Probabilistic analysis with random shear strength (COV)

1.0 Introduction

This tutorial introduces the ability to define variability on the shear strength of the material itself. It has two important advantages:

1. It eliminates the need to define variability on multiple individual parameters for a material, particularly helpful in cases where parameter-specific data may be sparse.
2. It can be applied to all material strength types, including Shear/Normal Function, all Anisotropic options, and Discrete Function.

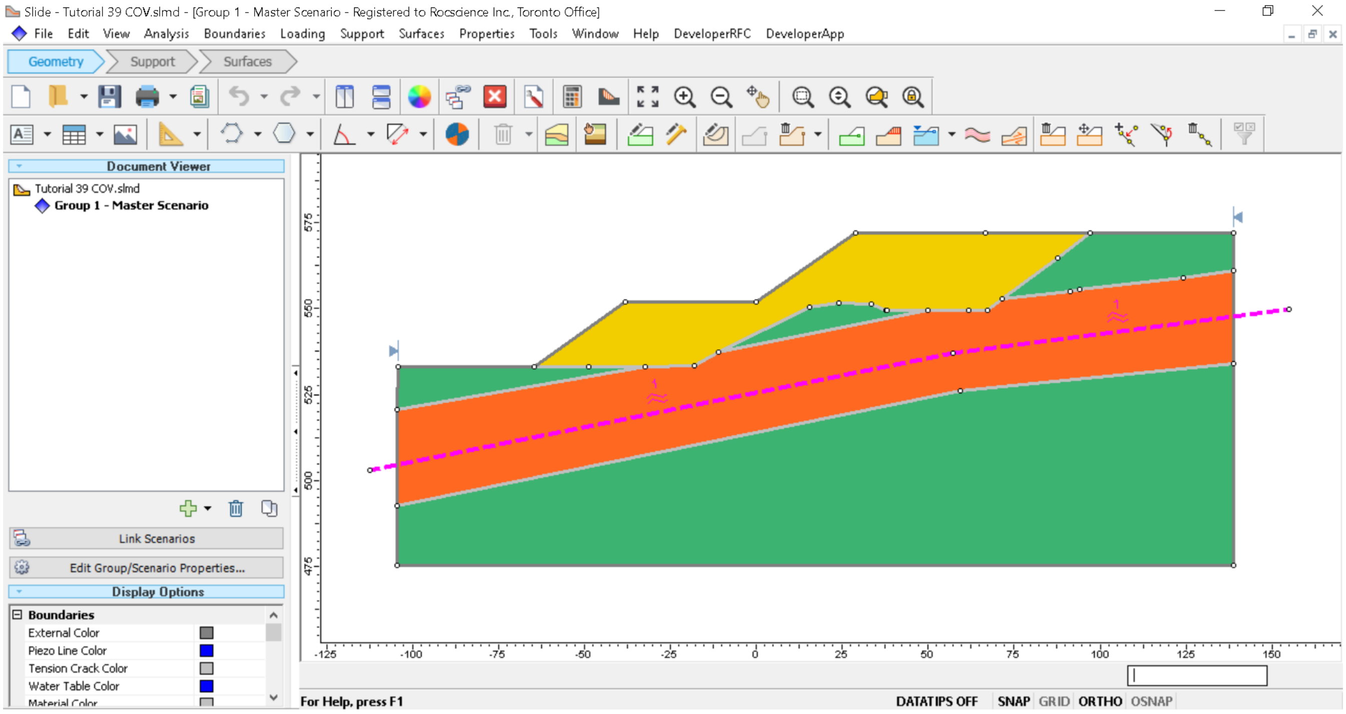
Finished Product:

The finished product of this tutorial can be found in the *Tutorial 39 COV.slmd* data file. All tutorial files installed with **Slide2** can be accessed by selecting **File > Recent Folders > Tutorials Folder** from the **Slide2** main menu.

2.0 Project Settings

After opening *Slide2*, select **File > Recent > Tutorials** folder from the *Slide2* main menu and open *Tutorial 39 COV – starting file*.

You should see the following open pit section:



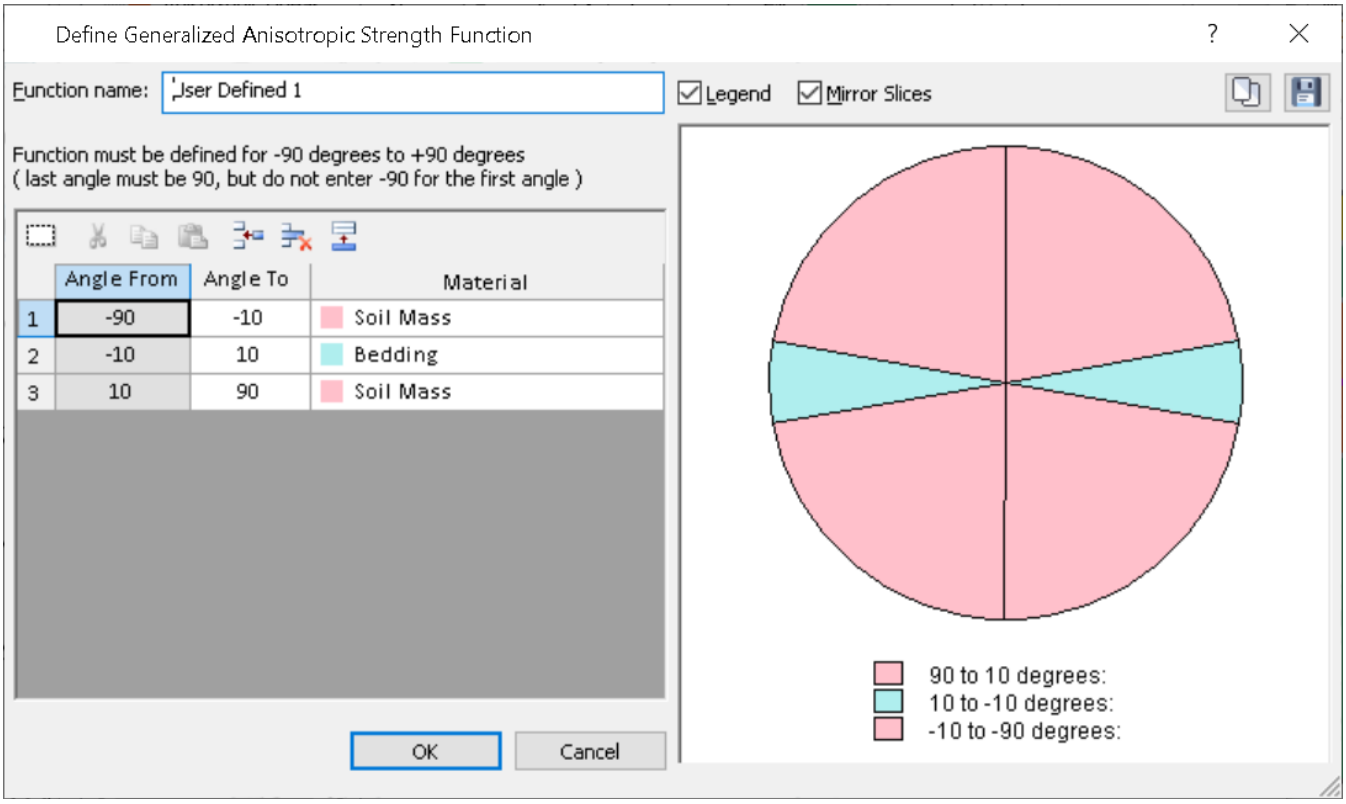
You can click on **Analysis > Project Settings** to see that the **Spencer method** is selected. You can also click on **Surfaces > Surface Options** to see that **Particle Swarm non-circular search** is selected.

3.0 The Model

Select **Properties > Define Materials.**

You will notice that the yellow material is a **Shale** with a **Shear/Normal Function** strength type. You can click "**Edit**" to see the Shear/Normal function.

The green material uses the **Generalized Anisotropic Strength Type**. You can click the **Pencil** icon to see that the function is defined by two other materials:



Click **Cancel** and select the **Anisotropic Linear** material. You will see this follows an anisotropic surface. Click **Cancel**.

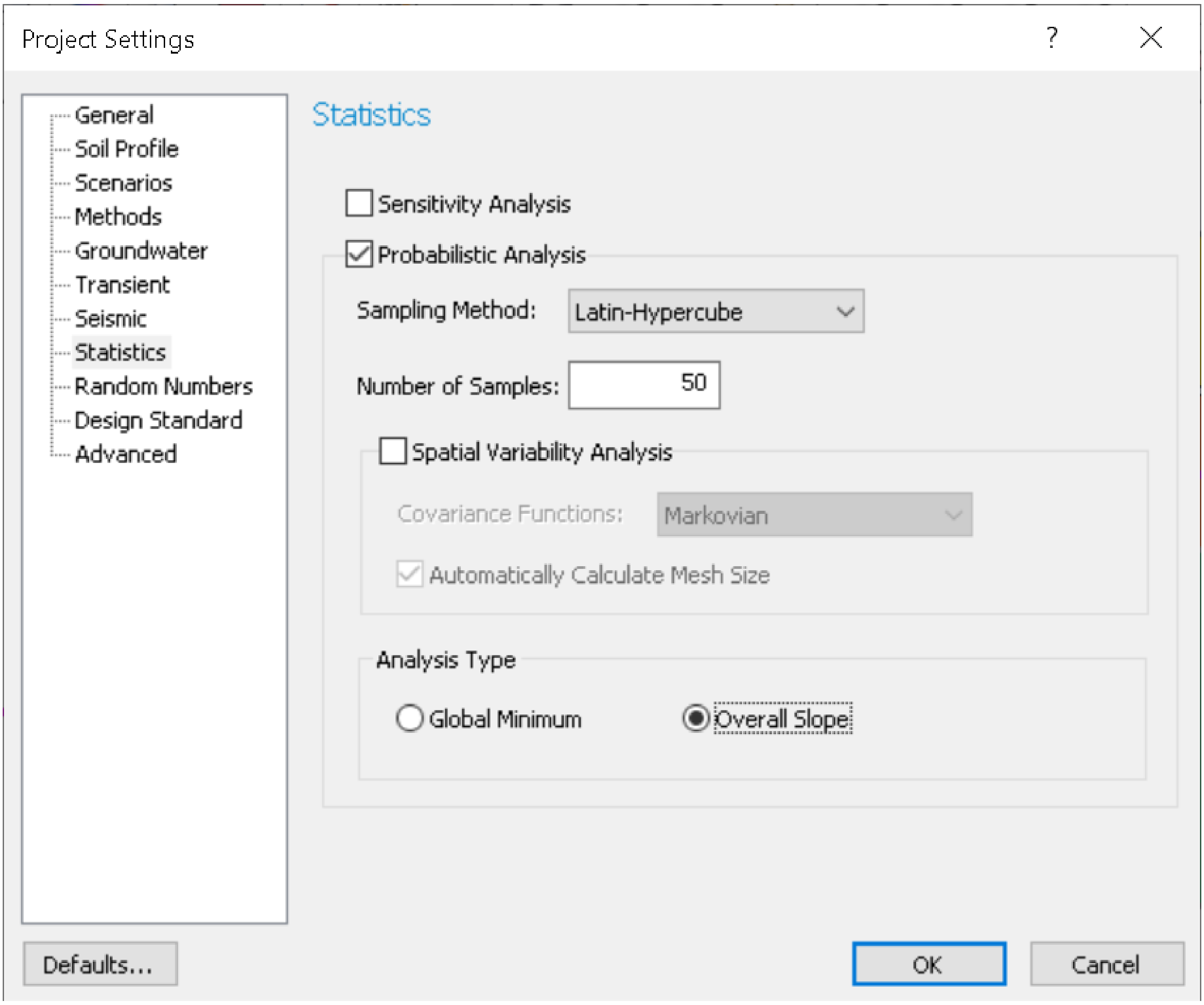
Click **Analysis > Compute** to run the analysis. Once done, select **Analysis > Interpret** to view the results. You will notice a minimum surface that intersects all three materials, with a Factor of Safety of about 1.2. Close Interpret and return to the Modeler.

3.1 COV OPTION

Right-click on the "**Group 1**" group in the Document Viewer and click "**Add Scenario**." Then right-click on the scenarios and click "**Rename**." In the dialog, name the new scenario "**COV**."

To use the COV option, we first have to enable **Probabilistic Analysis**. To do this:

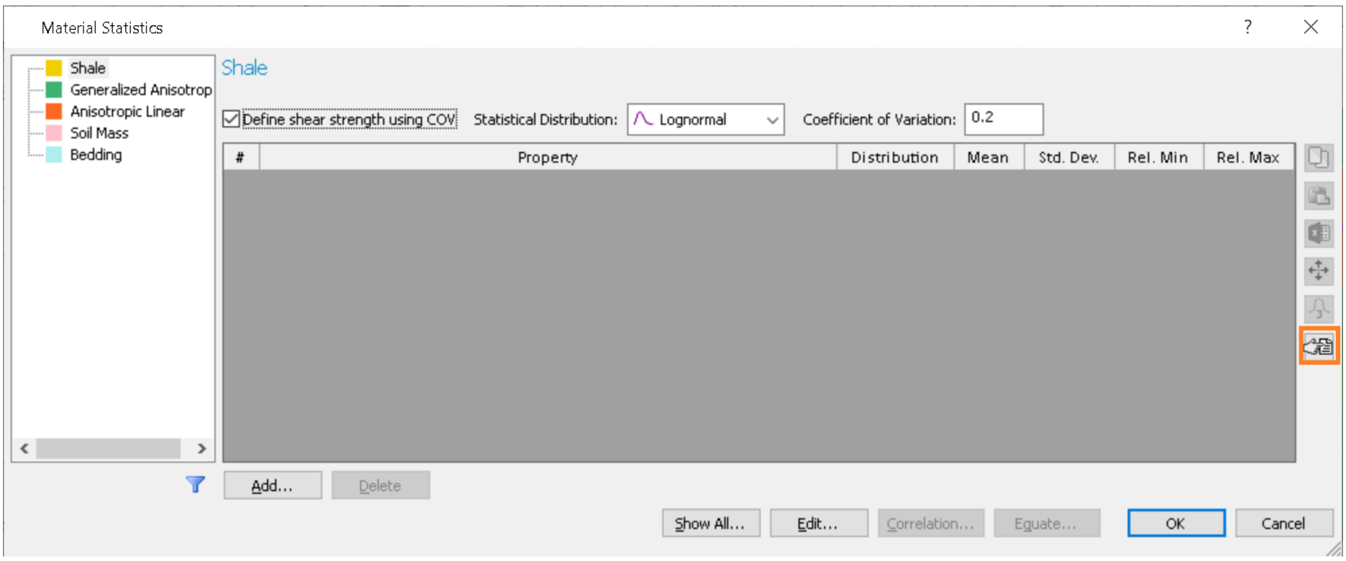
1. Select **Analysis > Project Settings.**
2. Click on the **Statistics** tab.
3. Check the "**Probabilistic Analysis**" box.
4. Then set the number of samples to **50** and the **Analysis Type** to **Overall Slope** as shown.
5. Click **OK**.



Now the **Statistics** tab will appear in the menu bar.

Select **Statistics > Materials**.

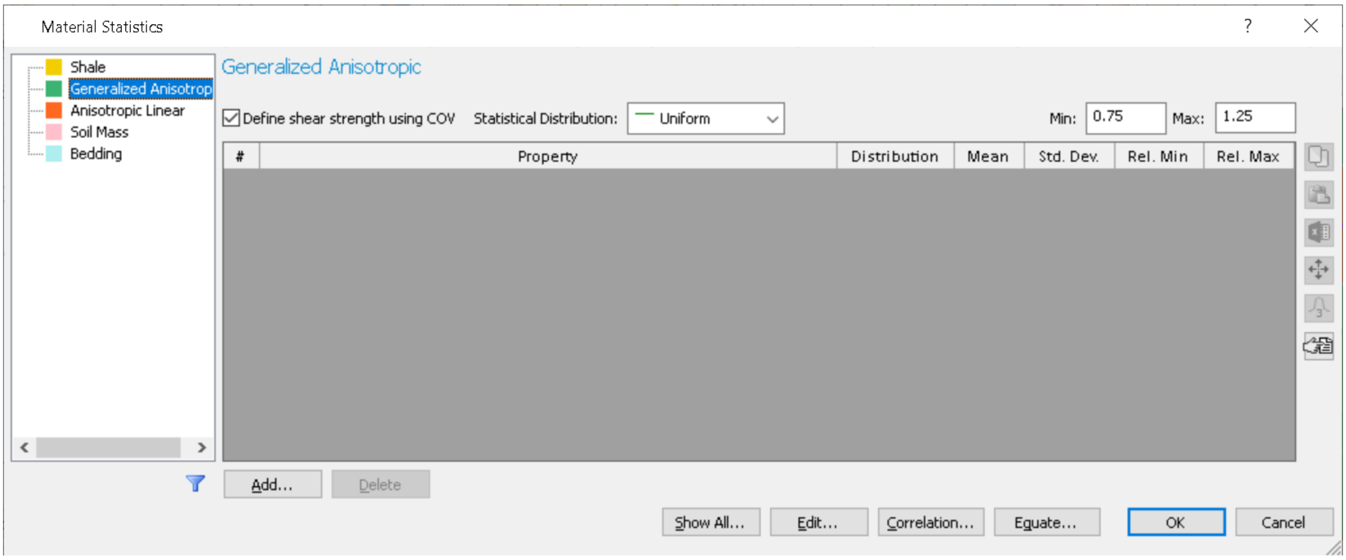
You will notice the "**Define shear strength using COV**" button. Check this to enable the option for the Shale material. You will see two input fields appear as shown:



This means that the shear strength of the Shale will vary according to a lognormal distribution, with a coefficient of variation of 0.2 The coefficient of variation is defined as the standard deviation divided by the mean. Because the shear strength value changes according to location, the user only needs to define the standard deviation as a fraction of the mean.

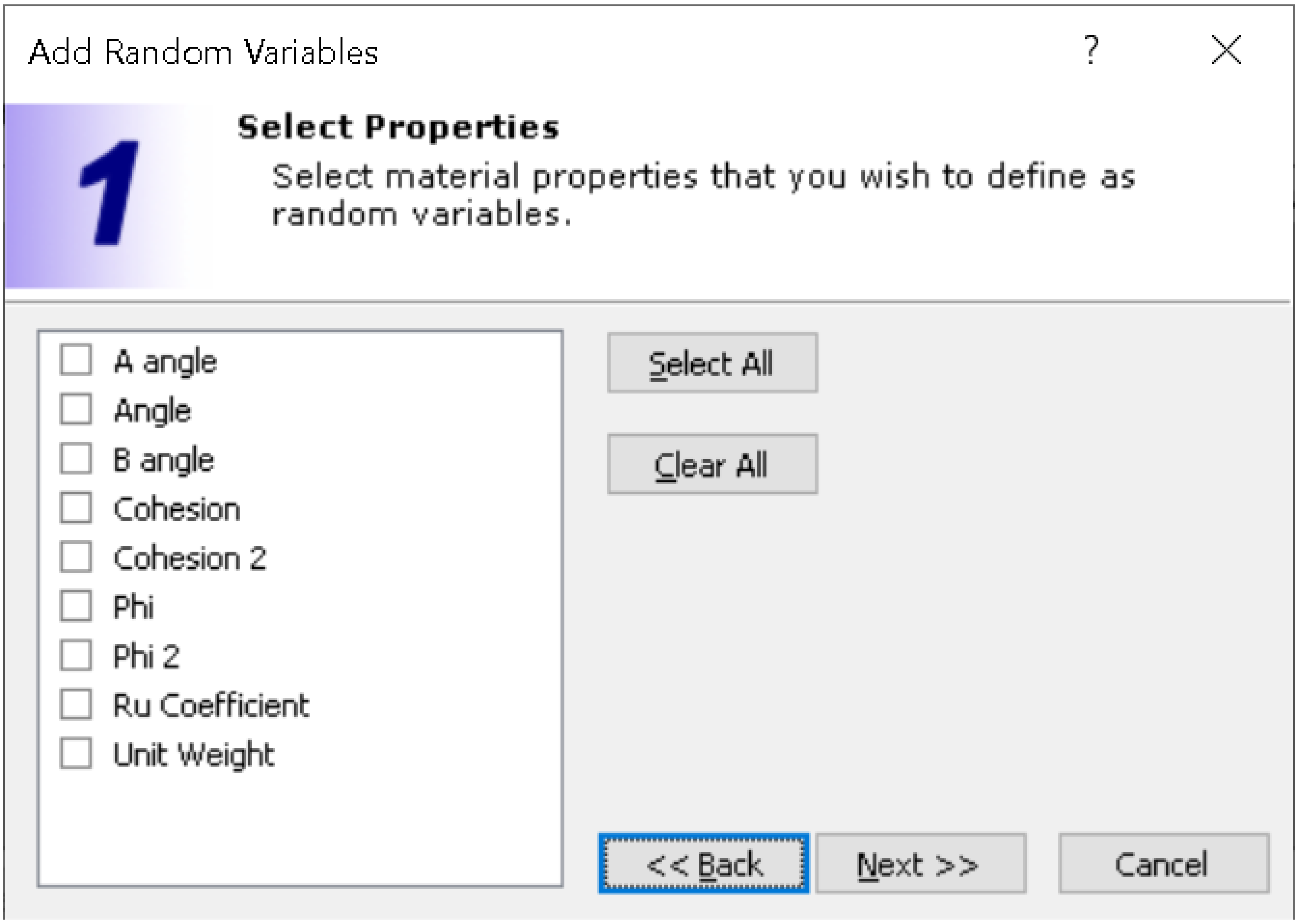
If the user would like to reference a typical range for a material, they can select the **COV table** button outlined in the image above. We see that COV values typically do not exceed 0.5. We see that for clay and silt the COV is typically less than 0.1, so we will input a value of 0.1 in the COV box.

Now click on **Generalized Anisotropic** in the sidebar and check the COV box. Select a **Uniform Distribution**. You will notice that the COV box is replaced by a range. This is because certain distributions (uniform, triangular, exponential) do not take a standard deviation (and hence a COV) input. Change the range to 0.75 and 1.25:



The meaning of this is that in each simulation the shear strength value calculated at a given location will be multiplied by a value between 0.75 and 1.25. Hence, we are saying that the shear value determined by the material input parameters may not be exactly that, and we want to consider some plus/minus variability in the shear strength.

Now select the **Anisotropic Linear** material. This time click the Add button. You will notice that all the individual parameters for this strength type can be defined as separate random variables.



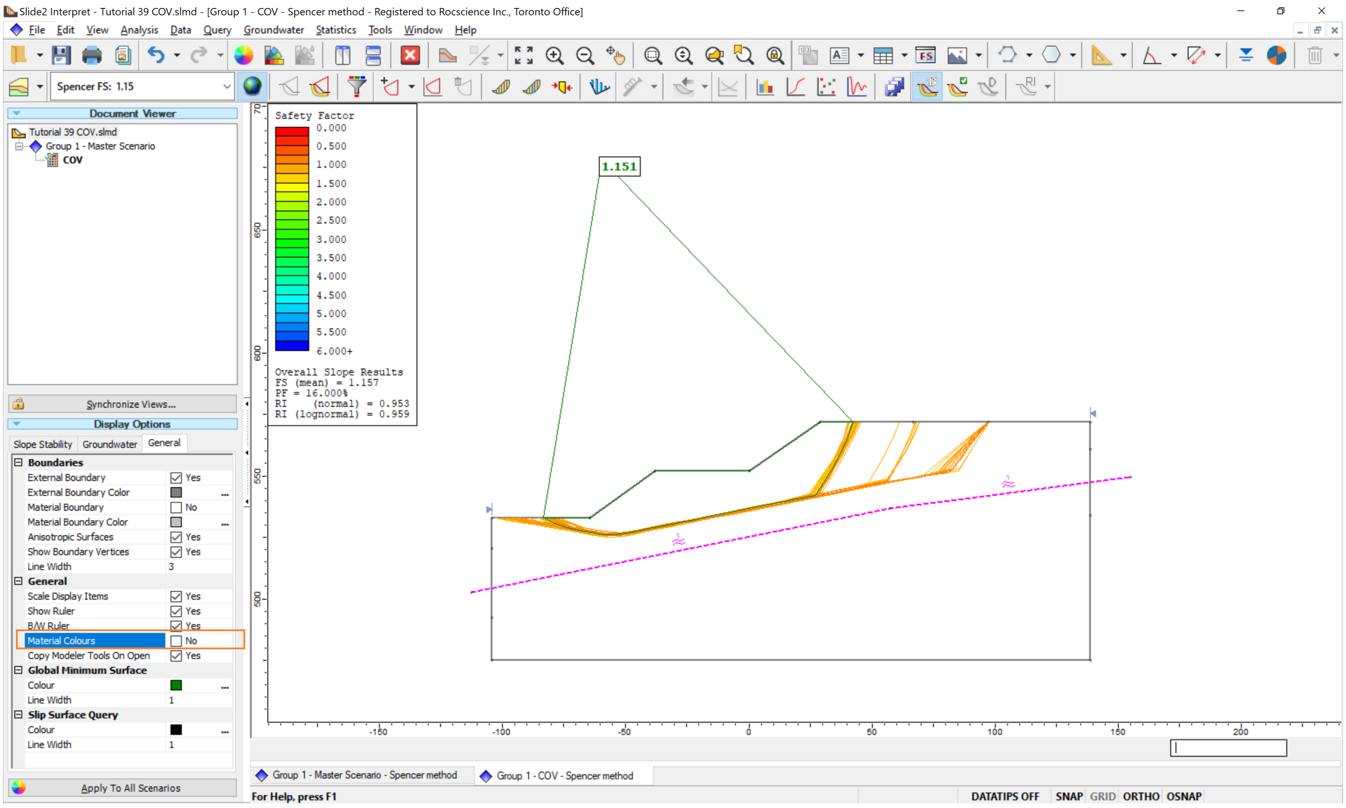
Alternatively, we can define the shear strength itself as a random variable. Select **cancel**, and define COV random variables with **Lognormal Distribution** and a COV of 0.2.

Notice that you can also define random shear for **Soil Mass** and **Bedding materials**, which make up the Generalized Anisotropic material. Keep in mind that if you do so, these random variables will be independent of the random shear in Generalized Anisotropic, meaning they will not be derived from the Generalized Anisotropic material's random shear. However, if you would like them to be dependent, you can always define correlation using the **Correlation** button as you see fit.

We will stick with these three random variables. Click OK. Now click **Analysis > Compute** and then OK in the dialog to proceed.

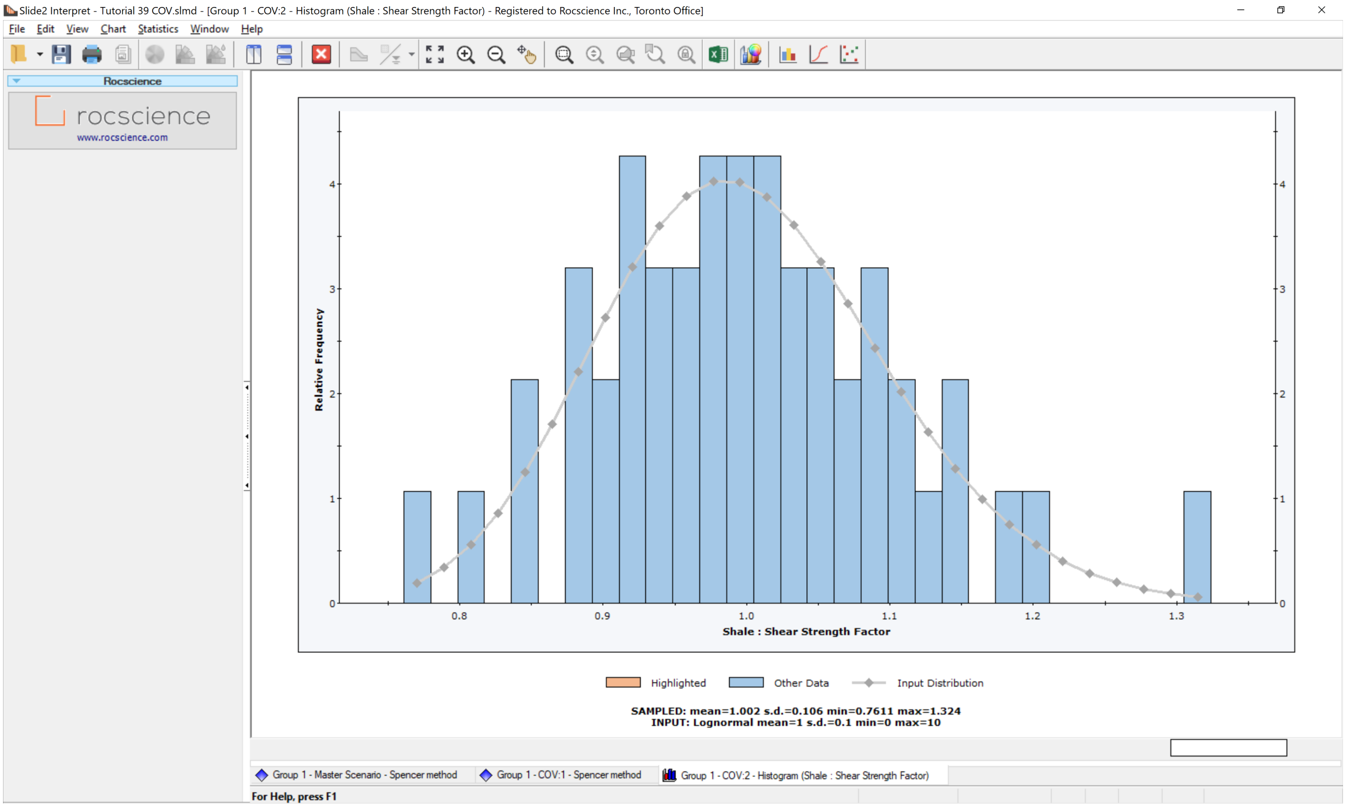
Because this is an Overall Slope analysis, a new limit equilibrium analysis is done in each of the 50 simulations and a new surface may be found in each. The computation may take a few minutes. Once done, open up **Interpret**.

We see that the Probability of Failure is 16%. Turn off the material colours from **Display Options** in the left sidebar to better see the minimum surfaces that were determined in each simulation.

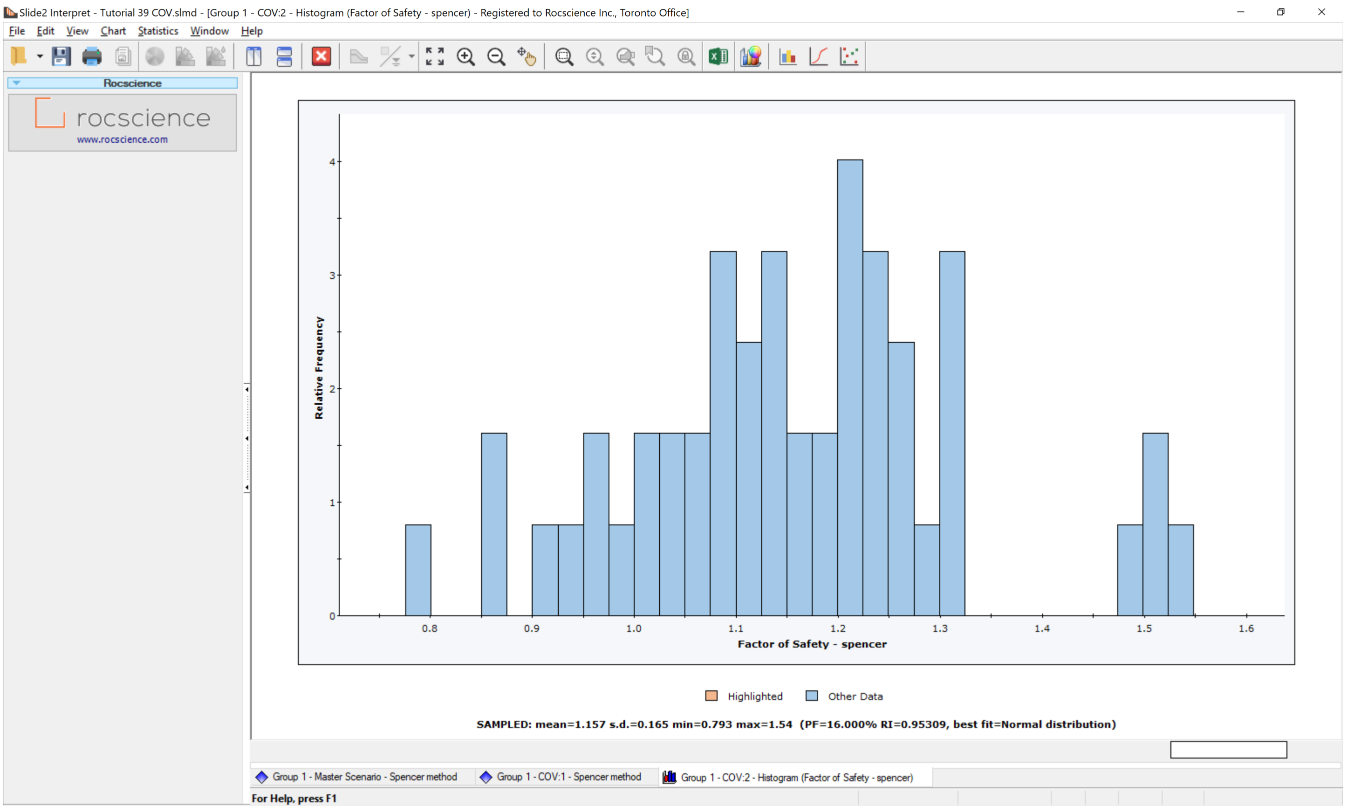


Notice that all surfaces adhere to the anisotropic surface. It is important to note that the random shear option means that the shear strength at each x,y point in the slope follows the distribution defined by the user throughout the 50 simulations. It does not mean that the anisotropic angle is random. For example, if you were to take the shear strength value at point (-50, 500) above, and make a histogram of the shear strength at that point from the 50 simulations, you would see the distribution shape defined for the Generalized Anisotropic material.

Select **Statistics > Histogram Plot** and plot the **Shale Shear Strength Factor**. You will see the lognormal distribution originally defined:



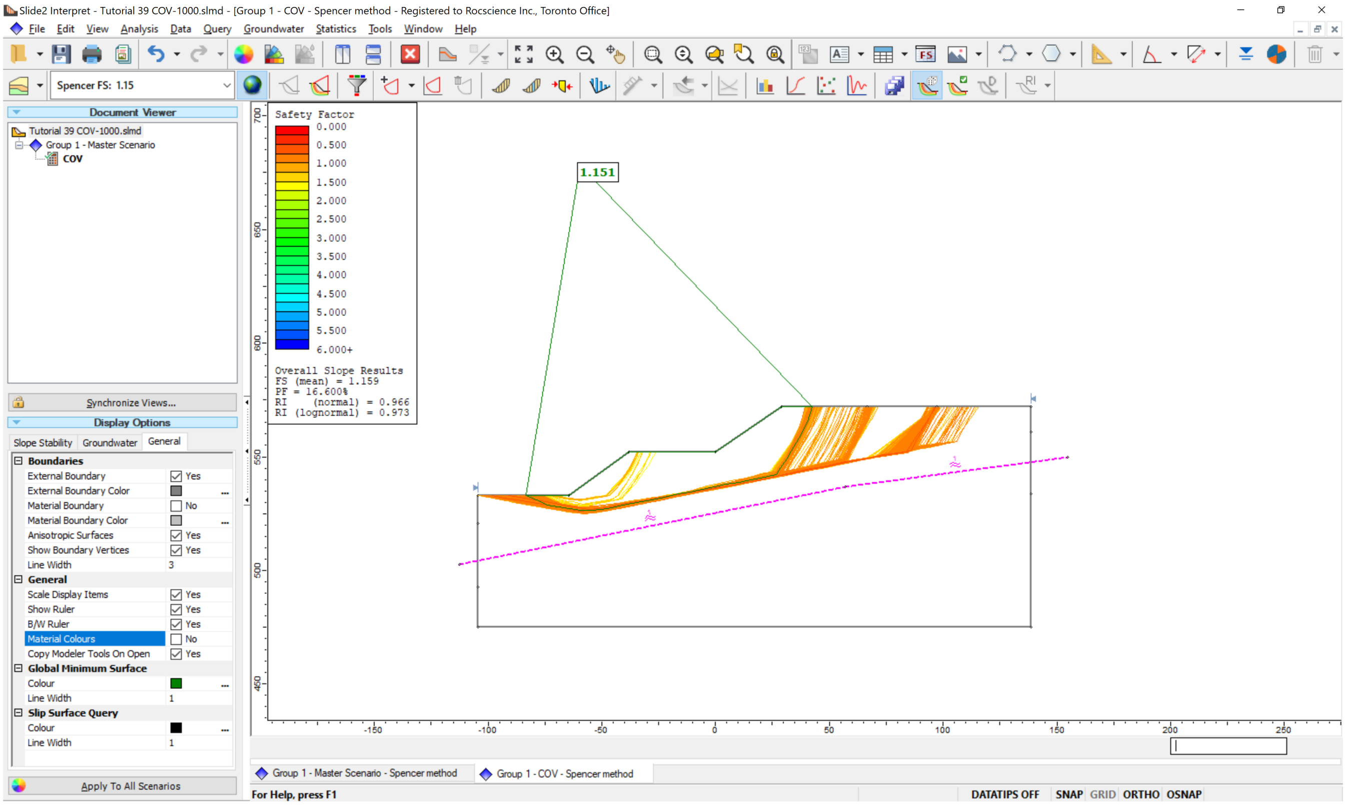
The mean is 1.0: shear strength is multiplied by 1.0 in the deterministic case. Right-click on the plot and select "**Change plot data**." Switch to **Generalized Anisotropic Shear Strength Factor** and you will see the uniform distribution we defined. Now switch to **factor of safety** and click **Done**.



These are the 50 factor of safety values computed: they range between approximately 0.8 and 1.5.

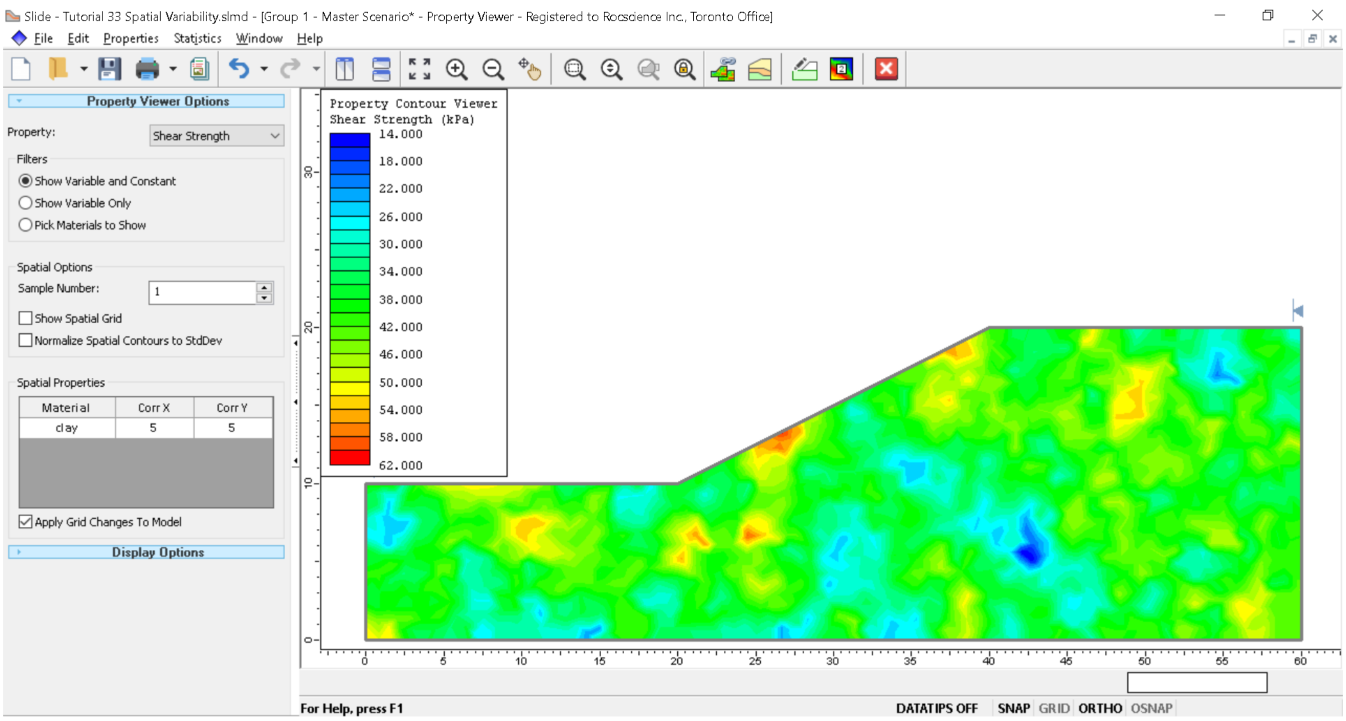
4.0 Additional Exercise 1

For the sake of the tutorial, we have computed a small number of simulations and see a small number of surfaces in varying locations based on the varying shear strength. As an additional exercise, the user can try running 1000 simulations to see the resulting failure modes and results.



5.0 Additional Exercise 2

The COV option is also available for spatial-enabled strength types. Try out [Tutorials 33] and [34] with random shear strength and compare to random cohesion and friction angle:



This concludes the COV tutorial.