Finding a Representative Friction Angle for Landslide Areas in Palos Verdes Using Infinite Slope Analysis

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Presented: Dec 17, 2012

Introduction

My project involves the occurrence of landslides in my home town of Palos Verdes, California. As part of my research, I found a landslide inventory map and an underlying geology map of the Palos Verdes area, and what was determined was that all of the landslides have occurred over Pre-Quaternary Bedrock. Since I have decided to use infinite slope analysis in order to determine where landslides would occur, the fact that the landslides occur over bedrock defies logic about landslides. Infinite slope analysis depends on the friction angle of the underlying soil, and bedrock does not necessarily have a friction angle and thus, makes infinite slope analysis obsolete. What may have happened is that a fissure could have been created in the bedrock due to an earthquake, and the crack in the bedrock could have been filled with some kind of clay or other soil. Thus, the landslides are actually occurring because the bedrock is slipping on the clay film.

Working under this assumption, the goal of my project is to find a representative friction angle for the areas where landslides occur in the Palos Verdes area. I will do this by creating a raster map that shows an area's factor of safety against a landslide, and I will try to match up the landslide map and the underlying geology to match up by varying the friction angle until the areas with known landslides have the lowest factor of safety (<1.5 in this case). Under the assumption that the landslides occur because of low-strength soil filling fractures of bedrock, the knowledge gained from this project will shed light on a characteristic of the underlying soil.

Area of Study

I focused my area of study to the Palos Verdes Peninsula, as there are a number of landslides that have occurred there. This area includes the following USGS quadrangles: Redondo Beach, San Pedro, and Torrance. Below is the area of study in the context of Los Angeles County, and the map includes the landslide inventory of the area.

Palos Verdes Landslide Inventory

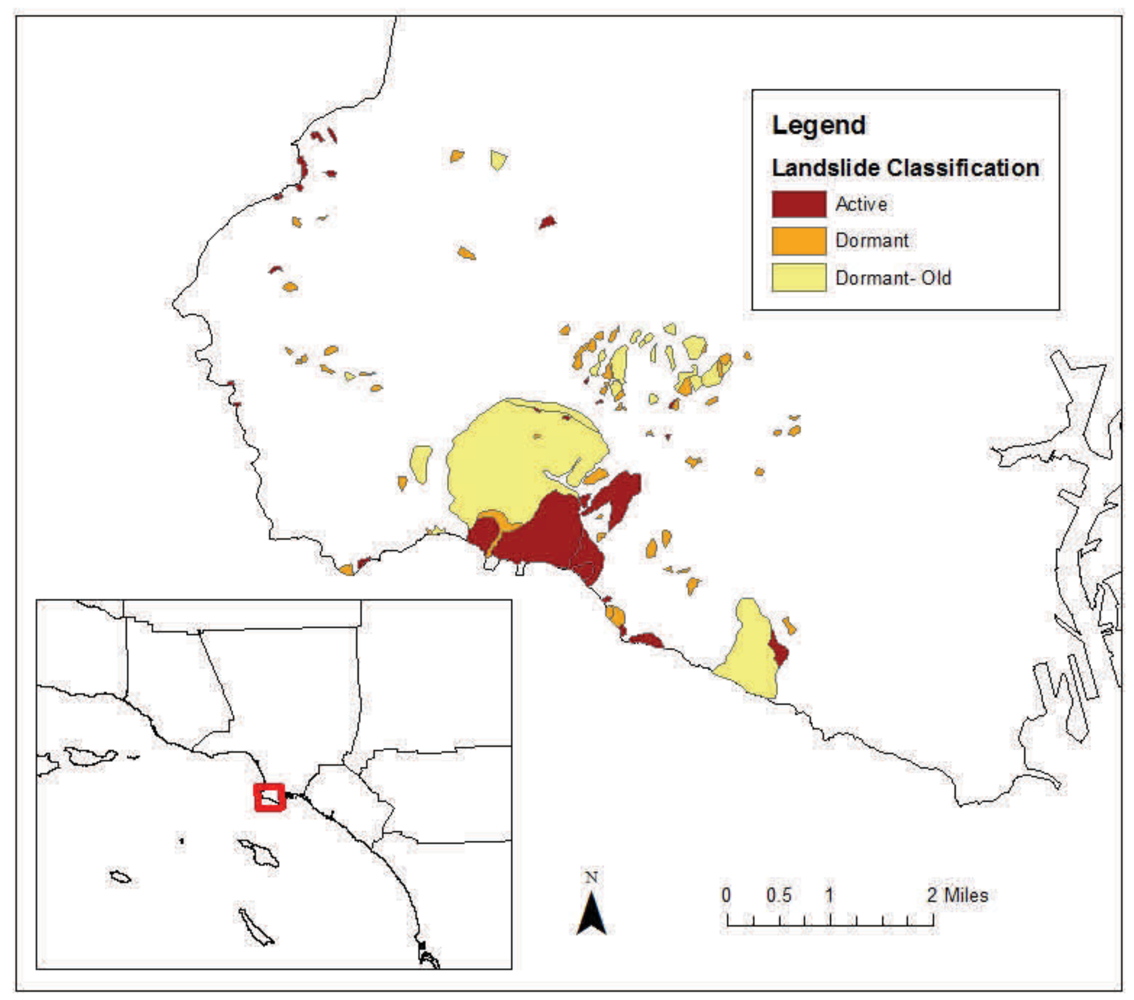

Figure 1: Area of Study

Methodology

The main output of this project is a raster showing the factor of safety against landslide in the Palos Verdes area, and this was achieved using infinite slope analysis. The equation used was:

$$FS = \frac{\tan \phi}{\tan \beta}$$

Where ϕ is the friction angle of the underlying soil, and β is the slope of the surface. The main data layers used are listed below, including their source:

Data Title	Source	Format
Elevation Map	USGS	Raster
Underlying Soils	California Department of Conservation	.PDF
Landslide Inventory	California Department of Conservation	.PDF

The .pdf files were converted to .jpeg files, georeferenced into ArcMap, and converted into .shp files. The Elevation and Underlying Geology maps were then put through the following model, of which the output was the Factor of Safety map. The model is shown below:

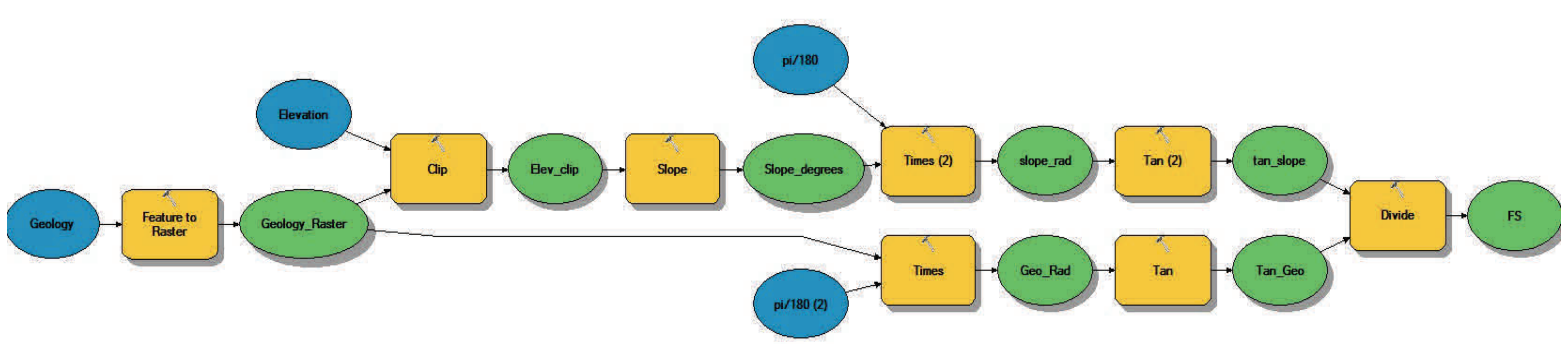

Figure 2: Factor of Safety Model

Results

Figures 3 and 4 are the two main input maps. Each geologic unit in Figure 3 is assigned a friction angle, ϕ. It is this parameter and the slope angle that is derived from Figure 4 that are input to the model to create Figures 5-8. The friction angle for the geologic unit Ls, which stands for landslides, is the angle represented in the titles of the maps. The red areas show a factor of safety of <1.5, which are the areas most susceptible to landslides.

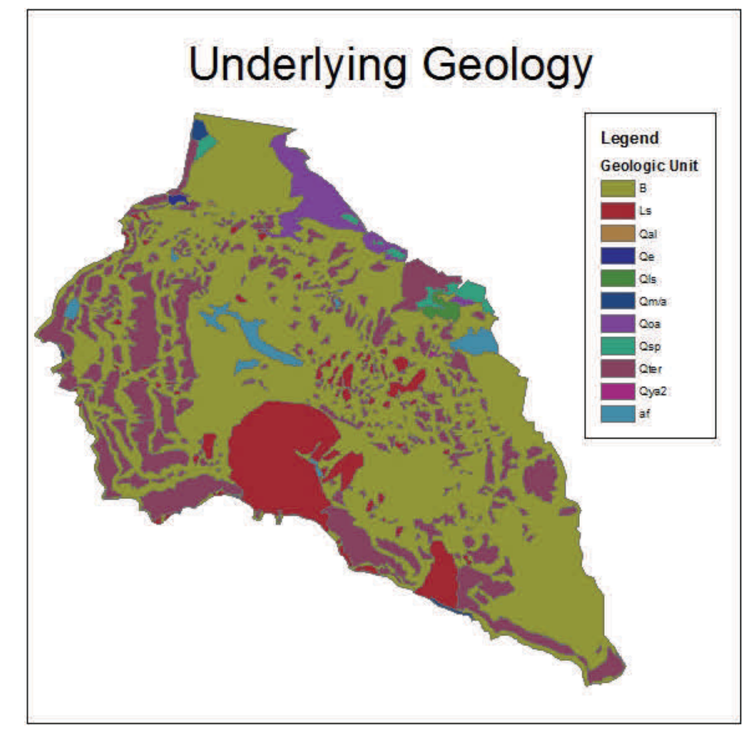

Figure 3

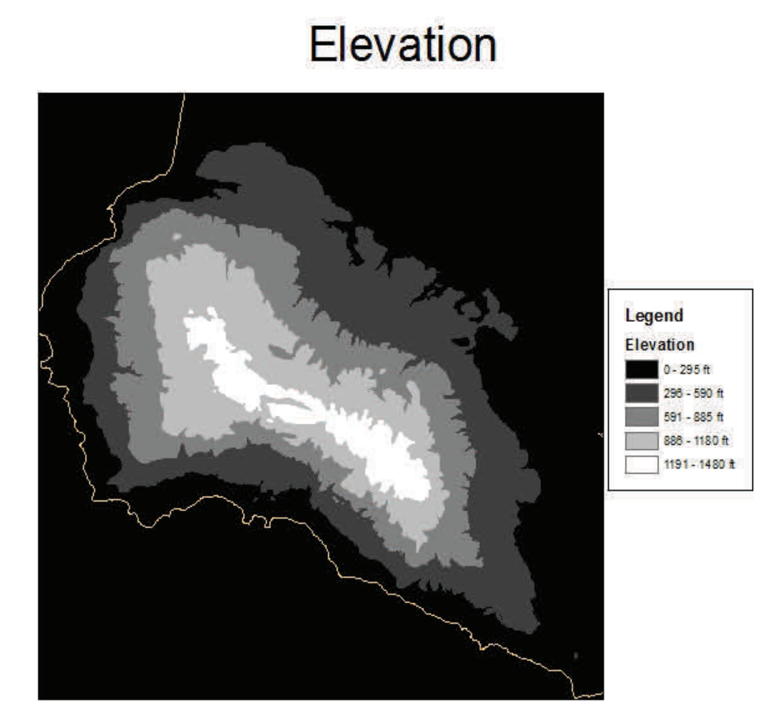

Figure 4

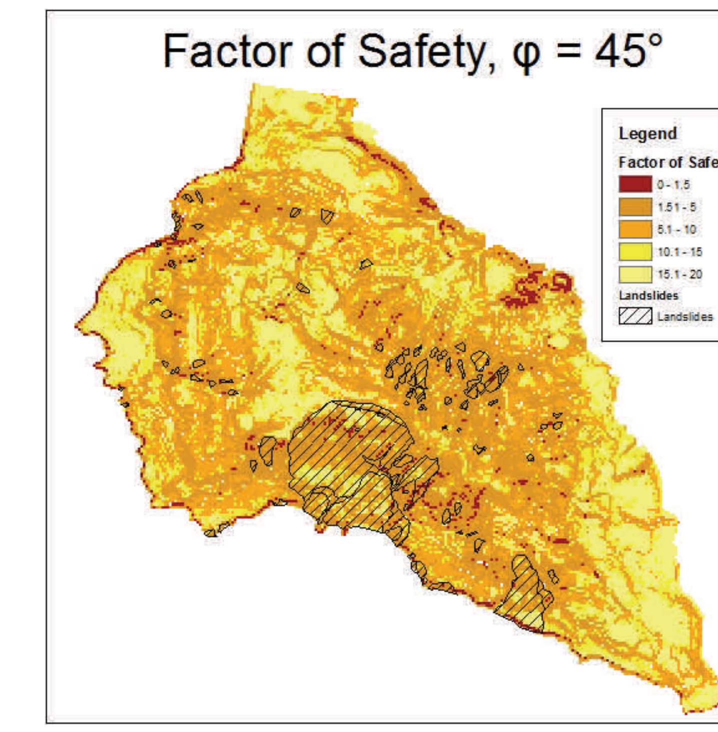

Figure 5

Figure 5 is the factor of safety of the Palos Verdes area if we are to assume that the landslides occur on bedrock, which is what the old geologic maps suggest. As the figure above suggests, landslide occurrence is highly unlikely in the inventoried areas assuming a friction angle of 45° because the inventoried areas hardly contain any red. The friction angle was varied in increments of 5° to produce maps similar to Figures 6-8. As the friction angle is lowered, the amount of red area that appears in the landslide areas increases, which is what we can expect based on the infinite slope analysis equation.

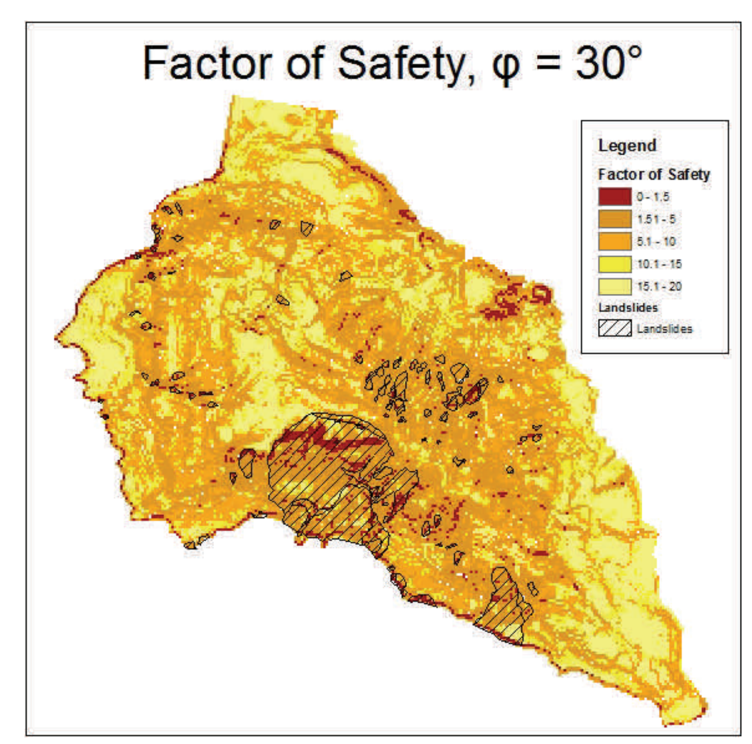

Figure 6

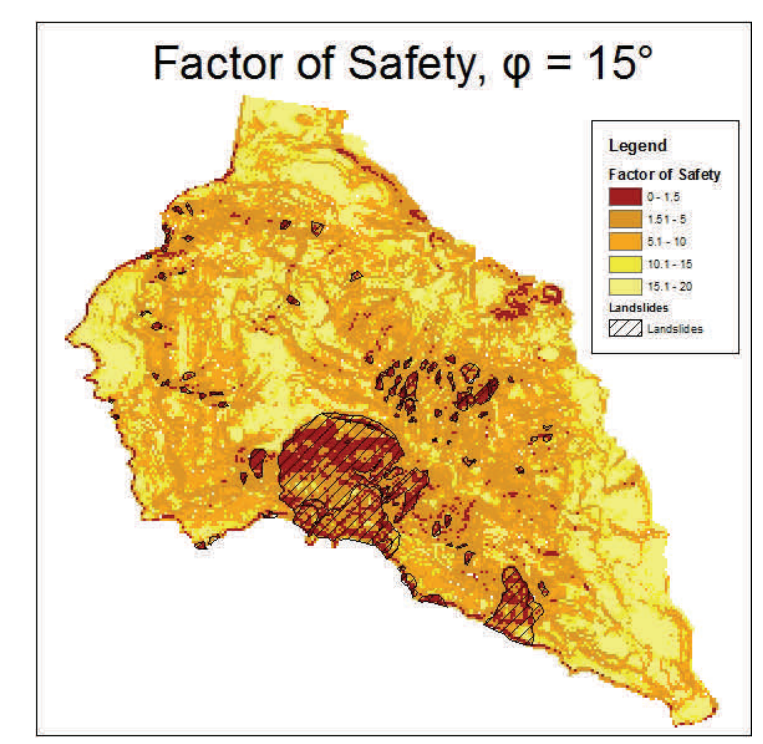

Figure 7

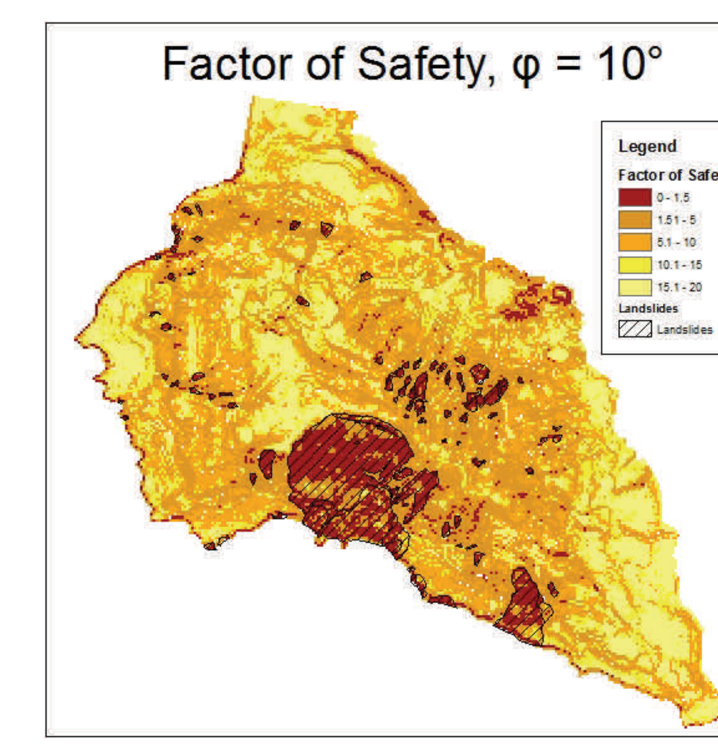

Figure 8

Conclusion

Based on the factor of safety maps created by the model, the angles at which the landslide areas have the most red are when ϕ = 15° and ϕ = 10°. However, using ϕ = 10° in infinite slope analysis is a more reasonable friction angle to use for the landslide units. When the friction angle changes from 15° to 10°, there is, visually, a significant more amount of red in the landslide areas, thus not only using ϕ = 10° more conservative when calculating factor of safety, but it is also more accurate as well. Through my literature review, I found a geologic map from the CA Department of Conservation of an area near Palos Verdes that includes landslides in the map. The friction angle the map used was ϕ = 10°, which validates the findings from my model.