GeoStudio Example File
Spatial Variation of Soil Properties

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Introduction

The undrained strength of a soft soil deposit is frequently a function of the effective overburden stress; consequently, soil strength varies with depth. In some cases, the undrained strength also varies laterally due to past loading conditions. This example demonstrates the use of spatial and linear functions to define spatially-variable material properties in SLOPE/W, using previously published findings from the Mohicanville Dike (Duncan and Wright, 2005).

Numerical Simulation

The model domain and material properties are based on the study described by Duncan and Wright (2005) summarizing undrained strength variation below the Mohicanville Dike (Figure 1). The undrained strength within the underlying peat changes laterally, while the foundation contours show both vertical and horizontal variation. The cohesion in the embankment is constant.
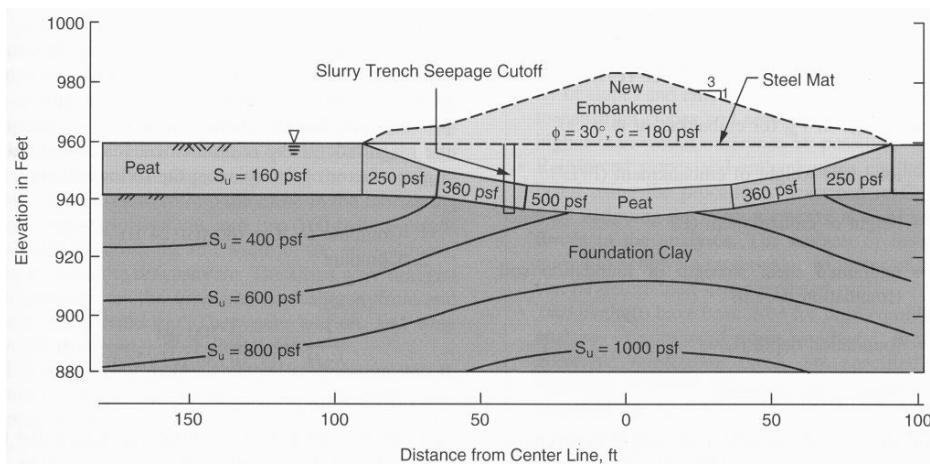

Figure 1. An example of spatial variation of undrained strength (from Duncan and Wright, 2005; Figure 8.9, page 147).

In SLOPE/W, regions representing the embankment, peat, and foundation clay were drawn (Figure 2). The Entry and Exit method defines the trial slip surfaces, such that the movement is from the top of the embankment to the left side of the domain. The Morgenstern and Price limit equilibrium method calculates the factor of safety for each slip surface.
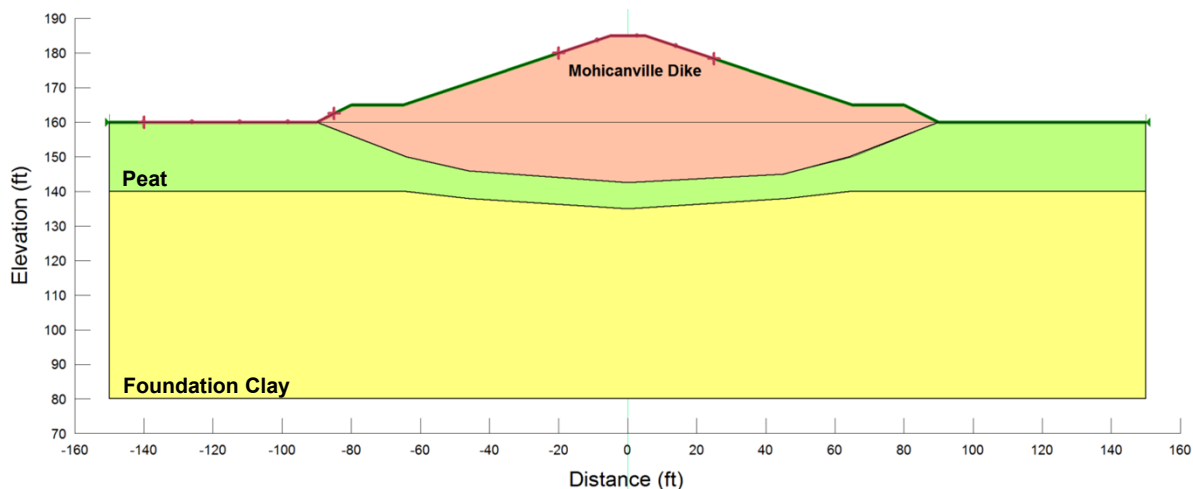

Figure 2. Analysis configuration and slip surface definition.

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As described above, the material properties within the embankment do not vary spatially. The Mohr-Coloumb material model defines constant properties throughout the embankment region. The embankment has a unit weight of 120 pcf, cohesion of 180 psf, and friction angle of 30°.

The Spatial Mohr-Coulomb model is applied to the peat and foundation clay. The peat friction angle is 0°, while its unit weight and cohesion are defined with linear functions (Figure 3). Linear functions allow the material properties to vary with either x or y coordinate. The linear functions associated with the peat cause the unit weight and cohesion to vary over x. Both material properties increase towards the center of the embankment (x = 0 ft), with maximum values of 121 pcf and 510 psf for unit weight and cohesion, respectively.
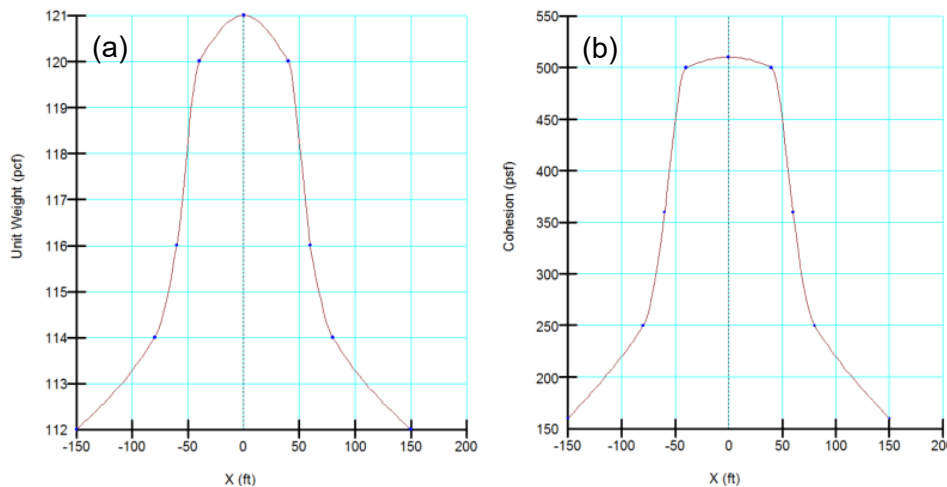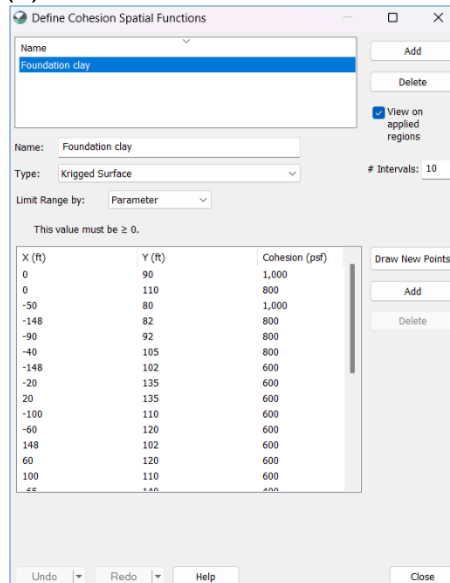

Figure 3. Linear functions defining the lateral variability in (a) unit weight and (b) cohesion of the peat.

The foundation clay has a constant friction angle of 0°. The unit weight and cohesion of the foundation clay are defined by spatial functions, which allow the material properties to vary in both the x and y directions. Spatial functions are comprised of x and y coordinates with the corresponding material property value at each point. The coordinates and material values are entered manually in the Define Spatial Functions dialogue box, as illustrated in Figure 4(a). Alternatively, the material property is entered and the corresponding point is drawn by clicking at the appropriate location. SLOPE/W contours the data within the associated regions. The spatial function is applied to a material in the Define Materials dialogue when the Spatial Mohr-Coulomb material model and spatial function option are selected as shown in Figure 4(b).

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(a)

(b)

Figure 4. Spatially variable cohesion in the foundation clay (a) based on the coordinates and cohesion values entered in the Define Spatial Functions dialogue, and (b) specified in the Define Materials dialogue under the Spatial Function option.

Contours for unit weight and cohesion can be drawn throughout the domain (Figures 5 and 6). These contours confirm that the material properties were correctly applied; the properties vary laterally in the peat, and both horizontally and vertically in the foundation clay, as in the original study (Figure 1; Duncan and Wright, 2005). The contours are not continuous over regions, as each region (or group of regions with the same function) is contoured separately.

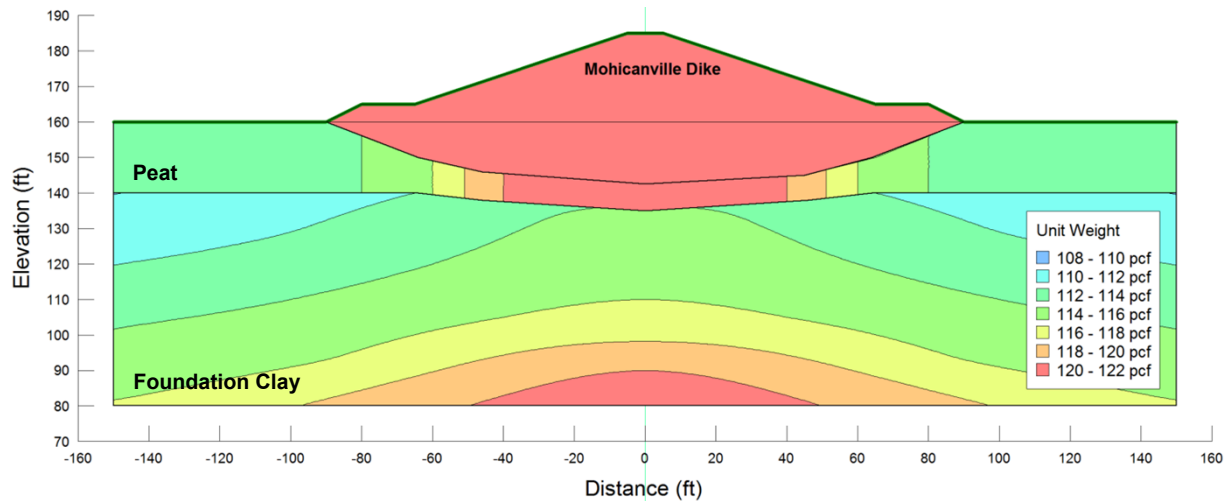# GeoStudio Example - Spatial Variation of Soil Properties

Figure 5. Unit weight throughout the domain, given the specified linear function for the peat and spatial function for the foundation clay.
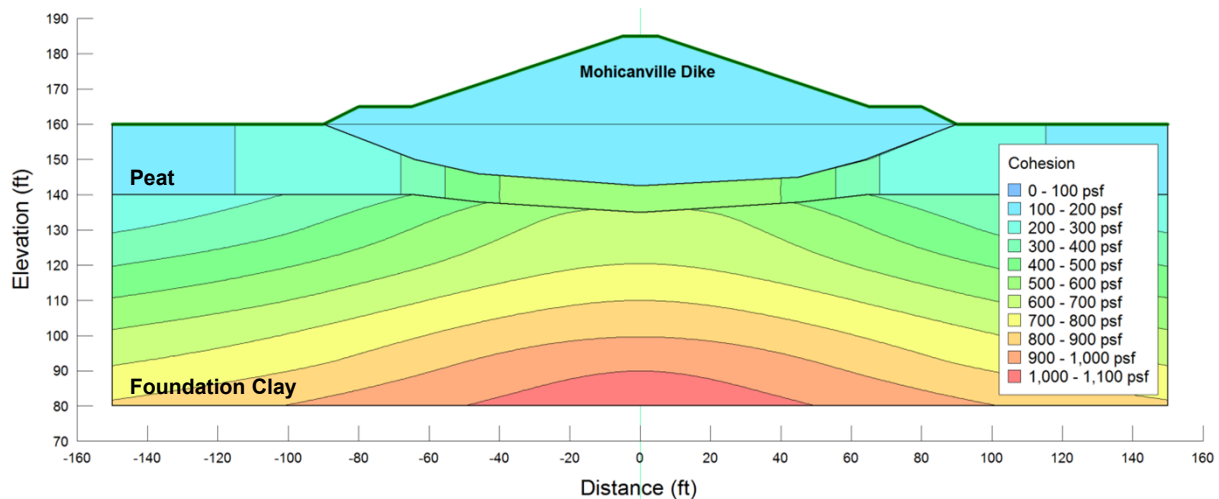

Figure 6. Cohesion throughout the modeled domain given the applied linear function in the peat and spatial function in the foundation clay.

Results and Discussion

The factor of safety color map illustrates bands of slip surfaces with similar factors of safety (Figure 7). The critical factor of safety is 1.262. Plotting a parameter along the slip surface via Draw Graph ensures that the material properties were correctly applied. For example, Figure 8 shows the variation in cohesion along the critical slip surface. The cohesion changes substantially throughout the foundation clay (-128 ft < x < 0 ft) given the spatial function; however, cohesion is constant when the slice base is in the embankment (x > 9.5 ft) or in the peat under the crest of the embankment (0 ft < x < 6.5 ft). These results correspond to the inputted material properties as the embankment cohesion was constant and the peat cohesion changed laterally with minimal variation under the embankment crest (Figure 6).
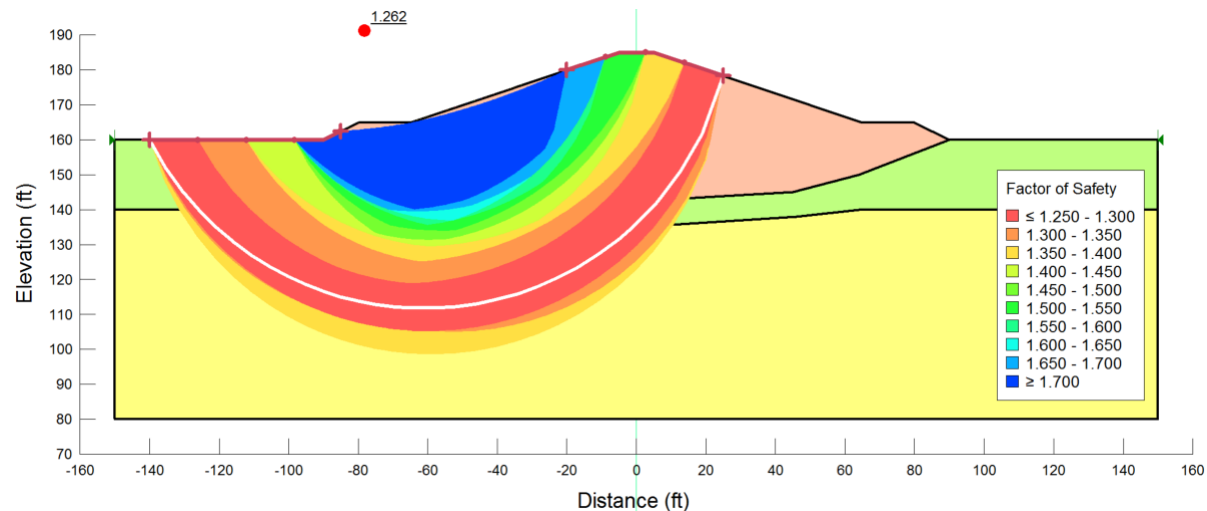
Figure 7. Factor of safety color map with the critical slip surface in white.
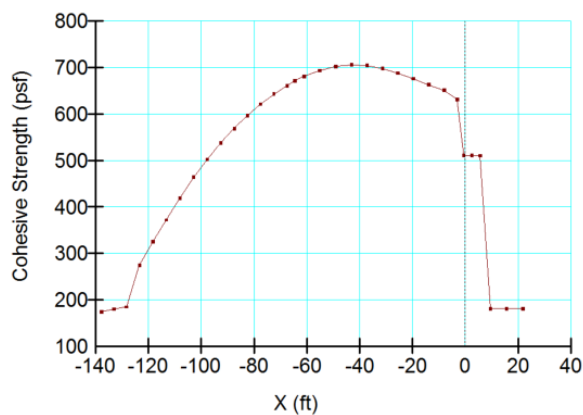

Figure 8. Variation in cohesion along the critical slip surface.

Summary and Conclusions

This example demonstrates the application of spatially variable material properties to regions in SLOPE/W. Linear functions allow material properties to change in one dimension (x or y), while spatial functions characterize variability in two dimensions (x and y). These functions may be applied to a material using the Spatial Mohr-Coulomb material model.

References

Duncan, J.M. and Wright, G. 2005. *Soil Strength and Slope Stability*, John Wiley & Sons, Inc., Hoboken, NY, USA.