Introduction

Triangulated Irregular Networks (TINs) are a surface representation of topography. Since TINs display the topography and are easily edited, they are a useful intermediate data format. Once a clean TIN has been generated, it is converted into Digital Elevation Model (DEM) raster surface, which is better suited for data analysis than a TIN.

Objectives

- Learn to identify and repair points and lines with vertical errors in a TIN.
- Learn to identify and repair area-of-interpolation errors due to survey extent.
- Learn to identify and repair cross channel dams.

Files Used for Tutorial:

The tutorial will guide you through opening the following files:

Map Document: TIN_Editing.mxd
Survey Geodatabase: CBW05583-031546_2013_Repaired.gdb
Layers to be used:
TIN
TIN_original
Survey_Extent
Breaklines
Topo_Points
EdgeofWater_Points

Site Metadata

Site Name: CBW05583-031546
Projection: UTM 11N
Watershed: Upper Grande Ronde
Visit Year: 2013
Visit ID: 1329

Instructions

Getting Started:

1. **DOUBLE CLICK** on the "TIN_Editing.mxd" project file and ArcGIS will open.
2. **ADD** the 3D ANALYST, SPATIAL ANALYST and TIN EDITING toolbars to your project.
3. Begin the exercises.

Exercise 1: Exploring TINs

1. The map window displays a TIN and the topo points from the survey. We have turned on the labels for the "Topo Points" layer to help navigate through this tutorial.
2. **START** exploring the TIN by **TURNING OFF** all layers except for the TIN.

Hint
Use the checkboxes in the Table of Contents to turn the visibility of any layer on or off.

3. In the TOC, you can see the symbology for the TIN. The colors for the polygons represent changes in elevation. In this example the elevation was collected in meters. Very light gray is the highest elevation on the TIN and light blue is the lowest.
   a. ***Is the downstream end of the survey at the top or bottom of the Map window?***

Hint
Water flows downhill from HIGH elevations to LOW elevations.

   a. Look at the elevation for the site. ***Does the range look reasonable for what you might encounter during a survey?***

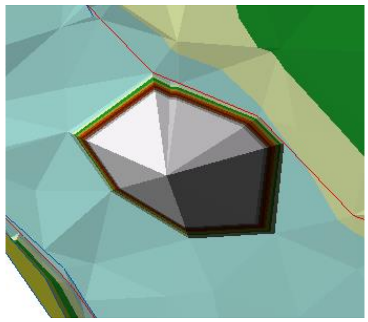
   b. Pan around the TIN to become more familiar with what a TIN looks like. ***Do you see the following?***
      i. A TIN is composed of triangles.

      ii. The triangles interpolate elevations between points.

   c. Some triangles have vertices of topo points, and some do not. ***Can you find a TIN vertex that doesn't have a topo point associated with it?***

TIP – Visualizing 3D Data in ArcCatalog
If you are having trouble visualizing certain parts of the TIN in the map view, you can use ArcCatalog to quickly visualize the TIN in a 3-D environment. ArcMap must be closed. 1. Use your WINDOWS START menu to **FIND AND OPEN** ArcCatalog. 2. Under the CUSTOMIZE menu, make sure the 3D ANALYST extension is checked. 3. Under the TOOLBARS menu, **UNCHECK** the 3D VIEW tools. 4. In the Catalog Tree, **NAVIGATE** to the TIN, and **CLICK** on it. 5. **SELECT** the "Preview" tab. 6. At the bottom of the "Preview Window", **SELECT** Preview: "3D view". You can now **PAN**, **ROTATE**, and **ZOOM IN** on the TIN to help visualize the 3D aspects of the TIN surface.

2. **ZOOM IN** to the portion of the survey shown in the image below. It is “Point_Number 494”, you can see information about the point by using the IDENTIFY tool, by looking in the attribute table or by using the FIND tool. Be careful to look at the “Point_Number” field not the “ObjectID” field.



7. **NOTICE** that the elevation at this point in the middle of the stream appears to be much higher than surrounding points (remember color indicates elevation)
   a. ***Is this a HIGH or LOW area of elevation in the TIN, relative to the TIN surface around it?***

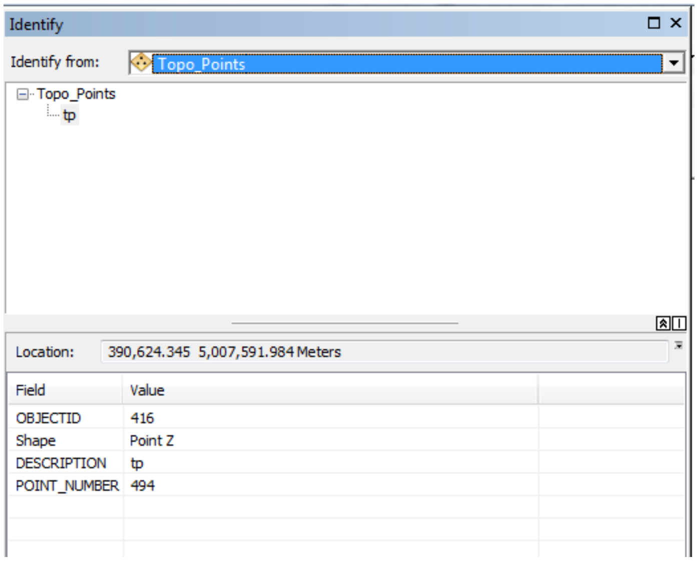
   b. ***Is this a real feature of the survey, like a boulder, that was surveyed in?***

   c. ***What might indicate this is a real feature that was surveyed in by the crew?***

8. For this exercise we will assume it is not a real feature and that this is an error in the surface. Something that looks like this is called a 'bust' point. Bust points have high elevations relative to the surrounding TIN area.
   a. **NOTICE** how the color banding covers 3 bands in a short distance.
      i. This is typical of a “Bust Point” where the Z value was incorrectly collected for the point. Often this is caused by an incorrect Rod-height entered in the Total Station.
      ii. The opposite of a Bust Point is a “Sink Point,” where the Z-value of a point is low relative to the TIN surface around it. A sink point looks very similar to a bust point except the color ramp will indicate that elevation is a low point, or hole, rather than a high point.

8. **TURN ON** the “Topo Points” layer. ***Is there a Topo Point in the center of this pyramid?***

9. If so, use the IDENTIFY tool , **CLICK** on the “vertex” of the bust point (the high point of the pyramid). In the IDENTIFY POINT window, the “Topo Point” layer should be selected in the dropdown.
    a. If this isn't the case, **CHANGE** the “Identify from” dropdown menu to “Topo_Point” by **CLICKING** the “IDENTIFY” tool icon again.



    b. ***What is the Point_Number (Topo Point layer)?***

10. Once a bust point has been identified as a Topo Point with a bad elevation, the next step is to do a TEST repair of the TIN NODE to see if changing the elevation repairs the bust. We will do this in the next exercise.

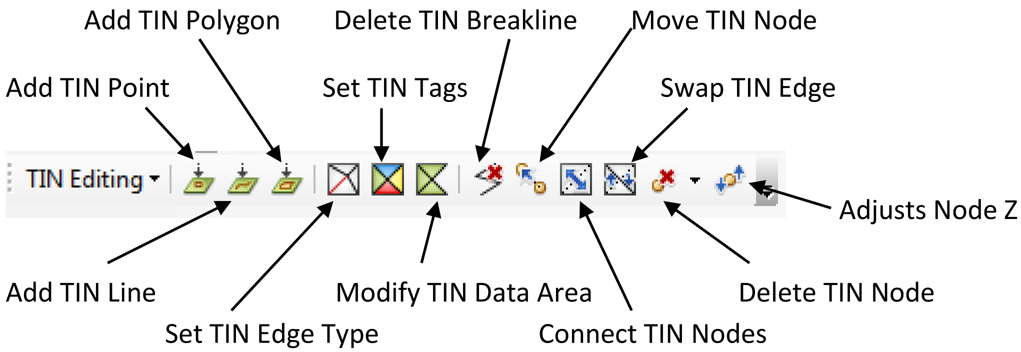
Exercise 2: Editing TINs

Adjust the Z-value of a TIN Node

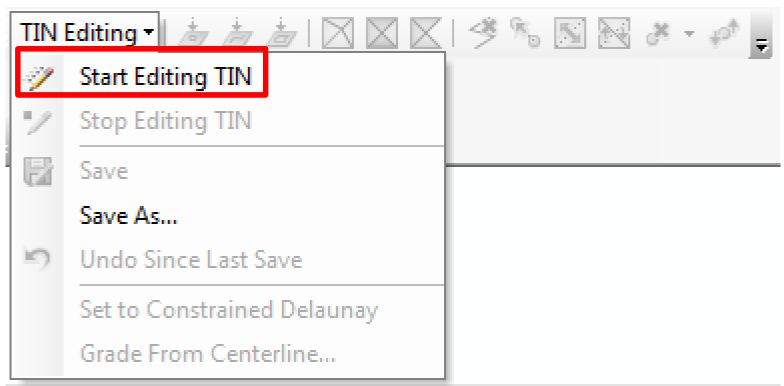
In this exercise you will learn how to edit the z-value of a TIN node.

1. Make sure the 3D ANALYST toolbar and TIN EDITING toolbar are turned on by going to the menu called CUSTOMIZE, then to TOOLBARS, and see if both toolbars are checked in the list.
2. Make sure the TIN you wish to edit is selected in the “Layer” box in the 3D ANALYST toolbar. For this exercise it is called “tin”.

3. Introducing the TIN EDITING toolbar.



4. **START** a “TIN Editing” session from the TIN EDITING toolbar.



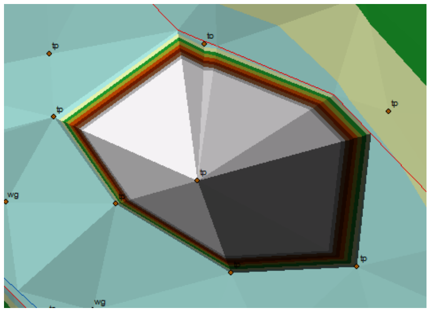
IMPORTANT – TIN Edits
Any edits you make to the TIN can only be undone to the last time the TIN was saved. It is recommended that you save your TIN often, but thoughtfully, since saving makes the edits permanent. If you do make or save an un-repairable edit, you can always create a new TIN from your data.

5. **RETURN** to the bust at topo point “494**”** if you have navigated away from it. For the purposes of this exercise, use whole meters to adjust the height of the points.

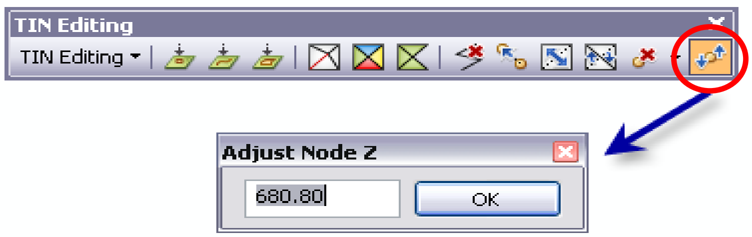
Surveying Tip!
Most of the time during a CHaMP survey, elevation error are due to a rod height change. Surveyors only use rod heights in increments of 0.5 m so rod, so any adjustment to the z value of the node should be in 0.5 increments. Rod height errors are easy to fix when the rod is adjusted in fixed intervals.

6. We want to keep this node and not delete it because there are only a few topo points around this node and it's providing valuable elevation information for the TIN.

7. **ZOOM IN** to the "point", similar to the screenshot above.



8. **CLICK** the "ADJUST NODE Z-VALUE" tool in the TIN EDITING toolbar. A box will appear that lets you set the z-value (elevation) of a node.

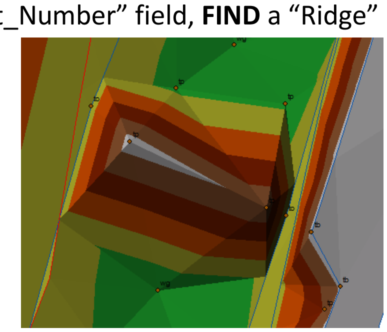


   a. **CLICK** on the "Point". ***What is the Z value?***

   b. **CHANGE** the "Z value" in the box to "1063.71**"** and **CLICK OK**.
      i. ***Does this look correct, or does it still look like a bust point?***

   c. C**HANGE** the "Z value" in the box to "1058.71" and **CLICK OK**.
      i. ***How does it look now?*** The color of the TIN for this area should now match the adjacent areas of the TIN, which means the elevations are similar.

9. We will now adjust Z values to deal with "Ridges", which is when two or more bust points are adjacent and the tin forms a ridge.
10. Using the "Point_Number" field, **FIND** a "Ridge" at numbers 926 and 927 --it should look like this:



a. One way to zoom to the points is to **OPEN** the "Attribute Table".
b. **SELECT** one of the point records by clicking in the gray box to the left of the record in the table.
c. **RIGHT CLICK** and **SELECT** "Zoom To".
    i. These two points form an artificially high "ridge." Artificial ridges, and their negative counterpart "artificial troughs", are created by points collected with an incorrect rod height in series. It is usually more common to encounter groups of points with incorrect rod heights rather than solitary ones.

11. **ADJUST THE HEIGHTS** of these "2 nodes" so that the ridge is no longer visible.

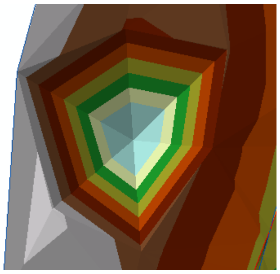
Hint:
If you don't know if this was a rod height error and the exact elevation change required, review the elevations of surrounding points to determine what a reasonable elevation would be for these nodes.

12. There is another "ridge" in the survey. **SEARCH** the "TIN", **LOCATE** the "ridge", and **REPAIR** the "ridge".
13. **SAVE** your TIN edits.

Delete a TIN Node

When an area is well defined by the breaklines and nearby points, it is sometimes better to delete the TIN node than adjust the elevation. Additionally, sometimes ArcMap adds nodes to TINs where Topo Points are not located to help generate triangles within the surface. These are called "artificial nodes", and sometimes these nodes end up causing irregularities in the surface that can be corrected by deleting the nodes. Now we'll practice deleting a TIN node.

1. **NAVIGATE** to topo point number "814" Shown in the image below.



2. ***Is this a Bust or a Sink?***

3. Since this area is already well defined by the breaklines and nearby points, we will choose to delete this point from the TIN.
4. **CLICK** the "Delete Node" tool in the TIN EDITING toolbar.

5. **CLICK** on the "Node" under the label of point "814".
6. **NOTICE** how the TIN is adjusted after the Point is removed. ***Does this look more reasonable?*** Note that the NODE from the TIN is being deleted, not Topo Point 814.

7. ***There is another Sink in the TIN, can you find and repair it?*** Decide whether to delete or adjust the Z value of the node.

8. **SAVE** the edits you have made by **SELECTING** "Save" in the TIN EDITING toolbar menu.

TIP – Points are NOT nodes
After you delete a node from the TIN, the point feature in the survey class will still show up, creating the appearance that you did not actually delete the node.

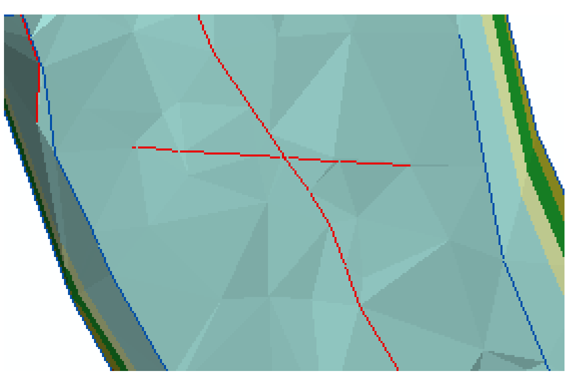
Editing Breaklines

Breaklines can be either "Hard" or "Soft", and can be used to help define the surface of a TIN.

- Hard breaklines: represent a discontinuity in a surface's slope and when used change the shape of the TIN surface. For example the top of bank and toe of bank lines are hard breaklines.
- Soft breaklines: let you add edges to triangles to better represent a feature in you data without changing the shape of the TIN surface. For example, you can use a soft breakline to connect two depressions in the stream channel so that a dam is not formed.

Sometimes it's necessary to edit breaklines, such as when breaklines have incorrect z values or are crossed. These issues can occur with rod height errors or if the rodman collects breaklines that are very close together (e.g. steep slopes).

1. **FIND** the area on the TIN that looks like the image below.



2. Field notes indicate that this breakline has been placed in the wrong spot. Hard breaklines are edges and should not cross because they can create irregular surfaces in the TIN.

3. We will use the DELETE BREAKLINE tool in the TIN EDITING toolbar to delete the breakline.

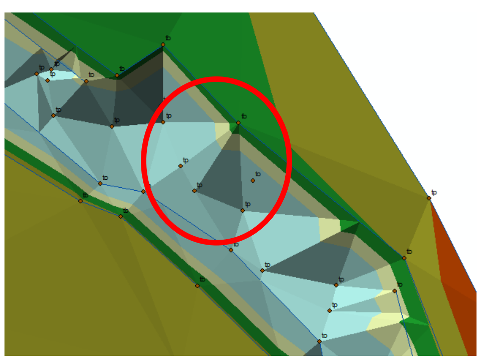
   a. Generally, this is a last-resort tool since we are losing a significant amount of survey information at this location, but sometimes it is the only way to repair a TIN.
   b. Ideally an error such as this should be repaired in the breakline feature class.
   c. In this case, deleting this line does not negatively impact the TIN because the features and elevations around the suspect breakline are all very similar and this was noted as a field error.
4. With the "DELETE BREAKLINE" tool highlighted, **CLICK** on the "line that crosses from left to right".
5. **SAVE** your TIN edits.

Editing Breaklines can be tricky…
Adjusting and editing breaklines is not as straight forward as you might think. Breaklines are not simple features that connect two nodes; rather, they are able to *insert* nodes in the TIN as needed to keep the Delaunay Triangulation. If you delete a node, move or add a breakline, additional nodes may be added along the breakline. To avoid this: 1. Do as much editing of the breaklines as you can in the point file, before they are incorporated in a TIN. 2. If you delete a node in the TIN along a breakline, it will usually add another along the breakline. 3. You may have to keep deleting these "artificial nodes" until you reach the next actual "surveyed node."

Connecting Nodes with a Breakline

Sometimes points are collected in the field with the same code but are intended to be connected together as a breakline. For small changes, it is acceptable to make edits directly to the TIN. (If an entire line is missing, it is better to create this feature in the Breakline Feature class and recreate the TIN).

1. **FIND** the location in the TIN depicted by the image below.

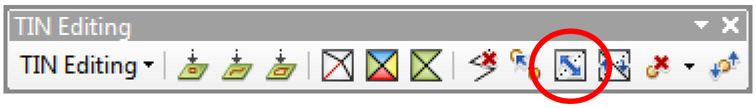


2. ***Can you see the 'prism' along the bank that protrudes into the channel?***

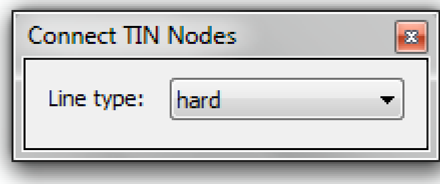
a. In this case, the survey team didn't connect several Toe ("to") points at the base of the bank. The TIN elevations at this location are higher than the surrounding channel.

b. We will add a hard breakline between these points by connecting the end nodes of the breaklines.

3. **CLICK** on the "CONNECT TIN NODES" tool.

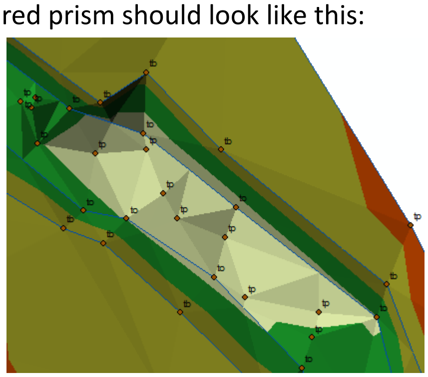


4. In the popup box, **SELECT** "hard line" line type.



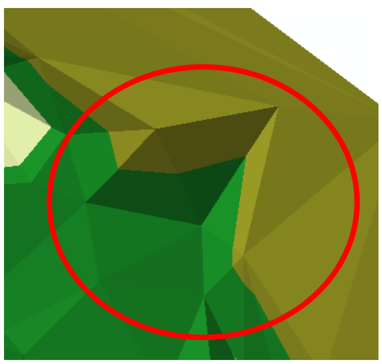
5. **CLICK** on the end node of one of the breaklines, then **CLICK** on each point that has a "to" label until you get to the end node of the other breakline. (See the 2 triangles in the image for your start and stop points if this is confusing).

6. If it seems the tools will not connect a particular pair of nodes, it is because the two nodes are already connected and the tool will not allow you to connect them again.
7. The repaired prism should look like this:



8. ***Do you see any more prisms along the water's edge?*** (**HINT**: there's one upstream of the one you just repaired)

Repair a Breakline

TIP – Artificial Notches
The inverse of the artificial prism we fixed in this example is known as a “notch.” Typically, these appear at the top and sides of a bank where “Top of Bank (tb)” lines are not connected. It is generally good practice to keep Top of Bank lines as continuous as possible, even if the slope of the bank becomes shallower. This helps prevent the formation of such notches. 

Turning TIN Triangles on or off:

Sometimes it's necessary to change the area of TIN interpolation and this is done by turning TIN triangles on and off. An example is when the Survey Extent area extends beyond the topo points at the upstream or downstream end of the survey (Figure A). It can also occur if the tolerance was set too high when you made the survey extent and there are triangles across and area with no survey points (Figure B).

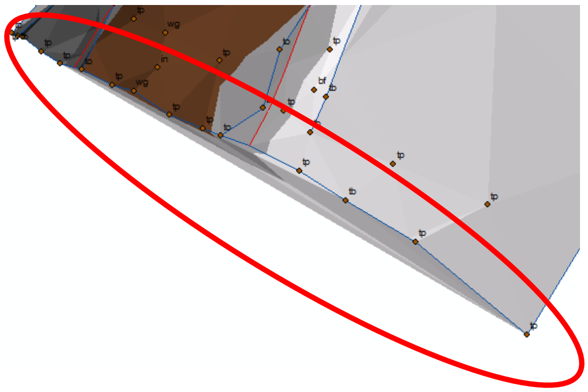


Figure A

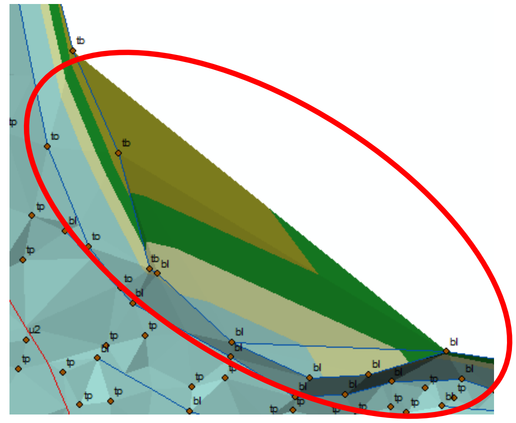


Figure B

1. **LOOK** at the edge of the TIN in Figure A.
   a. **NOTICE** how the TIN connects points across the stream to both banks, forming a "dam."
      i. ***Is this a likely part of the stream topography?***

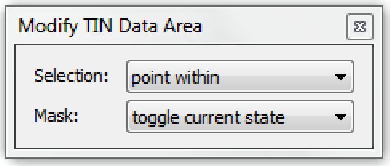
      ii. This might be a real feature, such as a beaver dam, or this might be an artifact of the TIN generation. In this case, it's because the survey extent polygon was not edited to follow the topo points at the end of the survey. If this were a beaver dam, it should have been mentioned in the field notes.
   b. **ZOOM** to the "lower end" of the TIN.
   c. **COMPARE** the "TIN", "Survey Extent" polygon and "Topo Points" layers.
      i. **NOTICE** that the "Survey Extent" polygon and "TIN" do not follow the "Topo Points" across the end of the channel.
   d. The triangles in this area are very long and thin, which means that survey points were not collected over a wide area and thus no information is provided by the survey crew about the topography between these two points.
      i. ***Do you trust the topography represented in this part of the tin?***

   e. For this exercise, we will clean up the unwanted triangles at the end of the survey by hiding them using TIN Editing.

Note
1. Since we are only editing the TIN, if the TIN is remade, this dam will reappear in the next version of the TIN. 2. Only if the Survey Extent was edited and the TIN was remade would this issue not reoccur with new versions of the TIN.

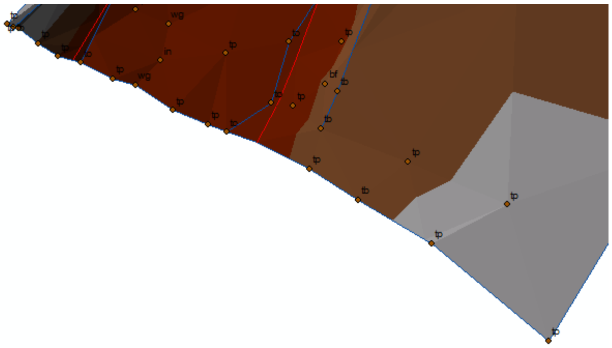
2. **CLICK** the “MODIFY TIN AREA” tool.

3. In the dialog box that pops up, **SET** the values the same as shown below. The values below are the easiest way to use this tool and we suggest using these at all times for this tool.



4. **CLICK ON** the outermost triangle. **NOTICE** how the TIN adjusts itself after the point is removed.

5. **CONTINUE CLICKING** on triangles until the edge matches the survey points and looks like the image below.



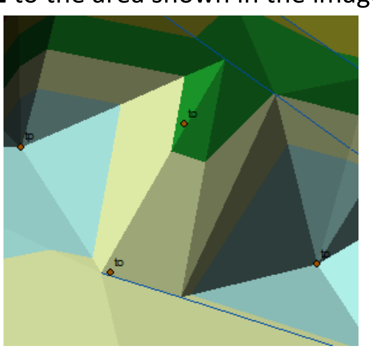
6. The TIN now follows the topo points at the end of the surface and no dams exist across the end of the survey.

TIP – Edit the Survey Extent Polygon
Ideally the best way to repair the aforementioned TIN Extent error is to edit the Survey Extent and generate a new TIN rather than just removing triangles in the TIN. This way, these changes are preserved if you need to generate new tins in the future.

Removing Artificial Dams:

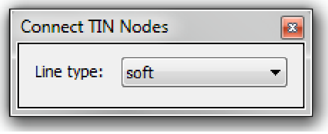
An "Artificial Dam" across the channel is formed by a lack or low density of topo points in the stream channel in an area of the survey. In the image below this artificial dam appears to block the flow of water (TIN color indicates the dam area in the channel is higher elevation than the blue areas upstream and downstream of the dam). It's difficult to predict when the geometry of survey points will generate a dam in a survey, but areas with low density of points, such as side channels, are high risk areas for this issue.

1. **NAVIGATE** to the area shown in the image.

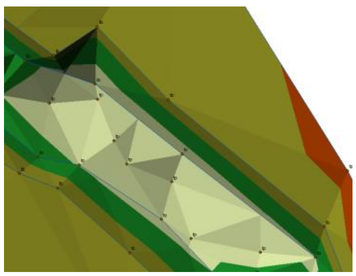


2. **NOTICE** how there is an artificial dam between the two points in the light blue areas. We will repair this by connecting TIN nodes to form a breakline.
3. **CLICK** on the "CONNECT TIN NODES" tool.

4. In the popup box, **SELECT** "Soft" line type. ***Why would we use a soft breakline here instead of a hard breakline?***



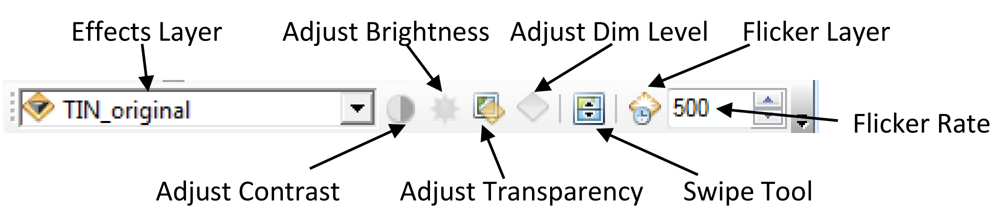
5. **CLICK** on the node for point number "611".
6. **CLICK** on the node for point number "613".
7. **USE** the "IDENTIFY" tool to determine the point number if you need to.
   a. A new breakline will define the lower elevation of the channel. This does add some interpolated elevations to this part of the channel; however, this is more realistic than what the tin was previously showing. For small sections of stream, this is an acceptable edit.



TIP – Thalweg lines prevent Dams
In narrow sites where it is difficult to capture a high density of points to maintain a pattern of equilateral triangles in the channel, survey the Thalweg as a continuous line (wg). This will force the TIN to maintain the low elevation of the channel to the Thalweg line and prevents the formation of artificial dams.

Comparing Your Repairs to the Original TIN.

1. When all your repairs are complete, your TIN color range will no longer be correct.
   a. **RIGHT CLICK** on the "tin" layer in the TOC.
   b. **CHOOSE** "Reset Legend Elevation Range" from menu.
2. From your working directory, **ADD**  the "TIN_original" file to your map document, if it is not already present.
3. **MOVE** it so it is above your edited TIN in the TOC and that both TINs are turned on.
4. **ADD** the "EFFECTS toolbar" to your screen, if you have not done so already. It will look like the image below.



5. In the "Effects Layer" box, **MAKE SURE** the "TIN_original" layer is selected.

6. **CLICK** on the “SWIPE” tool.
    a. A large black triangle will appear on the MAP DISPLAY screen.
7. **HOVER** the cursor over the TIN, **CLICK AND HOLD**.
8. **MOVE** the cursor on the screen and you should see “TIN_original” disappear and reappear.
9. **ZOOM** to where you made TIN repairs.
10. **SWIPE** the “TIN_original” layer across your edited TIN to see the difference between the two TINs.
11. If you did a good job editing, you may not see much of a difference.
12. After all TIN editing is done, we recommend scanning the entire TIN to review the final result.

Finish and Close

1. On the TIN EDITING toolbar, **SELECT** “Save”.
2. **SELECT** “Stop Editing TIN” to exit the TIN editing mode.
3. **SAVE** the “.mxd document”.
4. **CLOSE** ArcMap.

Continue Editing the TIN

Take this opportunity to explore how the tools we have discussed affect the TIN (Remember to SAVE your tin before you attempt this!). Try deleting a ‘good’ breakline or node and see how the TIN changes. Then, use the “Undo since Last Save” command under the “TIN EDITING menu” to restore your TIN.

Resources

ArcGIS 10.1 Help

http://resources.arcgis.com/en/help/main/10.1

TIN Editing Toolbar

http://resources.arcgis.com/en/help/main/10.1/index.html#//006000000006000000