Using Raster Analysis Tools to Model Wildfire Risk in Southern California

This model is intended as an instructional tutorial of GIS raster analysis tools and is NOT an authoritative fire risk model.

Check out the companion walkthrough video at https://youtu.be/phRrBQ8FZ2A!

Wildfires pose a significant threat in an increasingly arid California landscape, threatening habitats and wildlife, human lives and property, air quality, as well as long-term impacts on soil, flooding, erosion, and water quality. In this exercise, we will explore GIS raster analysis tools by analyzing elements of fire risk within a study area of Southern California forests and mountain ranges. The 5 criteria we will be using in this analysis include:

1. Slope – Steeper slopes are more vulnerable to fire and more difficult to fight
2. Land cover – Wildfires are fueled by vegetative land covers. Water, rock, and developed surfaces are unlikely to be affected.
3. Proximity to roads – Wildfires are more likely to be set near roads
4. Visibility of fire lookout towers – Fires are more likely to burn and expand if they can't be seen from lookout towers as an early warning system. *Lookout towers are less important to modern-day firefighting but will help to illustrate an important spatial analysis operation in this exercise.*
5. Aspect – South-facing slopes receive more direct sunlight which often results in drier, more flammable vegetation.

Setup your project

1. Create a new ArcGIS Pro project in your class folder named **WildfireRisk**
2. Download the project data here and extract it into your new project folder.
   The download contains data for a Southern California study area but the data sources are all publicly available and could be easily acquired to complete this project for another location in the United States. Data sources include:

SRTM Digital Elevation Model	https://earthexplorer.usgs.gov/
California Roads Network	https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2021&layergroup=Roads
Land Cover	https://www.mrlc.gov/data
California Fire Lookout Towers	http://www.peakbagging.com/Peak%20Lists/CA_Lookout1.html
US Parks and Forests	https://www.arcgis.com/home/item.html?id=f092c20803a047cba81fbf1e30eff0b5

3. Change the coordinate system of your map to NAD 1983 UTM Zone 11N. *If you are following along in a region outside of southern California, please select your own UTM Zone. [See this site to find your UTM zone](#).*
    a. If you can't remember how to do this, right-click your map in the Contents pane > Coordinate Systems.

Elevation Processing

Before 2000, elevation data was based on land-based survey methods and stereo aerial photography but NASA only needed 11 days to capture the data for a global elevation model at a 30-meter resolution as part of the Shuttle Radar Topography Mission (SRTM). The SRTM elevation model is still the de-facto standard for regional GIS projects but new higher resolution products are now also available. SRTM data is easily and freely available to download in arc degree tiles (1 tile for each degree of latitude/longitude) from USGS Earth Explorer. The tiles for this project are included in the project download to save time.

4. Add the 5 SRTM DEM tiles to the map. Notice that you can see the boundaries between each tile because the shades of gray are stretched based on the values in that layer.
5. In order for us to work with these, we'll need to process these 5 individual rasters into a single combined raster using a **Mosaic** operation. Open the Geoprocessing panel (Analysis > Tools) and switch to the Toolboxes tab to see a list of all the available toolboxes. Browse to **Data Management Tools** > **Raster** > **Raster Dataset**
6. Open the **Mosaic to New Raster** tool.
    a. Add the 5 tiles as inputs
    b. Set the output as your project gdb
    c. Name the output **SoCal_DEM**
    d. Set the number of bands to 1
    e. Set the pixel type to **16 bit signed**. This pixel type allows for integers between -32,768 – 32,768.
    f. Run the tool and review the results. The DEM is now "seamless".
7. Remove the original 5 individual tiles from the map
8. The DEM tiles have been mosaicked into a new raster but it is in the wrong coordinate system for this project. Open the **Project Raster** tool:
    a. Set the SoCal_DEM as the input
    b. Name the output **SoCal_DEM_UTM**
    c. Change the output coordinate system to **Current Map.** This will set it to NAD 1983 UTM Zone 11N and set a Geographic Transformation for you.
    d. Change the **Resampling Technique** to **Bilinear interpolation**. This setting is important because pixels are being moved around so ArcGIS has to interpolate (estimate) new cell values. **Bilinear interpolation** is a better technique to use for continuous data like elevation vs **Nearest Neighbor**, which is better for discrete data.
    e. Run the tool
9. Remove **SoCal_DEM** to avoid confusion.

Define the Study Area

Defining a study area for your project can both help speed up processing as well as standardize the shape and extent of outputs. The input data often comes in all different extents and scales (global, National, regional, local, etc) but a study area can help ensure that all outputs are of a consistent size and shape.

10. Add the **StudyArea** shapefile from the data download. This polygon follows the major highways in Southern California that surround the region's mountain ranges.
11. Next we'll buffer the StudyArea to avoid *edge effects*. Use the **Buffer** tool to expand the study area by 1 kilometer. Save the output to your project gdb and name it **StudyArea_1km**
12. Remove the original study area layer to avoid confusion.

Extract the Elevation Data to the Study Area "Mask"

13. Open the Geoprocessing pane and browse to **Spatial Analyst Tools** > **Extraction.** Most of the raster processing tools are going to be found in Spatial Analyst toolbox. I highly recommend *browsing* the list of tools rather than searching for them because you learn about other helpful tools in the process. Take a look at the other extraction tools available to you.
14. Find and open the **Extract by Mask** tool. Set the input to **SoCal_DEM_UTM** and the mask to the buffered study area. Save the result to your project gdb and name it **DEM_StudyArea.** This will use the coordinate system of the input but the output will be in UTM.
15. Remove the original DEM to avoid confusion.

Analyze Slope

Wildfires spread faster on steep slopes and are more difficult to fight. A Slope raster computes the steepness of each cell and can be easily derived from a DEM. In this step we'll generate a slope raster and evaluate it as being risky or not (1 or 0).

16. Browse to **Spatial Analyst Tools** > **Surface** and open the **Slope** tool and set the DEM as the input.
    a. Use the **percent rise** option.
    b. Name the output **Slope_StudyArea**

    The resulting slope raster will have the same cell size and extent as the input DEM.
17. Change the symbology of the resulting layer to the color scheme named **Slope** and review the output**.**
18. In terms of wildfire risk, a single 30m pixel with a steep slope probably isn't a big problem, but a cell surrounded by steep slopes could pose a problem. To do this, we'll analyze the "neighborhood" of cells around each cell to get the average slope using the **Focal Statistics** tool. Open the **Focal Statistics** tool.
    a. Set the input to **Slope_StudyArea**
    b. Name the output **Slope_FocalMean**
    c. Set the neighborhood to a 3x3 rectangle of cells.
    d. Set the Statistics type to Mean. This setup means the resulting cell value will be average of the slopes surrounding the cell.
    e. Run the tool
19. Change the symbology of the resulting layer to the color scheme named **Slope** and compare to the original slope layer. You'll notice the focal mean result appears "smoother".
20. Find and open the **Greater Than Equal To** tool.

   a. Set Input 1 to the Slope raster and Input 2 to **30**.
   b. Name the output **Risk_slope**

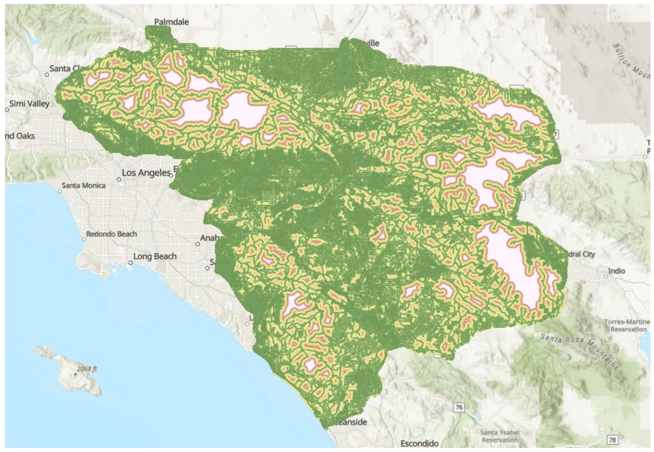
   This will create a new raster where each cell is assigned a 1 if the value is >= 30 or a 0 if it's less that 30. A wildfire may obviously happen at a cell with less than a 30% rise, but it is less likely for the purposes of this exercise.

21. Explore the two slope layers to see where some of the higher risk areas are based on slope.

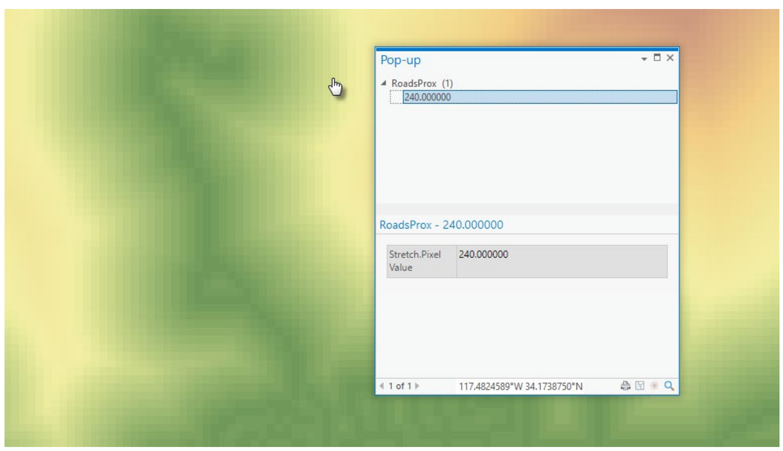
Analyze Proximity to Roads

Fires are often started, either intentionally or not, near roads. In this step we will identify those areas closest to roads and therefore at higher risk to wildfires. The source for roads is the US Census through their TIGER program. This data is publicly available for download for each county from [the Census website](). To prep for this assignment and save you some time, I downloaded the roads for the counties in our study area, **merged** them together, and have provided them for download for this project.

22. Add the **Roads_SoCal_Tiger** shapefile to your map. This is a large dataset with more than 401,000 line features so it may take a moment to load.
23. Open the **Euclidean Distance** tool
    a. Set the input raster as the roads layer
    b. Name the output **RoadsProximity**
    c. Set the Cell Size to 30
    d. Switch to the Environment tab
        i. Set the Output Coordinate System dropdown to **Current Map**. This should set it to the UTM coordinate system we set earlier. *If not, go back to the project setup steps and fix that first.*
        ii. We don't need to run this operation on all of the roads in our dataset, just the study area so set both the **Processing Extent** and **Mask** to your buffered study area layer.
        iii. Set the Snap Raster to **DEM_StudyArea**. This will make sure that all the pixels line up squarely with the DEM to help with any subsequent overlay operations.
    e. Run the tool. *This is calculating the distance from each 30m cell to the closest road, so it can take a few moments (but probably under a minute).*
24. When the tool finishes, switch the Stretch Type to **Standard Deviation** (on the Appearance ribbon). This stretch makes it a little easier to see what is happening here.



25. Zoom in closer until you can start to see the individual pixels and click on the map to show the popup with the pixel value. The value of each cell is the distance to the closest road. Any cells that fall directly on the road would have a value of 0. The distance units are in the **linear units** of the coordinate system – which in the case of UTM is meters. This is why we were careful to set the coordinate system earlier!



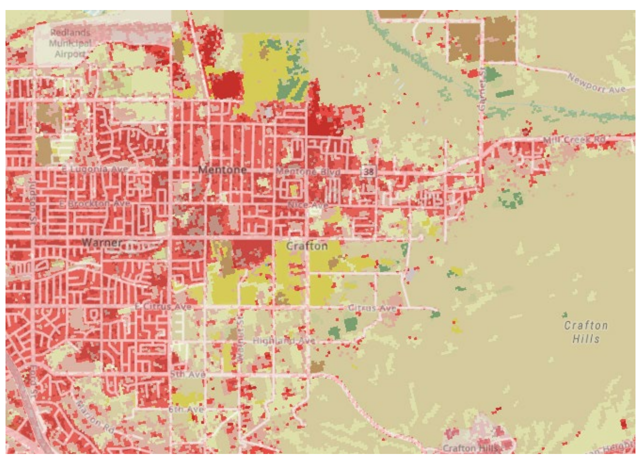
26. Now we know the distance of each cell to a road but, just like we did with slope, we need to determine whether the slope is "risky" or not. For this example, we'll use a threshold of 100 (1km) – if the distance value is less than 1000, we'll characterize that cell as risky. Open the **Less than** tool and set the first input raster as **RoadsProximity** and the 2nd input as a constant of 1000. Name the output **Risk_Roads**.
27. Review the result. All cells within 1 kilometer has a value of 1 and everything further gets a 0. You might start thinking at this point that we could assign varying *levels* of risk (like high, medium, & low) based on how far each cell is – if so, good thinking! This is a little more advanced, but we will look into that in future exercises!
28. Turn off all layers other than the two risk layers and take a minute to compare them. Toggle the top layer on/off and try using the Swipe tool to compare the two layers. Where are both of these conditions true? Notice that most urban areas close to roads are relatively flat, so would have a reduced risk of wildfire (based solely on these 2 conditions).

Analyze Land Cover

Land cover refers to the physical surface at a location on the earth and is generally classified as different types of vegetation (forest, grass, scrub), paved/developed, water, snow, etc. The National Land Cover Dataset (NLCD) is an ongoing joint project by scientists from USGS, USFS, NOAA, BLM, and more to classify the land cover of the contiguous United States into 20 categories at a 30 meter resolution through the interpretation of satellite imagery. The NLCD is freely available for download at their website - https://www.mrlc.gov/data. A subset of this dataset is provided in the data download for this project.

We will use land cover to help understand fire fuels available in each cell. Forest and scrub land covers are more likely to burn than developed covers (or water for that matter).

29. Add the NLCD_SoCal tiff file to your map. The image is added with a predefined color scheme. Each cell value is associated with a land cover type. See this page for a list of the types - https://www.mrlc.gov/data/legends/national-land-cover-database-2019-nlcd2019-legend
30. Open the attribute table and see that the land cover type names are listed next to the cell value. Also included are the RGB color combinations and the number of cells with that value/type.
31. Change the basemap to an imagery basemap and zoom in to Redlands or another area you know well. Toggle the landcover layer on/off and use the Swipe tool to compare to better understand this layer. Take note of the resolution and level of detail. Do the land cover types line up to what you know of the area?



32. Next we'll use the **Reclassify** tool to change values based on existing values. In this case, we'll be changing the land cover values to risk values (1 or 0) based on available fuels. Look through the list of land cover classifications and think of them in terms of wildfire risk…which type *values* are susceptible to spreading a wildfire?
    Open the **Reclassify** tool and set the input raster to the NLCD raster.
    a. Set the **Reclass field** as **Value**
    b. Click the **Unique** button at the bottom of the list. This will populate the table with all of the values found in the table.
    c. Set new values based on wildfire risk – water, developed land, barren land, crops, and wetlands will be 0 (no risk) and all other vegetative types will get a value of 1 (risky).

Unclassified land covers will get the special value of **NODATA** which is essentially an empty pixel that won't be displayed on the map.

Value	New
0	NODATA
11	0
21	0
22	0
23	0
24	0
31	0
41	1
42	1
43	1
52	1
71	1
81	1
82	0
90	0
95	0
NODATA	NODATA

d. Name the output **Risk_Landcover**

e. Check the box **Change missing values to NODATA**. *This shouldn't really make a difference for us because we set a new value for everything but it'll help catch any mistakes.*

f. Switch to the Environments tab

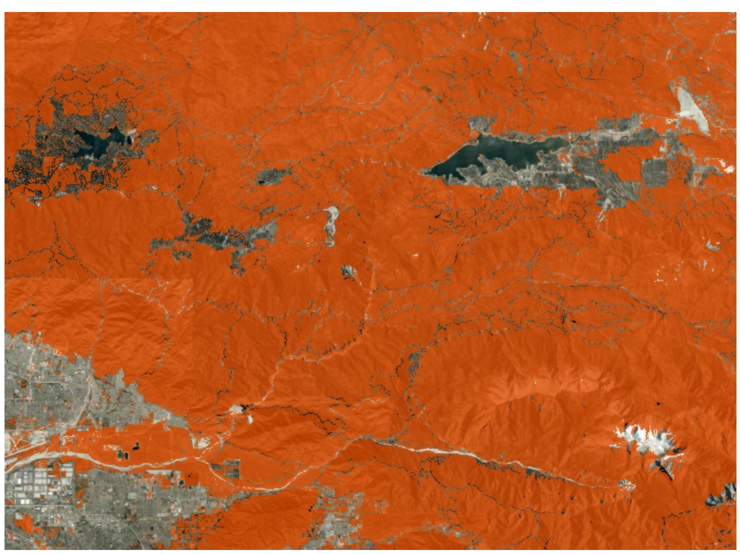
   i. Set the Output Coordinate System to Current Map (UTM Zone 11)

   ii. Set the **extent** AND **mask** to the buffered study area. This will force the result to be clipped to the study area for you as opposed to the larger southern California extent of the input.

   iii. Set the **Snap Raster** to **DEM_StudyArea** to align the pixels in the output

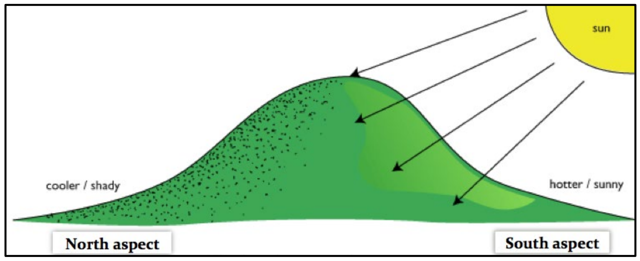
g. Run the tool.

33. Review the result. Change the symbology and set the 0 value to **No Color** so that the only color on the map is the riskier high-fuel pixels drawing on top of the Imagery basemap**.** Use the transparency slider to better understand those areas.



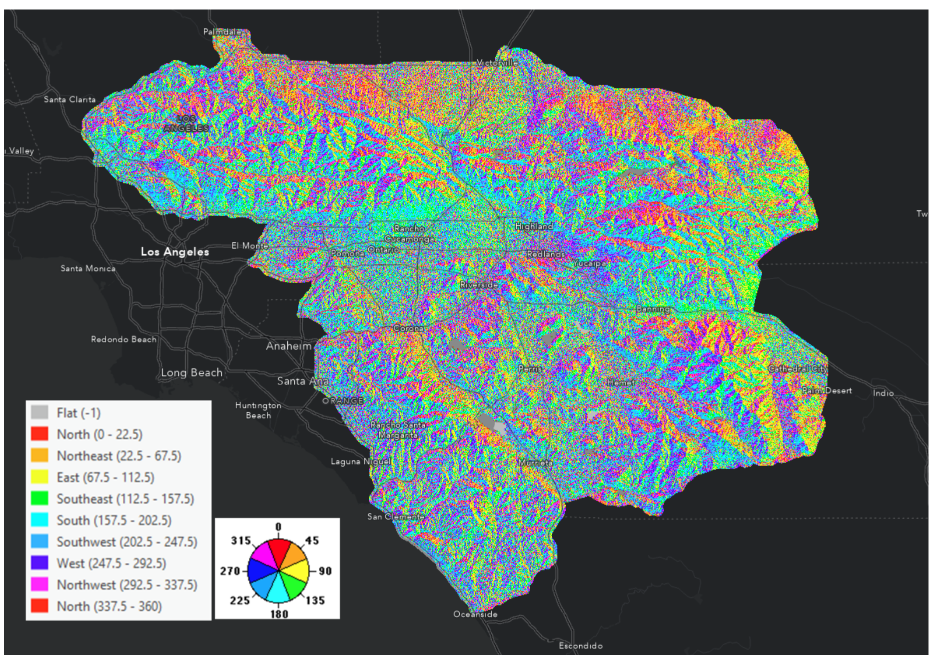
Analyze Aspect

The **aspect** of a location refers to the compass direction (north, south, east, west) of the downhill slope. This is an important component of this model because south-facing slopes receive significantly more daily sun (in the northern hemisphere) and therefore often drier and more combustible.



Aspect is another dataset that is easily derived from a DEM. We will run the Aspect tool and then reclassify the values so that south-facing slopes are a wildfire risk and north facing slopes are not.

34. Open the Aspect tool and set the input as **DEM_StudyArea** and name the output **Apect_StudyArea**.
35. Run the tool and review the result. The output of an aspect operation is like a vibrant psychedelic piece of art! Expand the layer in the Contents pane to see what the colors mean.
36. Click on a cell to see a pixel value. This number is the *compass direction* (0-360) of the slope. Those cell values are grouped into cardinal directions and color-coded for the map.

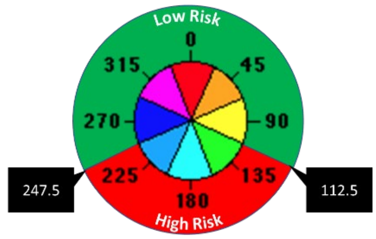


37. Now let's use a tool to change the values to our 1/0 wildfire risk. We'll do that using a simple Reclassify operation again, but this time we'll set a range of values instead of changing individual values.

Open the **Reclassify** tool and set the input as the aspect raster and make sure the Reclass field is set to **VALUE**. You'll notice that the reclassification table now shows Start and End columns (it didn't do that when we reclassified land cover).

a. Change the first row to set a range from **-1** to **112.5** to a new value of **0**
b. Set the next row with a range of **112.5** to **247.5** to a new value of **1**
c. Set the 3rd row with a range of **247.5** to **360** to a new value of **0**
d. Remove all other rows by clicking on each one and hitting the Delete key. You can leave the last NODATA line (it will actually reappear even if you delete it).

Start	End	New
-1	112.5	0
112.5	247.5	1
247.5	360	0
NODATA	NODATA	NODATA



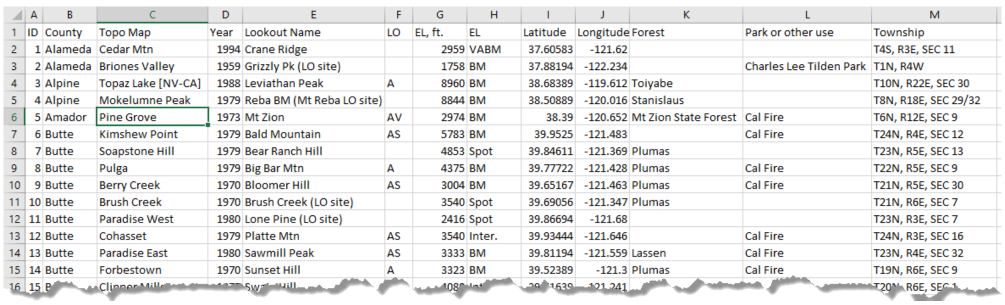
e. Name the output **Risk_Aspect**
f. Run the tool

38. Review the result. Change the symbology and set the 0 value to **No Color** so that the only color on the map is the riskier south-facing pixels drawing on top of the Imagery basemap**.** Zoom into a mountainous area and use the transparency slider to better understand those areas.

Analyze Fire Lookout Tower Visibility

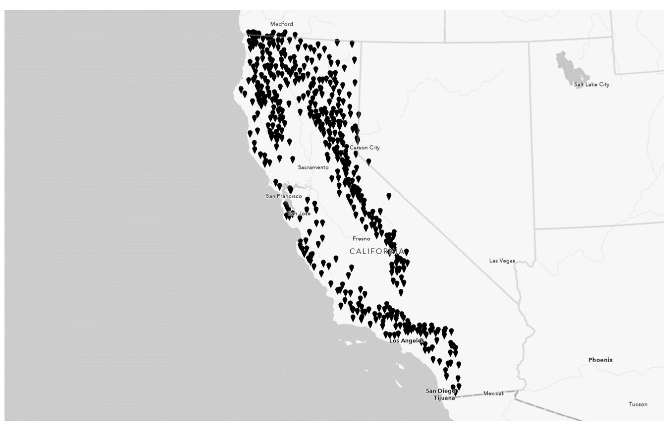
Fire lookout towers still play a significant role in southern California's fire prevention strategy. Volunteers stationed at towers on peaks across the region are credited with spotting and alerting fire crews to dozens of fires per year – fires that you've never heard of because they were extinguished before they could spread. In this step, we will use these towers to explore visibility analysis.

39. The data download includes a csv table of all the fire lookout towers in California. See the screenshot below and note that it has a Latitude and Longitude field that we can use to map the locations. These coordinates were collected using WGS 1984.

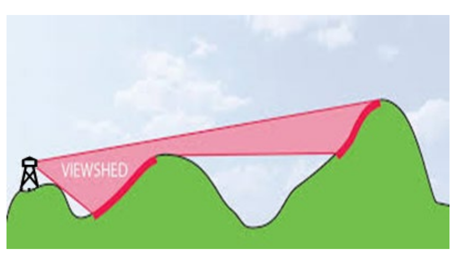


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	County	Topo Map	Year	Lookout Name	LO	EL, ft.	EL	Latitude	Longitude	Forest	Park or other use	Township
2	1	Alameda	Cedar Mtn	1994	Crane Ridge		2959	VABM	37.60583	-121.62			T4S, R3E, SEC 11
3	2	Alameda	Briones Valley	1959	Grizzly Pk (LO site)		1758	BM	37.88194	-122.234		Charles Lee Tilden Park	T1N, R4W
4	3	Alpine	Topaz Lake [NV-CA]	1988	Leviathan Peak	A	8960	BM	38.68389	-119.612	Toiyabe		T10N, R22E, SEC 30
5	4	Alpine	Mokelumne Peak	1979	Reba BM (Mt Reba LO site)		8844	BM	38.50889	-120.016	Stanislaus		T8N, R18E, SEC 29/32
6	5	Amador	Pine Grove	1973	Mt Zion	AV	2974	BM	38.39	-120.652	Mt Zion State Forest	Cal Fire	T6N, R12E, SEC 9
7	6	Butte	Kimshew Point	1979	Bald Mountain	AS	5783	BM	39.9525	-121.483		Cal Fire	T24N, R4E, SEC 12
8	7	Butte	Soapstone Hill	1979	Bear Ranch Hill		4853	Spot	39.84611	-121.369	Plumas		T23N, R5E, SEC 13
9	8	Butte	Pulga	1979	Big Bar Mtn	A	4375	BM	39.77722	-121.428	Plumas	Cal Fire	T22N, R5E, SEC 9
10	9	Butte	Berry Creek	1970	Bloomer Hill	AS	3004	BM	39.65167	-121.463	Plumas	Cal Fire	T21N, R5E, SEC 30
11	10	Butte	Brush Creek	1970	Brush Creek (LO site)		3540	Spot	39.69056	-121.347	Plumas		T21N, R6E, SEC 7
12	11	Butte	Paradise West	1980	Lone Pine (LO site)		2416	Spot	39.86694	-121.68			T23N, R3E, SEC 7
13	12	Butte	Cohasset	1979	Platte Mtn	AS	3540	Inter.	39.93444	-121.646		Cal Fire	T24N, R3E, SEC 16
14	13	Butte	Paradise East	1980	Sawmill Peak	AS	3333	BM	39.81194	-121.559	Lassen	Cal Fire	T23N, R4E, SEC 32
15	14	Butte	Forbestown	1970	Sunset Hill	A	3323	BM	39.52389	-121.3	Plumas	Cal Fire	T19N, R6E, SEC 9
16	15	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]			[illegible]

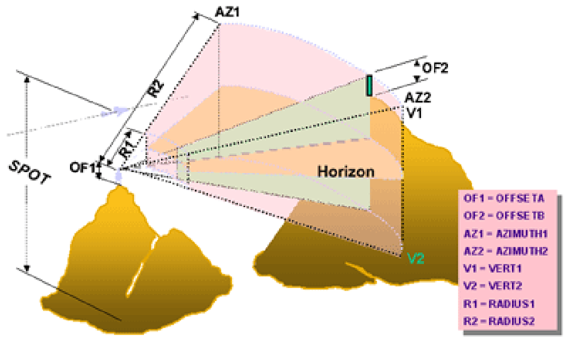
Find the FireLookoutTowers.csv table in the data download and export the table to a point feature class named **LookoutTowers** (the z field is not necessary).
Reminder: Right-click > Export > Table to Point Feature Class.



Next we'll run a **Viewshed** analysis, which calculates the locations visible from an observer point or set of observer points based on terrain (a DEM). Those observers in this case will be the towers.

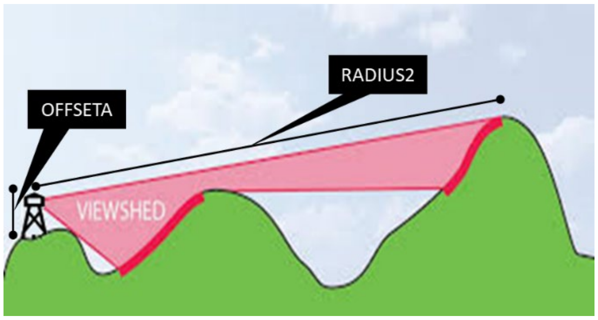


The Viewshed tool allows us to enter a maximum visible distance and the height of the observers (towers) to more accurately model the visible area from the towers. Because the distance and height might be different per observer, the tool looks for a few pre-defined field names that you can use to set those. Those fields are SPOT, OFFSETA, OFFSETB, AZIMUTH1, AZIMUTH2, VERT1, VERT2, RADIUS1, and RADIUS2. See the image below and see [Esri's help topic] to help understand those settings.



The two settings/fields that we're concerned with are OFFSETA and RADIUS2.

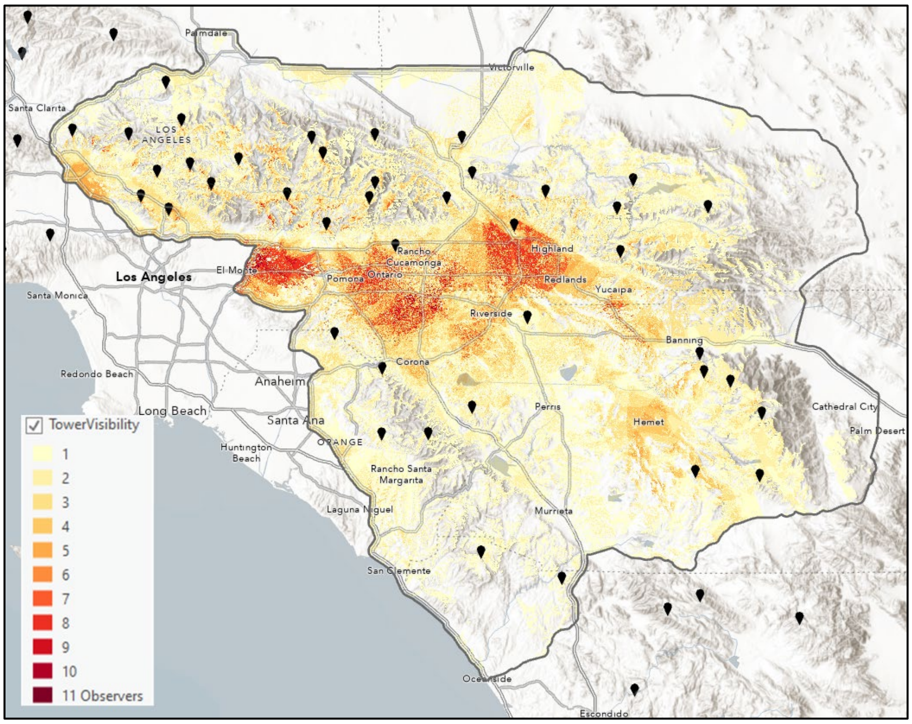
- OFFSETA is the height of the observer above the surface.
- RADIUS2 is the maximum distance that an observer can effectively see.



40. Add 2 new LONG type fields to the **LookoutTowers** point feature class named **OFFSETA** and **RADIUS2**.
41. Calculate the **OFFSETA** field to **10** and the **RADIUS2** field to **32187**. These numbers will be interpreted as meters because the coordinate system is in meters. We don't have individual tower heights, so we'll just assume an average of 10 meters.
    If you forgot how to calculate a field: right-click the field name in the table > Calculate Field
42. Now we can run the **Viewshed** tool.
    a. Recall from previous activities that geoprocessing tools use selected features to run tools on a subset of data. We only want to run the viewshed analysis on the tower points within our study area - so use the **Select By Location** tool to select the tower points that fall within our study area.
    b. Open the **Viewshed** tool and set the input as your study area DEM, the lookout tower points (with the selection applied) as the observers features, and name the output **TowerVisibility.**
    c. Switch to the Environments tab and set the following:
        - Output Coordinate System to **This Map** (NAD 83 UTM Zone 11N)

- Mask to the buffered study area
- Snap Raster to the study area DEM

43. Run the tool *(this process can take a few minutes)* and review the output and what the symbol classes are in the Contents pane. The resulting raster values are the number of observers/towers that can see that cell. So the darker cells are the most visible by the towers while the empty/transparent cells can't be seen by any towers.
    Click on an empty cell and note that the cell value is 0 not NODATA. This color scheme just isn't showing the 0 values in the symbology.



44. For the purposes of this analysis, let's say that any cells that can't be seen by a tower are considered "risky" while any cells that can be seen by even 1 tower will be considered no risk for this criteria.
    You could use the **Equal To** tool to accomplish this, but we'll use the **Raster Calculator** for this step to do the same thing. The **Raster Calculator** is a powerful tool for doing raster analysis using **Map Algebra** expressions that perform one or more tools. Each of the tools in the Spatial Analyst toolbox can be written into **Map Algebra** expression in a fairly simple Python syntax.
    Here are a few simple examples:

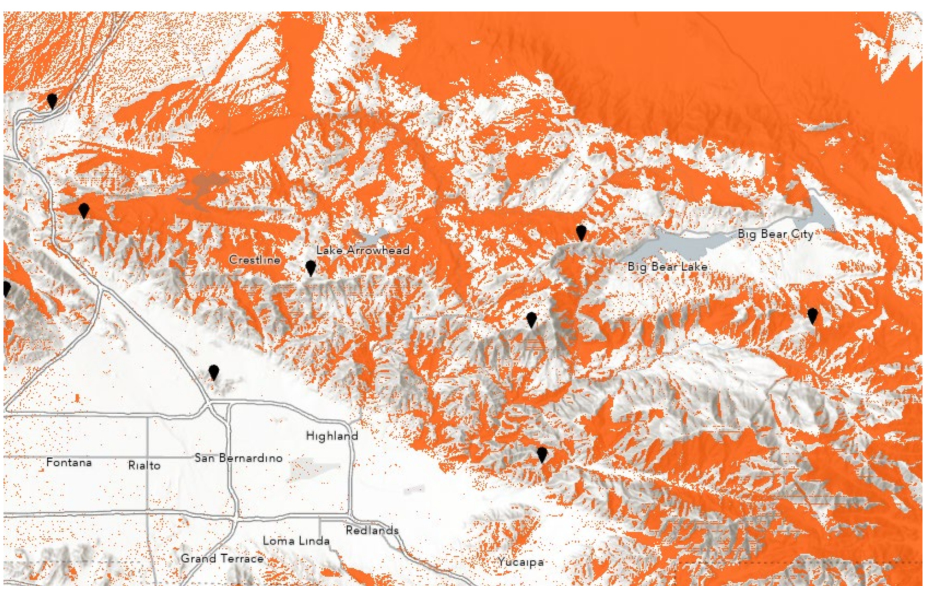
> <u>Add overlapping raster cells (and/or a constant) together</u>
>
> **<Raster1> + <Raster2> + <Raster3> + 100**
>
> *This could also be accomplished using the **Plus** tool but would have to be run multiple times*
>
> <u>Basic math between rasters and constants</u>
>
> **(<Raster1> + <Raster2> + <Raster3> + 100) * 3.28084**
>
> <u>Greater Than Equal To</u>
>
> <**Raster1> >= 100** or <**Raster1> >= <Raster2>**
>
> *This is the equivalent of running the Greater Than Equal To tool. Other logical operators work the same way. <u>Equal To</u> is two equal signs per Python convention:* <***Raster1> == 1***
>
> <u>Distance from roads with a max of 1000 meters</u>
>
> **EucDistance("Roads_SoCal",1000)**
>
> *For more information on using the Rater Calculator see: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/raster-calculator.htm*

Open the **Raster Calculator** tool and enter the expression below. You can double-click from the list of rasters to add them to the expression (or type them into the box).

```
"TowerVisibility" == 0
```

Name the output **Risk_Towers** and run the tool.

45. Review the output and compare to the other risk layers to understand where some of high-risk areas overlap among all of the criteria.



Overlay the Criteria Rasters to Find Common High-Risk Cells

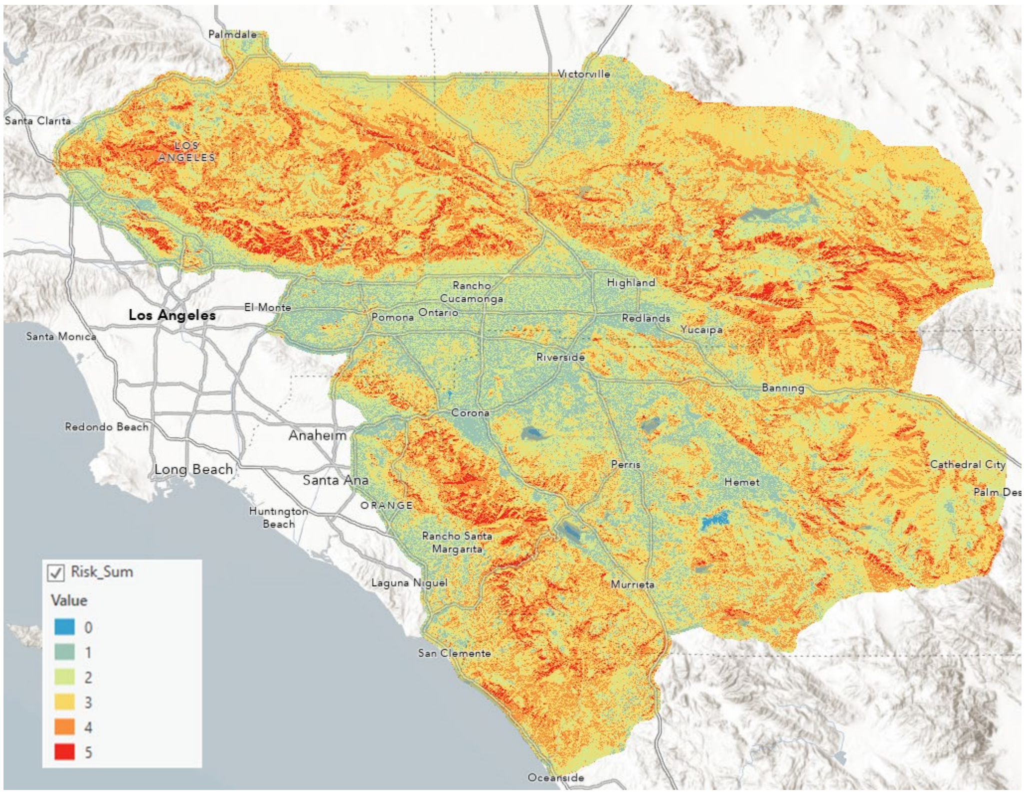
Raster-based overlays simply perform a math, logic, or other operation on overlapping pixels. In this simplest case, we'll simply add the rasters together. We have 5 risk criteria with scores of 1 or 0 (slope, proximity to roads, land cover, aspect, and tower visibility) so if we add up the values of all the cells, we'll end up with the number of high-risk criteria of the cell; a score of 5 means all of the criteria had a value of 1 (high risk), anything less means that one or more of the criteria had a value of 0 (no/low risk).

46. Open the Raster Calculator and add up all 5 of the risk rasters. Your expression should look something like this:

```
"Risk_Slope" + "Risk_Roads" + "Risk_Landcover" + "Risk_Aspect" + "Risk_Towers"
```

    Name the output **Risk_Sum** and run the tool.

47. Change the symbology of the output to the **Prediction** color scheme. *Remember you can show the names of the schemes by checking the box under the list.*
48. Review the result. Zoom in and explore the mountainous regions and check that you can understand the results and why certain areas evaluated the way they did.



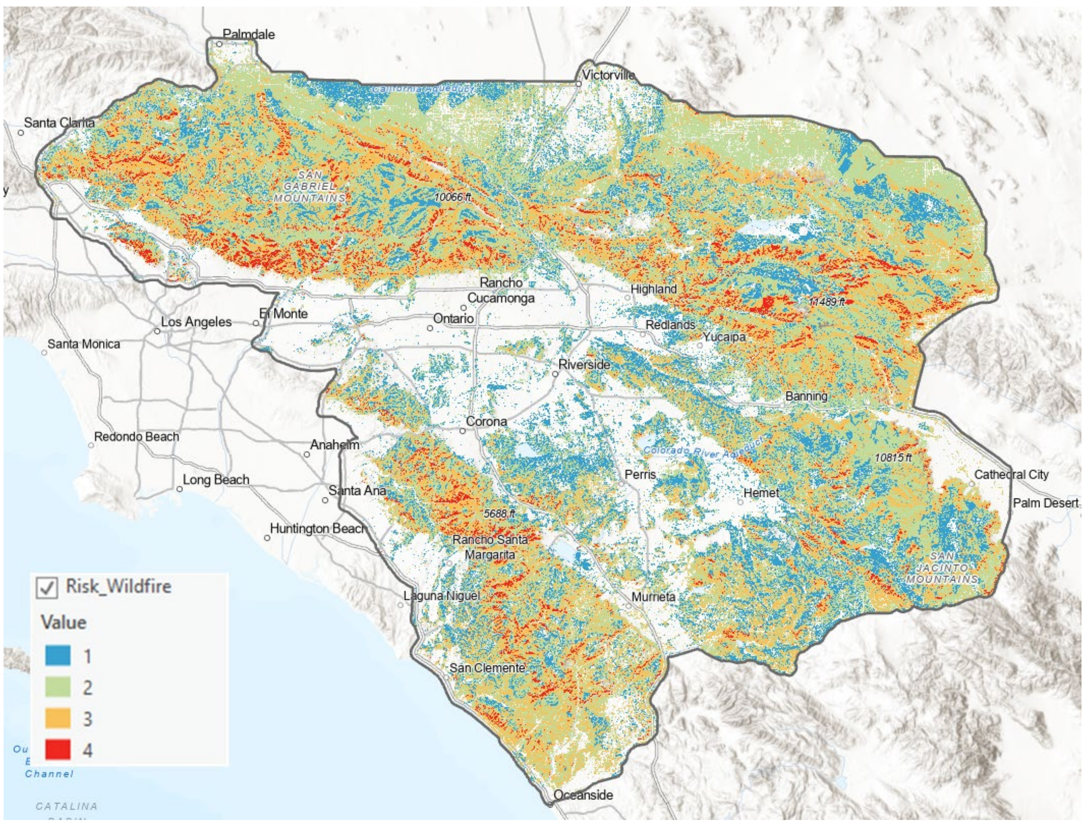
Overlay the Criteria Rasters Using Land Cover as and Exclusion Area

While the results are correct, it doesn't really make sense that densely urban areas and even lakes can have results of 1 or more. For this case, let's use some simple math to exclude no-risk land cover cells from consideration. We'll add up the other 4 criteria rasters just like the previous step, but this time we'll multiply it by the landcover risk. That will effectively reset the risk back to 0 for no-risk landcover cells (because we'll multiply the sum by 0) and leave the sum intact for risky landcover values (because we'll multiply the sum by 1).

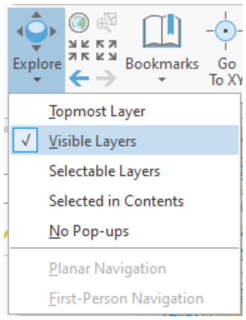
49. Open the Raster Calculator and add up the 4 risk rasters other than landcover and multiply that sum by the landcover risk (use parenthesis for order of operations). Your expression should look something like this:

```
("Risk_Slope" + "Risk_Roads" + "Risk_Aspect" + "Risk_Towers") * "Risk_Landcover"
```

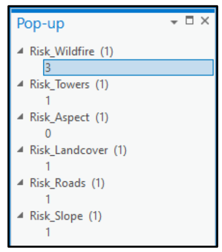
50. Name the output **Risk_Wildfire** and run the tool.
51. Change the symbology
    a. Confirm that a Unique Values symbology is set
    b. Remove the 0 value (right-click > Remove)
    c. Set the color scheme to Prediction. 0 will be empty/clear because we removed it from the symbology.
52. Turn off all of the other risk and criteria layers so that only the final wildfire risk layer and the basemap are displayed (I'd suggest the Topographic or Imagery Hybrid basemap).
53. Review the result by panning and zooming around the map. The highest risk score is now 4 because landcover wasn't included in the sum.



54. To check *why* a cell evaluated the way that it did:
    a. Turn on the 5 risk criteria layers.
    b. Change the popup mode to show all Visible Layers in the dropdown under the Explore tool (on the Map ribbon).



c. Click on the map to show the popup. The popup will show the result for each of the criteria to help understand the final score.



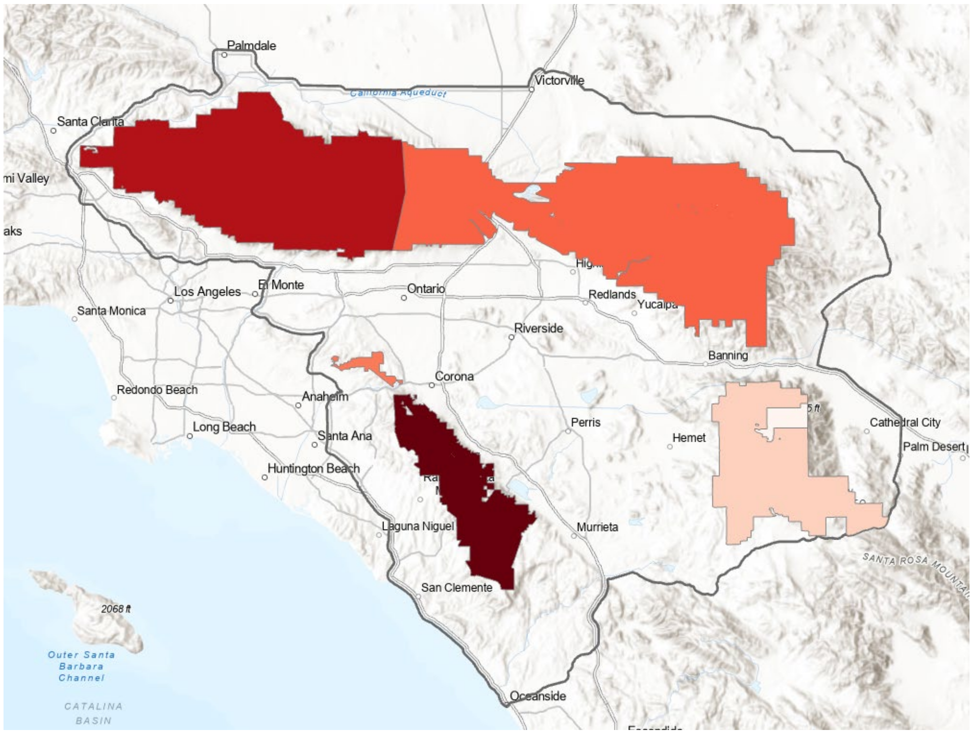
55. Turn off all layers except your final wildfire risk layer and a basemap (whichever you'd like). **Take a screenshot of ArcGIS Pro and save it to be submitted for the assignment.**

Use Zonal Statistics to Compare the Wildfire Risk of Parks

A **Zonal Statistics** operation is one that calculates stats (such as sum, mean, min, max, & std) for all of the cells that fall within a "zone". These zones can be defined as polygons in a feature class or as a raster where zones share a cell value. In this step we'll use this tool to find the average wildfire risk within polygons of large state and national parks in the study area.

56. Add the StudyAreaParks shapefile to your map and look at the attribute table to see what we have to work with. There are 6 park polygons with the name and type of park.
57. Browse to the **Spatial Analyst > Zonal** toolset and expand it to see the available tools. You'll see there are two zonal statistics tools, **Zonal Statistics** allows you to pick one statistic and results in a raster and **Zonal Statistics as Table** results in a standalone table (no geometry). That table can always be joined back to the polygons if needed.
58. Open the **Zonal Statistics as Table** tool.
    a. Set the input zone data as the parks layer using the NAME field as the zone field.
    b. The input raster will be the final wildfire risk raster
    c. Name the output **ParkWildfireStats**
    d. Confirm that the **Ignore NoData** checkbox is checked and the **Statistics type** is set to **All**
59. Run the tool and open the output table (it'll be at the very bottom of the Contents list in the **Standalone Tables** section). Note the various statistics included as fields for each park. This is just a table though so we can't use it for mapping yet – we'll use a JOIN to do that.
60. Join the zonal statistics table to your park polygon layer (right-click the layer > Joins & Relates > Add Join). The join field is NAME.
61. Click on a park polygon to see that the popup now includes all of the wildfire risk stats for that park.

62. Change the symbology of the parks to an **Unclassed colors** type and set the field to **MEAN**.
63. Change the color scheme to **Reds Continuous** and review the result. The polygons are now displayed to show the average wildfire risk in the park.



Now let's label the polygons to show the name of the park and the average wildfire risk.

64. Turn on labels for the parks layer and set the label field to NAME. The labels should now be displayed for each park polygon.

66. By default, these expressions are written in the Arcade programming language. In Arcade (and most other languages), you can combine text strings using the + sign. Test this out by adding the string "**Name:** " to the beginning of the expression. *Notice the space after the colon to make the label a little cleaner.*

```
"Name: " + $feature['StudyAreaParks.NAME']
```

Click Apply and review the result

67. We're going to set an expression that shows the park name followed by the fire risk value in parenthesis like: **Angeles National Forest (2.27)**. Remove the Name string that you added in the previous step and combine the name with the risk mean in parenthesis (below).

```
$feature['StudyAreaParks.NAME'] + " (" + $feature['ParkZonalStats.MEAN'] + ")"
```

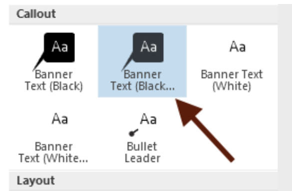
Click Apply and review the result on the map.

68. Notice the long numeric string is more accurate but not ideal for display purposes. We'll use the **Round()** function to round to the two digits after the decimal.
Add the **Round()** function to the Mean (below)

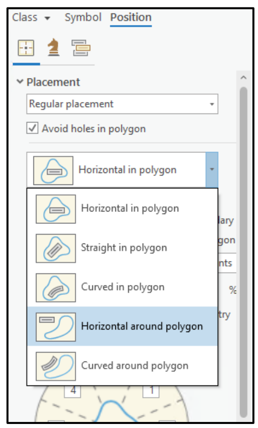
```
$feature['StudyAreaParks.NAME'] + " (" + Round($feature['ParkZonalStats.MEAN'],2) + ")"
```

Click apply and review the result.

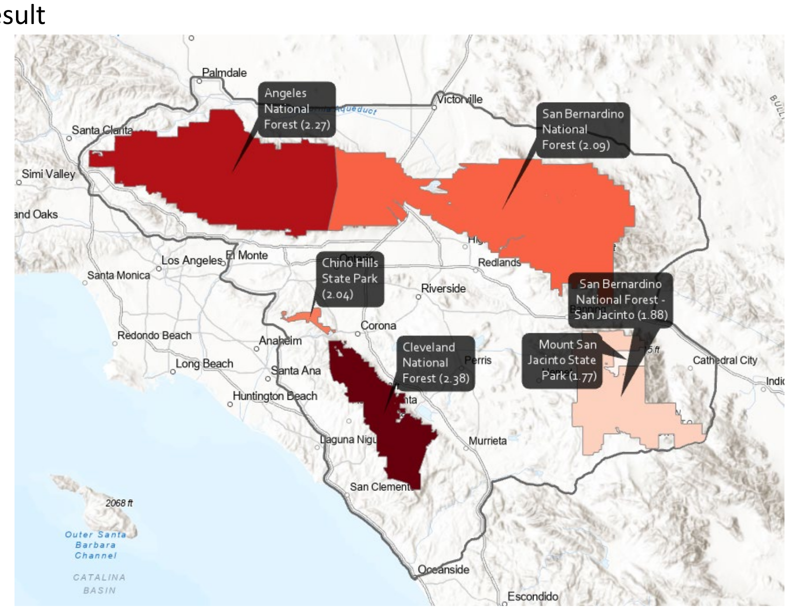
69. The labels are working great but probably a little hard to read. Let's deal with this using some balloon callouts.
    From the Labeling ribbon, find the Text Symbol style gallery. Click the dropdown and scroll down to **Banner Text (Black 25%)**



    This puts the labels in boxes but centers them in the middle of the polygon so we don't see the *leader lines*.



71. Review your result



72. Turn off all layers except your park layer and a basemap (whichever you'd like). **Take a screenshot of ArcGIS Pro and save it to be submitted for the assignment.**

Recap

In this exercise, we used a number of raster processing tools to explore wildfire risk in Southern California. These tools include:

- Mosaic to New Raster
- Extract By Mask
- Slope
- Reclassify
- Focal Statistics
- Logical operators (Greater Than Equal To, Less Than, etc)
- Aspect
- Viewshed
- Mathematical Operators (Plus, Minus, Times, Divide)
- Raster Calculator and "Map Algebra"
- Zonal Statistics

Extra Challenge

Add a new Scene into your project and copy/paste the criteria and risk layers into the scene to better understand how terrain affects the model.