

Delineation of high landslide risk areas as a result of land cover, slope, and geology in San Mateo County, California

Introduction

Problem Overview

This project attempts to delineate the high-risk areas within San Mateo, California, that are most prone to landslides. The principal method used is based on a ranking system built from 3 key features which include the elevation (used to calculate the slope), rock types, and land cover. The result is a raster with a qualitative ranking, which shows concentration of risk in specific areas. The study shows that softer rocks and vegetation cover have an effect on landslides especially where the elevation is lower. Furthermore, as a result of moderate amount of rainfall, high alluvium concentration near rivers, and large (coastal) human population, the hydrographic flow lines will also be used to assess the risk levels within the county.

Background

San Mateo has a total area of 1919 km², of which 1,163.1 km² (or 61%) is land and 756.1 km² is water (US Census). The county is bound on the west by the Pacific Ocean, and on the east by the San Francisco Bay. Directly towards the north is San Francisco County and City, and to the south is Santa Clara County. It is often referred to as a peninsula. The Bay Area Corridor is strongly juxtaposed to the agricultural parks and preserves, and undeveloped lands within the rural Coastside. Bay-side watercourses drain the eastern part of the county including San Bruno Creek and Colma Creek. Streams draining the western county include Frenchmans Creek, Pilarcitos Creek, Naples Creek, Arroyo de en Medio, and Denniston Creek. These streams originate in the northern part of the Santa Cruz Mountains which run through the entire county.

Objective

The objective of this study is to determine the areas that have a high risk of landslides on as a result of the slope, land cover/use, geology and water flow. In order to achieve this, the ArcGIS software will be used in conjunction with relevant location data obtained online.

Data

Data Required

Relevant to the San Mateo County:

- 1) Digital elevation model (DEM)
- 2) Land use/cover
- 3) Hydrographic data
- 4) Geological map
- 5) County boundaries

Data acquisition

The risk assessment for this project requires calculations using data 1) through 4), and 5) for the confinement of area of study. The DEM, hydrographic, and land cover data were all obtained simultaneously from the USGS seamless server which is easily accessible to the public (<http://nationalmap.gov/viewer.html>). Figure 1 below shows how data can be obtained from the map provided and how datasets 1), 2) and 3) can be obtained through this method.

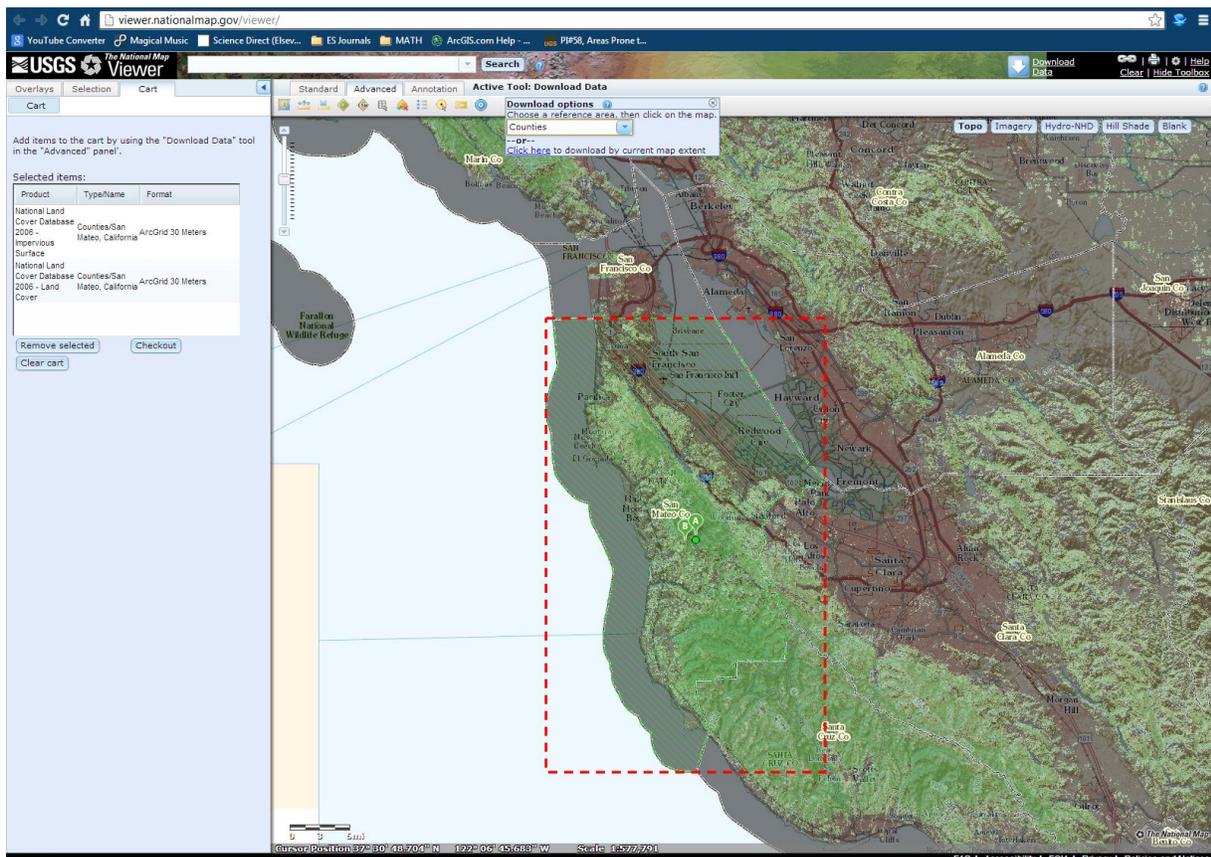


Fig. 1. National Map Viewer by USGS showing acquisition of San Mateo County land cover data.

The data could be chosen by selecting the *Download* button in the *Advanced* tab, and then choosing the reference area by Counties and selecting San Mateo, which is the area of interest for this project, then the most recent data is chosen for each. The data was provided via email, and then downloaded. The county boundaries for the map extent show in Fig. 1 were also selected, so that the adjacent counties could also be represented. Although not obtained at first, during the data processing a polygon of the San Mateo county was needed since the clipping procedures were not working with the boundaries obtained initially. This was obtained from the U.S. Division of Agriculture (USDA) website (<http://datagateway.nrcs.usda.gov/GDGOrder.aspx>). Lastly, the geological map was obtained from USGS Geologic Downloads section as a KMZ file that could be opened in Google Earth (<http://geomaps.wr.usgs.gov/sfgeo/geologic/downloads.html>) shown below in Fig. 2.

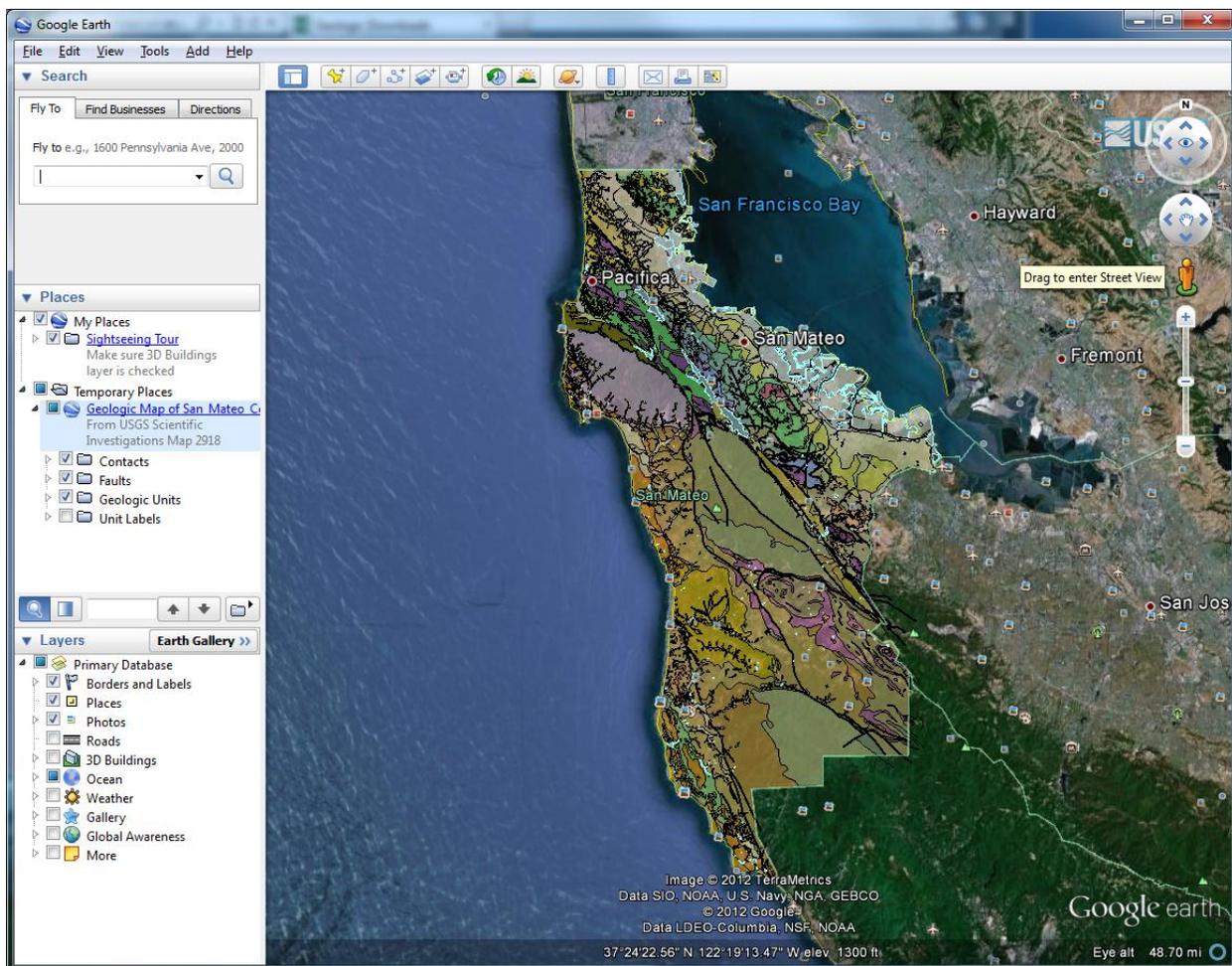


Fig. 2. Geological map of San Mateo downloaded from USGS and opened in Google Earth (KMZ).
Once all the data has been acquired, the processing in ArcMap and Catalog can begin.

Data Preprocessing

Since the data that was obtained from various sources it is important to convert them to formats that can be opened and used on ArcMap. The USGS National Map data (Hydrography, boundaries, land use, elevation) were all downloaded into compressed zip folders. These can be easily extracted, making the relevant shapefiles available for addition onto ArcMap. These were then opened onto ArcMap (see below Fig. 3).

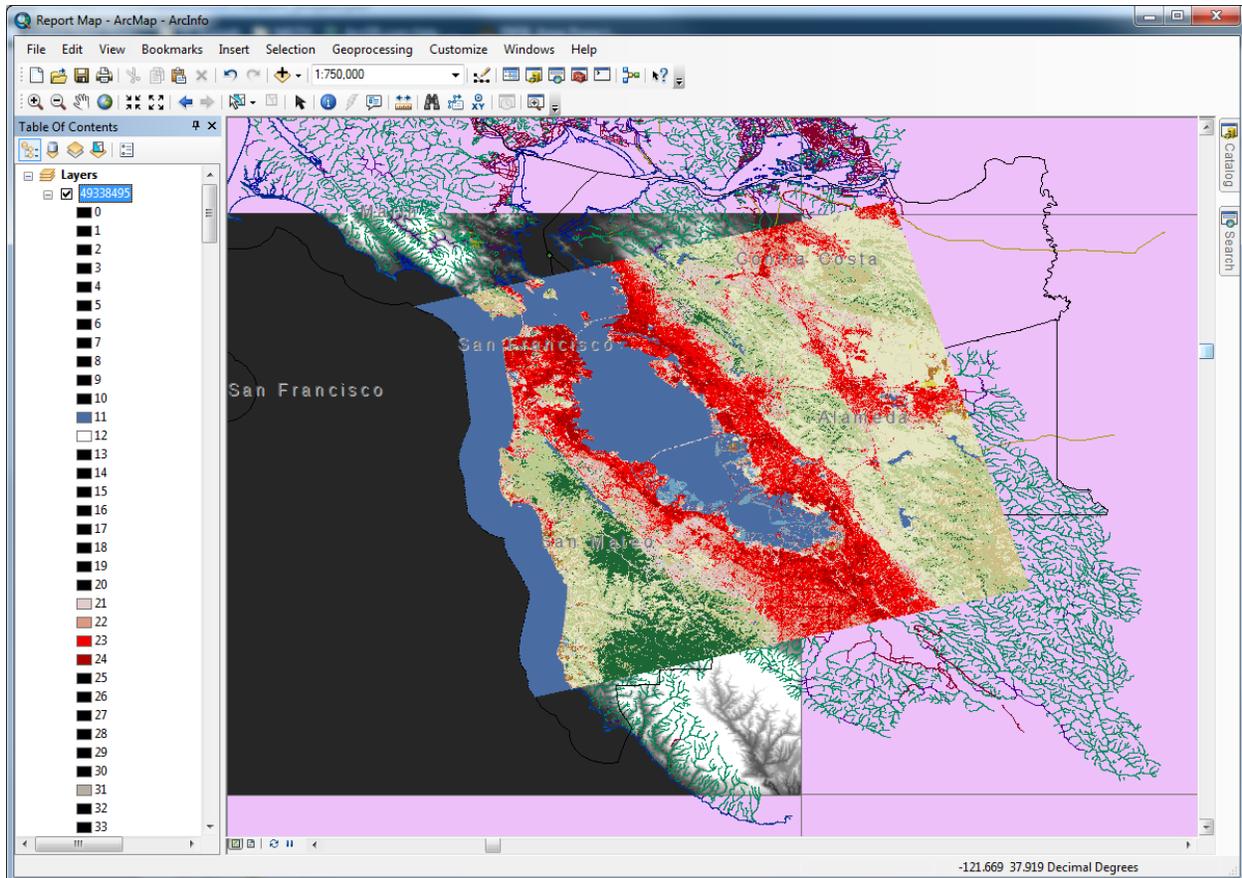


Fig. 3. USGS National Map Viewer data (including boundaries, elevation, land cover, and hydrography).

However, the geological units data was downloaded in KMZ format. Using Google earth, this was converted to a KML file (used the Save Location As... option, and choose KML format). ArcMap has the tools to **convert from KML to shapefiles**, and can be accessed using the Search tool and inserting “convert” and “kml” as key words (see Fig. 4. Below).

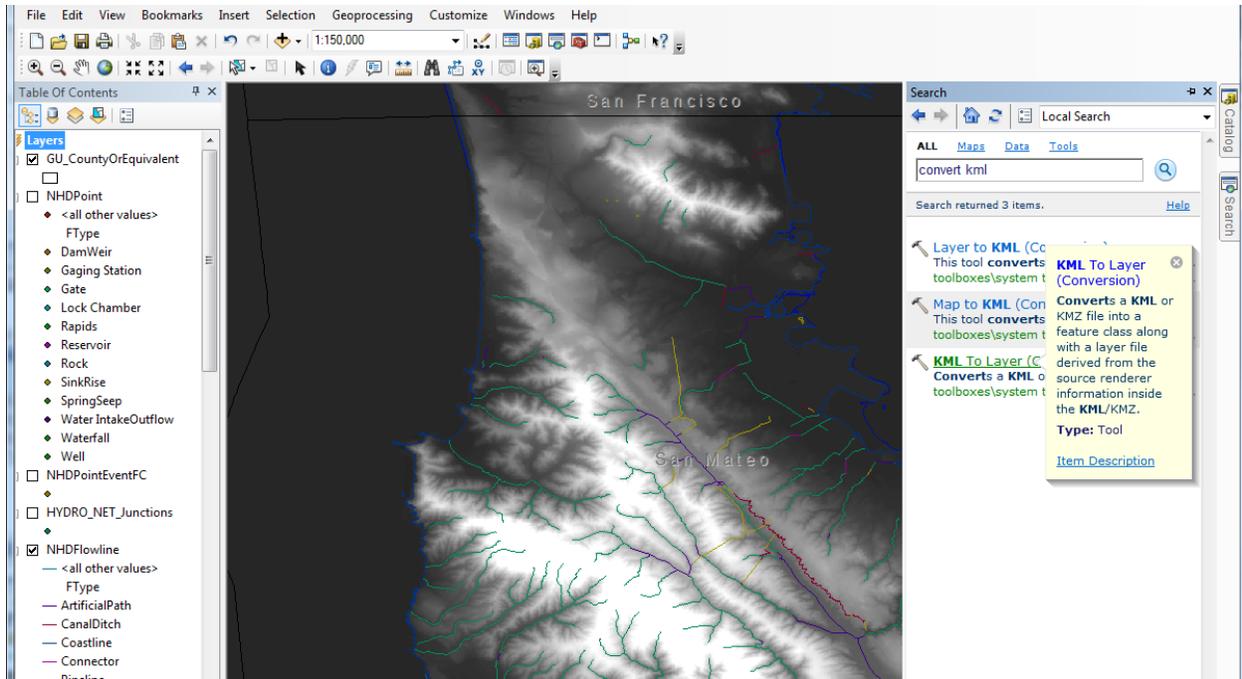


Fig. 4. Using the conversion tool to convert Geological unit KML to Layer file

However, another preprocessing step was required after this conversion process. The geological unit feature layer obtained was in a format wherein all the individual units were separate layers (see Table of Contents in Fig. 5 below). This could be fixed by using the **Merge** tool: all the individual units were placed in the input in order to create one individual layer. This can be accessed in the Data Management option using the Search tool (Fig. 5).

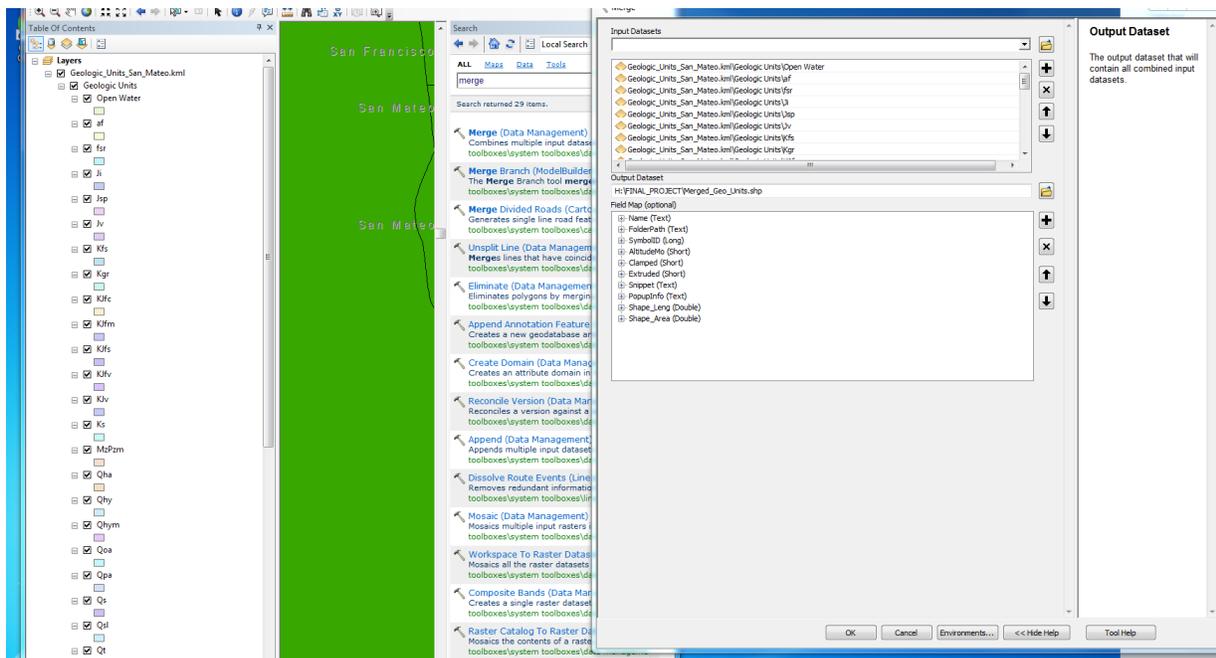


Fig. 5. Using the Merge tool to convert all the individual geological units into one unique feature layer.

Once all the layers are added onto ArcMap, it is then required to change the **Projection**. The projection chosen for this project is UTM Zone 10, NAD 1983. All the features and raster were converted by using the Search tool and inserting Project, and using the relevant tool for either features or rasters. (ie. for Elevation raster: Data Management tool > Projections and Transformations > Raster > Project raster, see Fig. 6 below)

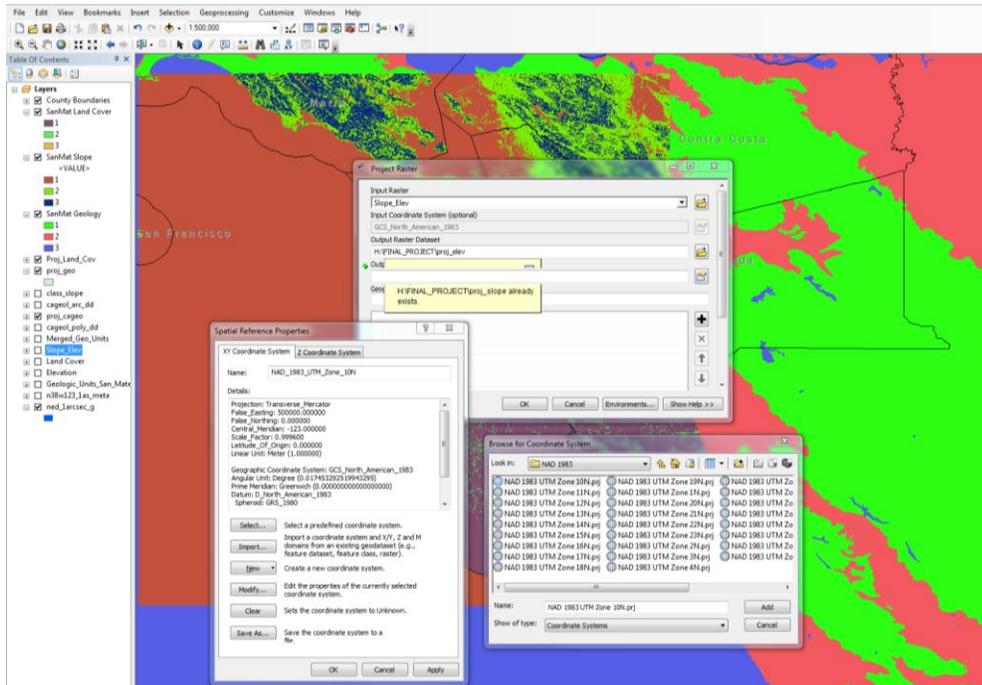


Fig. 6. Using the projection tool in order to change to UTMZ 10 for rasters.

ArcMap Processing

The identification of the areas that are at risk of landslides in the San Mateo relies on a ranking scheme. This scheme qualitatively ranks the levels of the three factors (slope, rock type, land cover) that contribute to landslides, with 1 being the lowest risk level, and 3 being the highest. The ranking system is shown below.

- a) **Geology:**
- Hard/igneous rocks are ranked **1**
 - Soft/ alluvium rocks are ranked **2**
 - Water bodies are ranked **3**
- b) **Slope:**
- 0 - 15° angles are ranked **1**
 - 15 - 30° angles are ranked **2**
 - 30 - 90° angles are ranked **3**

c) **Land Cover:**

The raster provided was in the format of the USGS classification system shown below:

Hence the ranks were chosen in the follow fashion (mostly dependent on vegetation cover):

Water	Developed
11 Open Water	21 Low Intensity Residential
12 Perennial Ice/Snow	22 High Intensity Residential
	23 Commercial/Industrial/Transportation
Barren	Forested Upland
31 Bare Rock/Sand/Clay	41 Deciduous Forest
32 Quarries/Strip Mines/Gravel Pits	42 Evergreen Forest
33 Transitional	43 Mixed Forest
Shrubland	Non-Natural Woody
51 Shrubland	61 Orchards/Vineyards/Other
Herbaceous Upland Natural/Semi-natural Vegetation	Herbaceous Planted/Cultivated
71 Grasslands/Herbaceous	81 Pasture/Hay
	82 Row Crops
	83 Small Grains
	84 Fallow
	85 Urban/Recreational Grasses
Wetlands	
91 Woody Wetlands	
92 Emergent Herbaceous Wetlands	

Forested Upland, Herbaceous (Natural and cultivated), Wetlands are ranked **1** (high vegetation cover)

Developed is ranked **2**

Water, Barren, Shrubland are ranked **3**

Fig. 7 Classification scheme land cover from USGS

In order to create these ranks a specific procedure is used, which is explained in detail below. It requires building a slope raster, converting the geology from feature to raster, reclassifying the data sets, and ultimately combining these 2 in order to create one universal ranking scheme taking into account every factor.

Obtaining Slope Raster

The slope of the area of interest can be derived by using the Elevation data acquired. Using the Spatial Analyst toolbar, selecting **Surface Analysis** and then **Slope**, it is possible to input the elevation data and choose an output cell size. Here the size chosen is 30 since the other rasters have approximately this value. The result can be symbolized and is shown in Fig. 8 below.

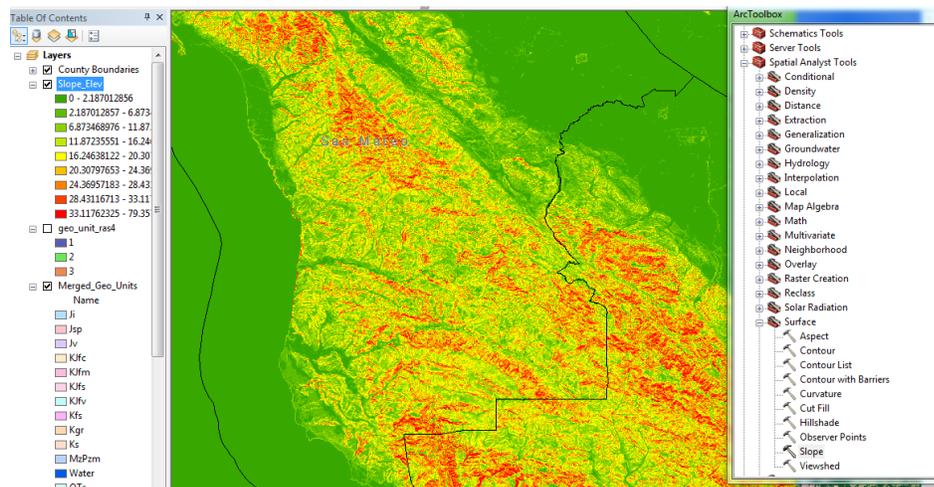


Fig. 8. Resulting slope raster derived from the elevation raster with red representing high slope values.

Create Geology Raster

In order to allow for the ranking of rock units, it is first necessary to convert from a feature to a raster layer. Using again the Spatial Analyst toolbar, or simple the Search tool, select **Convert and Features to Raster**. Note, however, that a field needs to be specified in order to assign the required value for the output raster dataset. We want this field to be the rank (1, 2, or 3) of the specific rock type. This can be added before the conversion by using the **Editing** tool. Click on Start Edition and open the Attribute Table for the geology layer. It is possible to **Add a new Field**, containing Short Integers, and it can be called “Codes”. Then, the the values for each polygon can be added manually if the units are listed in order of rock type as shown below in Fig. 9.

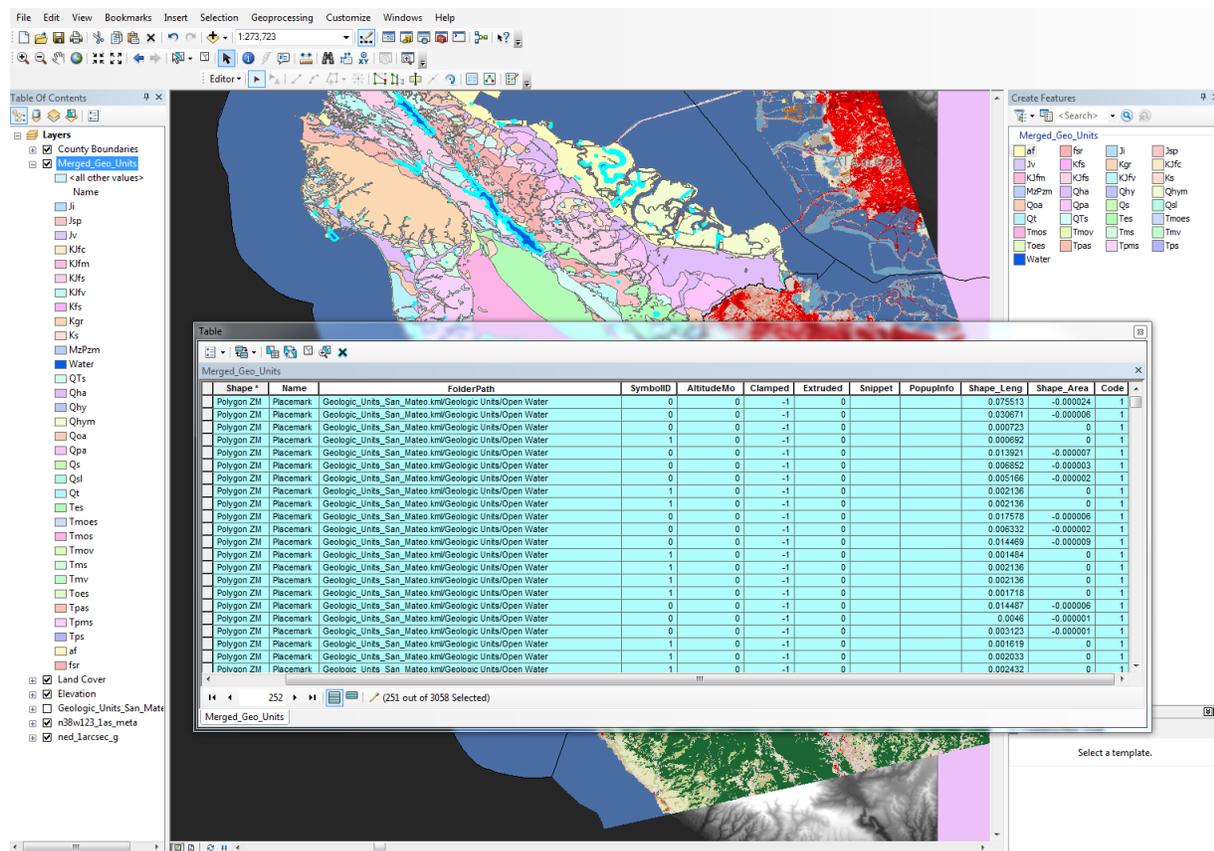


Fig. 9. Addition of rank values into “Code” field whilst in editing mode for the geological units.

Once this has been achieved, the conversion tool can be used as shown below in Fig. 10, although the cell size should also be 30 as was the last (slope) raster created. This results in a raster layer like the one shown in Fig. 11 which delineates risk levels as a result of the rock type.

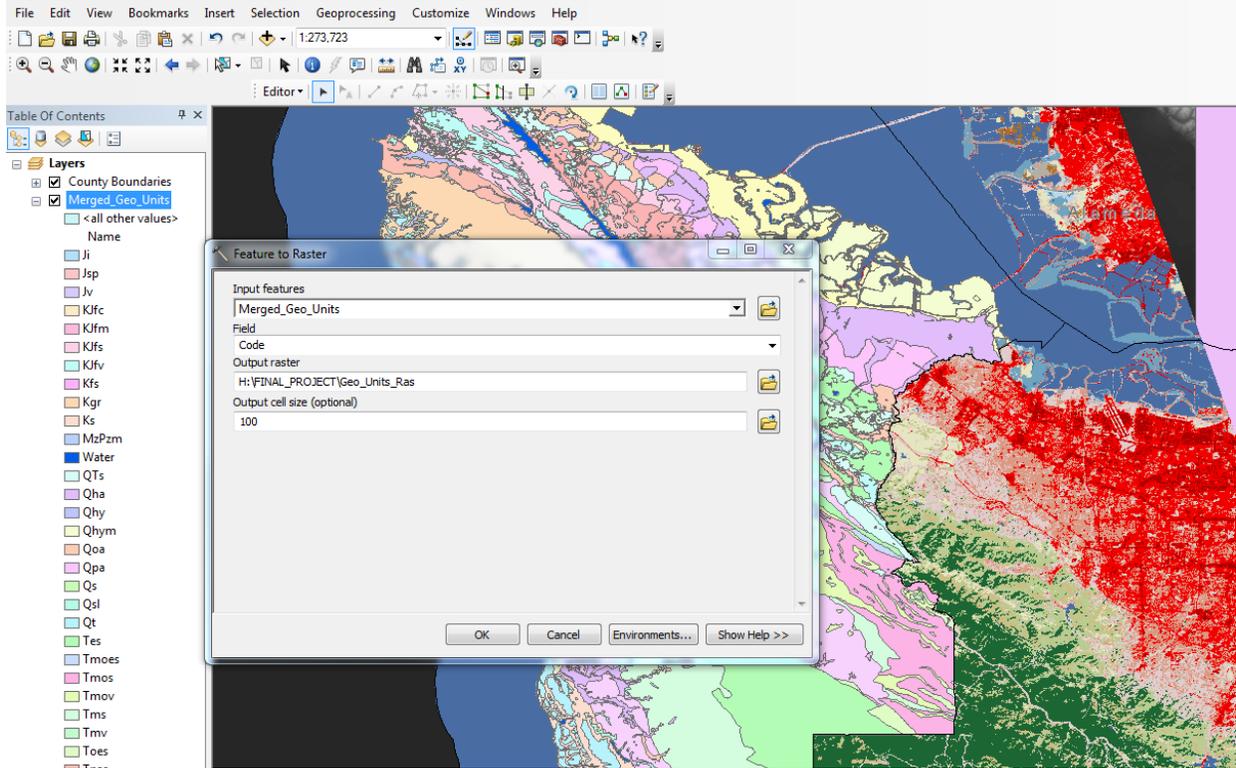


Fig. 10 Using the conversion tool from feature to raster and selecting “code” as the raster field.

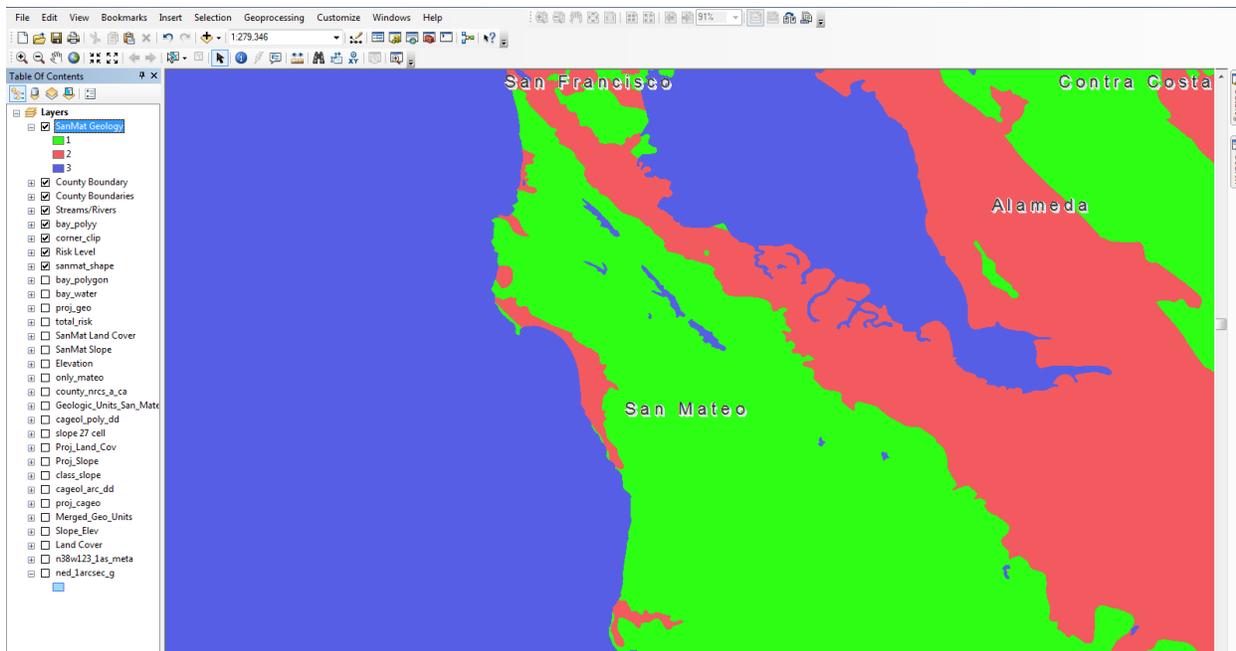


Fig. 11. Resulting raster layer with ranks from 1 (low) to 3 (high) of landslide risk based purely on geology.

Data Set Reclassification

Although the geology-related risk raster is already classified into the 1-2-3 rank, it is still necessary to classify the other 2 rasters (slope and land cover) into the same rank. Once again, the Spatial Analyst toolbar is selected, and this time the **Reclassify** tool is chosen. The input raster for the slope will be the dataset that was just derived above from the elevation, which contains values of angles which vary from near 0 to 79 degrees. The reclassification is shown below in Fig. 12, with old values being the angle value and the new values ranging from 1-3. The resulting raster is shown in Fig. 13.

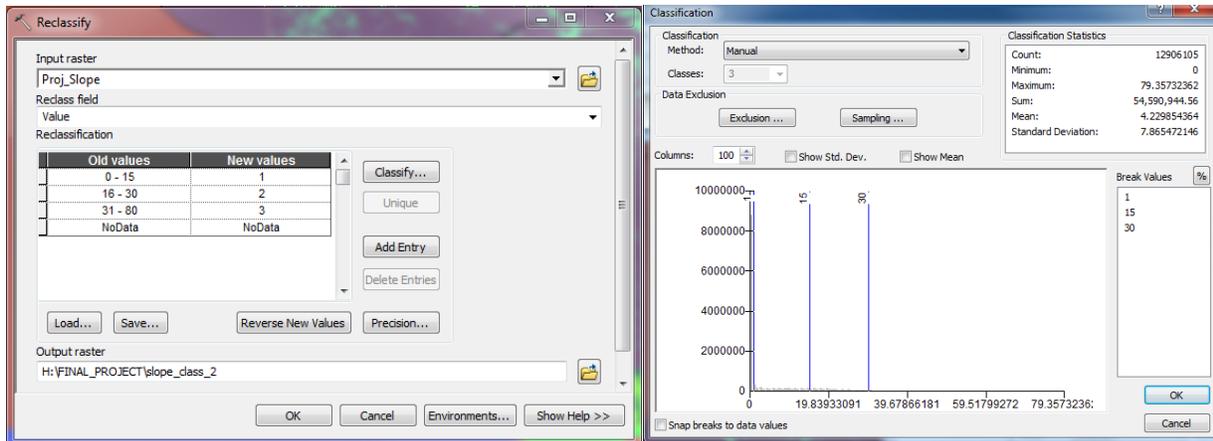


Fig. 12. Showing the reclassification scheme and how the values are split into the 3 risk levels.

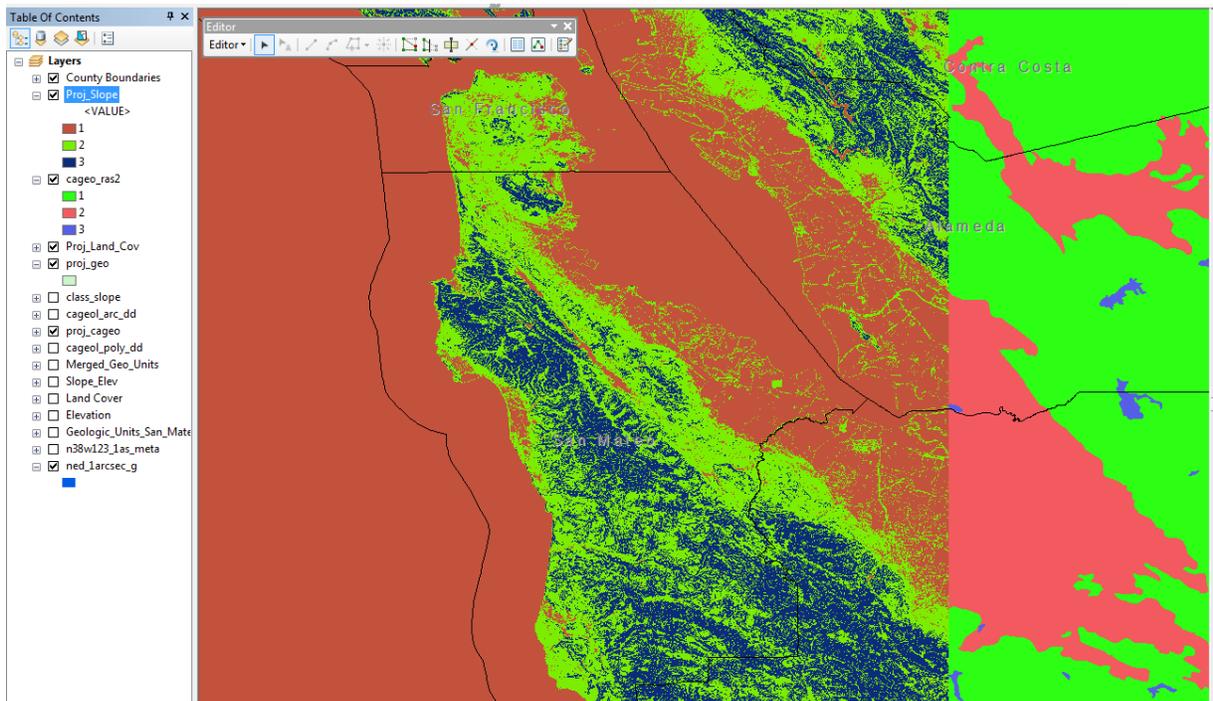


Fig. 13. Resulting raster layer with landslide risk ranked from 1 (low) to 3 (high) due to slope.

Lastly, we can reclassify the Land cover raster values. These are given in the USGS format and the old values are the class number, which can be substituted by the equivalent rank number specified previously (see Fig. 14 below). For example, note in Fig. 14 how the “Barren” land values (31, 32, 33), which result in high risk due to lack of vegetation, are assigned the highest risk value of 3. Every other null value is assigned a 2 for moderate, as are developed regions, and low risk (high vegetation) areas are given 1. The results is the raster layer shown in Fig. 15.

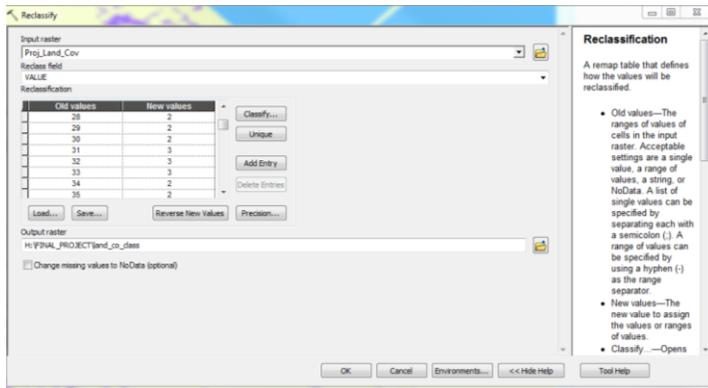


Fig. 14. Reclassification of land cover values into a ranking from 1 to 3 from the USGS classifying scheme.

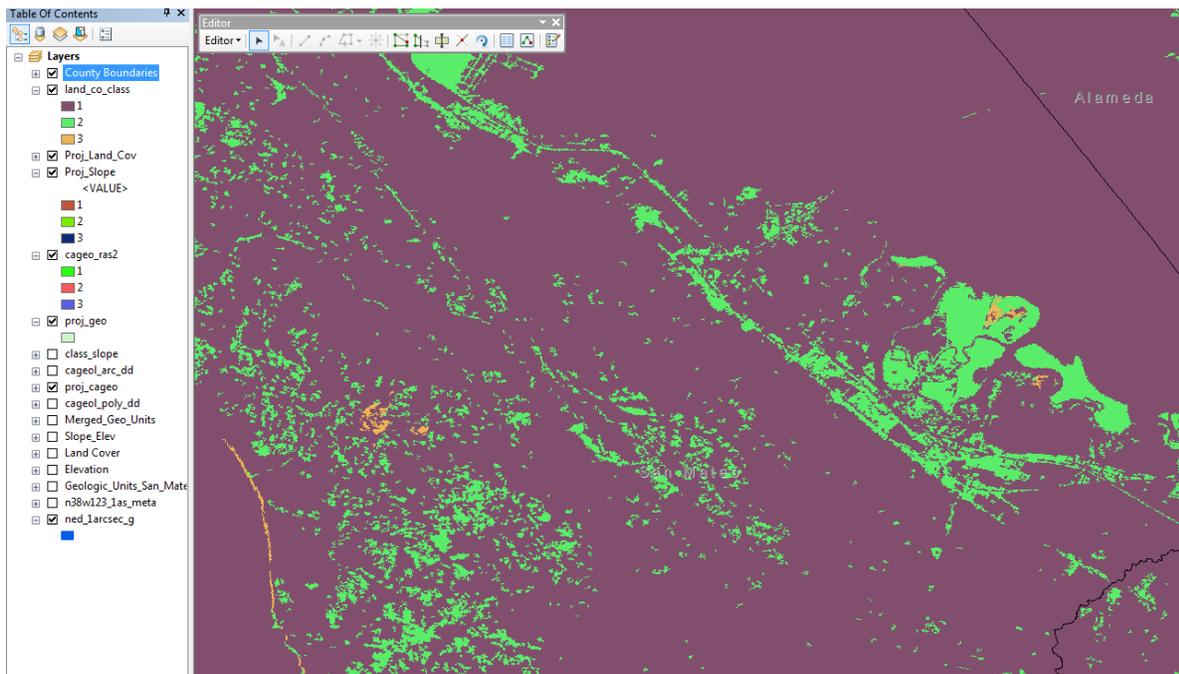


Fig. 15. Final raster layer showing landslide risk level from 1 to 3 due to vegetation cover.

The 3 raster datasets (geology, slope, land cover) have now been put into a common ranking scheme. This now allows for us to analyze the risk whilst taking into consideration all the factors.

Data Set Addition

Before the 3 layers can be combined, it is necessary to make sure that the cell size (X, Y) for all rasters is the same. Although the slope and geology layers have a cell size of 30, the land cover has one of approximately 27.7. This can easily be changed to 30 by using the **Resampling** tool. Use the search tool and use key words cell size, and then the window can be filled in as shown below in Fig. 16, specifying the output as the required cell size.

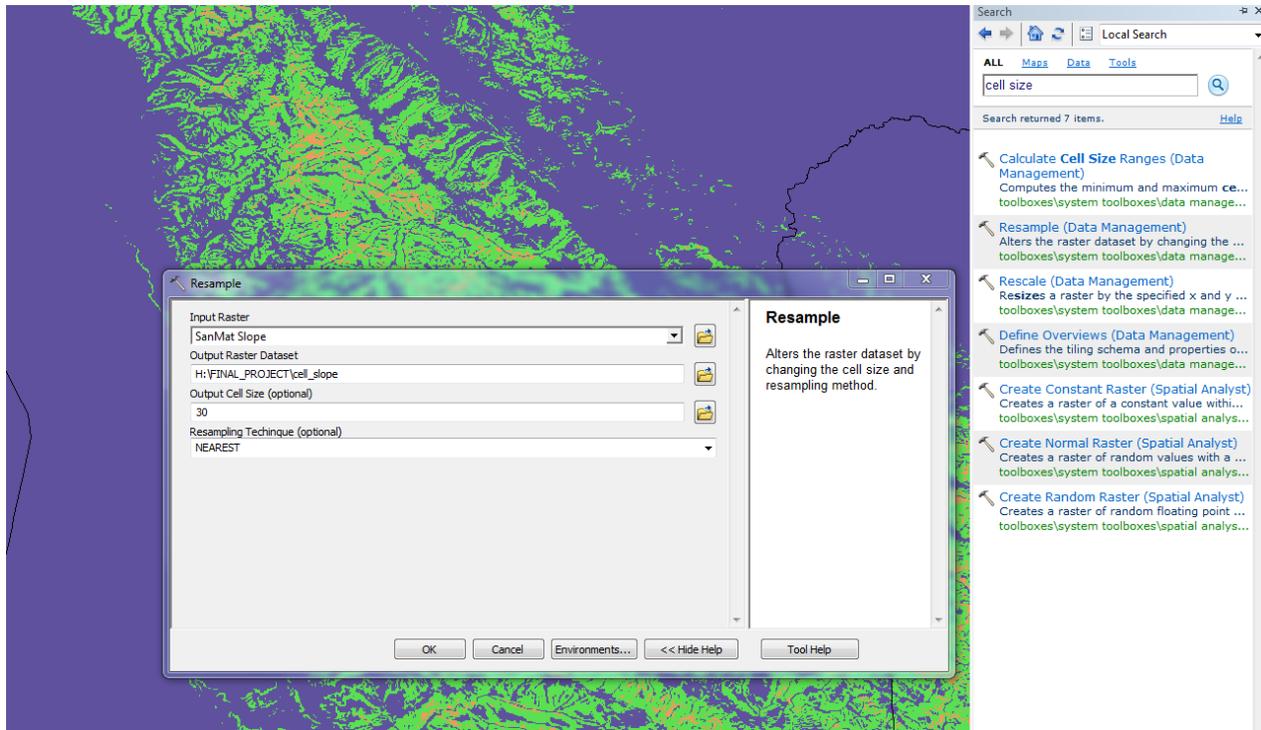


Fig. 16. Using the resample tool to change raster cell size.

All the factors above are essential in considering the landslide risk of a location, and all three will be considered equally and no weighting is used. In order to superimpose all the data, the Spatial Analyst toolbar is selected, and now the Raster Calculator is used to perform the combining of data sets. All that is required is a simple addition of all three layers, shown below in Fig. 17. Note that the output area will only consist of that which is overlapped by all three rasters. Note the transparency is used in order to emphasize the area of interest. The resulting ranking scheme will have values ranging from $(1+1+1)=3$ to $(3+3+3)=9$. These can be altered into any other required label (whether qualitative or quantitative). The result is shown in Fig. 18.

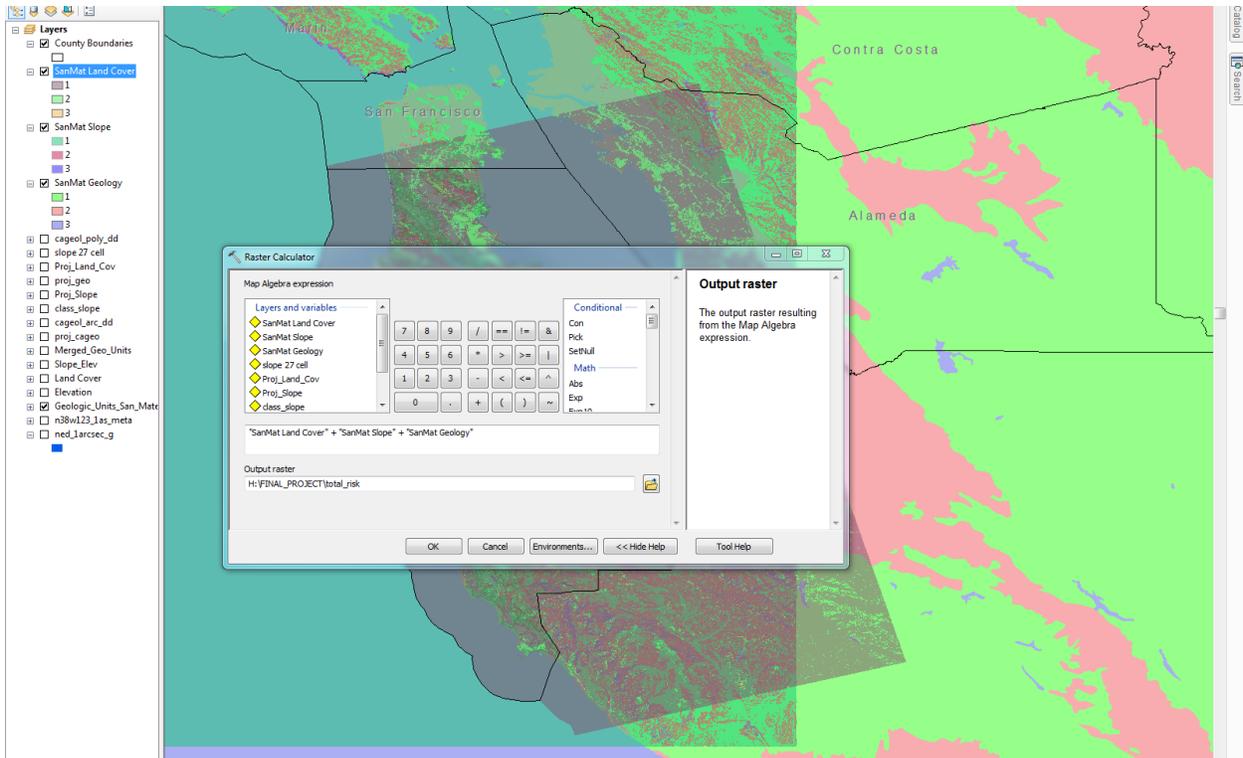


Fig. 17. Using the raster calculator to add the 3 rasters to obtain classification based on all 3 factors.

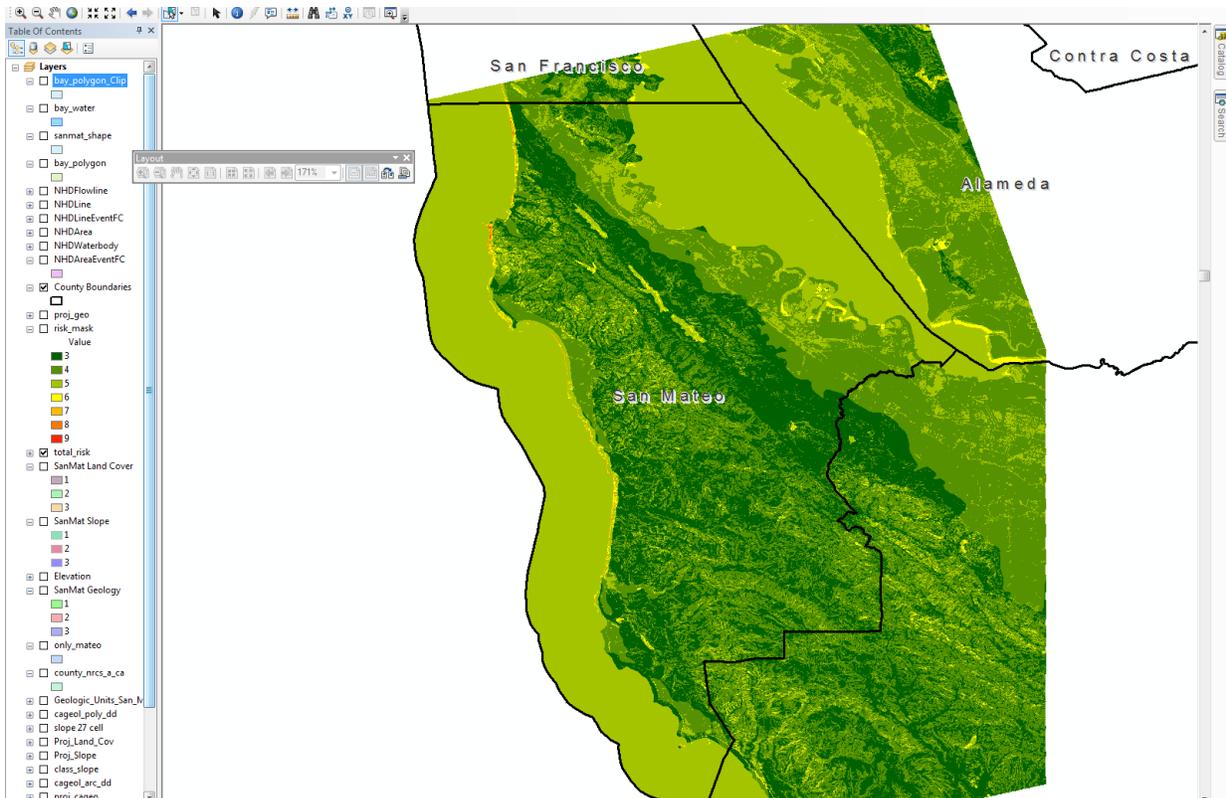


Fig. 18. Resulting addition of rasters and final value of risk classification of San Mateo.

Note that the darker greens represent low risk values(3), and red are high risk (9). The last tasks are to reduce the area to that of only San Mateo County, and then to add the hydrography data of relevance to the landslide risk assessment.

Reducing to Area of Interest

This is done by using the polygon of San Mateo obtained from the USDA, and using the Spatial Analyst toolbar, select the **Extract by Mask** tool. The Mask should be the county polygon of San Mateo and the result is shown in Fig. 19 below.

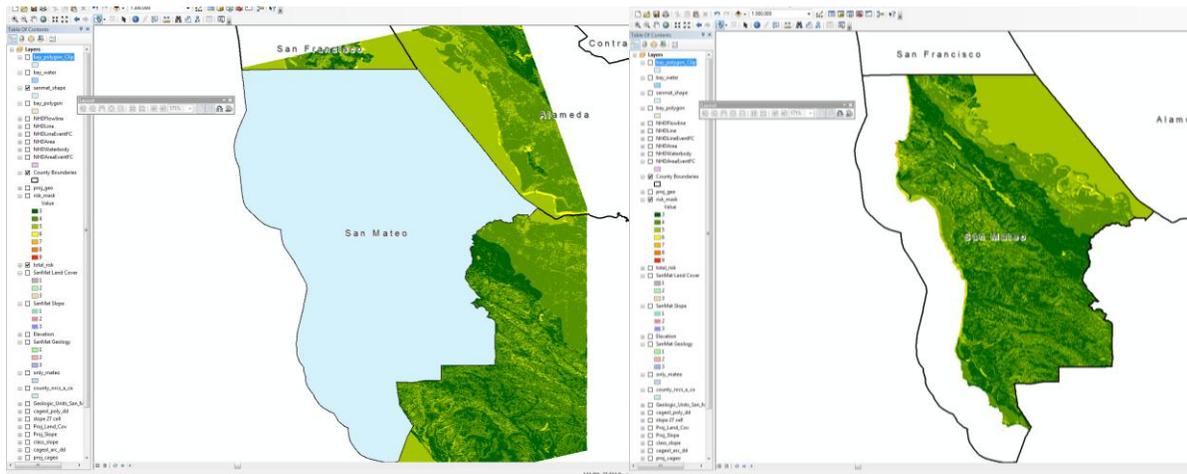


Fig. 19. Results of Extracting by Mask, in order to have only data within county of San Mateo.

Note however that the bay area is still included. A polygon for the bay area can be found in the Hydrography data which contains area polygons of all bodies of water. By selecting the bay with the Selection tool, one can then use Export Data, in order to create a single layer with the bay shape.

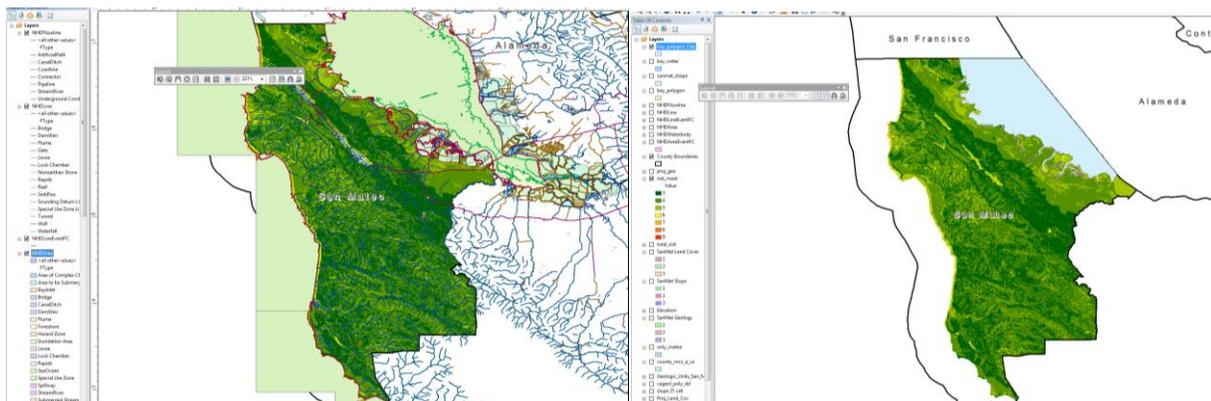


Fig. 20. Using the hydrography bay polygon to remove the risk assessment of the water in the bay.

It is clear that the hydrography data has too much information which is not relevant to the landslide risk assessment. As a result, everything is removed, except for the Stream/river flow lines. This is done by

using the **Select by Attribute** for the Hydrography layer. One can then Export Data, and the result is a layer with nothing but streams shown in Fig. 21.

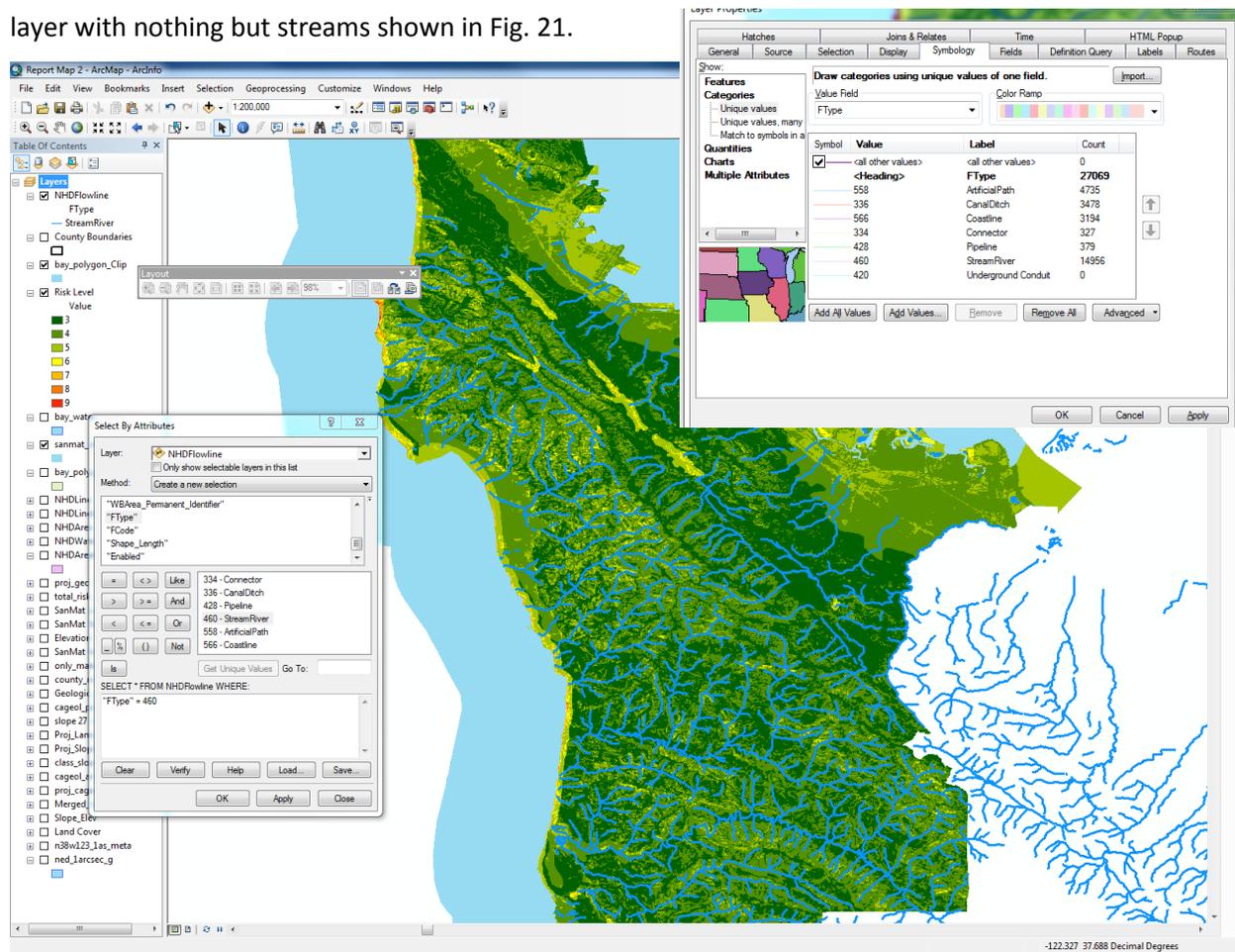


Fig. 21. Removal of all hydrography except for streams. Note the symbology window showing the attributes. However, another selection task is required because the streams are not confined to the county. This can be done by using Select by Location, and choosing those within the county (see Fig. 22).



Fig. 22. Using the Select by Location tool to select only streams in the county.

Once again this selection is exported and a new layer is formed with only the streams required.

The final result is shown below in Fig. 23.

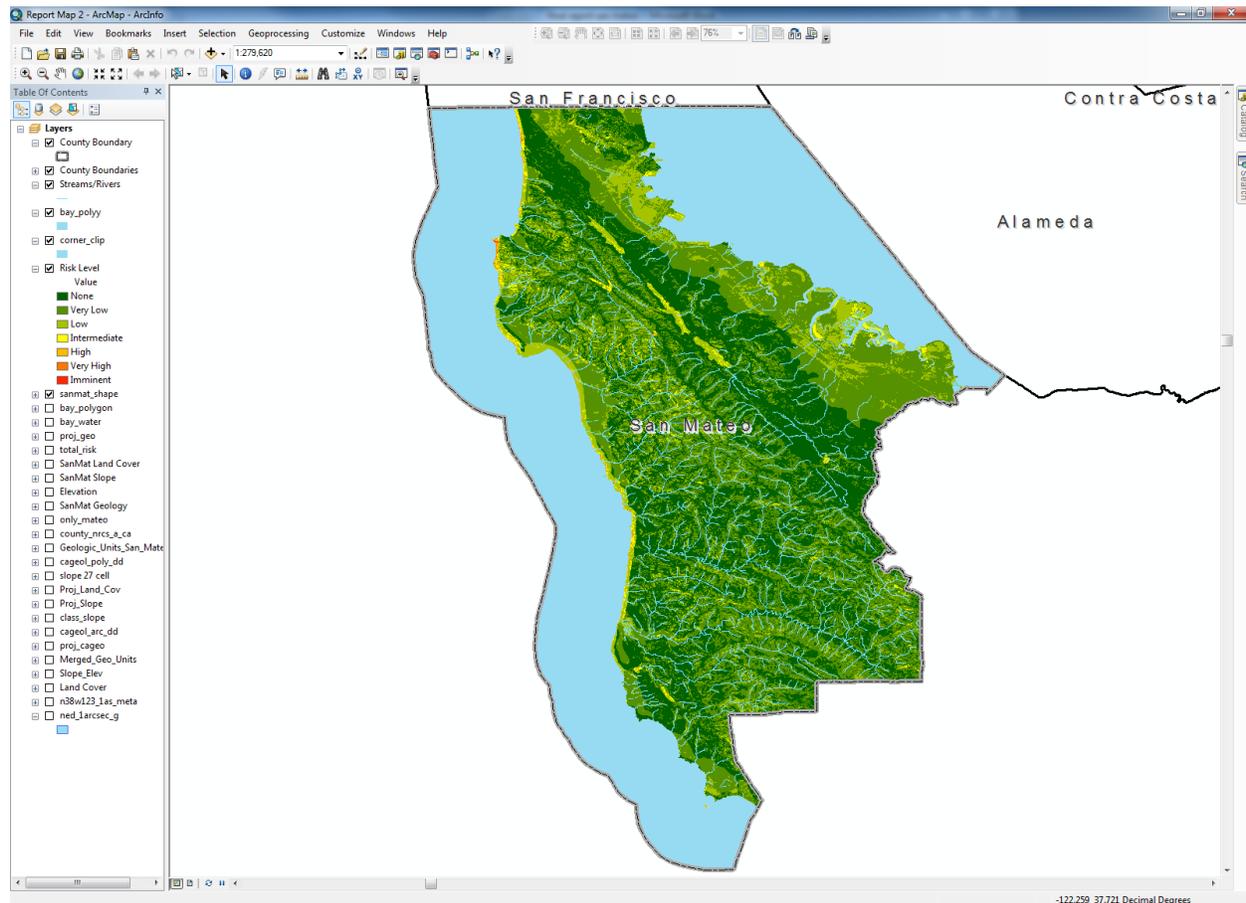


Fig. 23. Final risk landslide assessment of San Mateo ranging from none to imminent and including water flow lines.

Discussion/Conclusion

The final result of this project relied on various forms of data retrieved from multiple sources. These were all GIS data from either California or specific to the county. The analysis focused specifically on the geology, hydrography, slope, and land cover and used these physical factors in order to assess the plausibility of a landslide occurring. Looking at the final map generated, it appears that most of the county is under low threat. There are however areas of intermediate threat, and some coastal/lake areas which are also prone to landslides. These are shown in closer detail in Map 2. Most of the county is heavily vegetated despite the high elevation changes, which results in stabilization of material. Closer to inland the only areas which contain high risk are those near lakes which is consistent with observation, since some sort of mobile soil and moderate slope is required to activate landslides. It is also important to note that there are numerous factors that lead to high landslide risk, and as a result

of limited time (and data available) not all could be considered. Other factors are rainfall, rebound, earthquake types of vegetation). This risk levels were basic, with only 3 values. A more complex assessment could have been made with multiple levels for each, and also different weightings. It is also important to note different areas will have different predominant factors. The final raster from the calculation would have many more values and these would have to be reclassified into ranges of risk levels. Perhaps the seismic activity would have been the next most important factor to consider, due to the high seismic activity in the transform-fault area and the heavy population in the coastal areas.

The project was successful in delineating high risk areas, which is of large consequence for the highly populated coastal areas in the western shore of San Mateo County.

Resources:

"Census 2000 U.S. Gazetteer Files: Counties". United States Census. Retrieved 2011-02-13.

"Geography and Population of the County". (2010) Healthy San Mateo.

U.S. Geological Survey. The National Map Viewer. (2012). <http://viewer.nationalmap.gov/viewer.html>

USDA, GeoSpatial Data Gateway. (2012). <http://datagateway.nrcs.usda.gov/GDGOrder.aspx>

Landslide risk assessment of San Mateo County, CA

6th December 2012 Gaia Stucky de Quay



High landslide risk areas in San Mateo, CA

6th December 2012

Gaia Stucky de Quay

