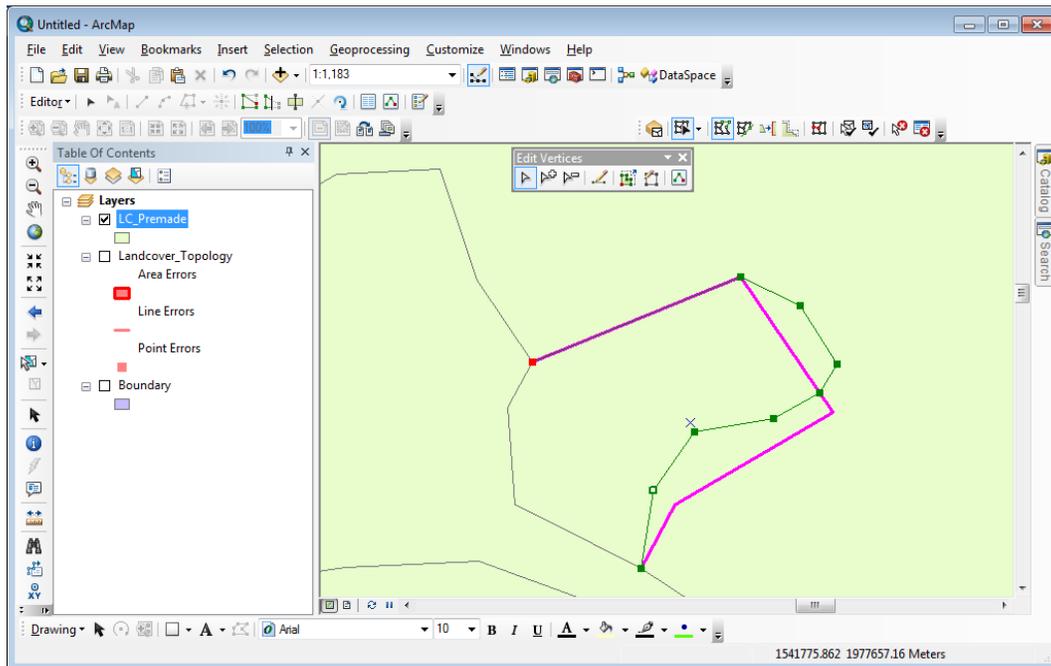
15. With the line segment selected, **double click the line**. This will return the individual nodes on that shared line segment.

You will also see the Edit Vertices toolbar turn on (unless you have disabled that option).



16. **Select** a node and **drag** it to a new spot. You can do this for multiple nodes on the segment.

Right Click on a line section and choose **Insert Vertex**. Repeat a few times for practice.



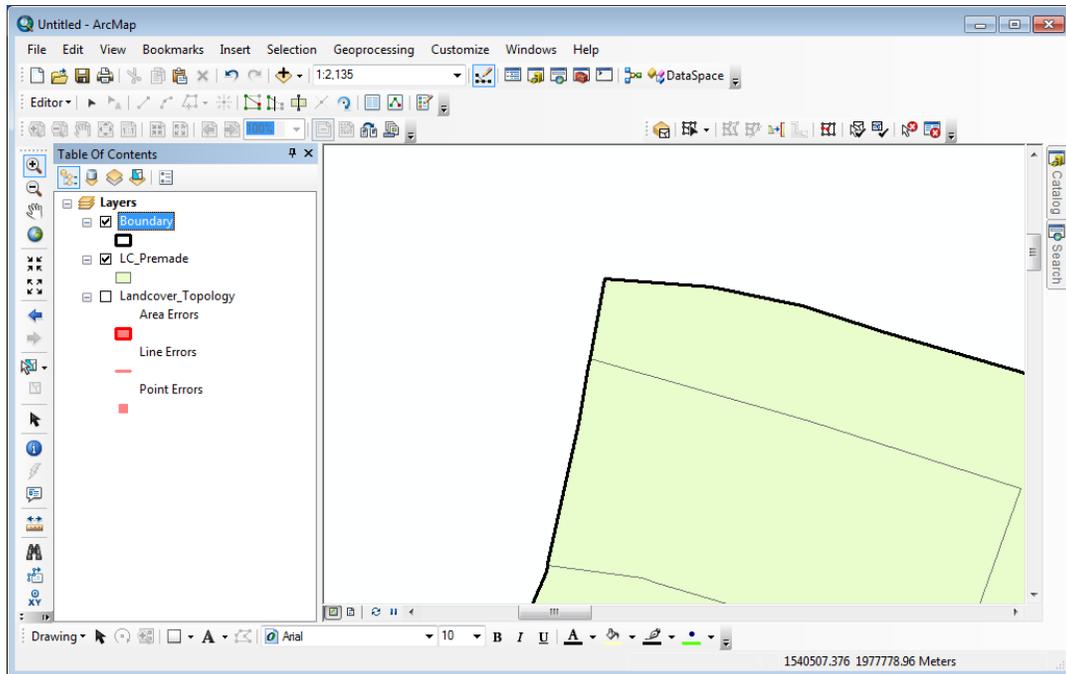
17. When you are happy with your new shape, **Left Click away from the line**. It will deselect all and adjust both polygons (along with other feature classes if related via rules) to your new vertices.

If you made a mistake, Click the Undo button!

18. To verify that your polygons have both adjusted, use **the Identify Tool** to highlight each, and you'll see both boundaries have adjusted.

19. Repeat for practice on another interior feature.

20. **Zoom to** the northwestern corner. **Turn the Boundary layer on**, make the symbology hollow with a thick outline so you can see both layers.



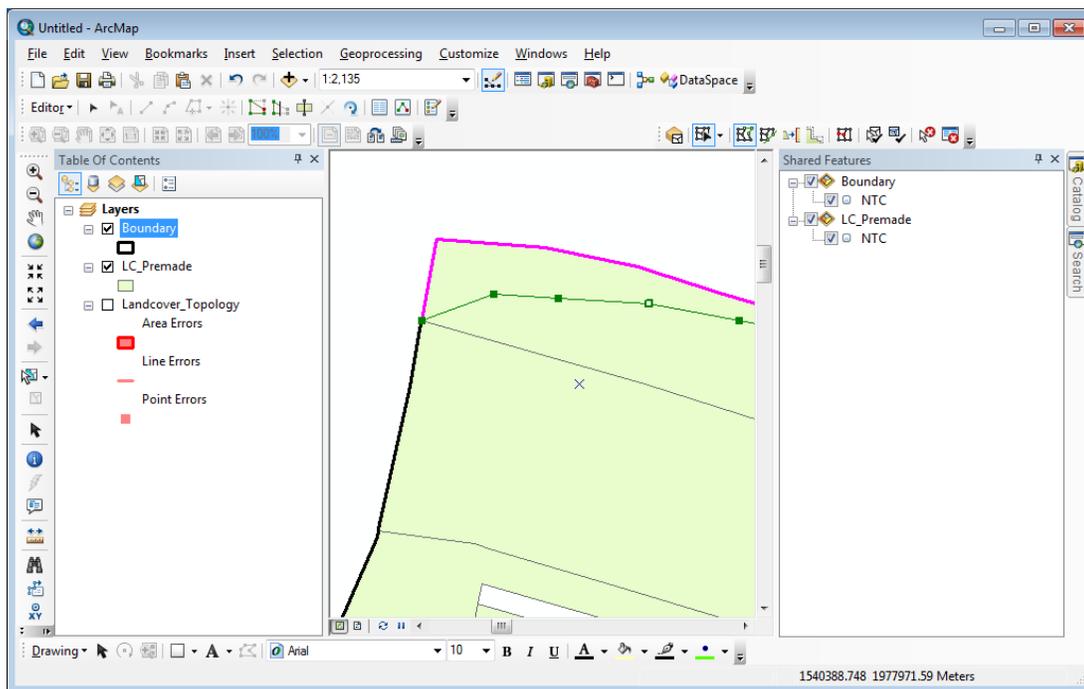
21. On the Topology Toolbar, **click on the Shared Features** button. This turns on a new window that displays the features selected during a topology edit. **Pin** this window to the right edge of ArcMap.

This is very useful when dealing with complex topologies!



22. **Select** the top corner linear feature. In the Shared Edit window, you will one feature for both the Boundary and LC_Premade selected.
23. **Double click** the line to enable vertex editing as you did in Step 14.

24. **Move** a few points to round the corner.



25. **Click away** to finish. You should notice that the landcover and boundary features have been adjusted!

This is very useful but also must be used carefully. When doing real work, we would almost NEVER adjust a boundary and landcover at the same time.

A more applicable example would be a boundary edge has been surveyed, and we are adjusting both a parcel and outer NWR boundary edge to match the improved data.

26. Zoom around and make a few additional changes.

27. **Save edits and Stop Editing.**