

# EXERCISE 8

## Local Analysis Using the Raster Calculator

### Introduction

Analyzing a raster on a cell by cell basis is referred to as Local Analysis. In this exercise you will explore the many functions available to analyze a raster on a local basis by using the Raster Calculator. The Raster Calculator is a Spatial Analyst function that provides powerful tools for performing multiple tasks: you can perform mathematical calculations using operators (such as addition and subtraction) and functions, and set up selection queries (similar to “Select by” queries done on vector data).

### Required Data

- **Mosaicked DEM—mtaire\_dell\_10m\_mosaic.tif**, this is the mosaic of two 10m Digital Elevation Model (DEM) rasters. They are located in a portion of the Wasatch-Cache National Forest, just east of Salt Lake City, UT.
- **Surface Layers**—either from previous exercise, or generate them again quickly for this exercise.
- **Slope from 10m DEM—slope\_10mDEM.tif**
- **Aspect from 10m DEM—aspect\_10mDEM.tif**
- **Utah Land cover—clipped\_ut\_lc.img**

### Prerequisites

It is assumed for this exercise that the Spatial Analyst extension and toolbar is activated. If you need help with this please refer to the ArcGIS help. It is also assumed that you are using the data provided or that you have DEM, Slope and Aspect rasters that you will be using for this exercise.



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# Part 1: Add the Raster

You need to add the three rasters to your ArcMap instance. You will be doing some Raster Math with these three rasters and in Part 2 you will explore some basic cell statistics functions.

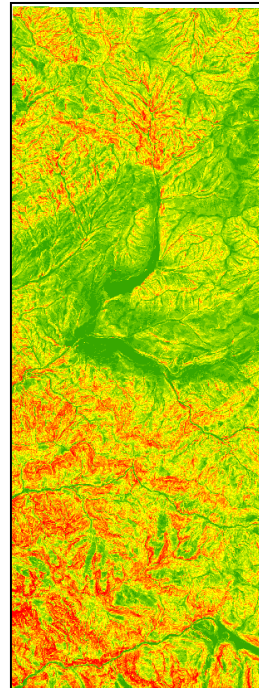
## A. Start ArcMap

1. Start ArcMap by clicking on the Start button and navigating to **All Programs, ArcGIS, ArcMap 10.**

## B. Add the Data

1. Click the **Add Data** button—if you don't already have the Slope, Aspect and DEM rasters in your ArcMap document.
2. Navigate to **C:\rgp\Data\DEM** and add **mtaire\_mtdell\_10mDEM.tif** and the Slope and Aspect rasters from Exercise 8.

- i. NOTE: If you re-add the Slope and Aspect layers from earlier outputs, they will not be displayed using the color scheme you see after they are first generated (like the ones in the graphics below), rather they will come in with the Default Renderer of Grayscale.



*Please make sure you have activated the Spatial Analyst extension. From the main menu navigate to **Customize, Extensions....***

*Ensure there is a check mark next to **Spatial Analyst**. Close the dialog when done. You will need this done before the next Part.*



## Part 2: Raster Calculator- The Basics

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Before you dive into raster math it is important to first familiarize yourself with the Raster Calculator so that you can use it more effectively. Like other geoprocessing tools, the Raster Calculator can be used in ModelBuilder, allowing the power of Map Algebra to be more integrated into your workflows.

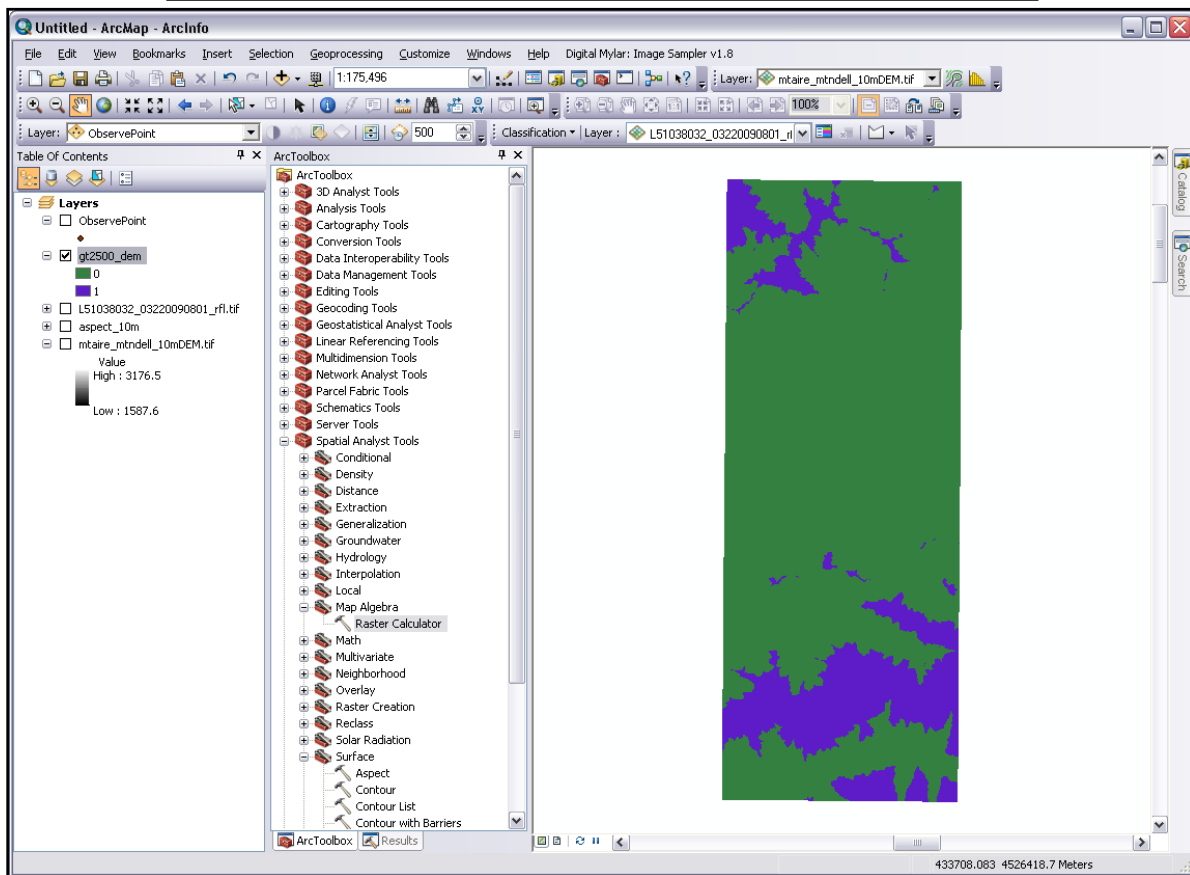
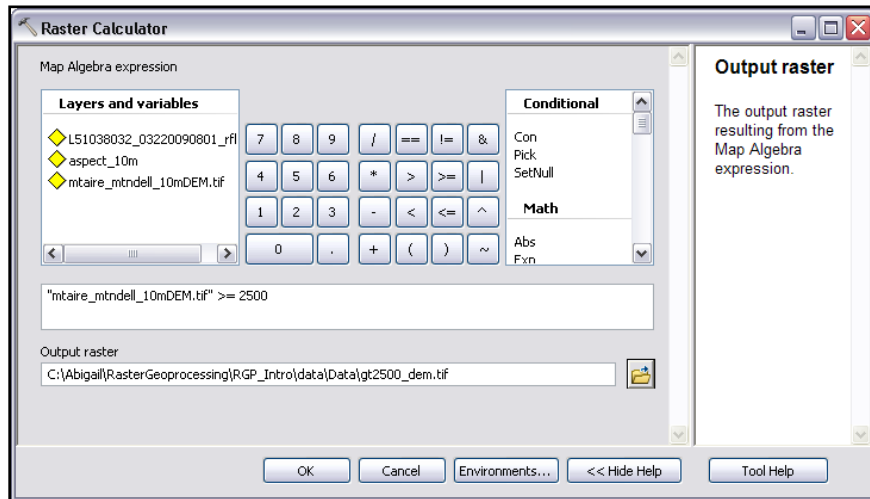
### A. Open the Raster Calculator

1. From the ArcToolbox, locate the Spatial Analyst toolset, click the “+” and navigate to Map Algebra, Raster Calculator.
  - i. The Raster Calculator opens. You will notice the “Layers & variables” window is populated with all of the current raster layers in the map document. These names can be double clicked to add them to the calculator expression that you will build.

### B. Building Expressions

1. The Raster Calculator requires that you understand a little bit about Map Algebra. To learn more about Map Algebra see Appendix 1.
  - i. Let’s try a really simple expression/query. In the Raster Calculator double click **mtaire\_mtdell\_10mDEM.tif**, click the **>=** button, and then type the number 2500. Your input should look like this **“mtaire\_mtdell\_10mDEM.tif” >= 2500**
  - ii. Choose an Output location and name it appropriately and Click **OK**.
  - iii. The output will return all cells with value 2500 as 1 and all cells less than 2500 with a value of 0. This is a simple way to query your rasters. Your output should look similar to the graphic on the next page.





*Recall the primary raster analysis operators:*

1. Arithmetic operators and tools (“+”, “-”, “\*”, “\”)
  - using an arithmetic operator, how would you add two rasters?
1. Relational operators (“<”, “>”, “<=”, “>=”, “+”)

- using a relational operator, how would you select all elevations less than or equal to 1000m?
- 3. Boolean operators (True/False expressions, using “And, Not, Or, Xor”)
  - using Boolean logic, could you find elevations in a DEM that are equal to both 1000m and 2000m?
- 4. Conditional tools (assign one value if a condition is true, and another value if it is false) (Con, SetNull, and IsNull)
  - using Conditional logic, how would you simulate a tree clearing in a Lidar canopy height raster?

## Part 3: Simple Expressions (True/False)

Let’s get started with a simple expression. Suppose you are interested in identifying the habitat of a selective plant which only grows at elevations above 2500 meters and below 3500 meters.

### A. Open the Raster Calculator

1. Open the **Raster Calculator (Spatial Analyst, Map Algebra)**.

### B. Build your expression

1. We are going to create a raster that identifies a specific elevation range for a plant that has specific growing conditions.
2. To start the expression, add an open parentheses “(”, then double click **mtaire\_mtdell\_10mDEM.tif** in the **Layer** window.
3. Click the **<=** button.
4. Type **3100** (the upper limit of the plant’s growing range) and then close the parentheses.
5. Next, click the **&** button because we need to include the lower limit of the growing range.
6. Add an open parentheses “(”, then double click **mtaire\_mtdell\_10mDEM.tif** again.
7. Click the **>=** button.
8. Type **2500** (lower limit of the plant’s growing range) and then close the parentheses.
  - i. Your expression should look like:
    - ii. **(“mtaire\_mtdell\_10mDEM.tif” <= 3100) & (“mtaire\_mtdell\_10mDEM.tif” >= 2500)**
9. Name the output **fickle\_plant.tif** and click the **OK** to calculate your expression.
  - i. After a few moments of processing, the resulting raster gets placed in your **Table of Contents** with the name **fickle\_plant.tif**.

### C. Check out your results

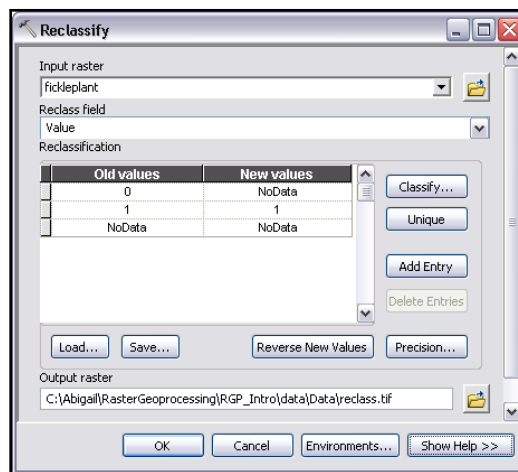
1. You will notice that the raster only has two values, “0” and “1”. The “0” value indicates the results of the expression that were false. In other words, the “0” values have elevations that are below 3100 meters and greater than 2500 meters. The “1” value indicates points that satisfied the expression. These are locations where we might find the fickle plant. **This was an example of two Relational operators combined by a Boolean operator.**

## Part 4: Using your Output

You have a raster selection that you would like to use in further evaluation or analysis. Let's explore some other options you have with that raster calculation from Part 3.

### A. Reclassify—Set NoData values

1. For the regions that didn't meet our criteria (aka "zero" in the output), let's change those to NoData using the Reclassify tool.
  - i. Can you recall the difference between NoData and Zero?
2. From ArcToolbox, navigate to **Spatial Analyst, Reclass, Reclassify**.
3. Choose **fickle\_plant.tif** as the **Input Raster**.
4. For the **New value** for "0" change it from 1 to NoData.
5. For the **New value** for "1", let's keep it as 1, so change it from 2 to 1.
6. Choose an Output location and name for your new raster.
7. Your window should look like the graphic to the right. Click **OK** to create a temporary raster with the new NoData settings.
8. Turn off your raster called **fickle\_plant.tif** output so you can see the effects of your Reclass.



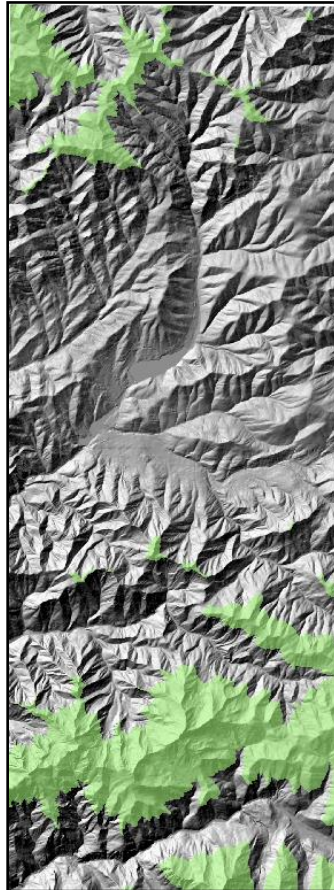
### B. Make layer transparent

1. Activate the **Effects** toolbar if it isn't already and dock it next to your other toolbars.
  - i. Hint: View, Toolbars, Effects **or** right click in the gray space around your other toolbars and the Toolbar list will drop down.
2. Choose **Reclass of fickle\_plant.tif** as the **Layer** on the Effects toolbar.
3. Adjust the transparency for the **fickle\_plant.tif** raster to 40%.

### C. Visualize results

1. Click the Add Data button and navigate to your hillshade raster. Add it to your ArcMap instance.

2. Move the hillshade below the **fickle plant** layer in the Table of Contents (your results should look similar to the graphic below).



## Part 5: Suitability Analysis

Suitability Analysis encompasses a wide range of possibilities, you just have to have a question in mind and be creative with utilizing the rasters that will help you answer that question.

*Goal: Explore the capabilities of the Raster Calculator for conducting a Suitability analysis.*

*Scenario: You have been tasked to locate areas that would be suitable for a new picnic area. Here are the ideal criteria for this new picnic area:*

1. *At less than 2500m elevation*
2. *On a south facing slope*
3. *On a slope less than 15 degrees*

*You will use some basic raster math to locate suitable picnic site locations.*

### A. Open Raster Calculator

1. From ArcToolbox, navigate to Spatial Analyst, Map Algebra, Raster Calculator.



2. Double click **Raster Calculator...** to open it.

## B. Build Elevation Expression

Using what you have learned about creating expressions, such as typing operators or clicking them from the calculator, build the following expressions to create raster calculations that will be used to find a suitable location for your picnic areas.

1. Enter the following query to achieve a calculation that identifies the areas that are less than or equal to 2500m.
  - i. **"mtaire\_mtdell\_10mDEM.tif" <= 2500**
  - ii. This expression will return all elevations that are less than or equal to 2500m a value and assign them a generic value of 1 and all other elevations a value of 0.
2. Set the output location and name your raster something appropriate. Don't forget to include the .tif or .img extension.
3. Click **OK** to run the calculation.

## C. Add Aspect & Slope Rasters

1. Click the **Add Data** button and navigate to your Aspect raster.
2. Add it to your ArcMap instance.
3. Click the **Add Data** button again and this time add the Slope raster to your ArcMap instance.
  - i. If you haven't created the Aspect and Slope rasters, you will need to refer to Exercise 8 or find the tools in the ArcToolbox under **Spatial Analyst, Surface**.

## D. Create South Facing Aspects raster

1. Open the **Raster Calculator** and enter the following expression:
  - i. **("aspect\_10mDEM.tif" >= 157.5) & ("aspect\_10mDEM.tif" <= 202.5)**
2. Set the Output location and name the output raster appropriately (e.g. south\_aspect.tif).
3. Click Ok to run the process.

## E. Create Low Slope angle raster

1. Open the Raster Calculator and enter the following expression:
  - i. **"slope\_10mDEM.tif" < 15**
2. Set the Output location and name the output raster appropriately (e.g. lessthan\_15.tif).
3. Click **OK** to run the process.

*At this juncture you have three new raster layers calculated from the elevation, aspect and slope rasters based on certain conditions. You will use these three rasters to locate areas of the greatest suitability. If you add the three rasters together in Raster Calculator, then the cells in the output with the value of 3 will be the "most" suitable locations, cells with 2 and 1 will be decreasingly less suitable.*

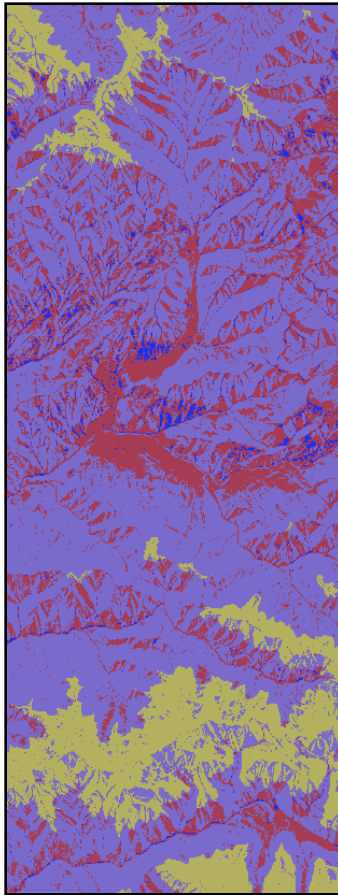
## F. Build Suitability expression

1. Open the **Raster Calculator**.
2. Enter the following raster math string to add all three conditional rasters together to pinpoint the most suitable picnic area locations:

- i. "lt\_2500.tif" + "south\_aspect.tif" + "lessthan\_15.tif"
- 3. Choose an output location and name it **picnic\_suitability.tif**
- 4. Click **OK** to create the suitability raster.

## G. Inspect Suitability Results

1. Your calculation results include 4 values: 0, 1, 2, and 3. Cells with the value of 3 are your most suitable locations because they are where all three of your criteria overlapped. Dark blue in the graphic below (your color scheme will likely be different) represents the most suitable locations (value of 3).
2. Take a moment and **Zoom** into some of these areas.
  - i. Now that you have these suitable locations what can you do with them?
  - ii. You may want to convert them to features (aka shapefile) for even further analysis.



## H. Convert Raster to Feature

1. From the ArcToolbox, navigate to **Conversion Tools, From Raster, Raster to Polygon**.
  - i. The **Raster to Polygon** dialog will open.
2. Choose **picnic\_suitability** for the **Input raster**.
3. Leave all other parameters at their defaults.

4. For the **Output features** set the location to **C:\rgp\Data\DEM** and name the output **suitability**.
5. Click **OK**.

## I. Display GRIDCODE values

1. Open the **Layer Properties** for the **suitability** shapefile.
  - i. Hint: double click the layer.
2. Click the **Symbology** tab.
3. Choose **Categories** from the **Show** pane.
4. Choose **Unique Values**.
5. From the **Value Field** dropdown menu, choose **GRIDCODE**.
6. Click the Add All Values button.
  - i. The 4 raster cell values will appear.
7. Click **OK** to display the values. You now have a vector output of your picnic site suitability analysis.

## Part 6: Conditional Statements

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Conditional statements are useful for exploring situations, even hypothetical situations. It still evaluates a true/false expression, but it allows you to “set” the output values of your chosen true and false results (instead of taking the generic 1 and 0).

**Goal:** Familiarize yourself with the Conditional tool—a powerful component of the Raster Calculator.

**Scenario #1:** Extract the land cover types (from *clipped\_ut\_lc.img*) that exist at elevations greater than or equal to 2000m:

**Scenario #2:** Extract the DEM elevation values for elevations greater than or equal to 2500m, and are south-facing slopes that are less than 10 degrees in steepness.

### A. Add Utah Land cover raster

1. Click the **Add Data** button and navigate to **C:\rgp\Data\Utah Landcover** and add the **clipped\_ut\_lc.img** raster to ArcMap.
2. Move the layer to the bottom of your display.

### B. Build a simple Conditional Statement

1. Open the **Raster Calculator**.
2. In the Expression window enter the following expression:
  - i. **Con (“mtaire\_dell\_10m\_mosaic.tif” >= 2000, 1, 0)**
  - ii. In reality, the above statement is not any different than a simple query of the DEM raster. The output will have a 1 where the condition is true and a 0 where it is false. **If you don’t enter a False value** (e.g 0), the default false output will be **NoData**. This is a good thing and a nice option and an easy way to set unwanted data values to NoData. *A query would*

*return the same result. The question is, how can we use the conditional statement in a more powerful way?*

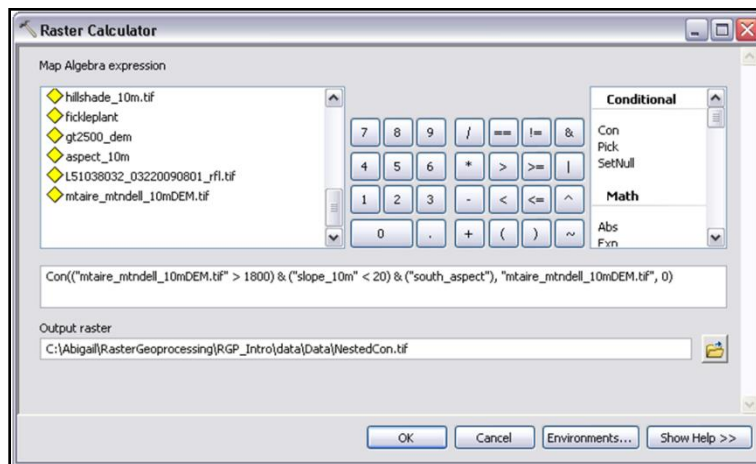
3. Set the output location and name the raster **test\_con.tif**. Click **OK** to run the expression.
4. Inspect your result.

### C. Build another Conditional Statement (Scenario #1)

1. Open the **Raster Calculator**.
2. In the Expression window enter the following expression:
  - i. **Con ("mtaire\_dell\_10m\_mosaic.tif" >= 2000, "clipped\_ut\_lc.img", 0)**
  - ii. The above conditional statement will return the land cover classes from the **clipped\_ut\_lc.img** that geographically coincide with the DEM and meet the above condition. This is a more powerful usage of the conditional statement.
3. Set the output location and name the raster **utlc\_con.tif**. Click **OK** to create the output. Inspect your result. How is it different from the result in step 2? Is it more useful? What other ways could you imagine using a conditional statement?

### D. Build another Conditional Statement (Scenario #2)

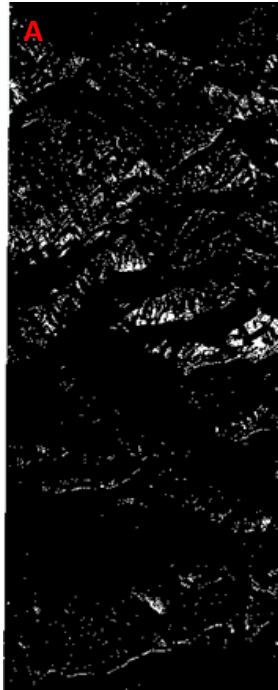
1. Open the **Raster Calculator**.
2. In the Expression window enter the following expression (see graphic below):
  - i. **Con(("mtaire\_mtdell\_10mDEM.tif" > 1800) & ("slope\_10mDEM.tif" < 20) & ("south\_aspect"), "mtaire\_mtdell\_10mDEM.tif", 0)**
  - ii. The above conditional statement will return the DEM elevation values from the **mtaire\_mtdell\_10mDEM.tif** that meet the above conditions; otherwise the false output will be set to 0. This is an example of nested conditional statements.
3. Set the output location and name the output raster **NestedCon.tif**.



4. Inspect your result (should look similar to Graphic A on the next page). What if you wanted to get rid of the 0 values and make them NoData? How would you do this? You could have left the false output value blank (not set it to 0) and this would make it default to Nodata. You can also use the Reclassify tool, or you can use the SetNull function in the Raster Calculator.

## E. Set 0 values to NoData using SetNull

1. From the **Spatial Analyst** toolbar open the **Raster Calculator**.
2. In the Expression window enter the following expression:
  - i. **SetNull ("NestedCon.tif" == 0, "mtaire\_mtdell\_10mDEM.tif")**
  - ii. Where the **NestedCon.tif** raster is equal to zero will be set to NoData, otherwise, if it does not meet that condition, it will get the values from the DEM (mtaire\_mtdell\_10mDEM.tif). See graphic B on the next page.



3. Set the location for the output and name it **SetNull.tif**. Turn off all other layers to see the effect of your process (your result should look similar to Graphic B)
4. Used the **Identify tool** to identify some of the elevation values of your output raster and the areas of NoData.
5. Explore your output, then close ArcMap when you are done.

### ***In Summary:***

*The take away from this exercise is vital to advancing your workable knowledge with raster manipulation and analysis in ArcMap. Local analysis and in particular using the Raster Calculator are powerful means for enhancing your understanding of your data as well as querying your raster data for analysis purposes..*

### ***Some things you should have learned:***

- 1. Local analysis performs functions and operations on each individual cell in the raster.***
- 2. The Raster calculator provides an easy interface for performing such operations and functions.***
- 3. Raster math is easily done in the Raster calculator.***

**4. Conditional statements are very powerful for “selecting” cells in your raster that meet a specific criteria and assigning the true condition a value other than 1.**

## Appendix 1: Map Algebra

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Map Algebra is a simple and powerful algebra with which you can execute all Spatial Analyst tools, operators, and functions to perform geographic analysis. The Map Algebra used in Raster Calculator has a syntax, or a set of rules, that must be followed to create a valid expression. In its most basic form, an output raster is specified to the left of an equal sign (=) and the tools, operators, and their parameters are on the right. Map Algebra provides a rich suite of tools for performing comprehensive, raster-based spatial analysis and modeling. Map Algebra expressions can consist of a single tool or operator but can also consist of multiple tools and operators.

For Example: `Con("mtaire_mtndell_10mDEM.tif" >= 2000,"mtaire_mtndell_10mDEM.tif",0)`

This statement will output a raster called 2500\_dem.tif where cells that have values greater than 2500 will be selected and set to that of the input values of the original DEM, otherwise the value will be set to 0.

Map Algebra allows you access to the Spatial Analyst tools, operators, functions, and classes through algebra. In its most basic form, an output raster is specified to the left of an equal sign (=) and the tools, operators, and their parameters are on the right. Map Algebra provides a rich suite of tools for performing comprehensive, raster-based spatial analysis and modeling. Map Algebra expressions can consist of a single tool or operator but can also consist of multiple tools and operators.

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	<b>ArcGIS 9.3</b>	<b>ArcGIS 10.x</b>
<b>Spatial Analyst</b>	Tools and operators accessed through ArcToolbox and Spatial Analyst Toolbar	Tools and operators accessed through ArcToolbox, Raster Calculator, & Python window.
<b>Map Algebra</b>	Accessed through the Raster Calculator, and Single Output Map Algebra (SOMA) & Multiple Output Map Algebra (MOMA) tools in ArcToolbox.	Map Algebra is accessed through the Raster Calculator, the Python window, or any Python Integrated Development Environment (IDE).
<b>Raster Calculator</b>	Accessed through the Spatial Analyst toolbar. Contained a button-like calculator interface to run single or multi-line Map Algebra expressions.	Accessed through the Spatial Analyst > Map Algebra toolbox. Retains the button-like calculator interface and used to implement simple and complex algebraic Map Algebra statements.

**Congratulations!** You have successfully completed this exercise.

