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1. Setting the Scene

Welcome back to the beautiful, coastal Navarro River Watershed (photo credit: Clinton Steeds). Using ArcGIS Pro, we will determine the probable nesting locations of the rare marbled murrelet (*Brachyramphus marmoratus*) in the Navarro River watershed. The marbled murrelet is a secretive bird, but it is thought to make its nests in old growth forests on steep (> 20 degrees), west-facing slopes within 35 km of the ocean at or around the 150m elevation.

This type of analysis is a common one, called a *suitability analysis.* It is used to help us answer the question of what locations meet a set of conditions.

Summary of Procedures

Create a new Project and add a digital elevation model. We'll generate *hillshade, slope and aspect* grids; load a coast distance raster and a grid of old growth forest patches.

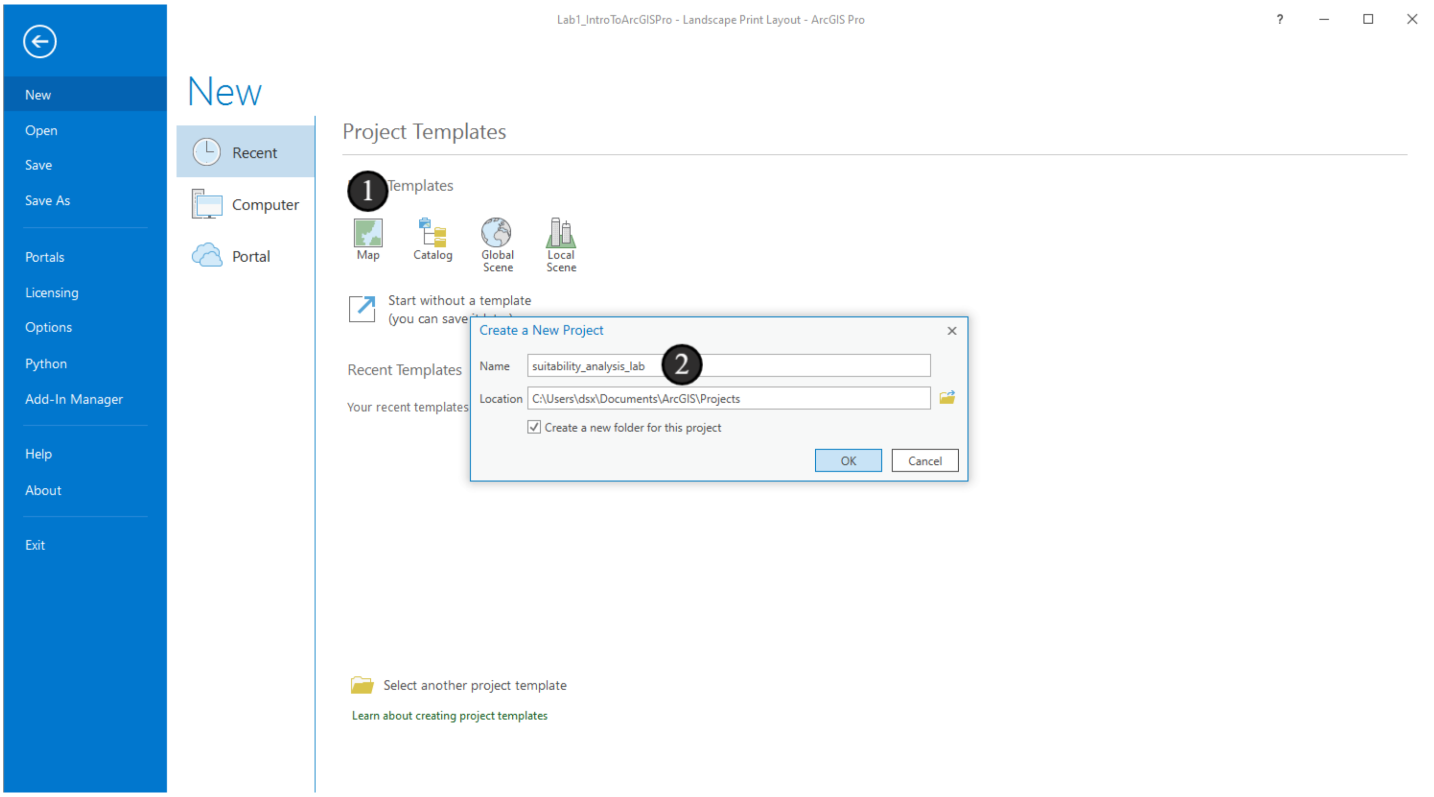
- Query grids to determine probable nesting locations based on outlined habitat parameters.
- Display resulting habitat patches draped over the *DEM* with *hillshade* as a brightness theme and elevation contours overlaid.

Review

1. We can set analysis options in environment settings
2. Suitability analyses are the process of determining what locations meet a set of criteria.
3. Symbology is the representation of data on a map

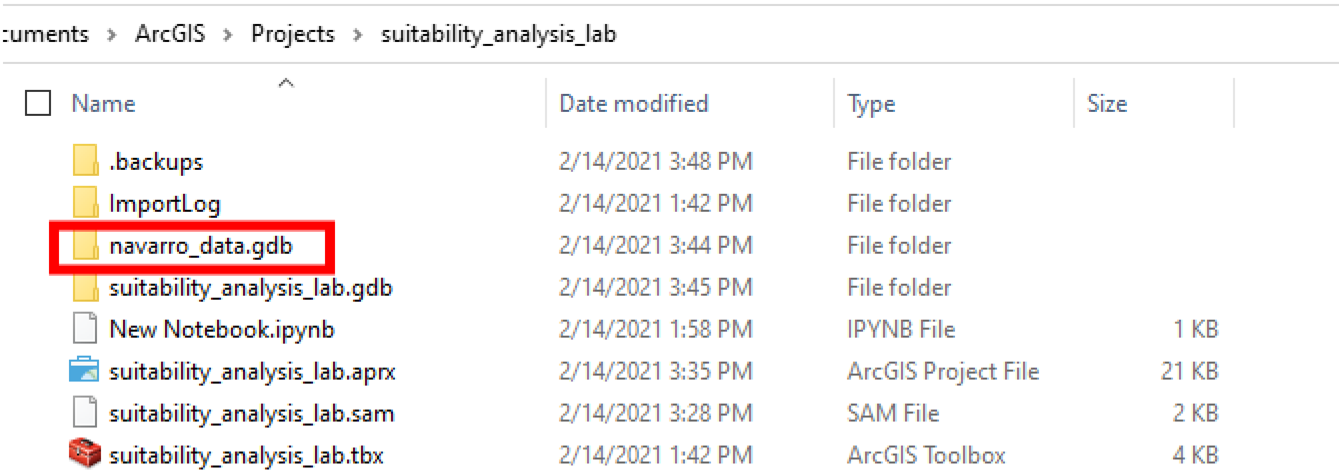
2. Create a new ArcGIS Pro Project

To start, create a new map project in the default location. Name the project *suitability_analysis_lab*.



2.1 Move the project data

As before, extract the downloaded geodatabase and move it into your project folder for easy and quick access within ArcGIS. In this case, move the folder named *suitability_analysis.gdb* into the *suitability_analysis_lab* folder.

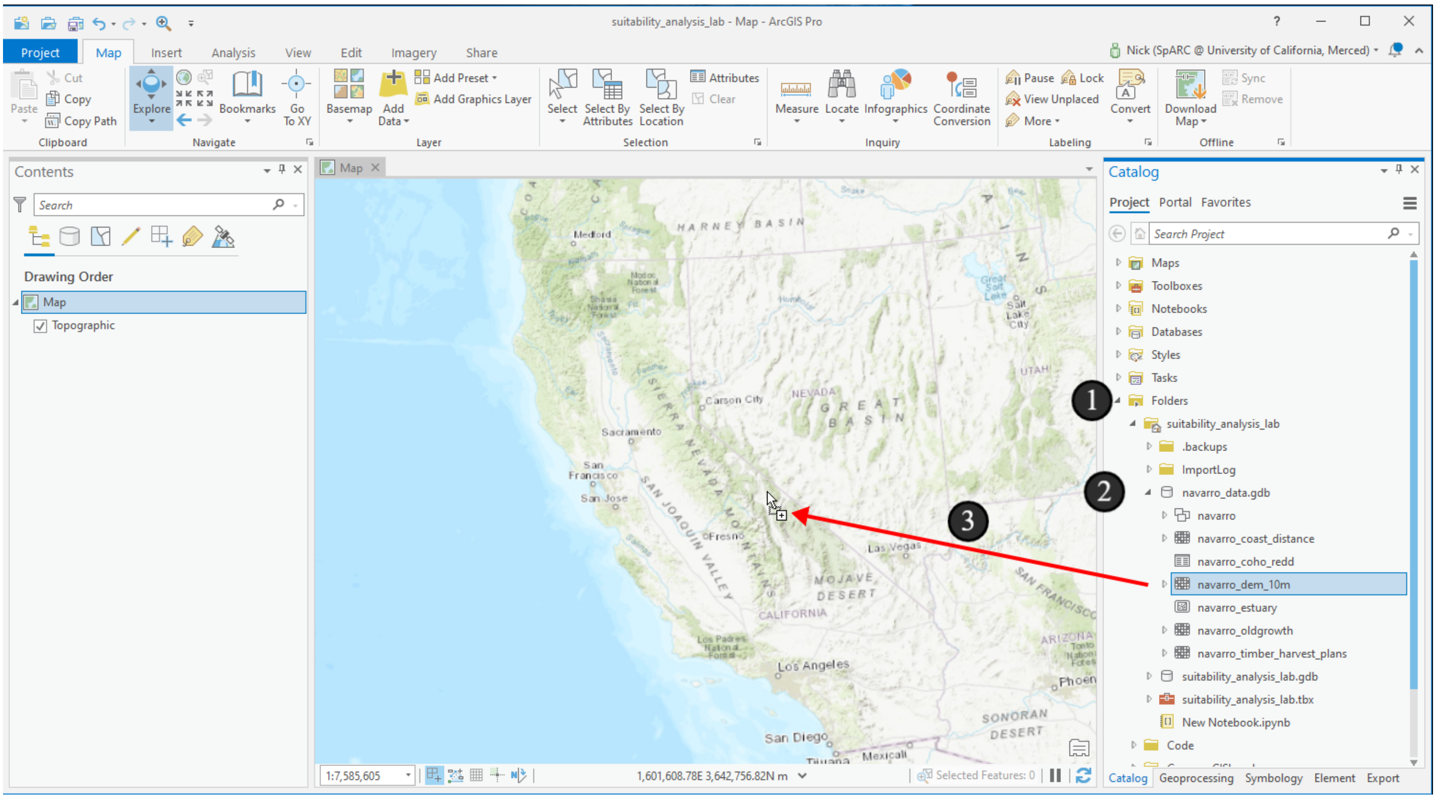


3. Add the Digital Elevation Model to the map

Once we have our project open and have moved the data into our project folder, we'll add some data to our map. You can use the Add Data button if you like, and this step will use an alternate method through the Catalog pane.

1. In the *Project* tab of the Catalog pane, expand the *Folders* section and the *suitability_analysis_lab* project folder
2. Expand the *navarro_data.gdb* geodatabase
3. Click and drag *navarro_dem_10m* onto the map

When adding data and looking inside of folders and geodatabases, note the icon differences – can you tell the difference between the data types it is indicating?



3.1 Look at the raster information

The digital elevation model we just added is a *raster*, sometimes called a *grid,* stored in our geodatabase. A digital elevation model does not require any special data structures beyond that, and the only thing that differentiates a digital elevation model from other raster data is that we know the values in the raster refer to elevations - that is, it's a conceptual distinction and not a technological one.

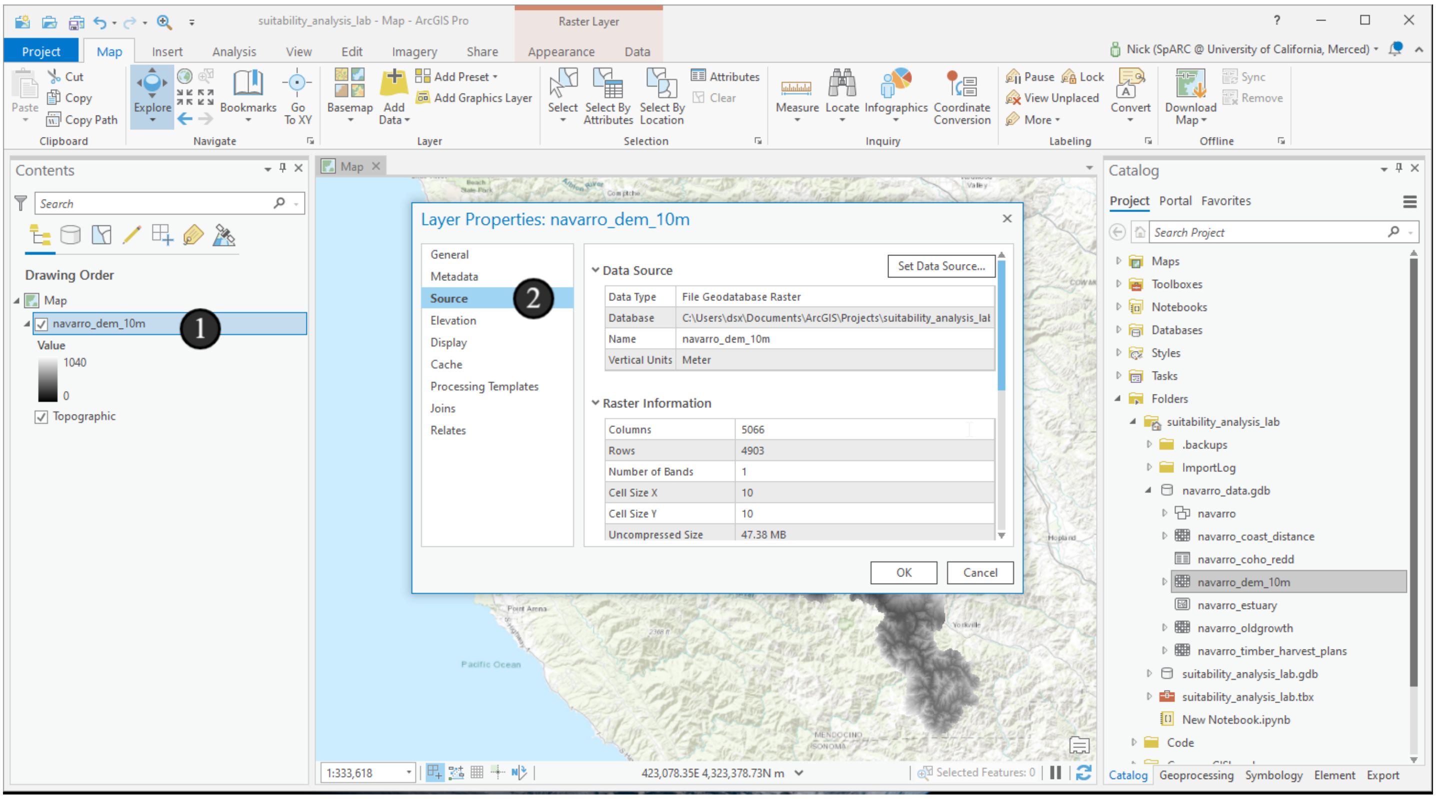
Take a look at the layer properties to learn a bit more about the parameters of this raster.

1. Right click on the layer and go to *Properties*
2. In the *Layer Properties dialog* that pops up, click to the *Source* section. Expand the different sections within it and look at the information. What's the cell size and what do you think its units are? What do the columns and rows mean in this context?

This particular DEM is a 10 meter DEM, which means each cell in the grid is 10 meters wide on each side (approximately - they're typically captured as geographic/angle-based coordinates instead of planar coordinates, which means the sides could actually be slightly different lengths throughout the grid based on latitude and the X and Y sides could differ - that's a distinction you don't need to memorize, but just be aware of - for our purposes, it's safe to think of it as a 10 meter DEM). This was a very high resolution DEM at the time it was captured, and is still high resolution for common data throughout the world, where 30 meter DEMs are widely available. When we think of what this means, that we only have one elevation value for a 10 meter by 10 meter area of ground, this is relatively coarse in many ways, depending on your analysis. For a landscape-scale project like we're doing, it's *probably* fine, but as we go through this tutorial, consider the ways that this *resolution* of DEM could limit our analysis or introduce potential error or where gaining local knowledge would be an important verification of our analysis.

Today, DEMs of 3 meters or even 1 meter aren't uncommon in the United States, and low cost drones are making DEMs with centimeter scale and accuracy for small localized areas possible for projects that need them - for that, consider the possible challenges that a DEM of that scale would create for landscape-scale analyses.

Before closing the dialog, I also recommend looking through the other parts of the properties dialog in the left column and familiarizing yourself with what's available here. If you're coming from ArcMap or QGIS, there's far less information in here that you need to work with than before. It's mostly in ribbons and panes now. When you're done looking around, close the dialog box.

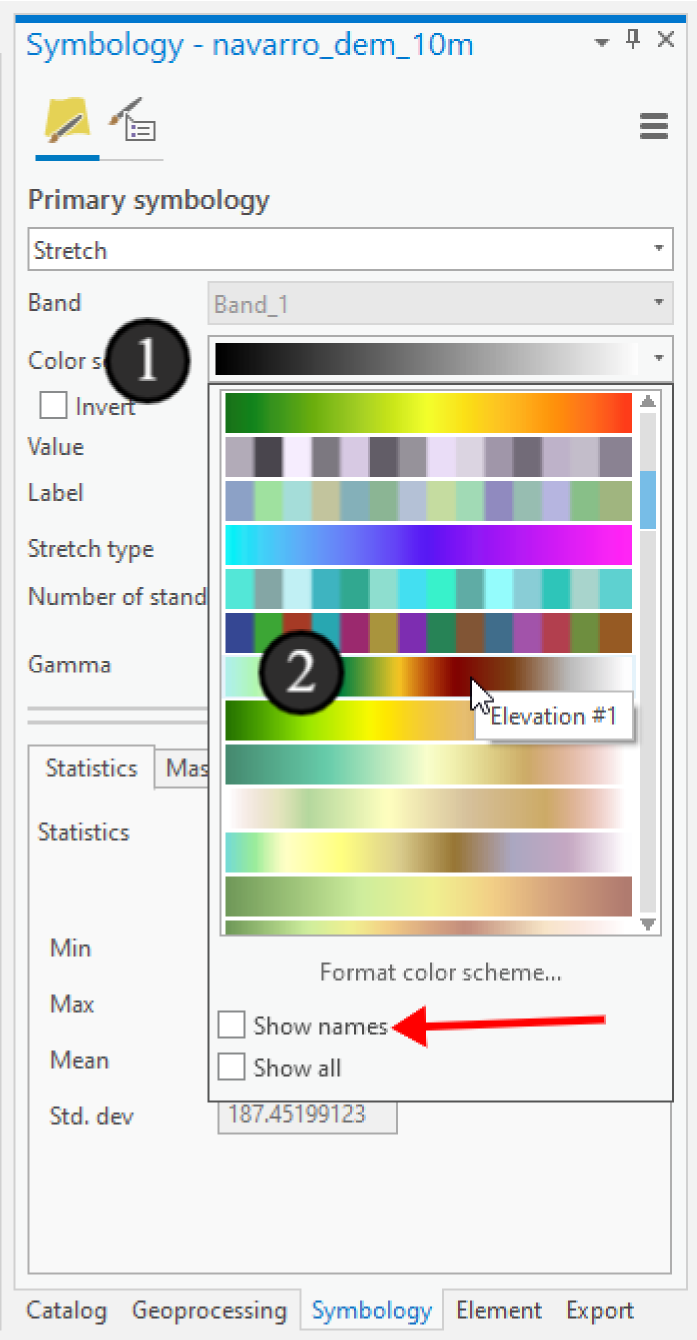

Layer Properties: navarro_dem_10m
General
Metadata
Source
Elevation
Display
Cache
Processing Templates
Joins
Relates
Data Source
Set Data Source...
Data Type File Geodatabase Raster
Database C:\Users\dsx\Documents\ArcGIS\Projects\suitability_analysis_lal
Name navarro_dem_10m
Vertical Units Meter
Raster Information
Columns 5066
Rows 4903
Number of Bands 1
Cell Size X 10
Cell Size Y 10
Uncompressed Size 47.38 MB
OK
Cancel
Contents
Drawing Order
Map
navarro_dem_10m
Value
1040
0
Topographic
Catalog
Maps
Toolboxes
Notebooks
Databases
Styles
Tasks
Folders
suitability_analysis_lab
.backups
ImportLog
navarro_data.gdb
navarro
navarro_coast_distance
navarro_coho_redd
navarro_dem_10m
navarro_estuary
navarro_oldgrowth
navarro_timber_harvest_plans
suitability_analysis_lab.gdb
suitability_analysis_lab.tbx
New Notebook.ipynb
Code
1
2

3.2 Change the DEM symbology

Now let's update the symbology. The default black to white is fine, but we can use something more familiar.

Open up the symbology pane for the layer (remember to have it selected in the Contents pane while using the Symbology pane). By default, it shows a symbology type of *Stretch*, which is what we want, so we just need to change the *Color scheme,* often called a *color ramp.*

1. Click the dropown for color scheme
2. Scroll down until you see *Elevation #1*. If it's hard to find, check the *Show names* box at the bottom to see the ramps by name instead of color.

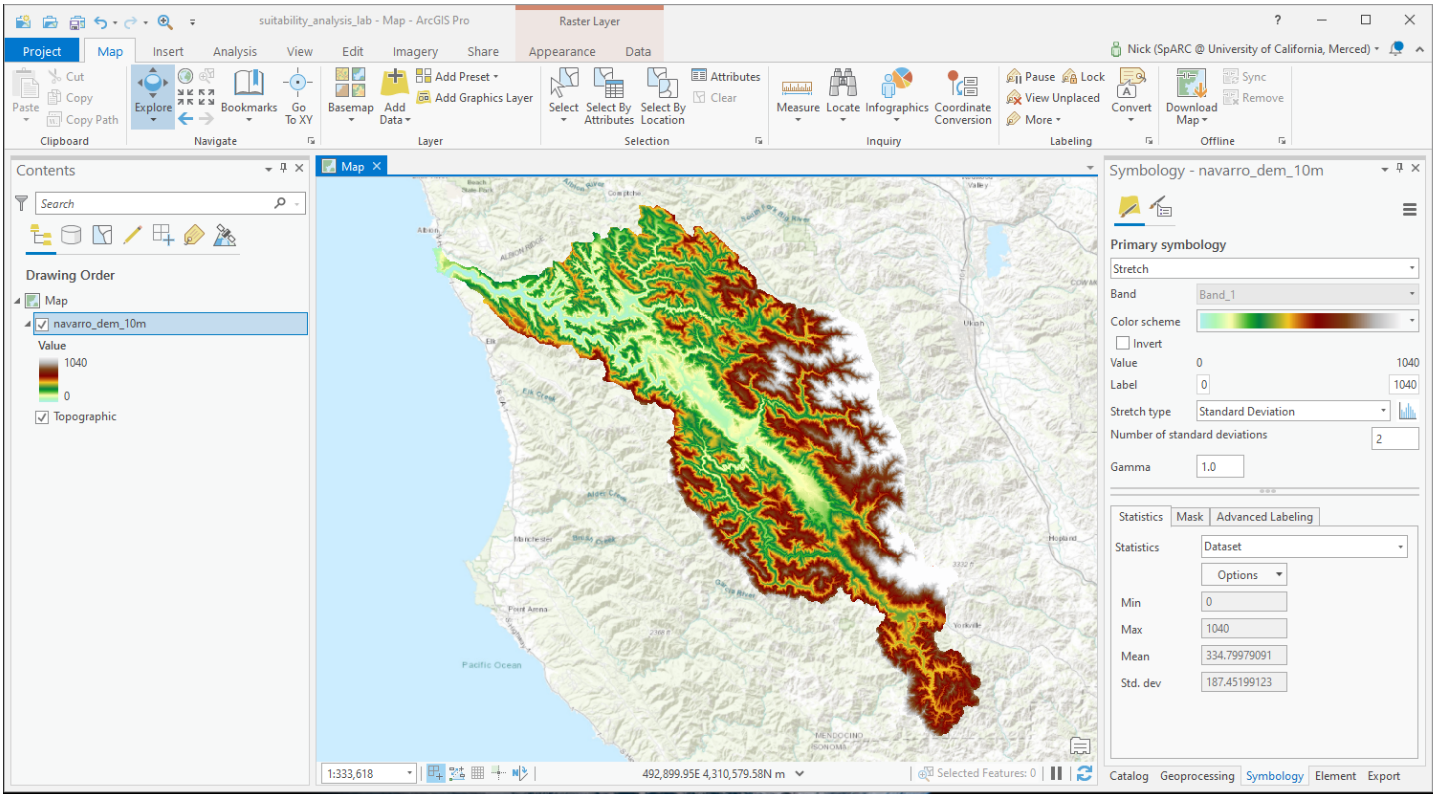


4. Set Elevation Symbology

First, take a look at the colors and see if you can get a decent sense of what this basin might look like. Consider that long valley running northwest to southeast. Do you think that's a valley or a distortion of our perception caused by the color ramp?

As another note, there are two types of color ramps I typically avoid, and this is one of those types:

- Color ramps that have many different sets of gradients within them. I'd usually say 2 gradients maximum (as in, fade from green to yellow and yellow to brown only) - beyond that, it's hard for the viewer to get a sense for what the data means. Elevation data is a bit different since it tends to behave more continuously than some other data sources and people have experience looking at these color ramps. But for a hard to comprehend example, look at some of the combined rain/sleet/snow forecast or hurricane intensity maps where the colors actually *repeat* within them. Very hard for a person not experienced in that area to interpret. In this case, do you think this elevation coloring is interpretable? Looking at this map, do you feel like you can intuitively understand which locations are high elevation and which ones are low elevation? Do you have any critiques of the use of this color ramp in this context?
- Color ramps that use red and green for important colors. For two reasons - first, red and green are widely interpreted as good and bad, so even if you aren't trying to suggest one is good or bad, it is subconsciously conveying that to many people. Second, they're an accessibility issue - red/green colorblindness, where someone can't distinguish between a red or green of the same saturation, is the most common type of colorblindness - red to green color ramps are challenging or impossible for people with this type of colorblindness to interpret. It's easy to avoid them (https://colorbrewer2.org from famous cartographer Cynthia Brewer is **the** resource to start with if you want to make accessible maps that are easy for everyone to interpret)

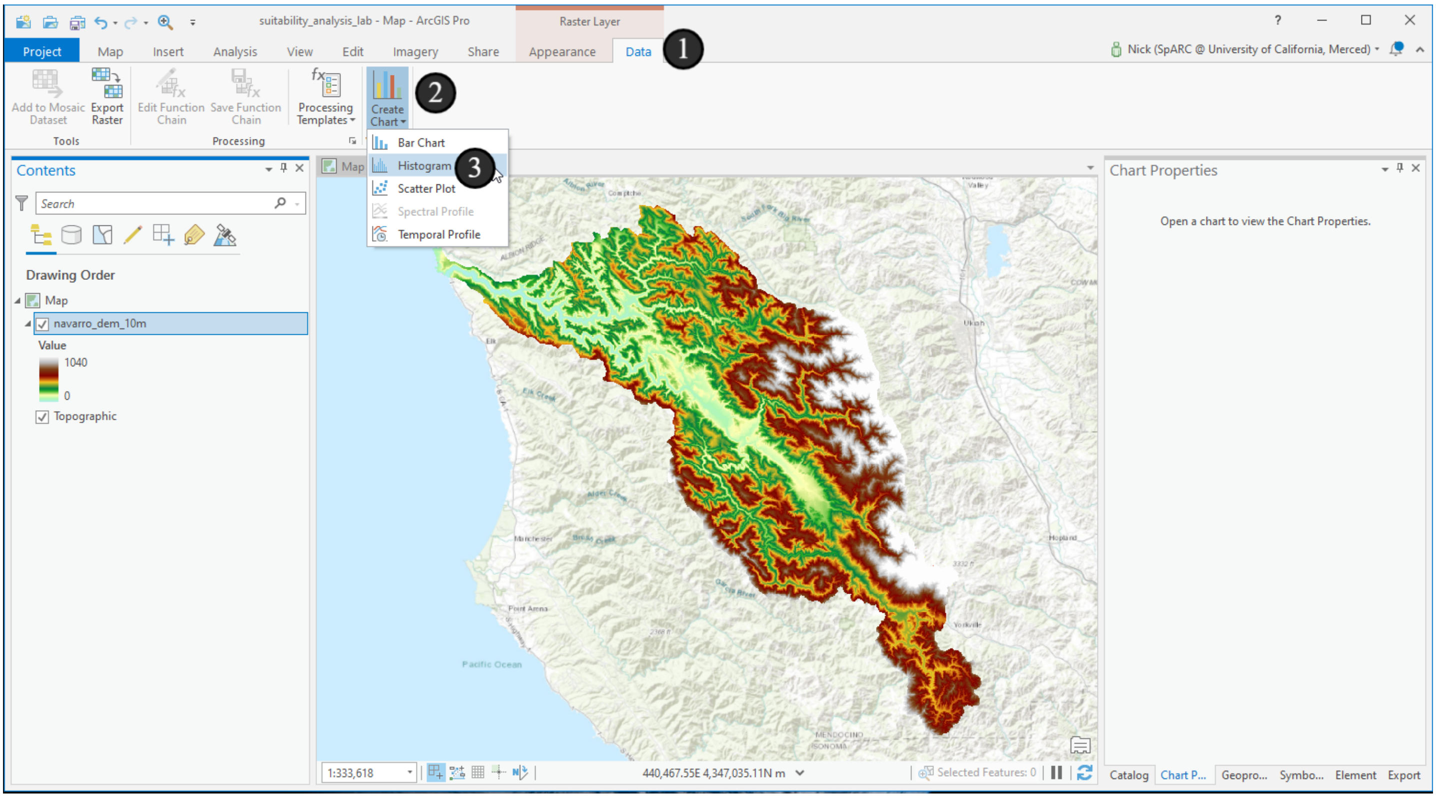


5. Make a histogram of elevation values

Now let's take the elevation out of the spatial realm and get a sense for the overall spread of elevation values within the watershed by making a chart of all the values, called a histogram.

Histograms are useful because they tell us about the *frequency* of each value or ranges of values - they count up how many times in a dataset values within a given range occur, and then plot those values as bars for all possible ranges of values - this will make sense in a moment.

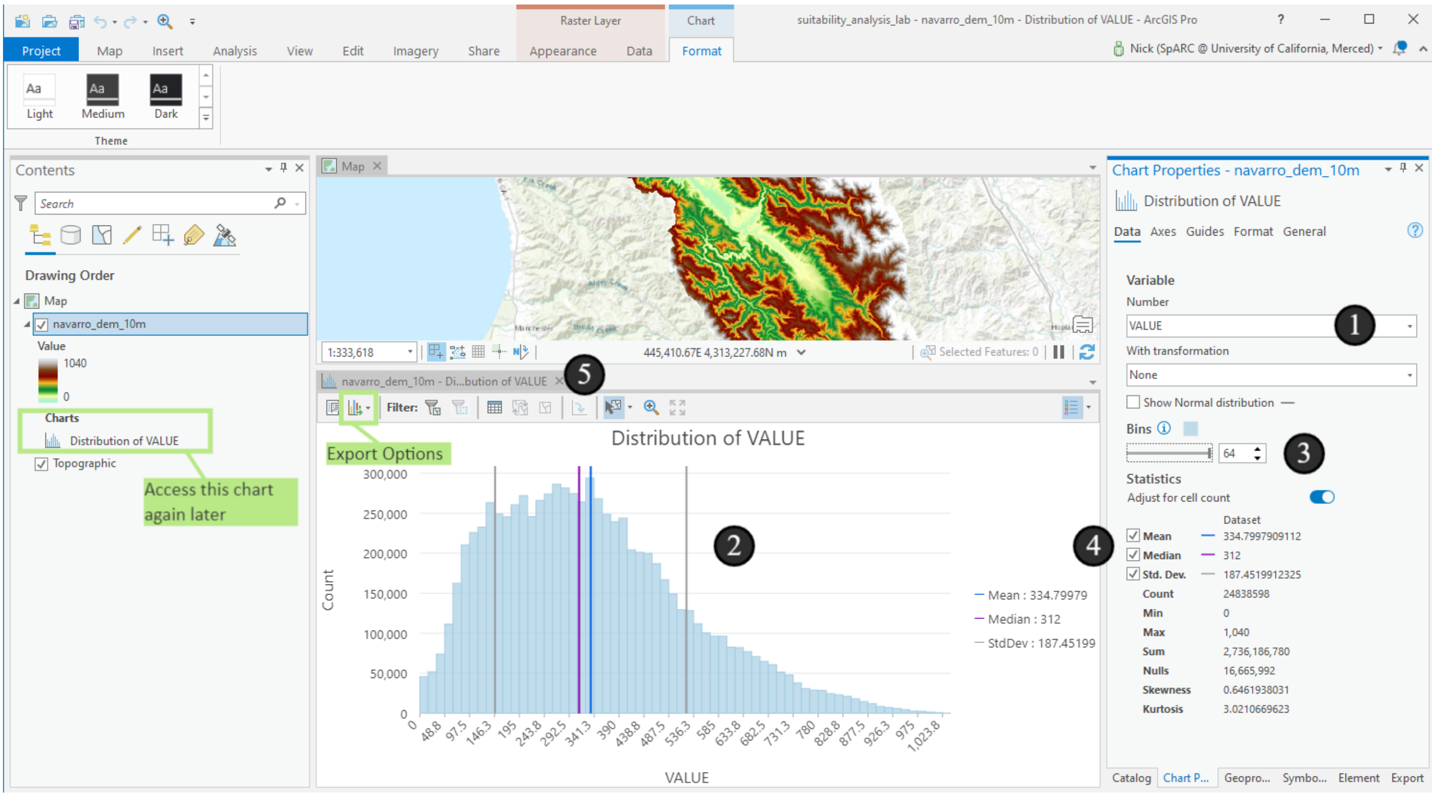
1. In the *Raster Layer* section of the ribbon, click the *Data* tab
2. Click the *Create Chart* button
3. Choose *Histogram*



5.1 Charting tools

We'll end up with an empty chart area at the bottom and a pane on the right for *Chart Properties*. We won't see an actual chart until we select what the data source for the values in the chart should be.

1. From the *Number* dropdown in the *Variable* section, choose *VALUE*. *VALUE* is a special variable name for raster data that indicates that rather than using a field, it should use the cell values across the whole raster.
2. A chart should already pop up, so examine it briefly. What is the most common value? Is it surrounded by other common values, or does it stick out on its own? Would you expect this distribution of elevations based on what you see spatially?
3. Let's change the chart a bit. Adjust the *Bins* slider all the way to the right. Move it around a bit and observer the impacts on the histogram. Does the number of bins change the interpretation of the frequency of each elevation or the overall interpretation?
4. Turn on the mean, median, and standard deviation lines to help us better understand the central values and spread in this elevation distribution. Is this DEM normally distributed (note the checkbox for comparing to a normal distribution)?
5. Note that charts can be exported to images elsewhere (a really fast way to get numeric information from otherwise-spatial data) and also that this chart is permanently in our Contents pane now - that is, we can close it and it's still saved in the project and we can open it again by double clicking on it in the contents. Feel free to modify the chart and then close it when you're done.

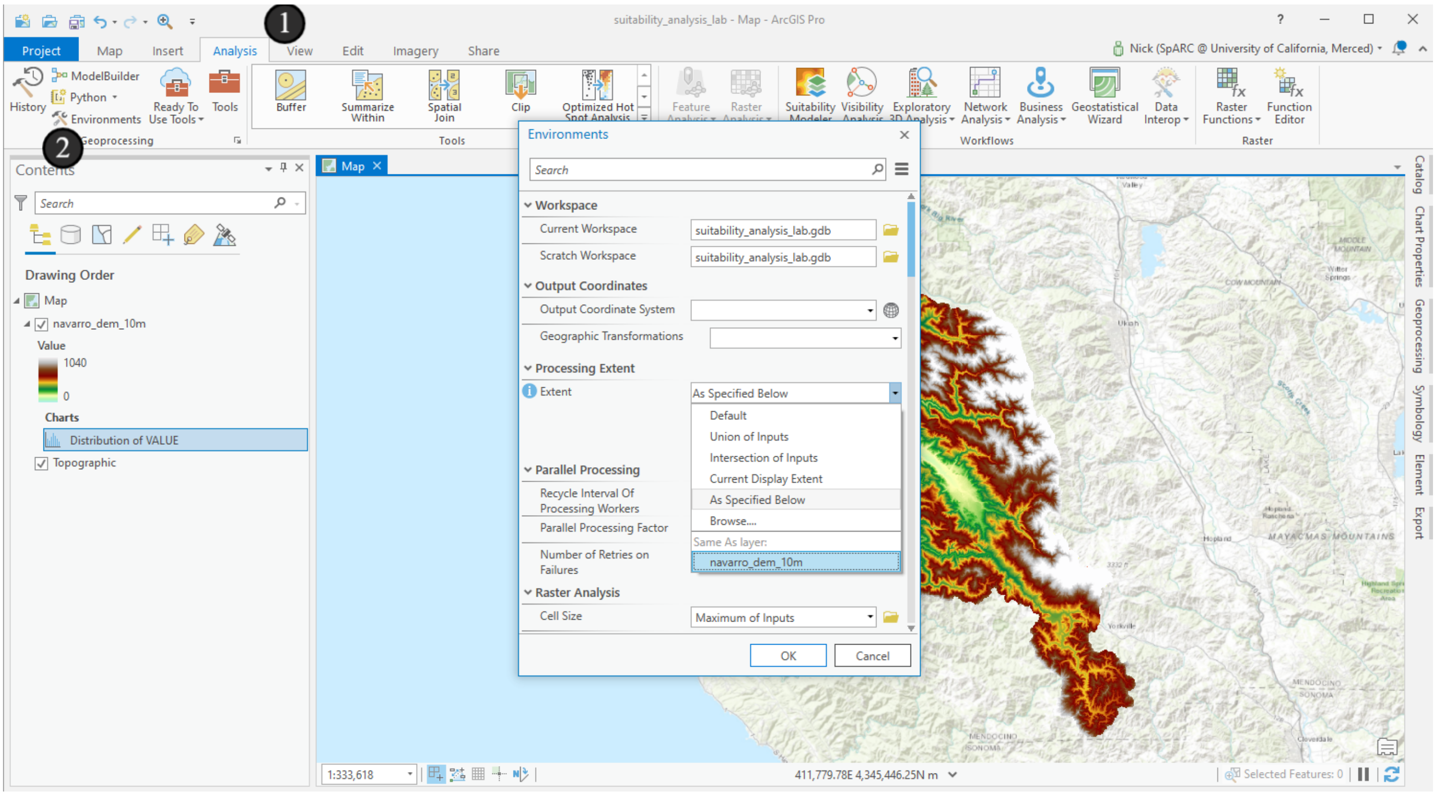


6. Set Environments for analysis

OK, now let's dive into a bit of analysis. To do that, let's set some *Environment Settings*, often simply called *Environments*.

Environments are variables that control the context of analysis tools and may affect how they behave. We can think of them almost like applications settings, but they impact the results of our analysis rather than controlling how something looks on our screen. In most cases, ArcGIS does the smart thing with environment settings by default, and we don't need to make these changes, but it's always good to do to make sure, and it's a good illustration of what's happening behind the scenes for us.

1. To get started, switch to the *Analysis* ribbon
2. Click the *Environments* button in the *Geoprocessing* ribbon.



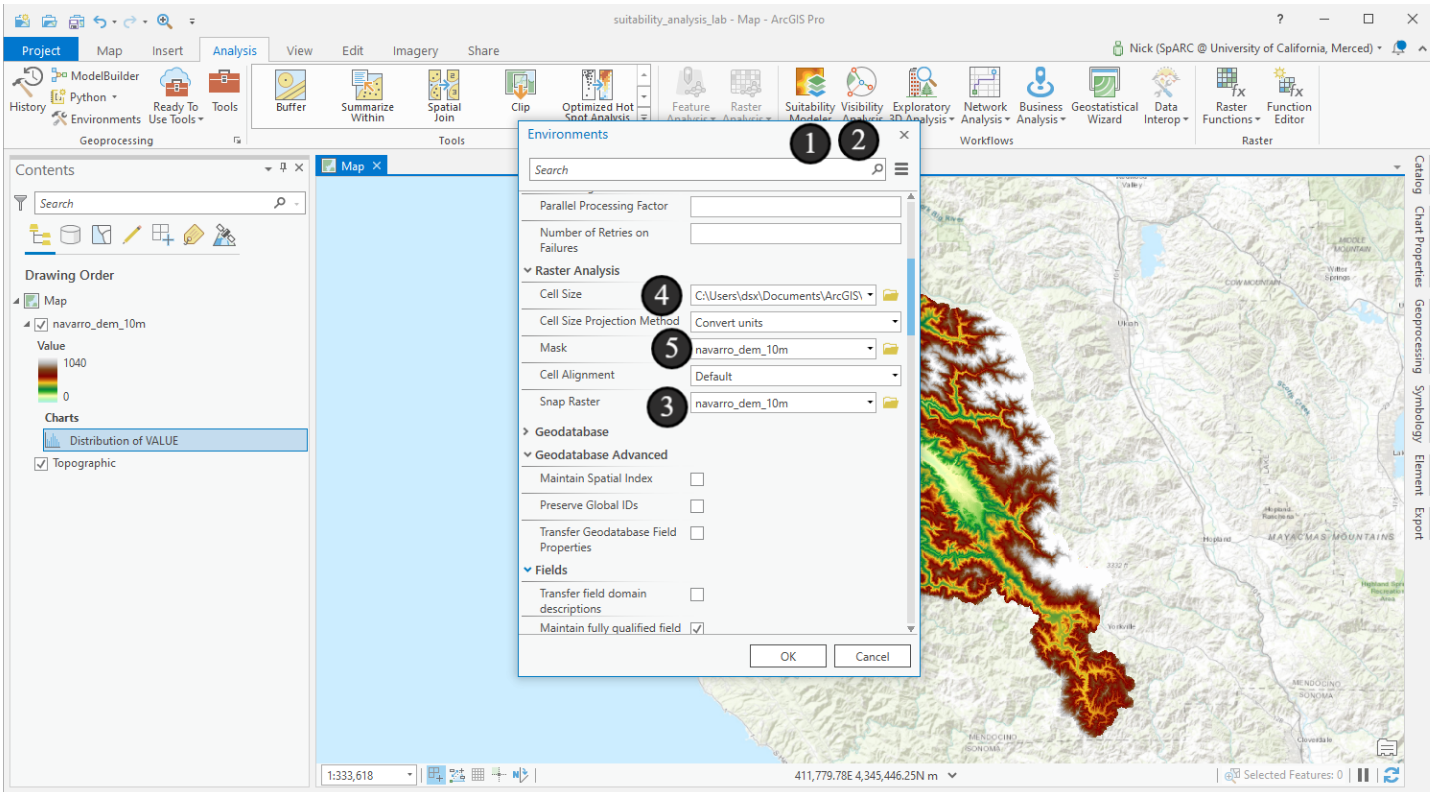
6.1 Set your Environments

The *Environment Settings* window will pop up. We're going to set five separate values here - we'll choose them all from dropdowns, though after we choose, ArcGIS might reinterpret it and show something different - this is normal - it reads data based on our selection, interprets it, and shows us the values we're using.

Most of the settings we're going to change will just ensure proper alignment of our output data with our input data - depending on the projection, cell size, etc, raster cells can slightly misalign. These settings help make sure everything lines up. Again, ArcGIS would choose smart defaults for these, based on the input data, in most cases.

1. We're going to set Output coordinates to be the same as *navarro_dem_10m* (not shown in picture - it's higher up in the box)
2. Set the *Extent* to be *Same as layer navarro_dem_10m* (also not shown)
3. Set the snap raster to *navarro_dem_10m* (what do you think this does? It has to do with cell alignment - note the help icons next to each value when you hover over it)
4. Set the cell size to be *Same as layer navarro_dem_10m* - this ensures that the output raster from any geoprocessing operation matches this one, even if we use an input raster that has a different cell-size
5. and finally, set the *Mask* to *navarro_dem_10m* - this setting basically says that any geoprocessing result where the value is located in a place that *navarro_dem_10m* has no value should also not have a value (or in other words, it should only keep values where we have the elevation data, even if other inputs have data in other locations).

What other environment settings might you set? Look around at what's available to get a sense for them for when you need them. Note also that ArcGIS help specifies for each geoprocessing tool the environment settings that affect them.



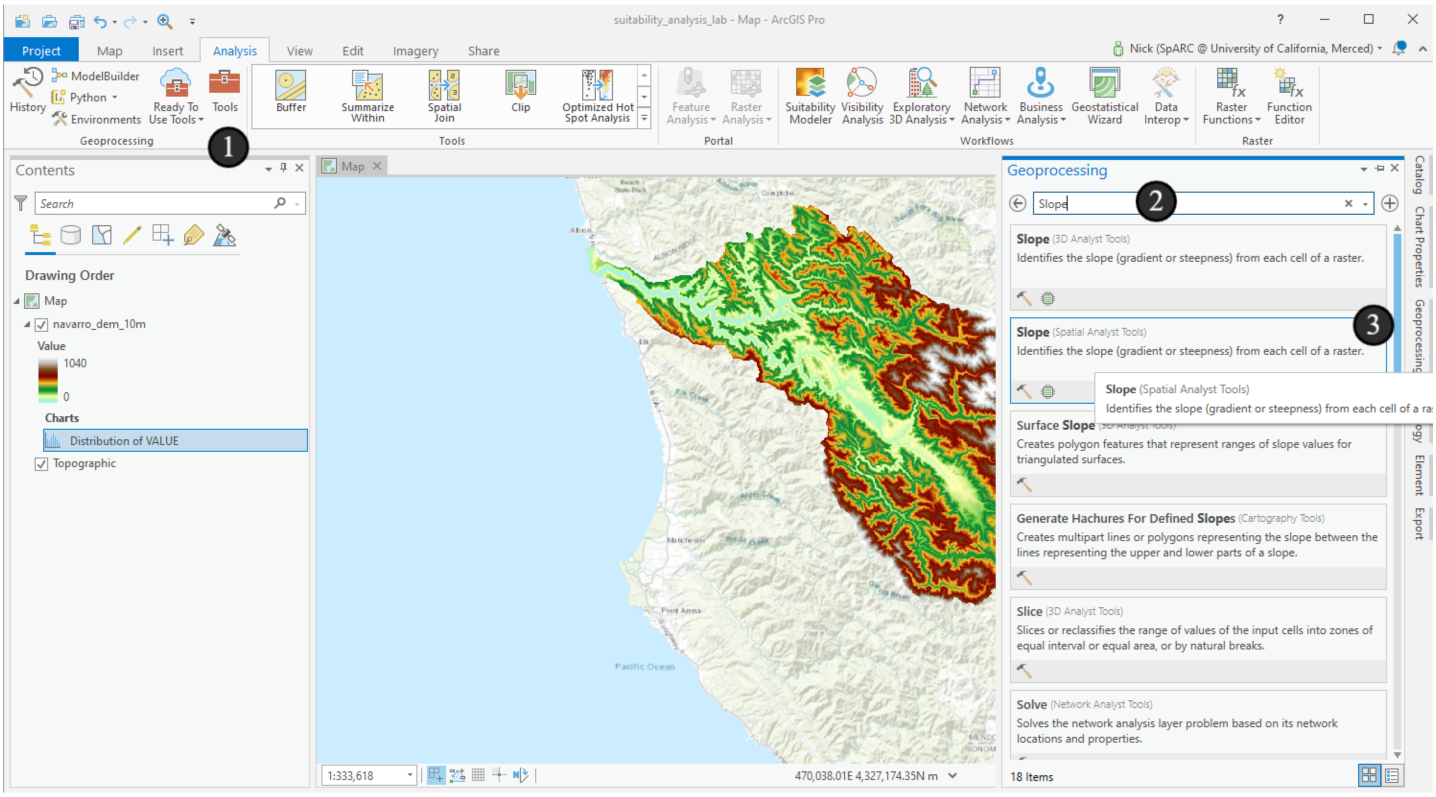
7. Calculate Slope

OK, now that we've set up our analysis environment, it's time to generate some data that will help in our analysis. We'll start with slope.

Recall that the marbled murrelet creates its nests on steep terrain (> 20 degrees) - so we'll need to incorporate that into our analysis. To begin this process, we'll make a slope raster from our DEM. Conceptually, if you know the elevations of each location, you can determine the slope to neighboring locations - that's what the slope geoprocessing tool does.

Locate the Slope tool either by using the Search panel in the Geoprocessing pane, or by finding it in the *Toolboxes* tab under *Spatial Analyst Tools > Surface > Slope.*

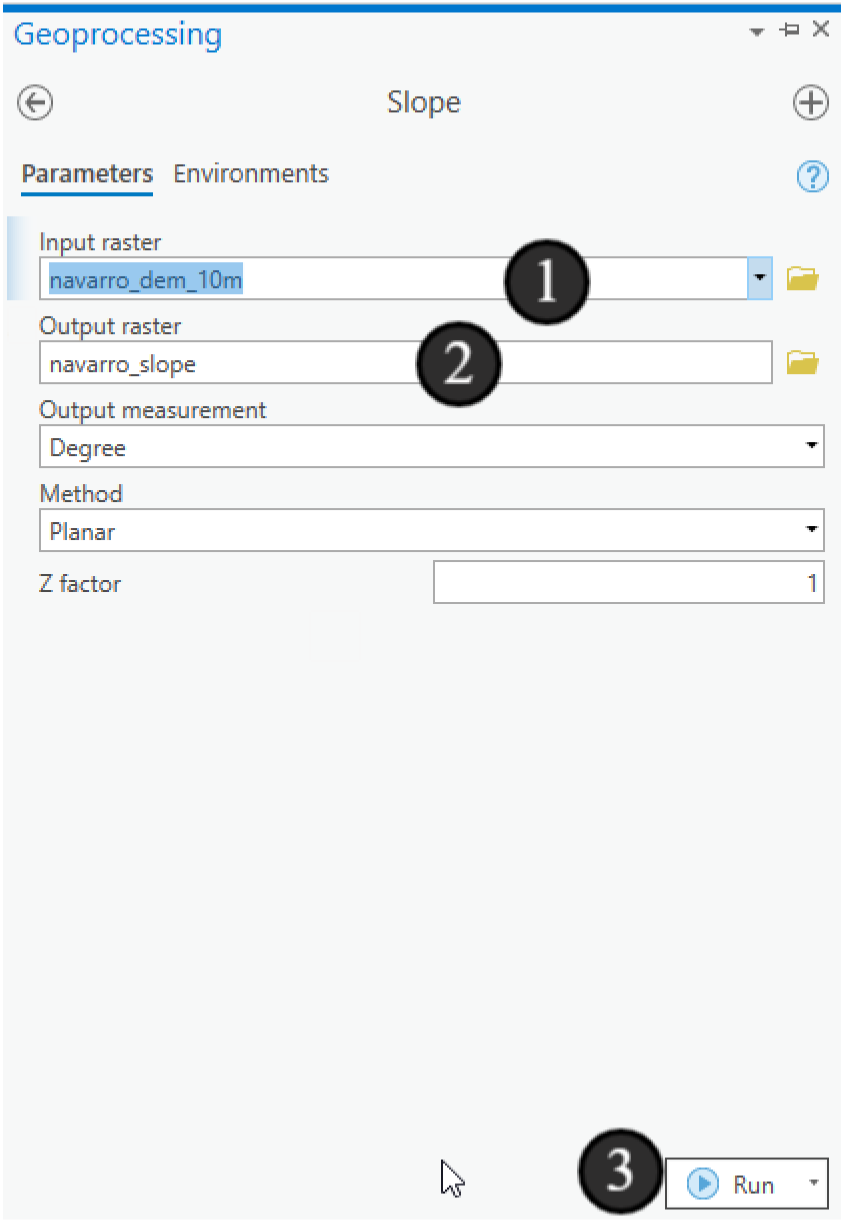
1. If the Geoprocessing tab isn't currently available in the right pane, you can open it from the *Tools* button on the *Analysis* ribbon.
2. Then search for the word "Slope"
3. I chose the second result since it's the version in the *Spatial Analyst Tools* toolbox, but it's functionally the same as the first one. Click on it to open the tool.



7.1

1. We'll use our DEM as our input raster
2. Give the *Output raster* the name *navarro_slope* in the same geodatabase it wants to save the outputs in by default.
3. For the Output measurement, what option should we select? Check the problem statement to determine what to use.
4. Click *Run* to execute the tool.

Once the slope raster is generated, we'll get a new raster in our Contents pane and drawn on our map.

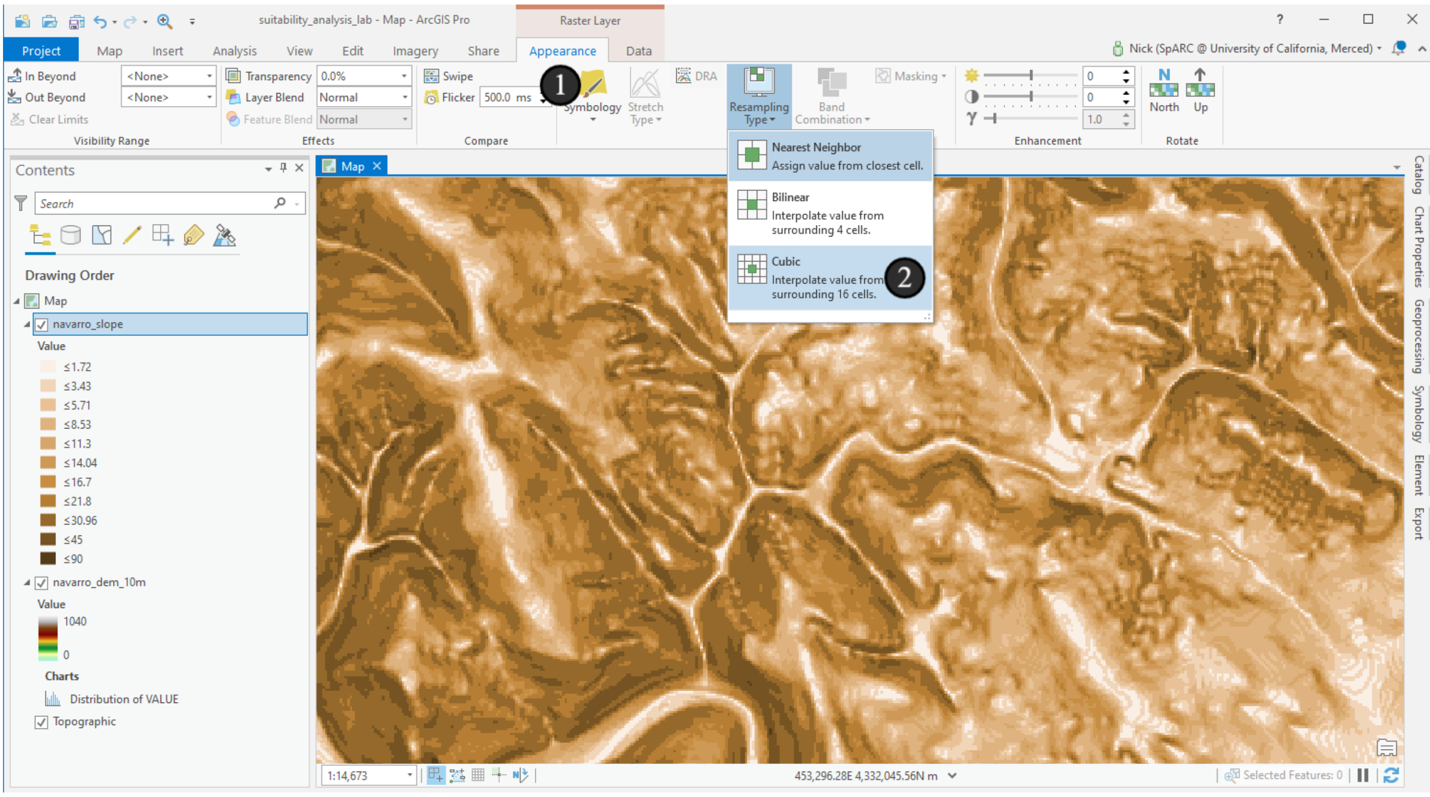


7.2 Pixelated slope!

Examine the slope of the Navarro DEM. Does it seem representative of a coastal watershed?

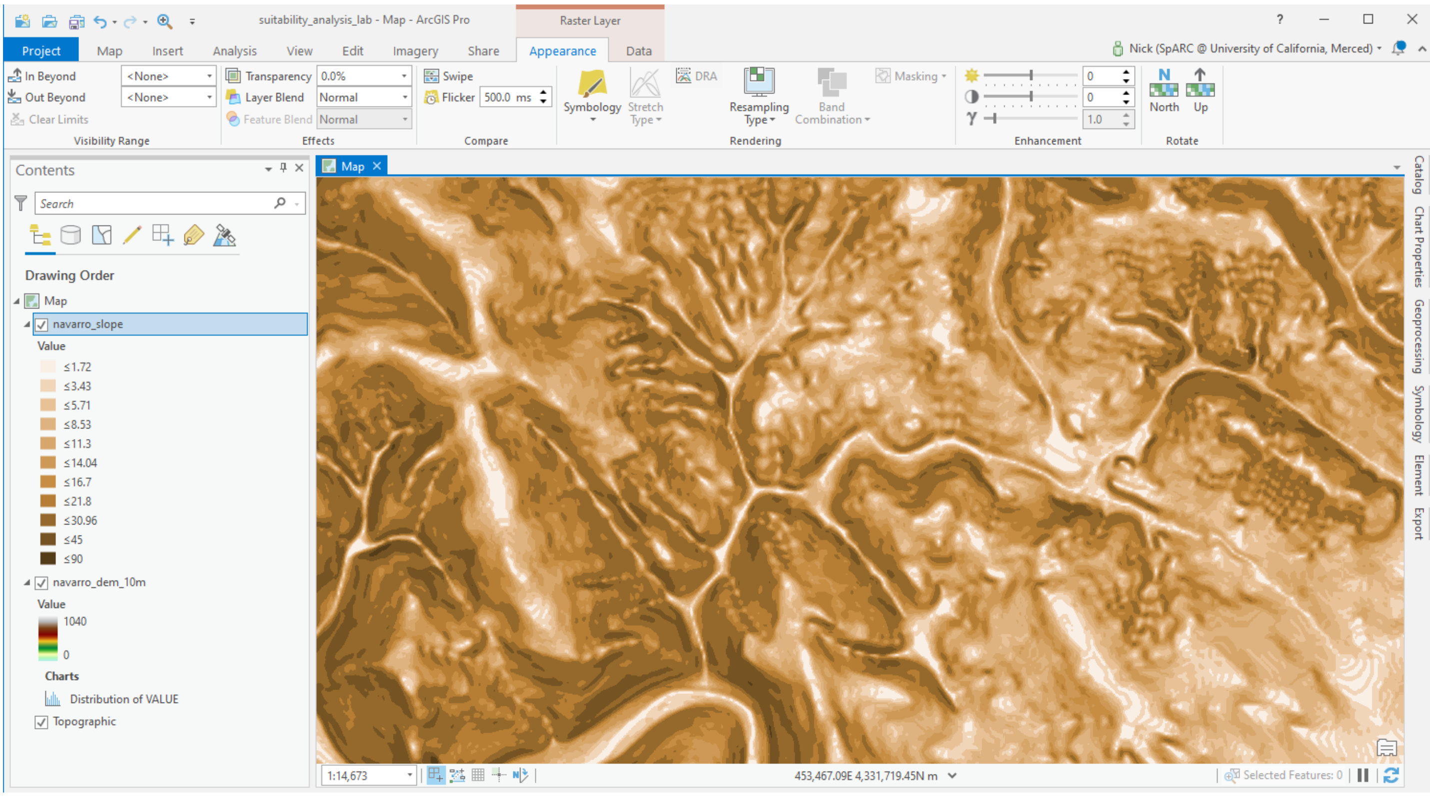
After looking around a little bit, zoom in until you can see the pixel boundaries. In many cases, it can be useful to see these since it helps show us the limits of our data, but sometimes it's less useful cartographically. We can change how it renders though so it's less pixelated when we zoom in.

1. Choose the *Appearance* ribbon in the *Raster Layer* section
2. Click the *Resampling Type* button and choose *Cubic* which smoothly interpolates the values on our screen at a higher resolution than the input data.



7.3 Cubic resampling

Take a look at the updated raster when you zoom in. Note that this isn't *real* new data - we wouldn't typically use this kind of interpolation as an analysis input, but it can be useful for visualizing still.

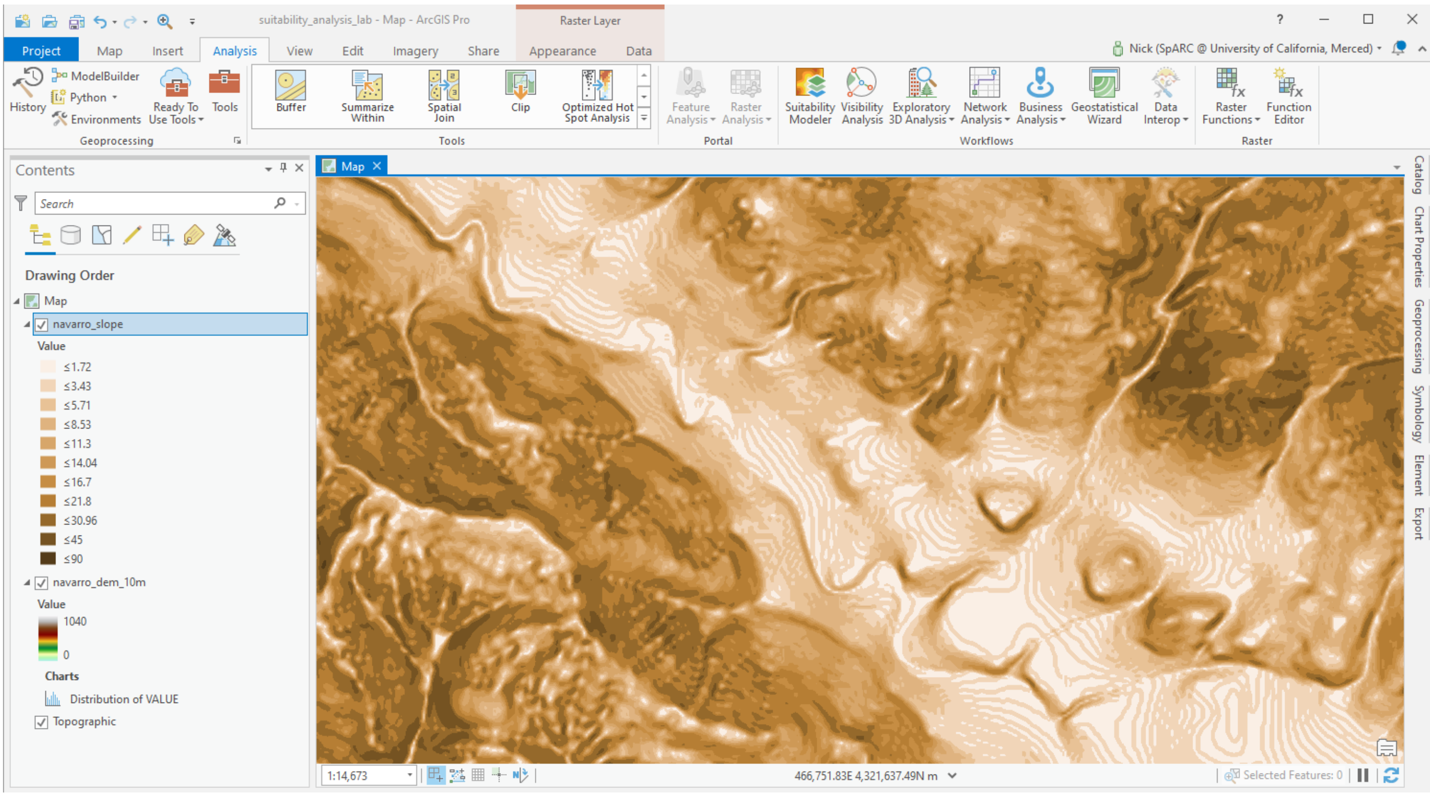


7.4 What's this?

What do you think is going on here where we get these bands of data and large flat areas with a higher slope location in between? Take a look at the digital elevation model in the same spots. Do you have any thoughts about what could be going on? Making a histogram of the slope raster could also help in understanding this (make sure that when you click to create the histogram that the slope raster is selected in the Contents pane, or right click on the slope layer itself to create the chart) - are there quite a lot of zero slope pixels? You may need to change the number of bins again to answer that question. Do we think this is real terracing?

My guess for what's happening here is that these areas have a relatively constant low slope, but that the sensor that collected the DEM data didn't have sufficient vertical resolution to distinguish between an elevation of 1.1 meter and 1.2 meters (for example). So minor variations between cells in the raster disappear and then it calculates no slope. And then eventually, as me move along the raster, we get a spot that has enough elevation difference to register as a different elevation value, which produces a slope value as well. Be on the lookout for data artifacts!

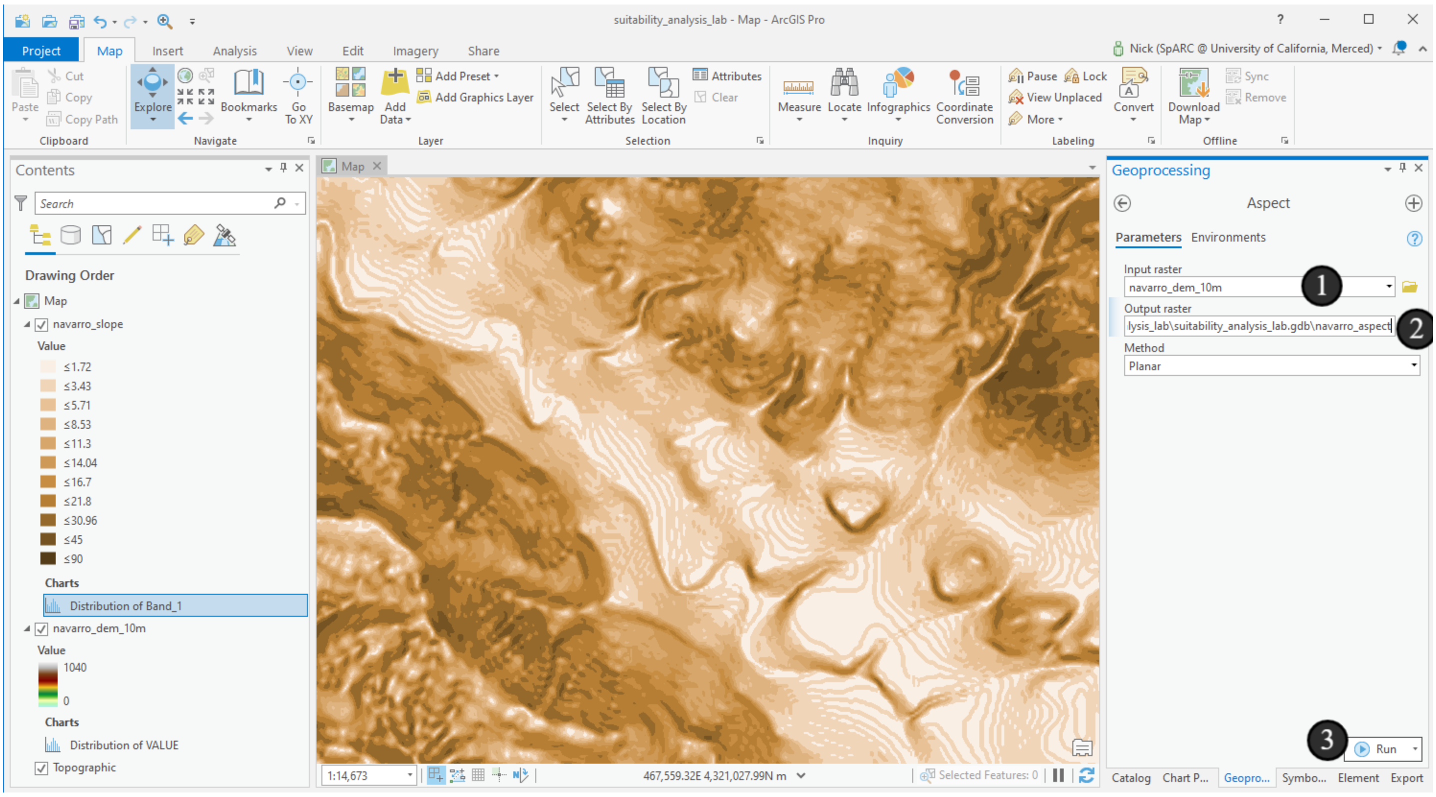
If you didn't already do so, make a histogram of the slope raster (again, make sure that when you click to create the histogram that the slope raster is selected in the Contents pane) and examine it in the context of the marbled murrelet's criteria for nesting (on the first page). Does it seem like there will be many potential sites based on the slope data?



8. Make an aspect raster now

Our next criterion is that the marbled murrelet prefers south facing slopes. To get directionality of slope, we'll use a different tool, the *Aspect* tool. Search for it in the geoprocessing tool box and open it up.

1. Use your DEM as the input raster
2. Name the *Output Raster* "navarro_aspect"
3. Leave the method as the default (hover over it to see an explanation if you'd like) and then click *Run*.



8.1 Aspect

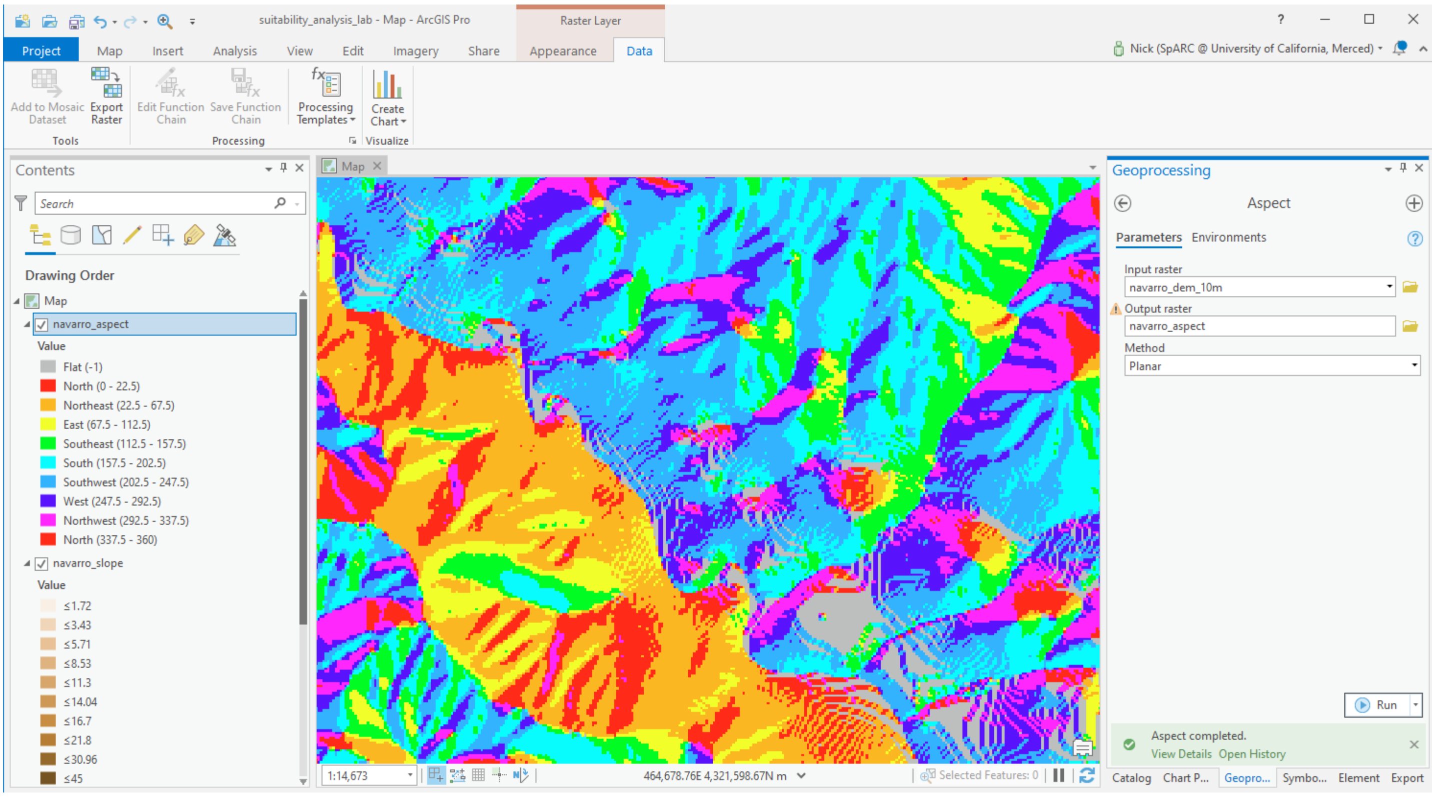
I love aspect rasters and their default visualization. By default, I feel like they're the Andy Warhol paintings of GIS.

Examine the symbology legend associated with the new layer. What are the values depicting?
What value is used for flat areas? Is there anything peculiar about the output? Make flat areas black and examine the output up close.
Do we see the same terracing here that we saw in the slope grid? What about in the DEM?

After inspecting the values a bit, make a histogram chart of the aspect raster as well:

- What pattern do you notice?
- Can you take a mean value of aspect?
- Is there a way to handle these data in a linear fashion?

Also, start thinking of what how we might filter an aspect raster for south facing slopes - do we just include the cells that are directly west, or do we also include southwest and northwest to some extent?

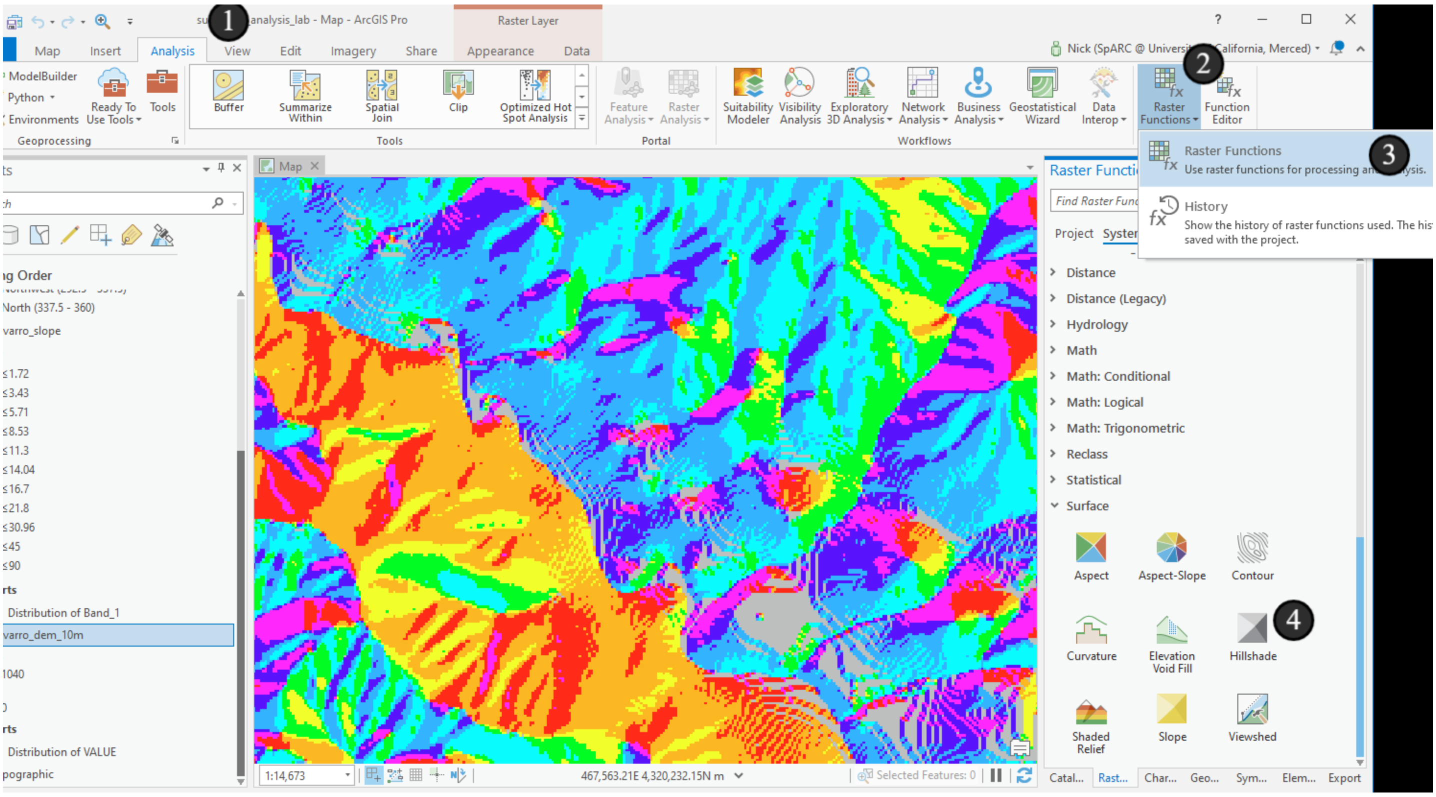


9. Make a hillshade

Now let's make a hillshade. We already have one in the background in the form of our basemap, but I like working with local data when I can, and we'll have more control over this display. You can do this with geoprocessing if you like (can you find the tool?), but we'll do it a different way this time, with a *Raster Function*.

Raster functions have existed for a while, but are much more accessible in ArcGIS Pro than in many other GIS packages. In short, a raster function can perform the same calculations as we've been doing for slope and aspect, but instead of saving out a new dataset, which can become a data management issue at times (and we don't always need to store our intermediate data if we can recreate it in a documented fashion), it just calculates it from the source all the time. When it's showing you the data on your screen, it calculates for your current view extent and resolution, making it something it can do rapidly since it isn't calculating it for the entire dataset. They can be used in geoprocessing too, at which point the whole dataset will be calculated, if needed.

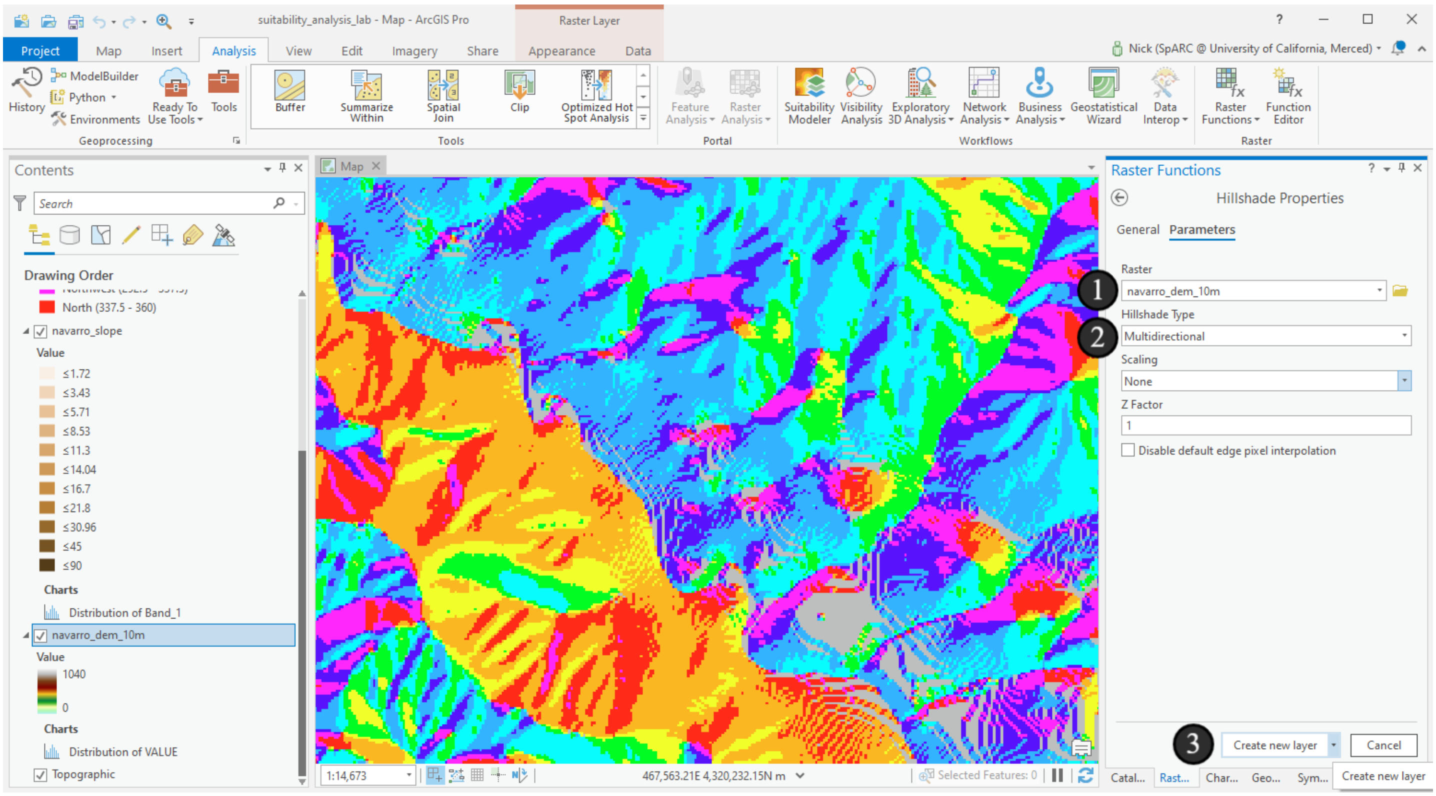
1. Open the *Analysis* ribbon
2. Click the *Raster Functions* button
3. And then click the *Raster Functions* option in the dropdown.
4. Scroll down and expand the *Surface* section, where you'll see some familiar items. Click the *Hillshade* option.



9.1 It looks like a geoprocessing tool and smells like a geoprocessing tool...

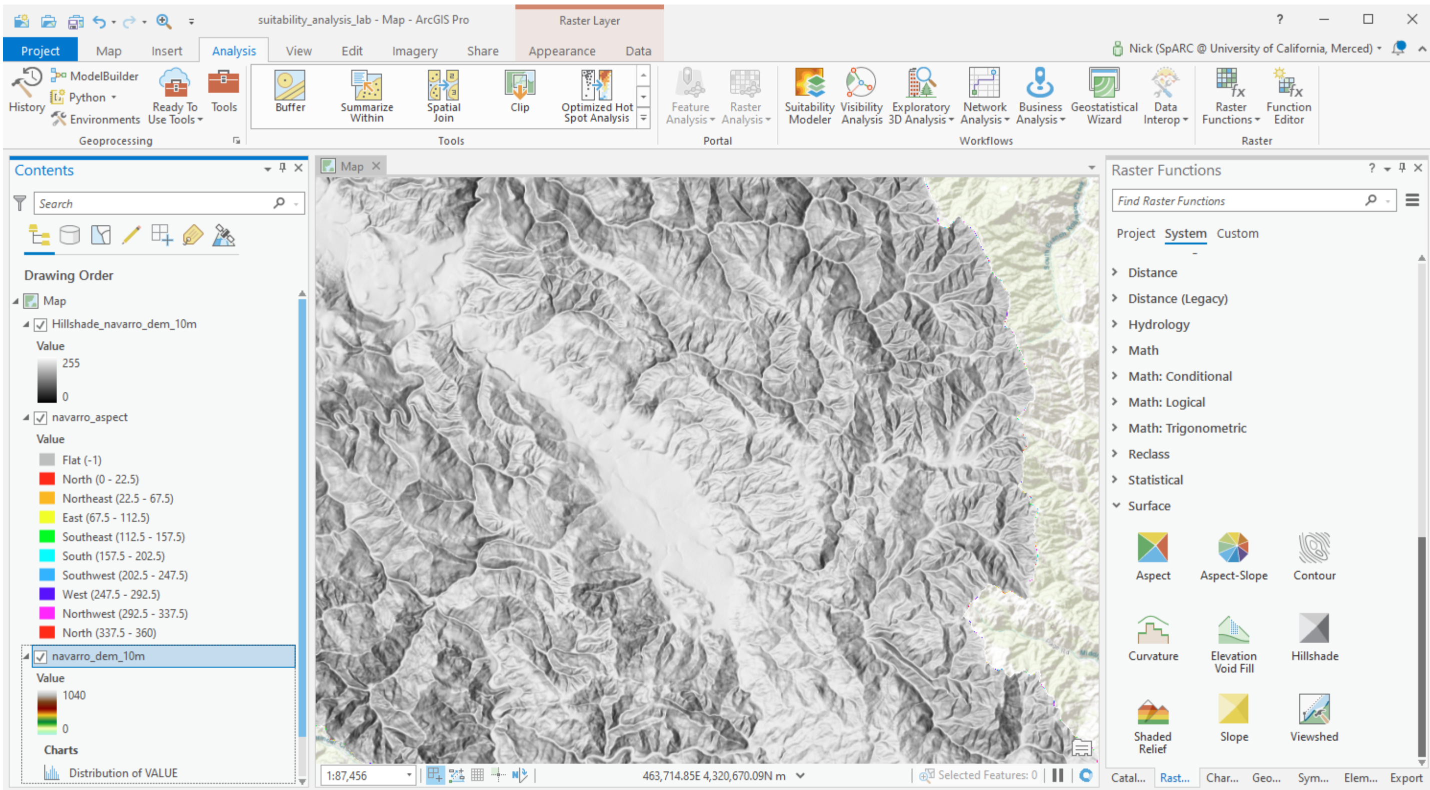
So, this will look like a geoprocessing tool - hooray for user interface consistency! But it's not a geoprocessing tool. You'll provide a set of inputs still and get an output, but instead of having a stored output location you provide, you'll click the *Create new layer* button at the bottom when you're ready (not yet).

1. For a hillshade calculation, we start with our DEM, so provide that as the input for the *Raster* parameter - you can select it from the dropdown
2. For *Hillshade Type* select *Multidirectional* - these are truly beautiful - older hillshades just look ugly to me in comparison. Feel free to try both options here though.
3. Leave the others at their defaults and then click *Create new layer*



9.2 The multidirectional hillshade

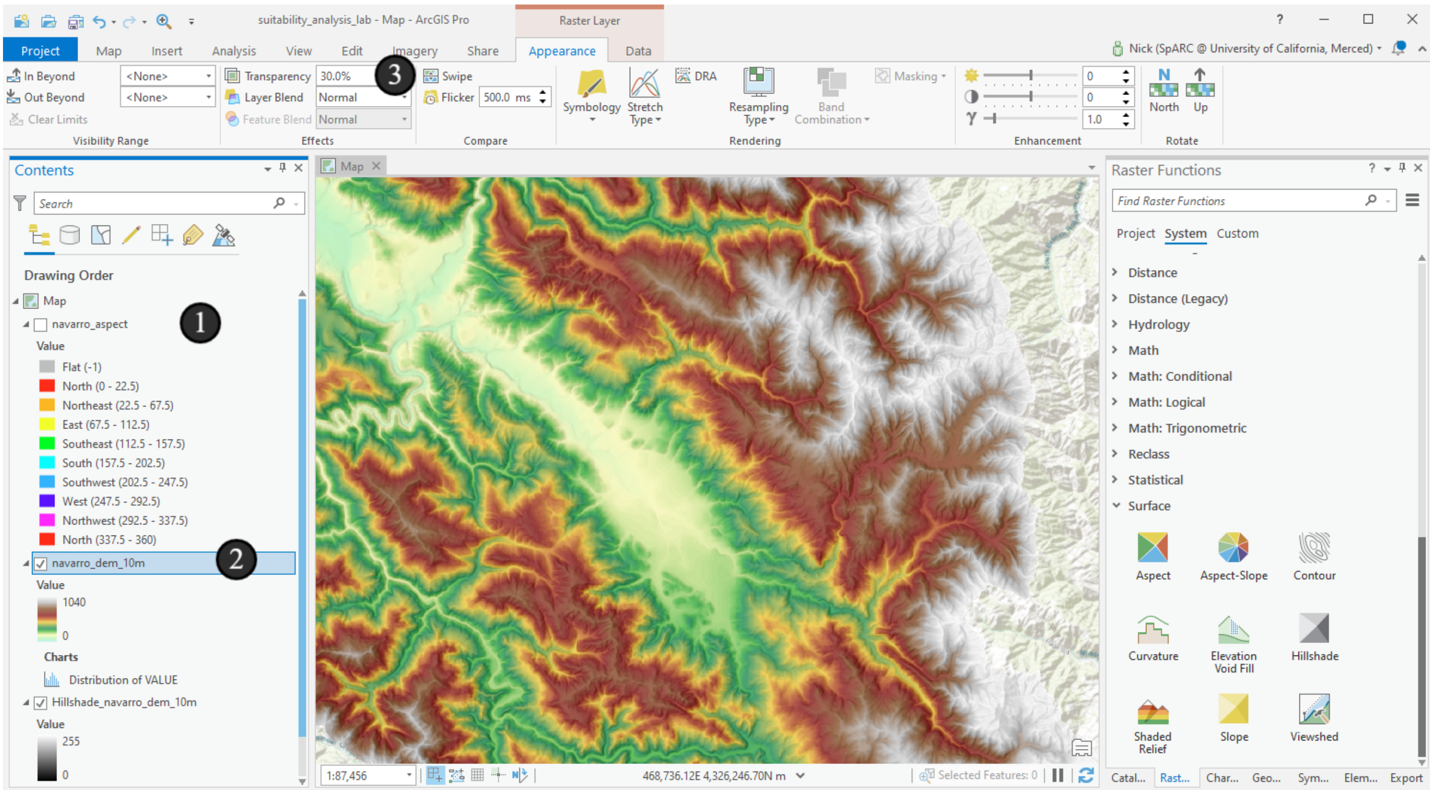
A new layer will show up in your table of contents and on your map and will redraw as you zoom and pan. Take a look around for a little bit - how does it look compared with the basemap?



10. Draping the DEM over the hillshade

Now we'll put some data on top of our hillshade and use the hillshade to enhance it. We typically call this process *draping* like a tablecloth - with the analogy that one layer will appear to sit on another layer and hug close to it. To do this, we'll move the DEM on top of the hillshade and make it semitransparent

1. Either turn off (uncheck) or move anything above the DEM and hillshade lower in your contents pane.
2. Make sure the DEM is above the hillshade in your contents pane so that it draws on top. At this point, your hillshade will be obscured.
3. Make sure the DEM is selected in your contents pane and switch to the *Appearance* ribbon. Change transparency to 30%. You should see an effect almost as if the hillshade is now colored by elevation.



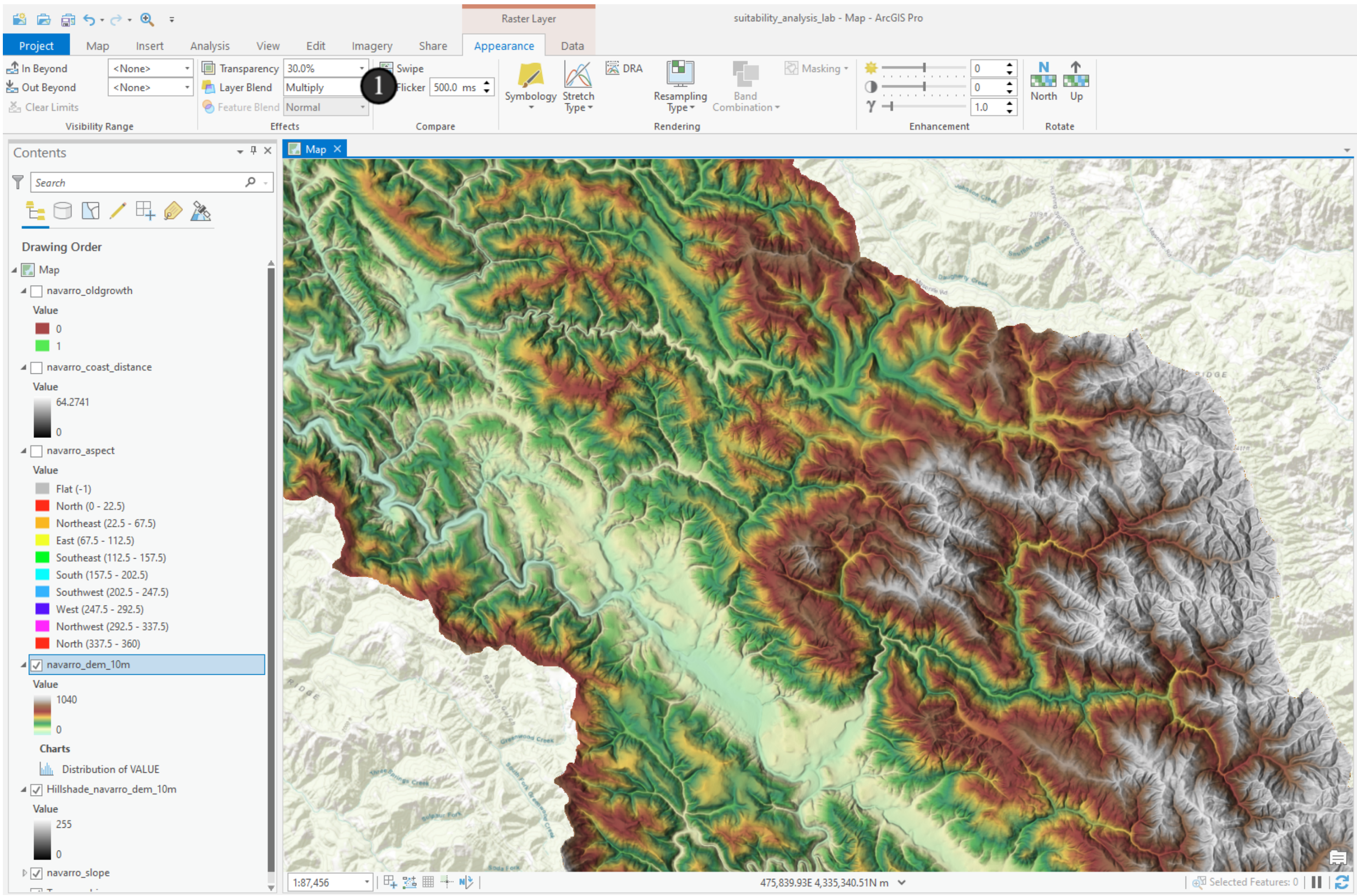
10.1 Draping: Part 2

This is already a pretty nice way, but a new feature in ArcGIS Pro lets us enhance these kinds of effects substantially, doing things that pro cartographers have previously had to take to other GIS packages or into graphics packages like Adobe Illustrator to accomplish. Beneath the transparency slider, there's an option for *Layer Blend* which controls how the software mixes the two datasets' pixels when they draw on top of each other.

1. Choose a few items from the dropdown and see how they behave. Eventually try the "Multiply" option and leave it there.

Multiply makes the data layer on top look truly "baked on", as if we had a hillshade that just happened to have the colors of the DEM already in the data.

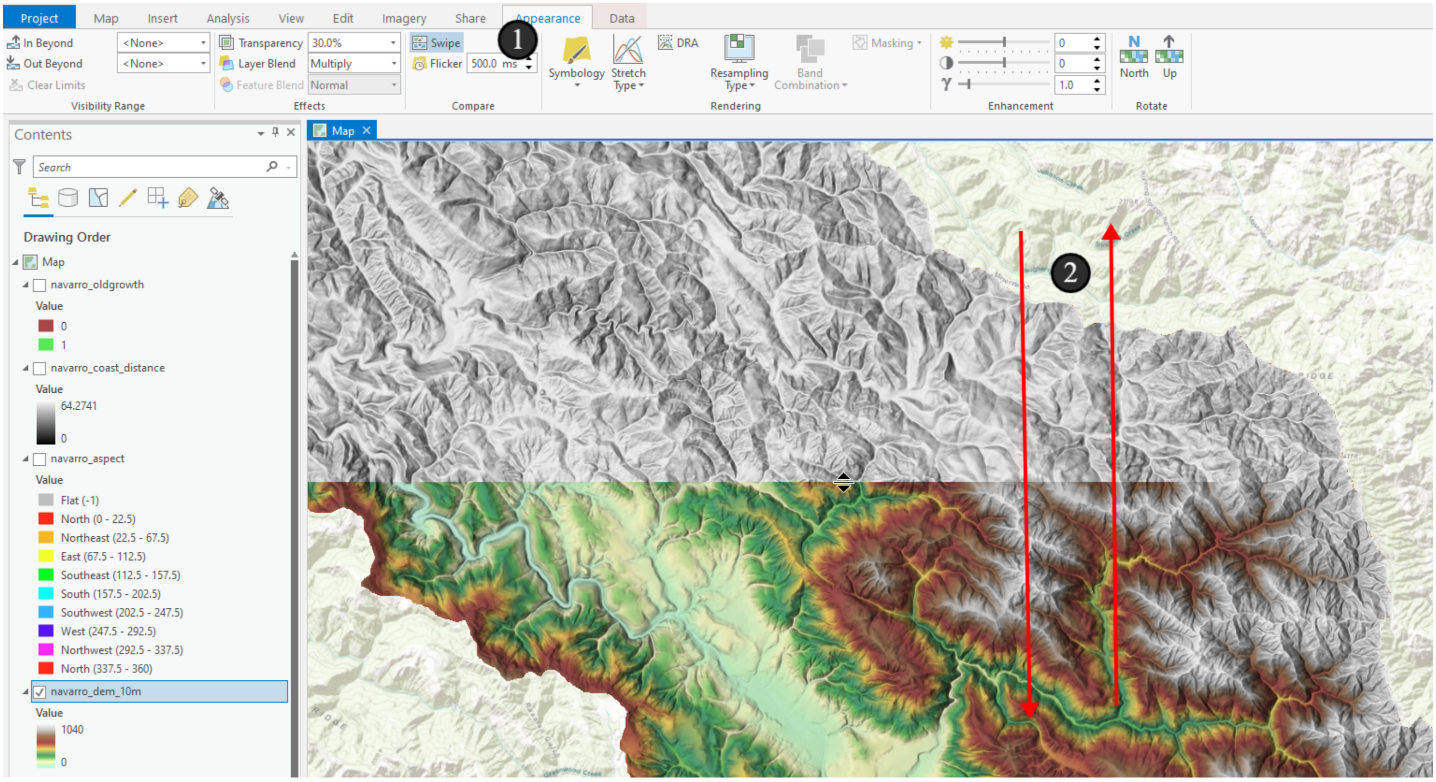
Also note that layer blend modes don't require transparency. When you set a blend mode, ArcGIS blends the layer down on top of the one below it regardless. The transparency we set lightens the layer up a bit and makes it work without changing the blend mode, if we wanted. I liked the lighter effect of it with the transparency, but set it to your preference.



10.2 Compare it

To see the effect we just created in action, we could just turn the DEM on and off a few times to compare, or we could use the Swipe tool which lets us compare rasters that are on top of each other.

1. Click the *Swipe* tool on the Appearance tab - make sure that *navarro_dem_10m* is selected in your contents pane - that controls your swipe.
2. Click and hold on your map in the top half and drag your mouse up and down to see a comparison that changes as you move your mouse. You could also click on the left or right to have a vertical comparison.



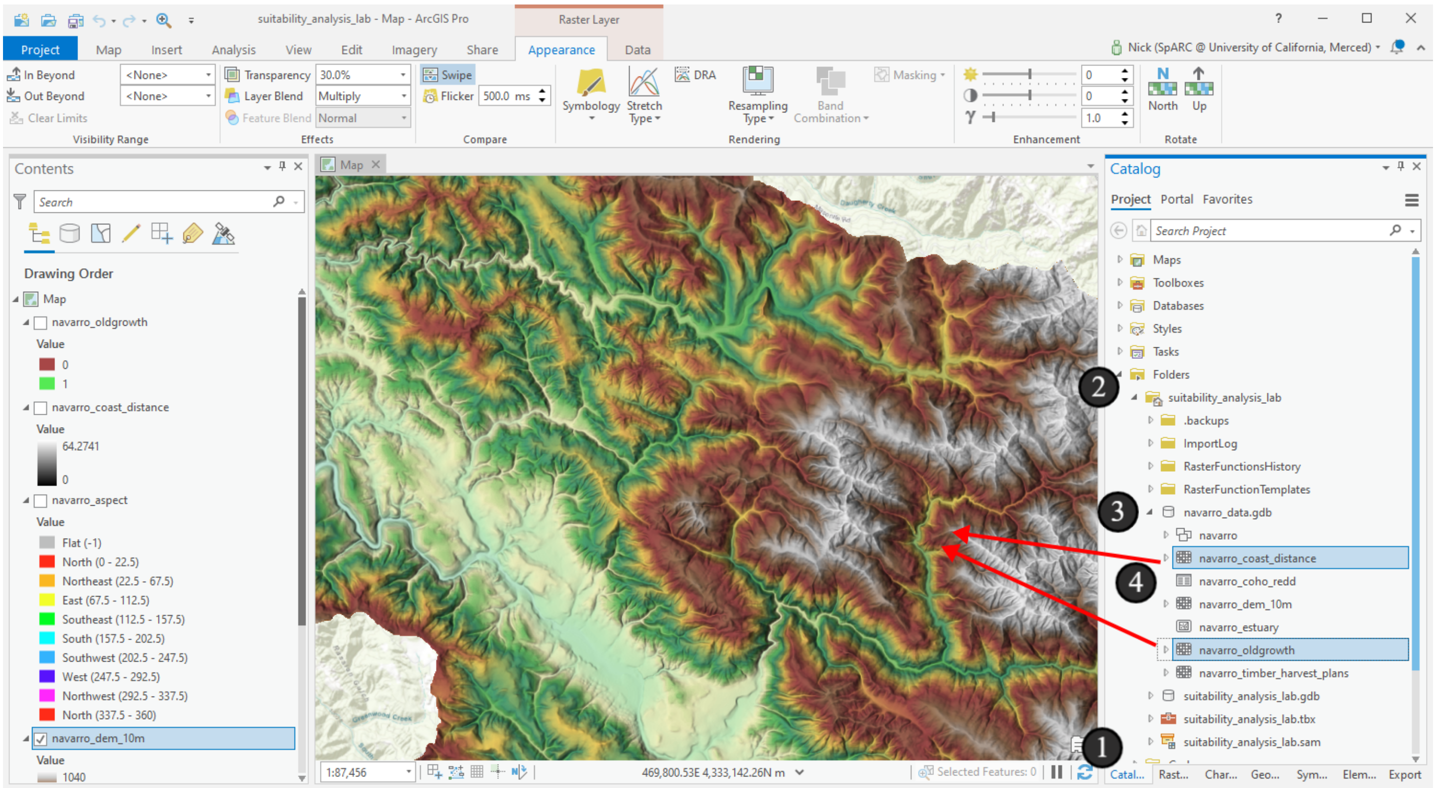
11. Adding more data

For the marbled murrelet habitat, we also need to know the distance from the coast and old growth locations. We've provided these for you for the purposes of this lab - they're in the *navarro_data* geodatabase.

You can add the data any way you like, but we'll do it from the catalog pane.

1. Expand the *Catalog* pane
2. Expand the *Folders* and *suitability_analysis_lab* tree items so you can see their contents
3. Expand the *navarro_data* geodatabase
4. click and drag *navarro_coast_distance* and *navarro_oldgrowth* onto your map to add them.

Take a moment to look at the data - what is the data type, what do you think it's conveying?

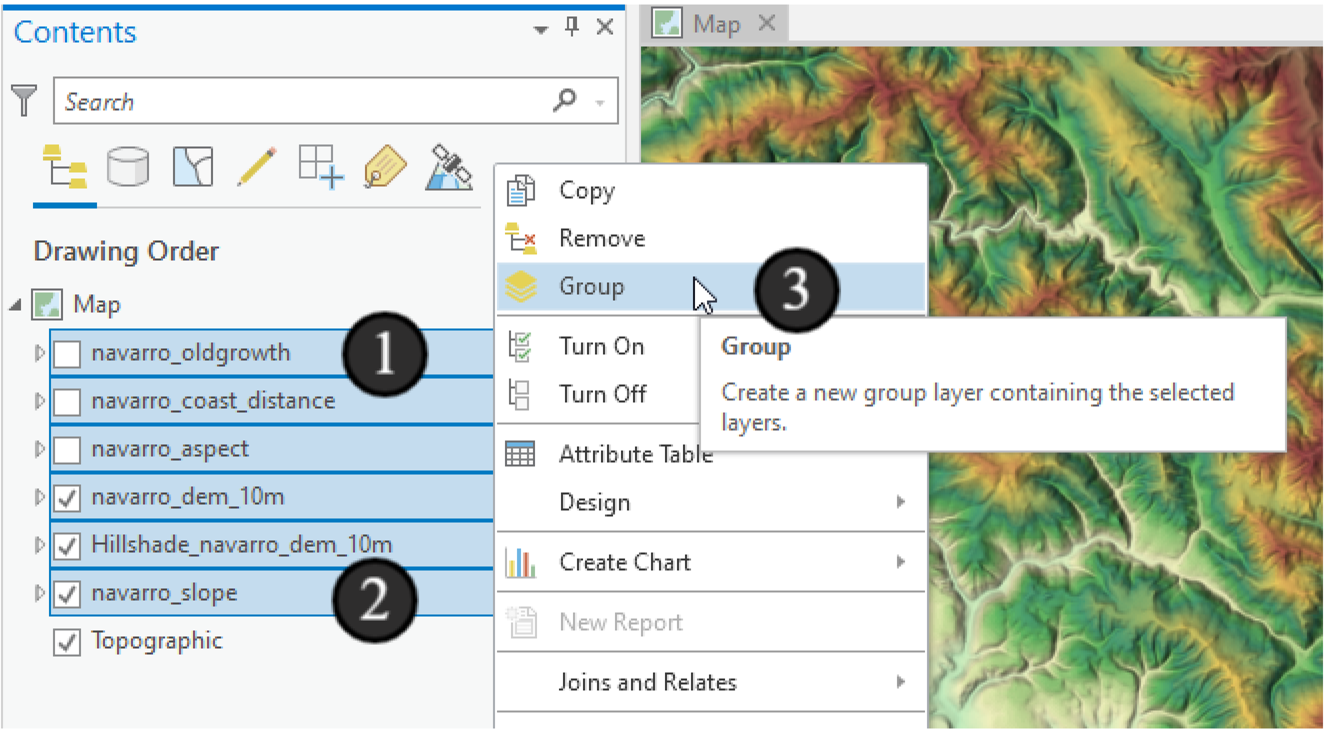


12. Data Management

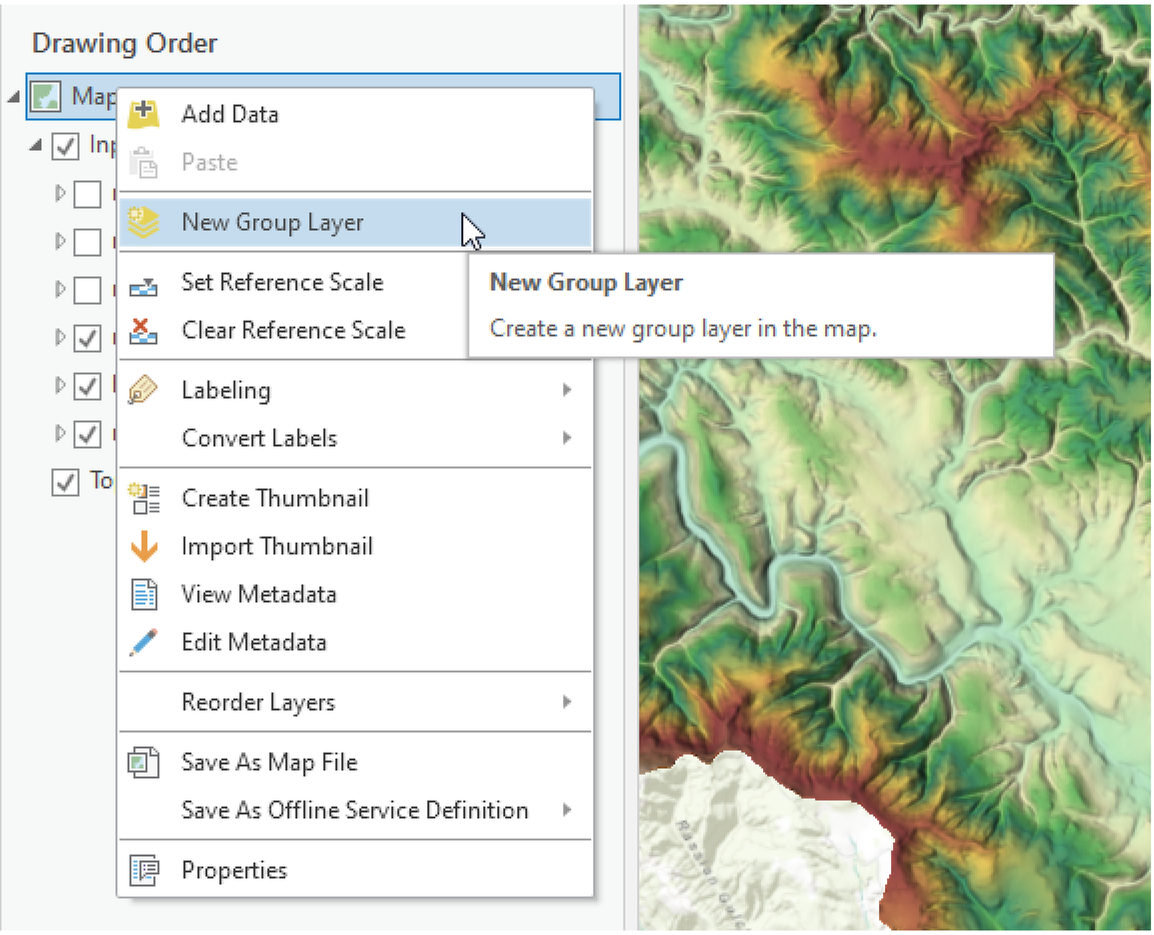
We already have quite a few layers, so let's do some document management work - Even though we generated many of the items we've already produced here, they're all *inputs* to our suitability analysis and we're about to generate a lot of intermediate analysis products based on suitability criteria, and results. So let's create some layer groups to keep things organized.

1. Click on the top item in your Contents pane
2. Hold down the shift key and then click the bottom item above the Topographic basemap
3. Right click and then choose *Group* in the context menu.

You'll see all the items are now nested under a layer named "New Group Layer" - rename this group layer as "Inputs". Play around a bit with turning items on and off, including the group layer. Note that each layer can still be turned on and off on its own, but that turning off the group layer hides them all, regardless of their own status.



12.1



Drawing Order
Map
Add Data
Paste
New Group Layer
Set Reference Scale
Clear Reference Scale
Labeling
Convert Labels
Create Thumbnail
Import Thumbnail
View Metadata
Edit Metadata
Reorder Layers
Save As Map File
Save As Offline Service Definition
Properties
New Group Layer
Create a new group layer in the map.

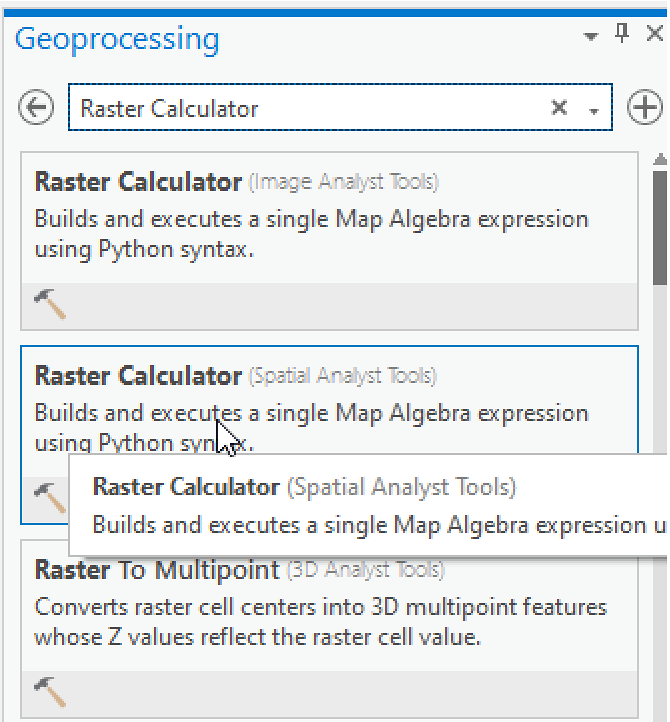
13. Running the Suitability Analysis

Next up, we start checking for suitability. For this, we'll use a new tool (to us, it's quite an old tool, really) called *Raster Calculator*.

If I think of the most basic things I might want to do with GIS, it's that I want to overlay data and run calculations on overlapping areas. In the vector world, it's the *Overlay* toolset that we've used for Spatial Joins and Intersections. In the raster world, the *Raster Calculator* is our tool. Much of what it does can be done with a combination of many standalone tools, but raster calculator lets us take overlapping pixels and run arbitrary calculations on them. At times it might feel a little like SQL expressions used for selections and subsetting or a little like Python expressions used for field calculations, but it's not really either one. It's its own beast.

Raster calculator lets us identify locations that meet specific conditions, making it even more like SQL subsetting and selection expressions. But instead of selecting pixels, we get an output grid telling us which pixels met the conditions and which ones didn't. We do this with *boolean logic,* which ArcGIS calls *Map Algebra*. Boolean logic lets us write expressions with conditions that result in a value of either True or False. ArcGIS evaluates these expressions for each pixel (such as, does the pixel face west? True/False) and then returns a new raster with the value of 1 for True and 0 for False, allowing us to feed these rasters into further mathematical or processing operations.

Let's go see it in action. Open up the geoprocessing pane and search for Raster Calculator. Choose the option that's in the *Spatial Analyst Tools* toolbox.



13.1 Calculate Slope Suitability

Let's start with slope since it's the easiest to work with. We need a way to pull the locations from our slope raster that meet the marbled murrelet's slope conditions of being greater than 20 degrees slope.

Now let's construct a query. Before you do, I recommend expanding the geoprocessing pane for working in Raster Calculator - the two column setup makes it easier to work with this way - you can hover your mouse over its left edge until your cursor changes to the double-arrow drag handle, then click and drag to expand.

1. Double click on *Inputs\navarro_slope* in the *Rasters* column to add it to our expression (you could also just type it, but then you have to get the syntax and quoting right). Double clicking it here takes care of any necessary quoting based upon the workspace the rasters are stored in (geodatabase, folder, etc).
2. Click into the expression box yourself and type > 20

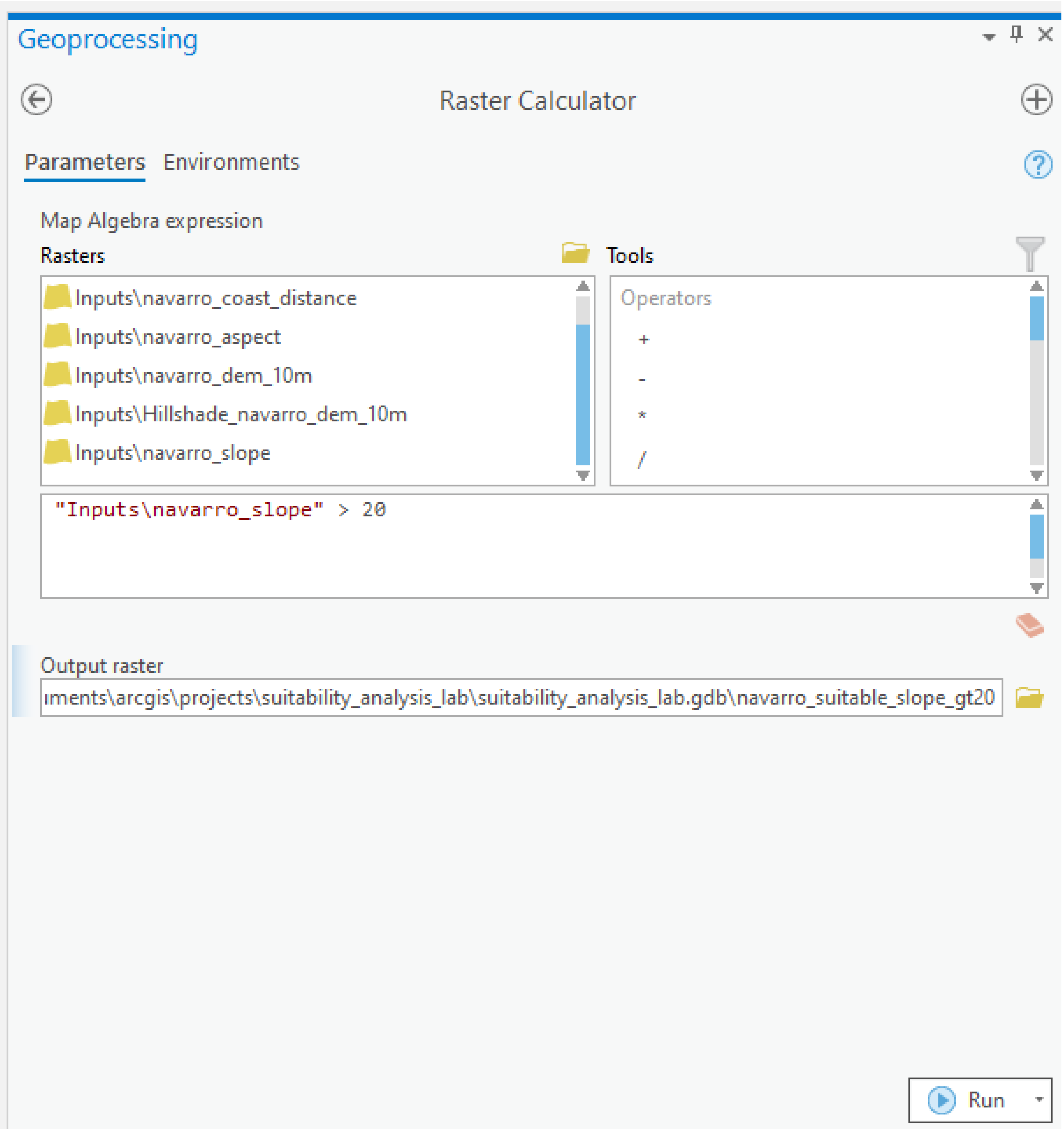
Your final expression will look like in the screenshot and will read:

```
"Inputs\navarro_slope" > 20
```

Consider what this means - we're saying "for every pixel in *navarro_slope* check if the value is greater than 20. If it is, place a value of 1 in the output for that pixel. Otherwise, use a value of 0". Remember also that we set our analysis mask environment, so areas outside of the watershed but within the rectangular extent of the watershed will get null values instead of 0.

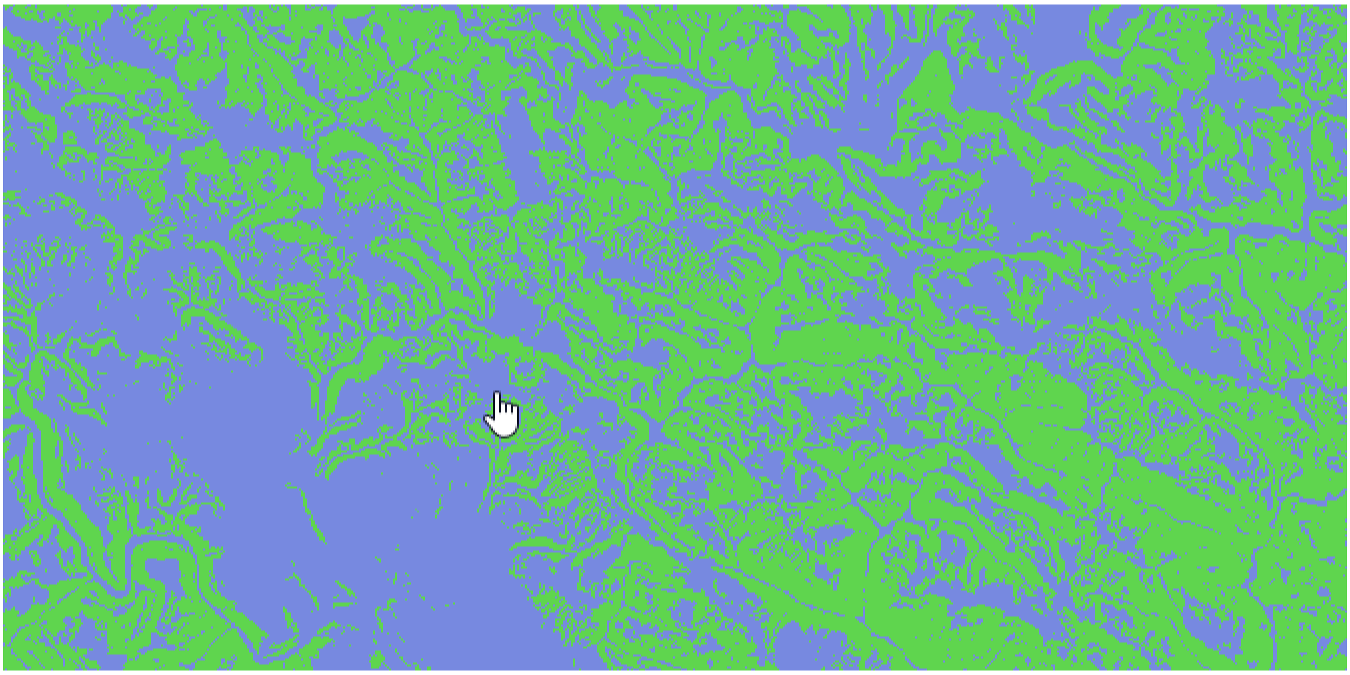
Save your raster output in your default geodatabase. Name it *navarro_suitable_slope_gt20* (3). I prefer descriptive names like this even though they're long because for intermediate products it makes it easier to understand what a data layer is, even if I'm not stopping to add metadata to everything. I tend to construct a name like this as *projectprefix_itemname_specifics* - so in this case I read it as part of the Navarro project here, it's a suitable slope calculation, and it's where slope is greater than 20 degrees. That last bit helps if we refine our criteria in the future, say to 25 degrees, and I create additional data products, I don't confuse them or have something like *suitable_slope2* for lack of a better naming scheme. For your own projects, come up with your own naming scheme that works for you, but I highly recommend something that has at least a little bit of detail!

Click run to see the result of the expression (4), then move the resulting raster into the *Suitability* group layer in the Contents pane by clicking and dragging.


Geoprocessing
Raster Calculator
Parameters
Environments
Map Algebra expression
Rasters
Tools
Inputs\navarro_coast_distance
Inputs\navarro_aspect
Inputs\navarro_dem_10m
Inputs\Hillshade_navarro_dem_10m
Inputs\navarro_slope
Operators
+
-
*
/
"Inputs\navarro_slope" > 20
Output raster
ıments\arcgis\projects\suitability_analysis_lab\suitability_analysis_lab.gdb\navarro_suitable_slope_gt20
Run

13.2 Examine the slope output

Take a look at the resulting raster. Look at which areas have values of 0 (false) and which areas have values of 1 (true) - do these results make sense? Did we get the expression right for what we were trying to do?



13.3 Do this three more times, but differently!

Let's now create the equivalent analysis grids for aspect, elevation, and coast distance. For each of these, we'll run raster calculator again - think about what your expressions will be.

(1) Aspect Expression:

```
("Inputs\navarro_aspect" > 225) & ("Inputs\navarro_aspect" < 315)
```

The parentheses and ampersand let us chain two conditions here - so for the expression to be *True* both of those conditions must be met

Consider why we might be using 225 and 315 as our filter values here - look at the symbology for the aspect data for hints.

Output raster: Name your output navarro_suitable_aspect_225_315

(2) Elevation Expression:

```
("Inputs\navarro_dem_10m" > 50) & ("Inputs\navarro_dem_10m" < 250)
```

Output raster: Name your output raster navarro_suitable_elev_50_250

Consider why we chose these numbers in the conditions before proceeding.

(3) Coast Distance Expression:

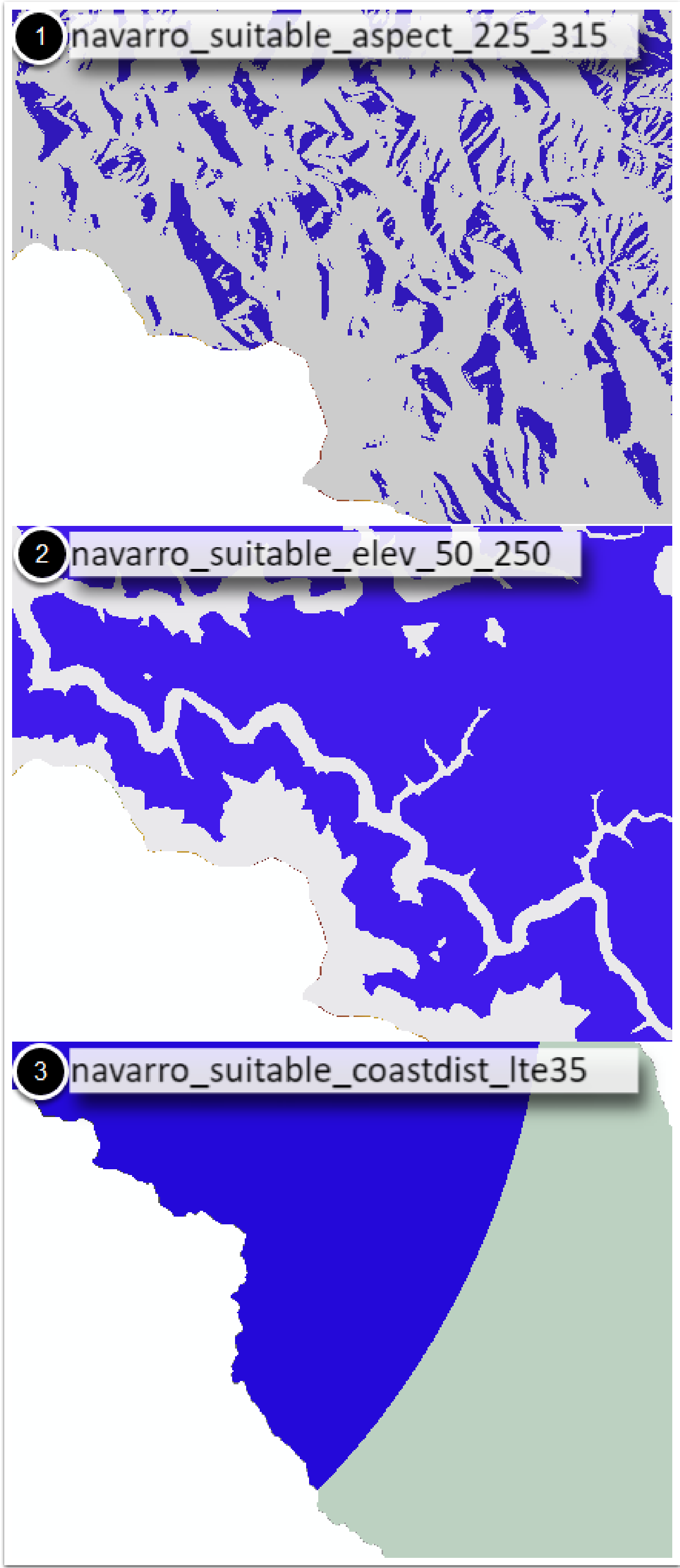
```
"Inputs\navarro_coast_distance" <= 35
```

Output raster: navarro_suitable_coastdist_lte35

Why is the coast distance <= 35? Should it be <= 35,000 instead? Look at the symbology for *navarro_coast_distance* to understand what value to use better.

Do we need to do anything with the Old Growth Raster? Take a look at it and think what its data might mean.

Inspect each of these results and ask yourself if they make sense - confirm for yourself through visual inspection that it appears we wrote the expression correctly based on what you expected the results to be (this makes sure we move on with valid data and that you understand how this is supposed to work!). Move each of these resulting items to the *Suitability* group layer before proceeding.



13.4 One last, big raster calculation before retirement

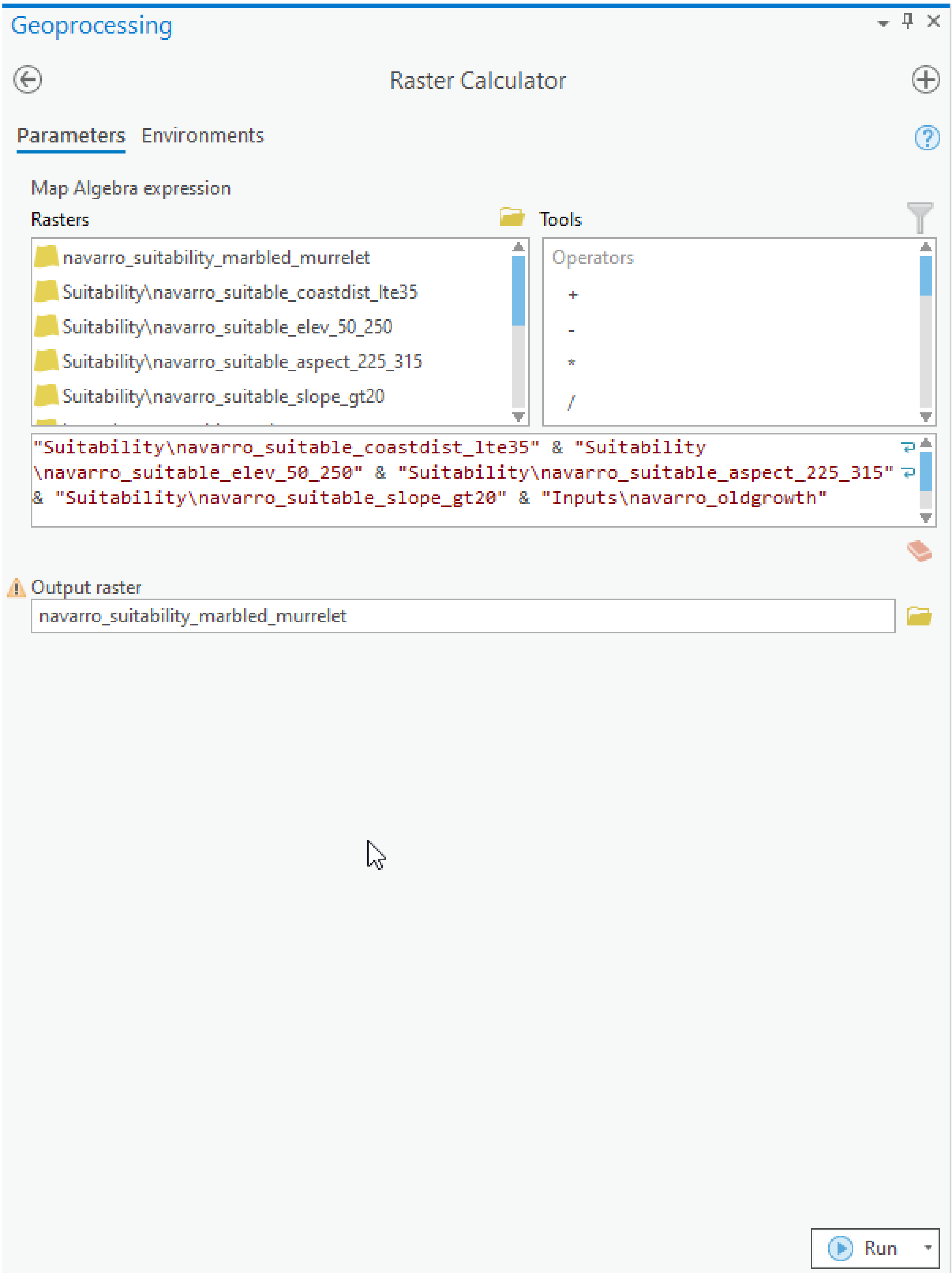
Ok, now we have separate rasters for suitability, based on each parameter. We need to combine them into a single raster indicating overall suitability for the species. If each raster habitat suitability raster uses 0 for unsuitable and 1 for suitable, then what combination of these rasters gives us overall suitability? Recall that the marbled murrelet needs *all* of these conditions to be met for suitable habitat - if any one of them isn't met, it's not suitable and we want to discard it.

We're looking for the locations where all of the rasters have a value of 1, correct? That's where each suitability requirement is met. To get a resulting raster indicating those locations, we'll again use raster calculator. In previous expressions, we've used the & operator to chain requirements - saying multiple criteria must be met. We'll do the same here. Once again, it's a question that raster calculator is answering for us ("where are these requirements met?"), but it's written a little differently. Since 0 is always "false" and 1 is always "true" we can jut chain together the layer names. For example, putting *"navarro_suitable_coastdist_lte35"* is equivalent to *"navarro_suitable_coastdist_lte35" == 1* in this instance. Knowing that, what does our full expression look like?

The expression you'll want to put in should be something akin to:

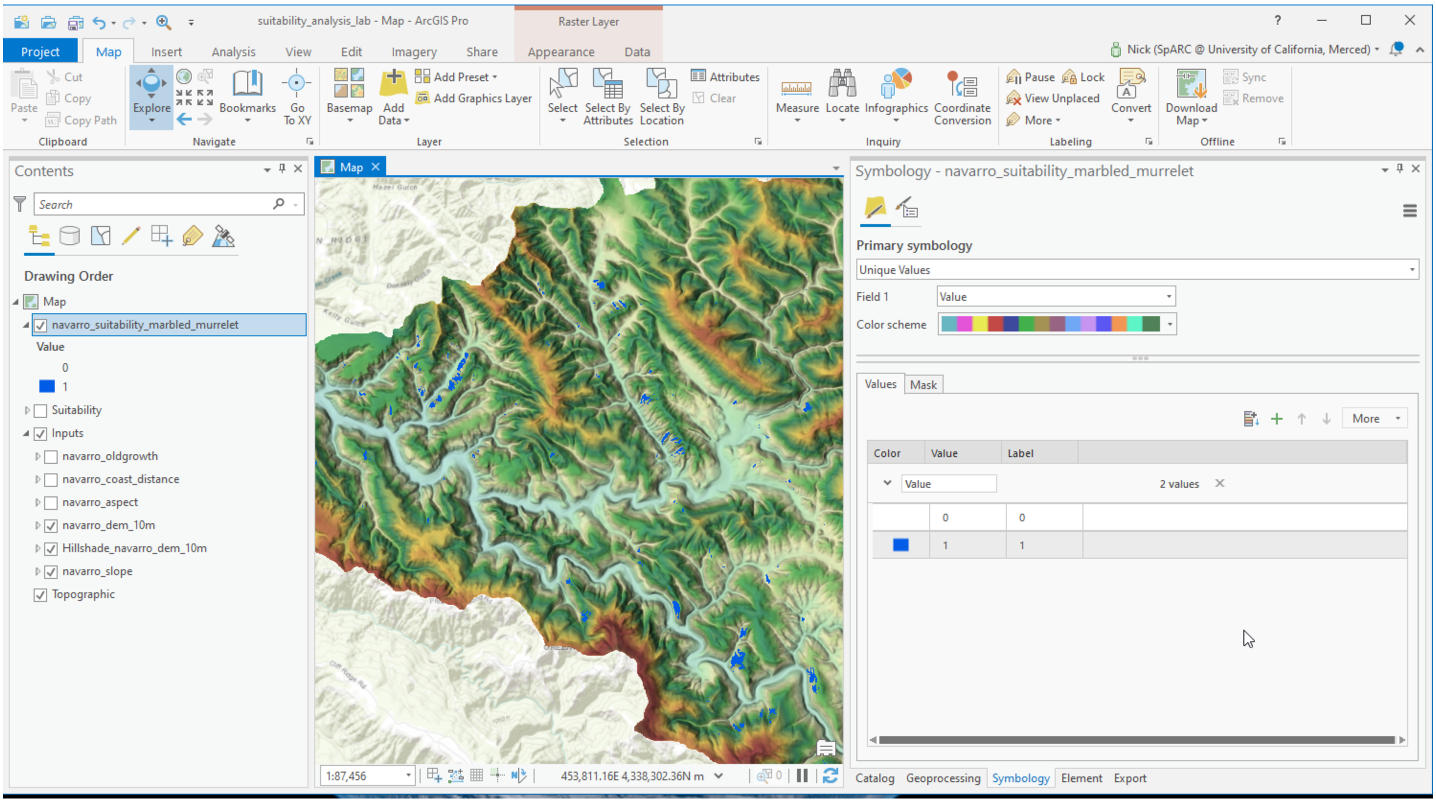
```
"Suitability\navarro_suitable_coastdist_lte35" & "Suitability\navarro_suitable_elev_50_2
```

Again, double clicking the layer names from the box instead of typing them will get the quoting correct for you, but if you already know that you're using the correct quotes, go ahead and type it in. You can also copy and paste the expression from here if you've kept all the layers moved to their correct group layers. Save the output in your default geodatabase and name it *navarro_suitability_marbled_murrelet*


Geoprocessing
Raster Calculator
Parameters
Environments
Map Algebra expression
Rasters
Tools
navarro_suitability_marbled_murrelet
Suitability\navarro_suitable_coastdist_lte35
Suitability\navarro_suitable_elev_50_250
Suitability\navarro_suitable_aspect_225_315
Suitability\navarro_suitable_slope_gt20
Operators
+
-
*
/
"Suitability\navarro_suitable_coastdist_lte35" & "Suitability\navarro_suitable_elev_50_250" & "Suitability\navarro_suitable_aspect_225_315" & "Suitability\navarro_suitable_slope_gt20" & "Inputs\navarro_oldgrowth"
Output raster
navarro_suitability_marbled_murrelet
Run

14. Our final suitability map

You'll get another raster as a result, effectively answering the question of "where is suitable habitat for the marbled murrelet" as the 0 and 1 value set we've seen before. Set the symbology for the unsuitable (0) values to transparent, and the 1 values to something like a blue, then show it with just your DEM/Hillshade combination below it (bottom image, below). Examine the locations. Does it seem like there are limitations to the analysis? What are they? Does the habitat show up where you'd expect it to?



14.1 Additional Considerations and ways to deepen the analysis

Questions

- Examine your output. How do they differ from the Old Growth patches?
- What about the quality of the patches, are there characteristics that might need further investigation? How might we go about that?
- What other data layers would be helpful to address this problem statement?
- What other habitat related information could be generated from your identified nesting patches?
- If this were a probability exercise, as opposed to presence/absence, which data might you use as weighting terms?
- Consider how we might have used raster functions to do some of these calculations - what would the implications for our workflow be?

Suggestions for Additional Work

Suitability analyses are a deep area in GIS and a common need. You can use them as part of habitat analyses like we just did, or for determining the location of critical infrastructure (transmission towers, fire lookouts), siting a business, etc. There isn't one way to handle them, and more complex suitability analyses use weights for each layer or probabilistic gradients rather than simple yes/no combinations. Consider how you could accomplish something like this with raster calculator. ArcGIS also has tools for suitability analysis, such as the *Weighted Overlay* tool that can support such analysis.

ArcGIS recently added the *Suitability Modeler* to handle more complex workflows and probabilistic calculations. I've only just started playing with it, but if you think that locating the best (or worst) spot for something, or identifying where something is likely to already exist, etc, is something you might spend more time doing, I'd recommend exploring it. You can find it on the Analysis tab. The concepts you learned here will translate over, but it gets more complicated very quickly. There's an entire help section on what the spatial modeler is, common workflows, and how to use it at https://pro.arcgis.com/en/pro-app/latest/help/analysis/spatial-analyst/suitability-modeler/what-is-the-suitability-modeler.htm