Water Table Statistics Tutorial

1. Introduction

In Slide2 it is very easy to account for a variable water table location, in either a Sensitivity or Probabilistic Analysis.

1. The Minimum and Maximum locations of the Water Table are specified graphically, by drawing the location of the limiting boundaries on the model.

2. A single random variable (a Normalized Elevation ranging between 0 and 1), is then used to generate Water Table elevations between the Minimum and Maximum boundaries, according to the statistical parameters entered in the Water Table Statistics dialog.

The finished product of this tutorial can be found in the *Tutorial 10 Water Table Statistics.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. Sensitivity Analysis

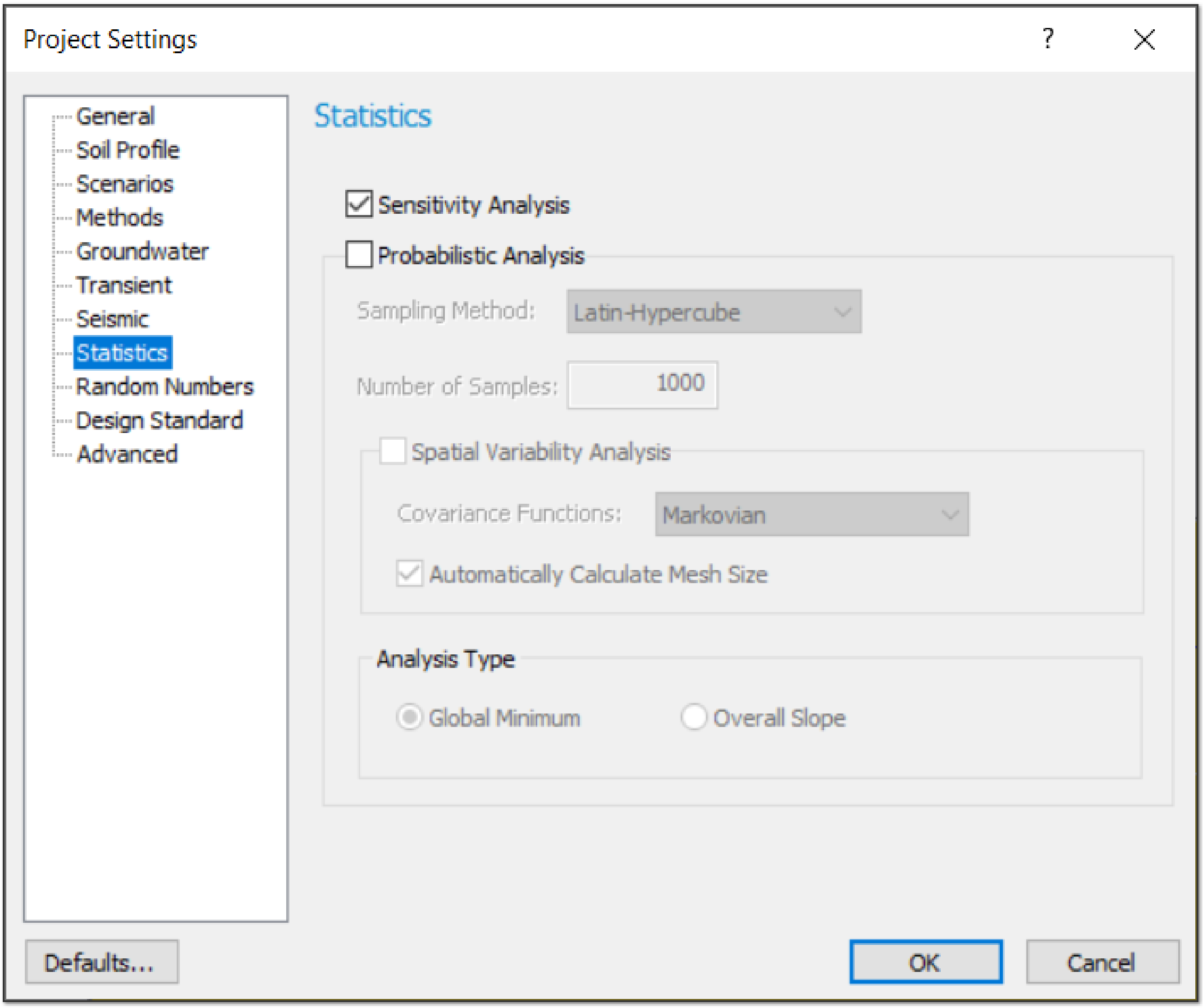
First, we will demonstrate a simple Sensitivity Analysis, using a Water Table. We will start with the Tutorial 01 file.

Select **File > Recent Folders > Tutorials Folder** from the Slide2 main menu, and open the *Tutorial 01 Quick Start.slmd file*.

PROJECT SETTINGS

To enable a Sensitivity Analysis with Slide2, you must first select the Sensitivity Analysis checkbox in Project Settings.

Select **Analysis > Project Settings**



In the Project Settings dialog, select the Statistics page, and select the Sensitivity Analysis checkbox. Select OK.

WATER TABLE BOUNDARIES

In order to define the upper and lower limits of a Water Table for the Sensitivity Analysis, we must define the Maximum and Minimum Water Table boundaries.

Select **Statistics > Water Table > Draw Max Water Table**

We will create the Maximum Water Table, by snapping to the vertices along the slope.

1. First, right-click the mouse and make sure the Snap option is enabled.

2. Now enter the following coordinates in the prompt line: (0,30), (50,30), (80,50), and (130,50).

3. Right-click and select Done from the popup menu or hit Enter.

Now let's create the Minimum Water Table boundary.

Select **Statistics > Water Table > Draw Min Water Table**

1. Snap the Minimum Water Table, to the slope vertices at (0,30) and (50,30).

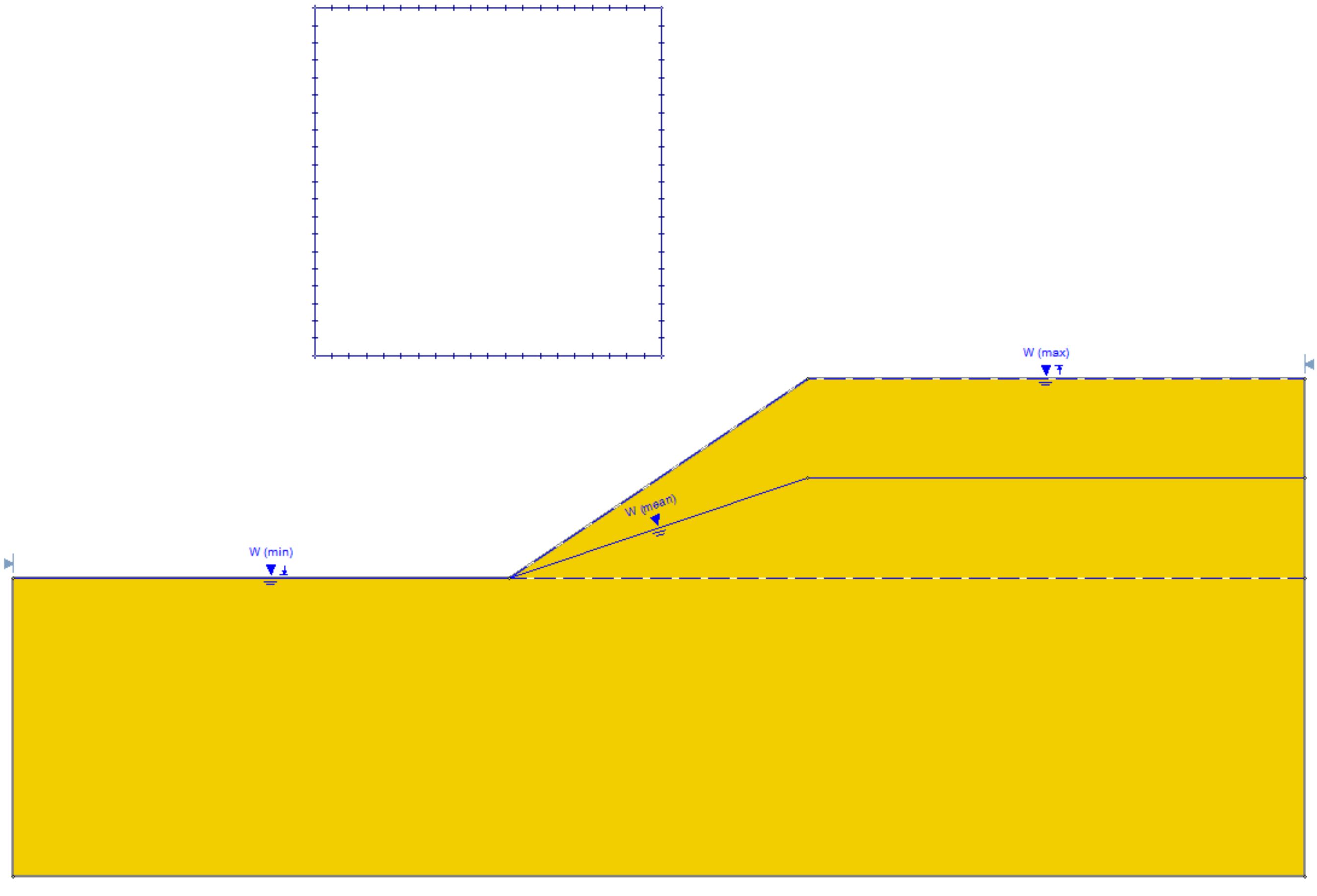
2. Now enter the point (130,30) in the prompt line. (Or alternatively, right-click the mouse and make sure the Ortho Snap option is enabled. Hover the mouse near the point (130,30) at the right edge of the model. When the Ortho Snap icon appears, click the mouse and you will snap exactly to the point (130,30) on the boundary.)

3. Right-click and select Done from the popup menu.

4. You will see the Assign Water Table dialog. Select OK to automatically assign the Water Table to all slope materials (only one material is actually used in this model).

You have now defined the Maximum and Minimum Water Table boundaries. When BOTH boundaries have been defined, you will notice that a THIRD boundary, the MEAN Water Table, is automatically calculated, and appears on the model.

Your screen should appear as follows.



Maximum, Minimum and Mean Water Table boundaries

MEAN WATER TABLE

So, how has the Mean Water Table been calculated? First, let's look at the Water Table Statistics dialog.

Select **Statistics > Water Table > Statistical Properties**

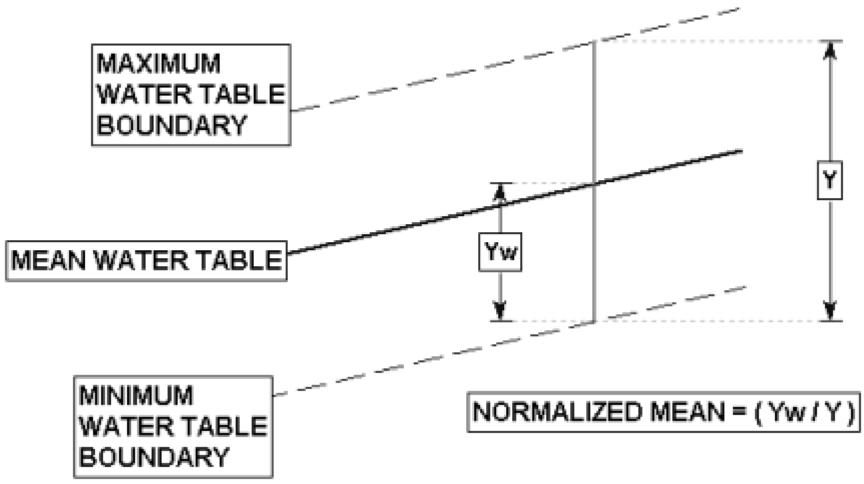
Note

A convenient shortcut to access this dialog, is to right-click the mouse on any of the three Water Table boundaries – Maximum, Mean or Minimum – and select Statistical Properties from the popup menu.

Normalized Mean

In the Water Table Statistics dialog, you will notice the Normalized Mean parameter.

The definition of the Normalized Mean water table location, is illustrated in the following figure. The Normalized Mean is simply the relative elevation of the Mean Water Table, along any vertical line between the Minimum and Maximum water table boundaries.



Definition of Normalized Mean water table location

The default Normalized Mean (= 0.5) produces a Mean Water Table which is exactly midway between the Minimum and Maximum boundaries, at all locations.

The Normalized Mean must have a value between 0 and 1.

3.0 Compute

Before we run the analysis, it is important to note the following:

• The MEAN Water Table will be used as the Water Table in the Deterministic Analysis.

• The Sensitivity Analysis is then performed on the Global Minimum slip surface located by the Deterministic Analysis.

• The Sensitivity Analysis is carried out by varying the Water Table location between the Minimum and Maximum Water Table boundaries, in 50 equal increments, and calculating the safety factor of the Global Minimum slip surface, for each location of the Water Table.

First save the file with a new file name: Tutorial 10.slim.

Select **File > Save As**

Use the Save As dialog to save the file. Now select Compute.

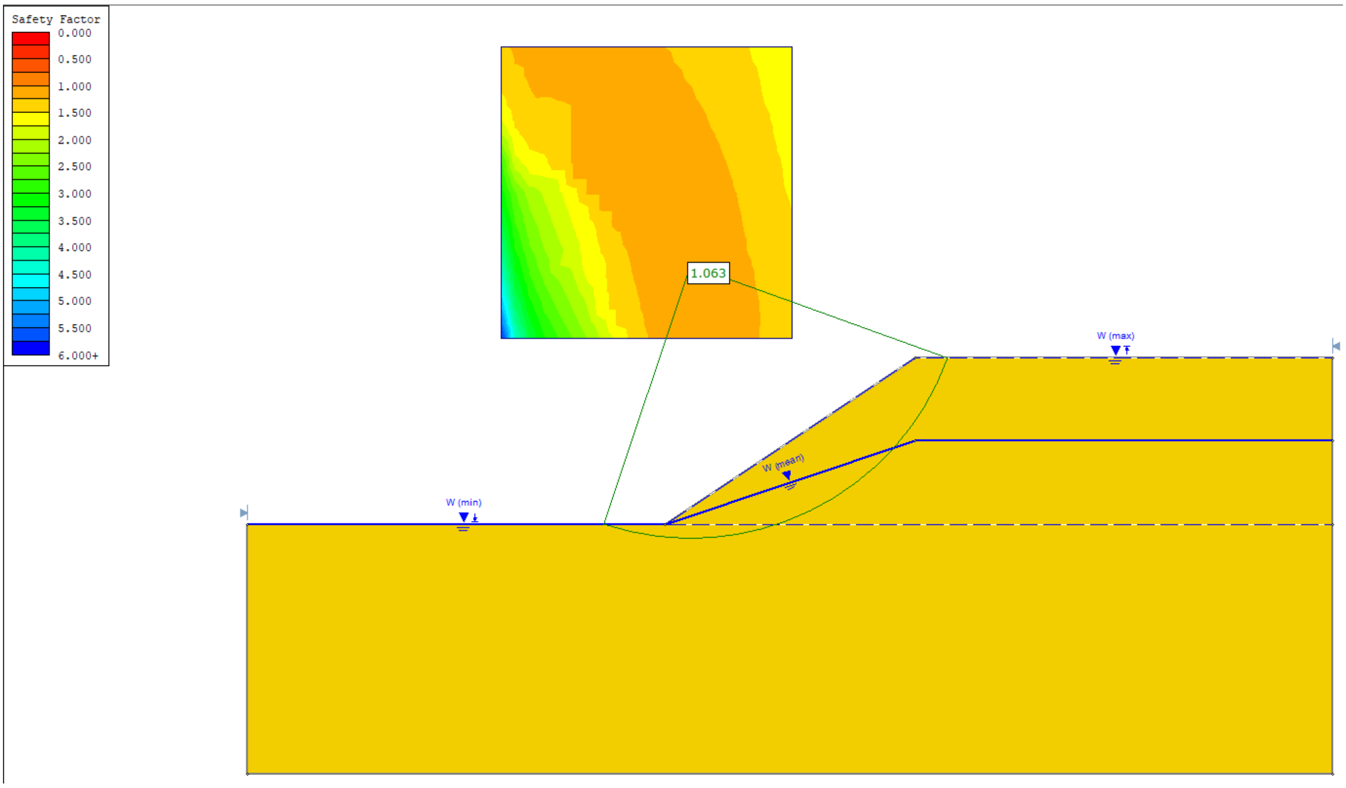
Select **Analysis > Compute**

4.0 Interpret

When the analysis is complete, view the results in Interpret.

Select **Analysis > Interpret**

You should see the following results.



Analysis results using Mean Water Table.

Let’s view the Sensitivity Plot of the Water Table location.

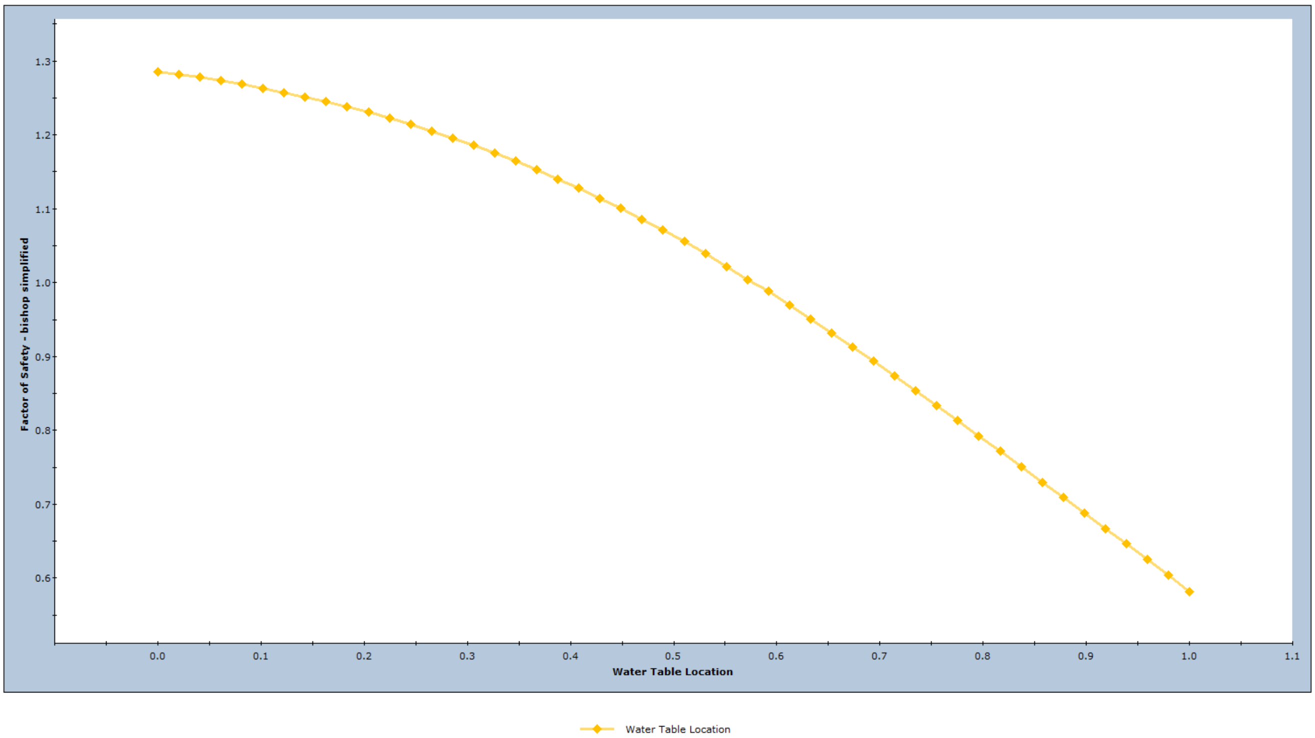
Select **Statistics > Sensitivity Plot**

Select the checkbox for “Sensitivity – Water Table Location”. Select the Plot button.

You should see the following Sensitivity Plot.

Note

- The Sensitivity Variable which represents the Water Table location (elevation), is a Normalized Variable with a range of [0, 1].
- ZERO represents the Minimum Water Table boundary.
- ONE represents the Maximum Water Table boundary.
- Intermediate values represent the relative elevation of the Water Table, along any vertical line, between the Minimum and the Maximum boundaries.



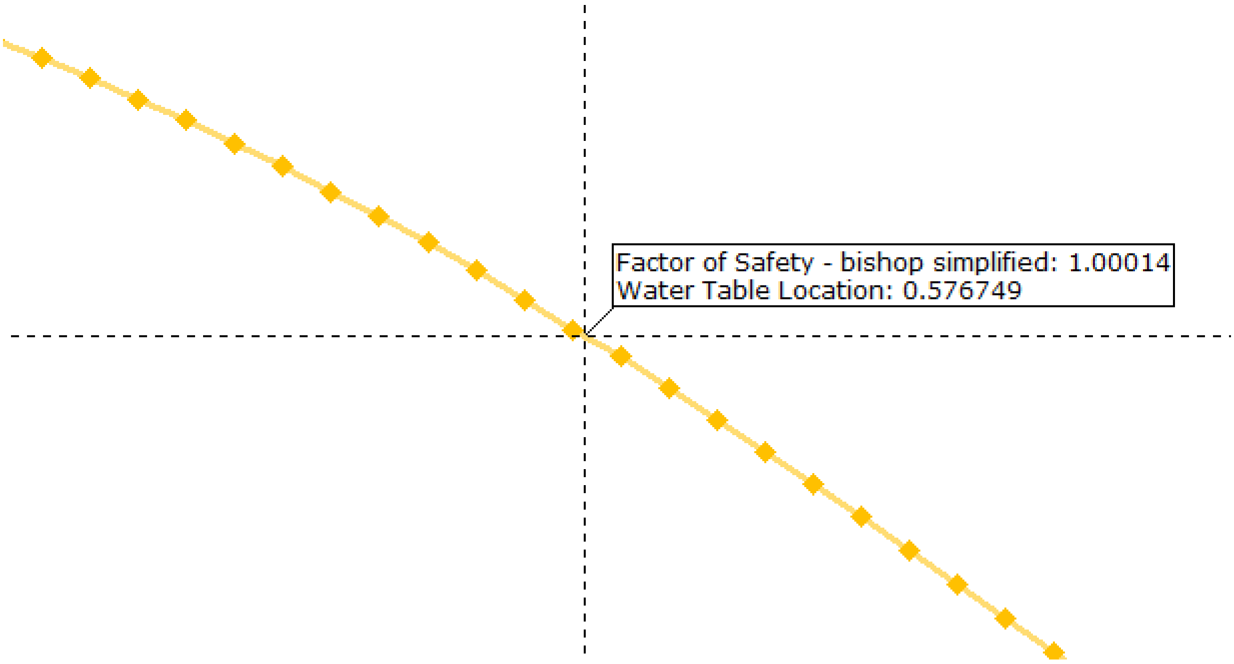
Sensitivity Plot of Normalized Water Table elevation

As you would expect, the highest safety factor occurs when the Water Table location = 0 (Minimum Water Table), and the lowest safety occurs when the Water Table location = 1 (Maximum Water Table).

If you want to determine the Water Table elevation which corresponds to a Safety Factor = 1, you can do this as follows:

1. Right-click on the plot and select **Sampler > Show Sampler**.

2. A dotted cross-hair line will appear on the plot. This is the Sampler and allows you to determine the coordinates of any point on the Sensitivity curve.



3. Move the Sampler until you locate the point on the curve where Factor of Safety = 1. This corresponds to a Normalized Water Table location equal to about 0.57.

4. This Water Table location (0.57) is just slightly above the Mean Water Table Location (= 0.5). This makes sense, because the Deterministic Safety Factor of the Global Minimum slip surface, is only slightly above 1 (equal to 1.063). Therefore only a slightly higher Water Table is necessary to reach critical equilibrium.

That concludes this simple demonstration of a Sensitivity Analysis using a Water Table.

Next, we will demonstrate a Probabilistic Analysis using the Water Table.

5.0 Probabilistic Analysis

The Normalized Water Table elevation, discussed in the first part of this tutorial (Sensitivity Analysis), can also be treated as a true random variable.

That is, in addition to the Mean location, it may also be assigned a Statistical Distribution and a Standard Deviation. Random samples are then generated, so that the variation of the Water Table elevation between the Minimum and Maximum Water Table boundaries, is modelled as a true random variable.

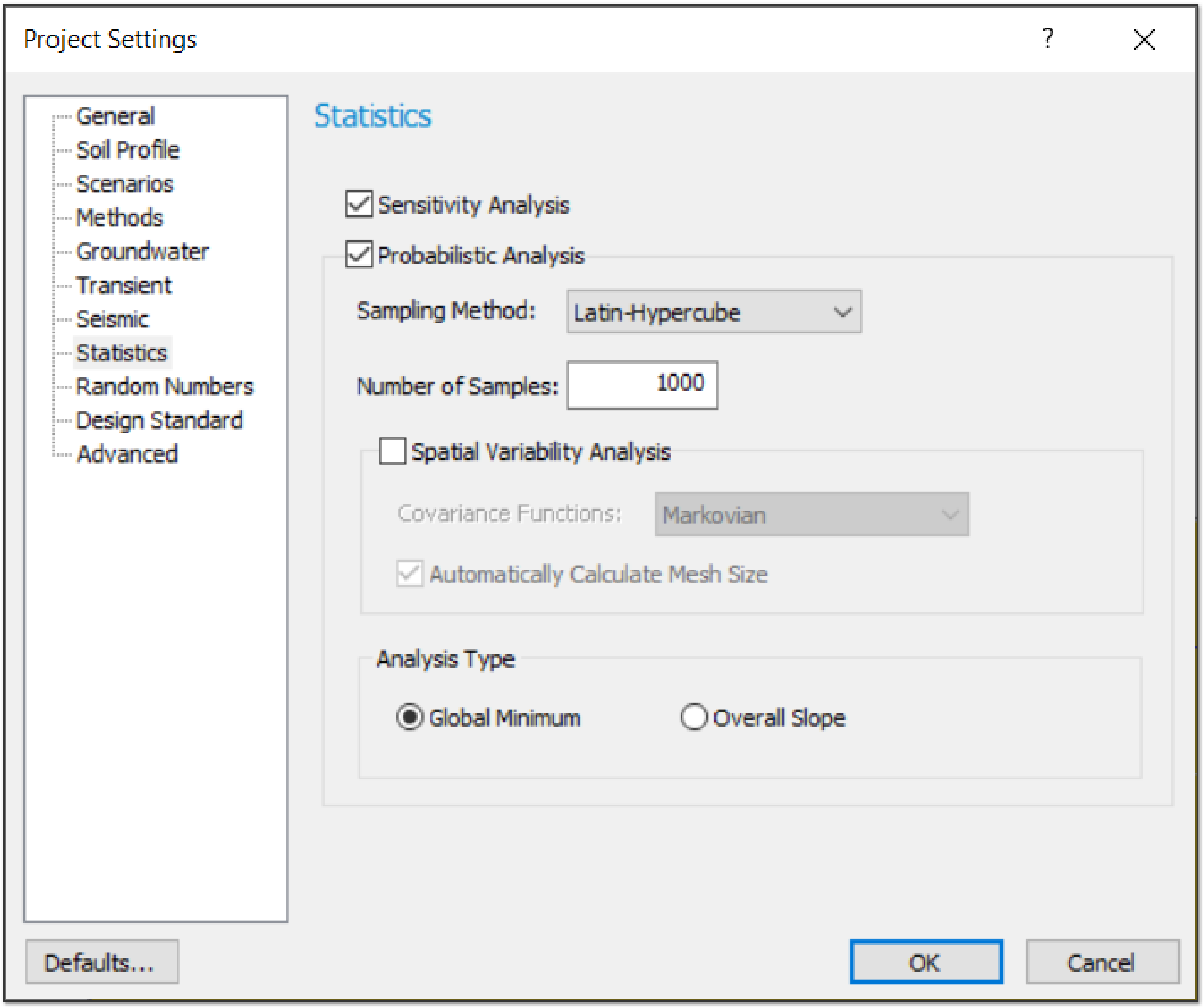
For this demonstration, we will read in a different file, the Tutorial 02 file. Select **File > Recent Folders > Tutorials Folder** from the Slide2 main menu, and open the Tutorial 02 Materials and Loading.slmd file.

Notice that the file we have read in already includes a Deterministic Water Table. We will incorporate the existing Water Table into the Probabilistic Analysis.

PROJECT SETTINGS

To enable a Probabilistic Analysis with Slide2, you must first select the Probabilistic Analysis checkbox in Project Settings.

Select **Analysis > Project Settings**



In the Project Settings dialog, select the Statistics page, and select the Probabilistic Analysis checkbox. Also, select the Sensitivity Analysis checkbox. Select OK.

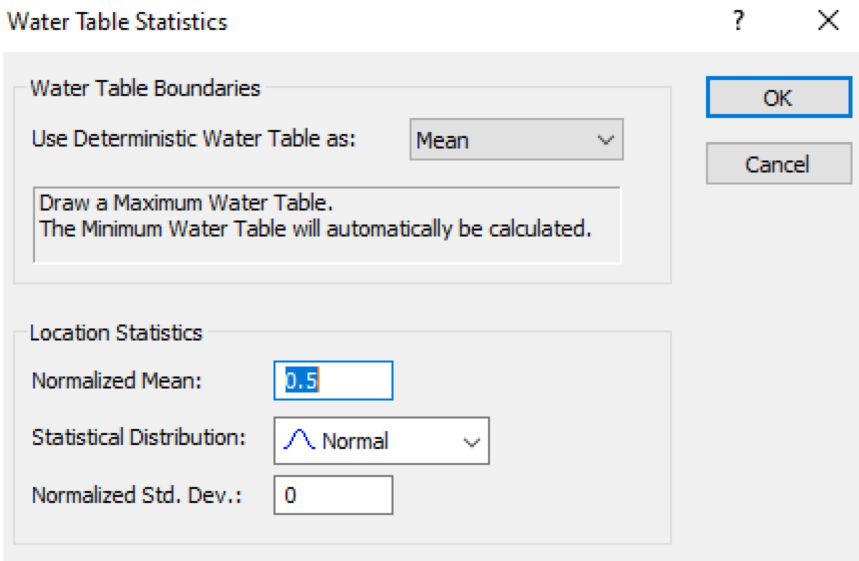
WATER TABLE BOUNDARIES

Notice that the file we have read already includes a Deterministic Water Table. We can incorporate the existing Water Table into the Probabilistic Analysis.

Select **Statistics > Water Table > Statistical Properties**

TIP: You can also right-click on the Water Table and select Statistical Properties from the popup menu.

In the Water Table Statistics dialog, the Use Deterministic Water Table As option allows you to specify that the Deterministic Water Table is to be used as the Mean, Minimum or Maximum Water Table boundary, in the Probabilistic Analysis.



By default, Use Deterministic Water Table = Mean. As indicated in the text tip in the dialog, you must now:

• Draw the Maximum Water Table boundary

• The Minimum Water Table boundary will then be automatically calculated from the Maximum and the Mean boundaries.

We will return to this dialog in a moment. For now, just select OK and we will define the Maximum Water Table boundary.

Select **Statistics > Water Table > Draw Max Water Table**

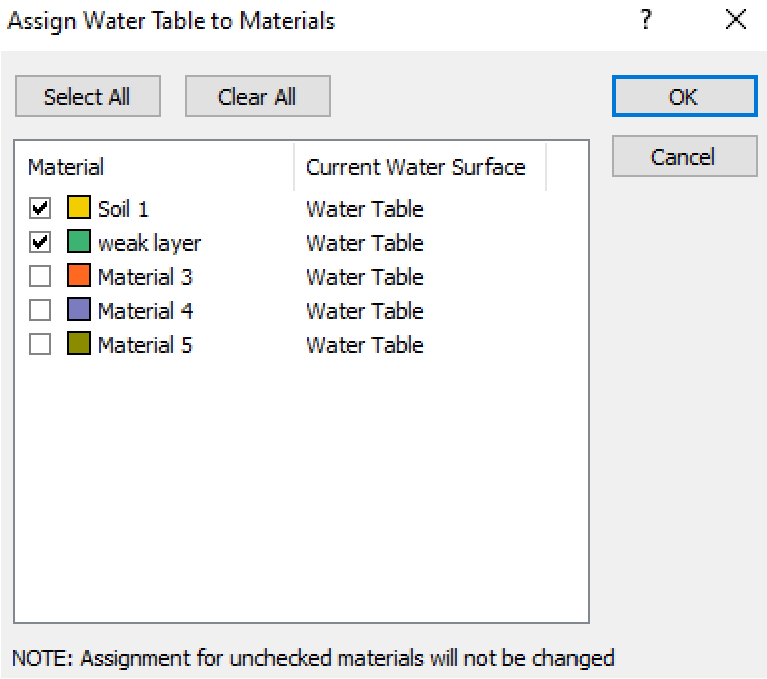
We will create the Maximum Water Table, by snapping to the vertices along the slope.

1. First, right-click the mouse and make sure the Snap option is enabled.

2. Now left-click the mouse, and snap the Maximum Water Table to the slope vertices at (5,28), (43,28), (67,40) and (100,40).

3. Right-click and select Done from the popup menu.

4. You will see the Assign Water Table dialog. Select the checkboxes for the first two materials (Soil and Weak Layer) and select OK to assign the Water Table to these materials.



Now observe the following:

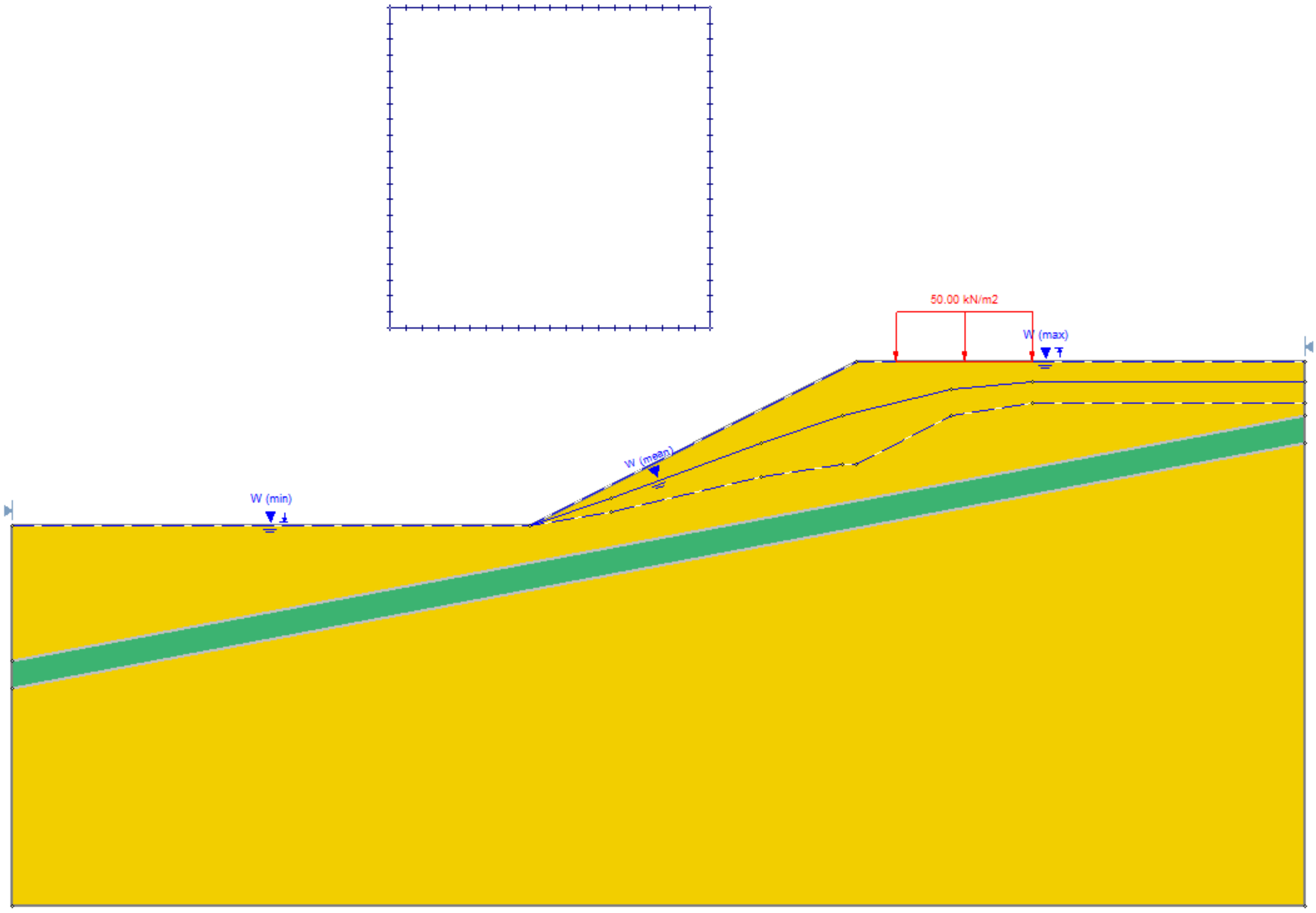
•The Maximum Water Table which we have just drawn, is defined along the slope surface.

• The original (deterministic) Water Table is now labelled as the Mean Water Table.

• The Minimum Water Table boundary has been automatically calculated.

Automatic Minimum Water Table

As you can see, once we have defined the first two boundaries (in this case, the Mean Water Table and the Maximum Water Table), the THIRD Water Table boundary is automatically calculated (in this case, the Minimum Water Table boundary). Your screen should appear as follows.



Maximum, Minimum and Mean Water Table boundaries

The Minimum Water Table boundary has been calculated, by assuming that the MEAN Water Table is at a relative elevation equal to the Normalized Mean in the Water Table Statistics dialog.

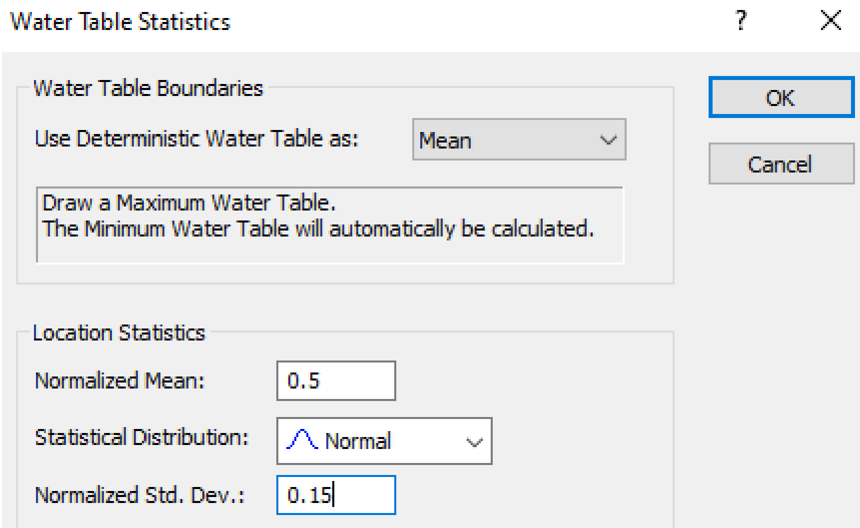
Because the Normalized Mean = 0.5 (the default), the Minimum Water Table has been generated such that the Mean Water Table is exactly halfway between the Minimum and Maximum Water Table boundaries, at all locations.

WATER TABLE STATISTICS

The statistical distribution of the Water Table location is specified by defining a Normalized Random Variable with a range of 0 to 1. ZERO represents the location of the Minimum Water Table boundary, ONE represents the location of the Maximum Water Table boundary. The distribution of the Random Variable between 0 and 1, specifies the distribution of the Water Table elevation, between the Minimum and the Maximum Water Table boundaries.

Let's return to the Water Table Statistics dialog, to enter a Standard Deviation for the Water Table random variable.

As a shortcut, you can right-click the mouse on any Water Table boundary (Minimum, Maximum or Mean), and select Statistical Properties from the popup menu.



We will use the default Statistical Distribution = Normal. Enter a Normalized Standard Deviation = 0.15. Select OK.

Normalized Standard Deviation

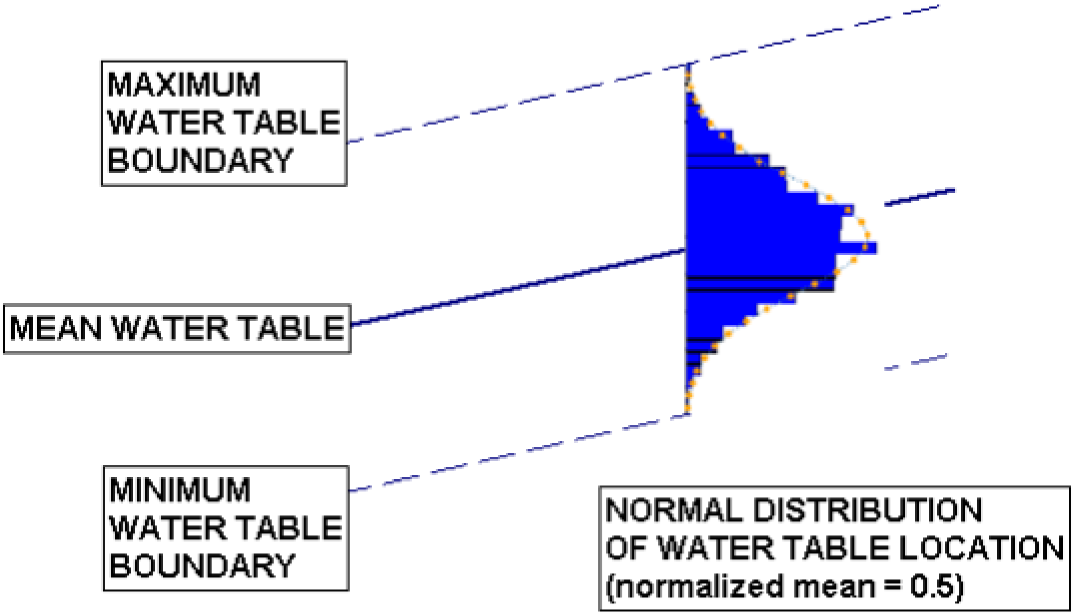
Because the Water Table location is specified using a normalized Random Variable with a range of 0 to 1, the Standard Deviation must also be specified as a Normalized value. Although the concept of a Normalized Standard Deviation may be a bit harder to grasp than the concept of a Normalized Mean, it is very simple, just remember:

• The Statistical Distribution you are defining for the Water Table location, is really for a Random Variable with a range of 0 to 1.

• Therefore, the Normalized Standard Deviation is defined accordingly.

For example: for a Normal Distribution, the Minimum and Maximum values should be located at approximately 3 Standard Deviations away from the Mean, in order to define a complete (non-truncated) Normal Distribution. For a Random Variable with a Minimum = 0, Mean = 0.5, and Maximum = 1, a Standard Deviation of approximately (0.5/3) = 0.17, will generate normally distributed samples of the Water Table location, between the Minimum and Maximum Water Table boundaries.

In effect, we will be generating a distribution of Water Table elevations, between the Minimum and Maximum Water Table boundaries, as illustrated in the next figure.



Normal Distribution of Water Table elevation.

6.0 Compute

First save the file with a new file name: Tutorial 10 prob.slim.

Select **File > Save As**

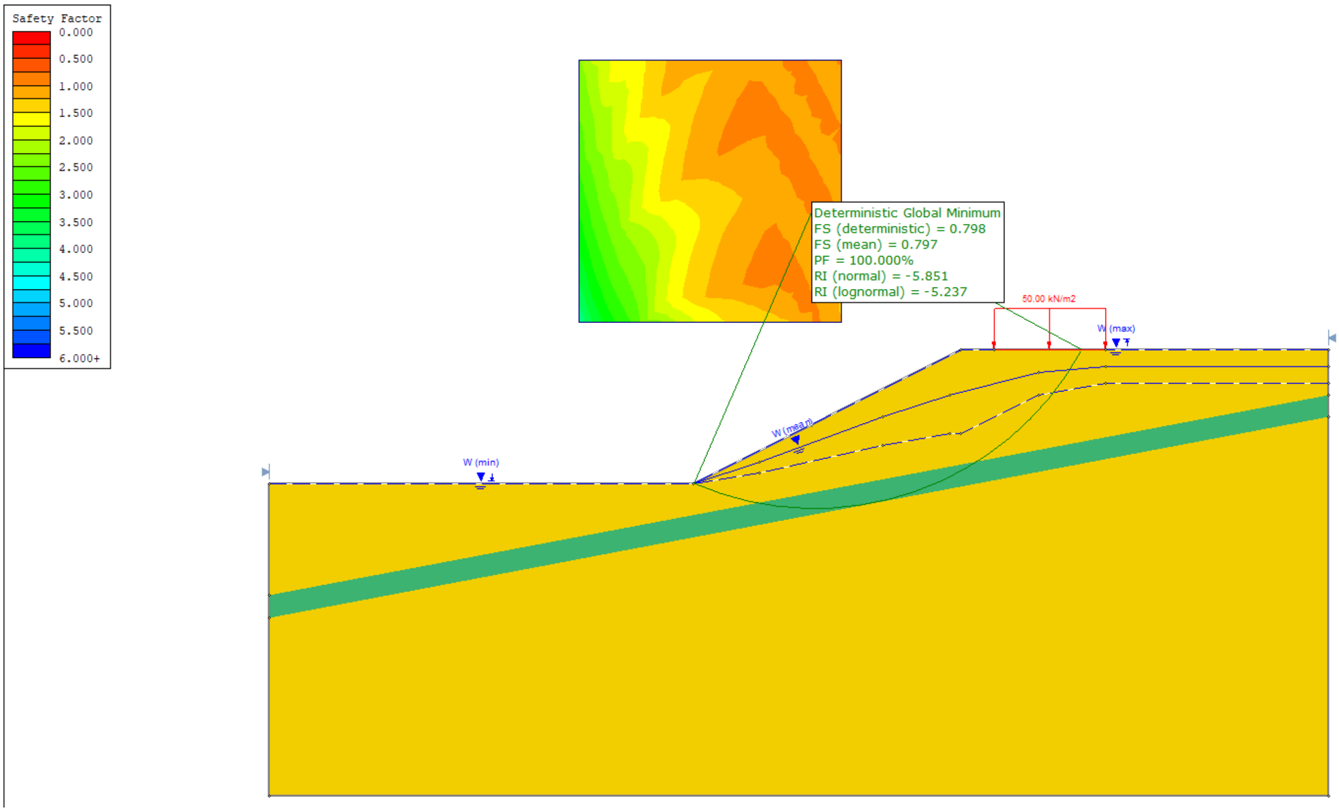
Use the Save As dialog to save the file. Now select Compute.

Select **Analysis > Compute**

When the analysis is complete, view the results in Interpret.

Select **Analysis > Interpret**

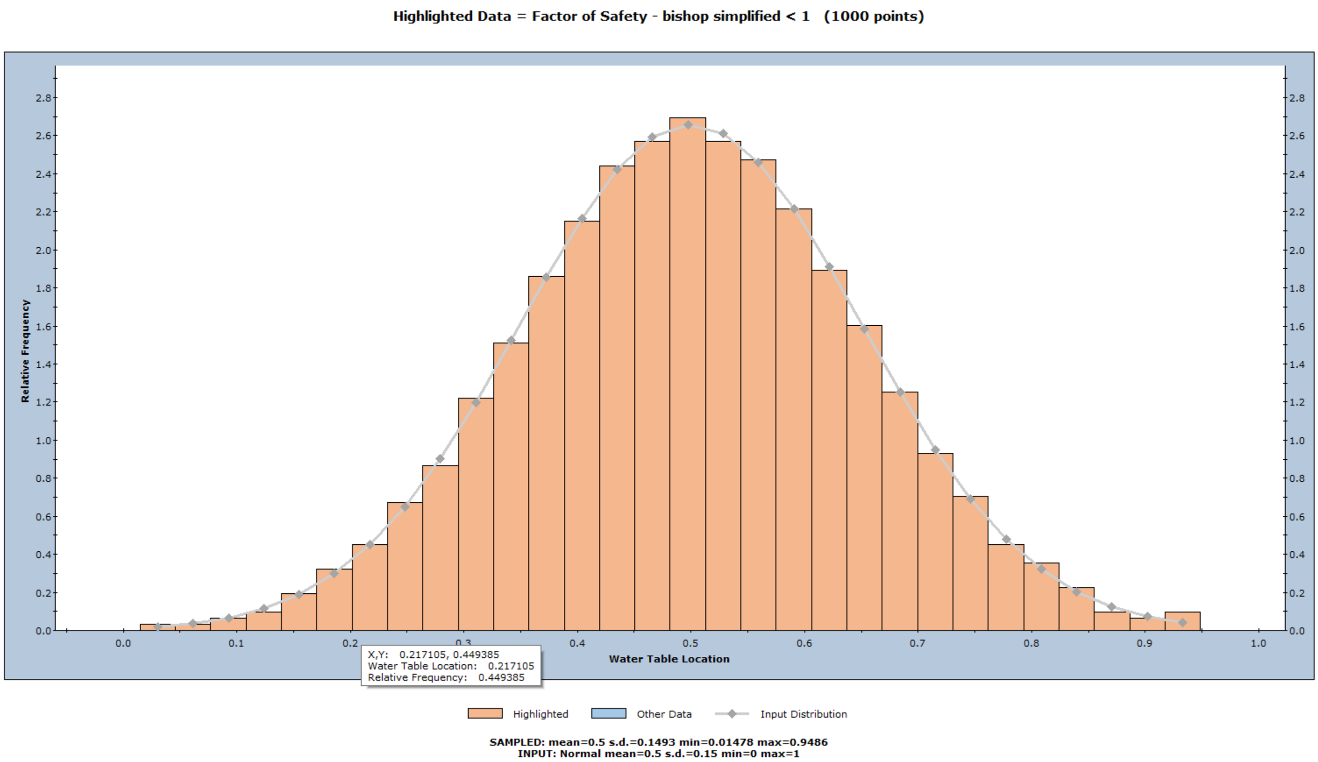
You should see the following figure.



Let's view a histogram of the Water Table location random variable.

Select **Statistics > Histogram**

In the Histogram Plot dialog, select "Water Table Location" as the Data to Plot. Select the Plot button.



Histogram of Normalized Water Table elevation

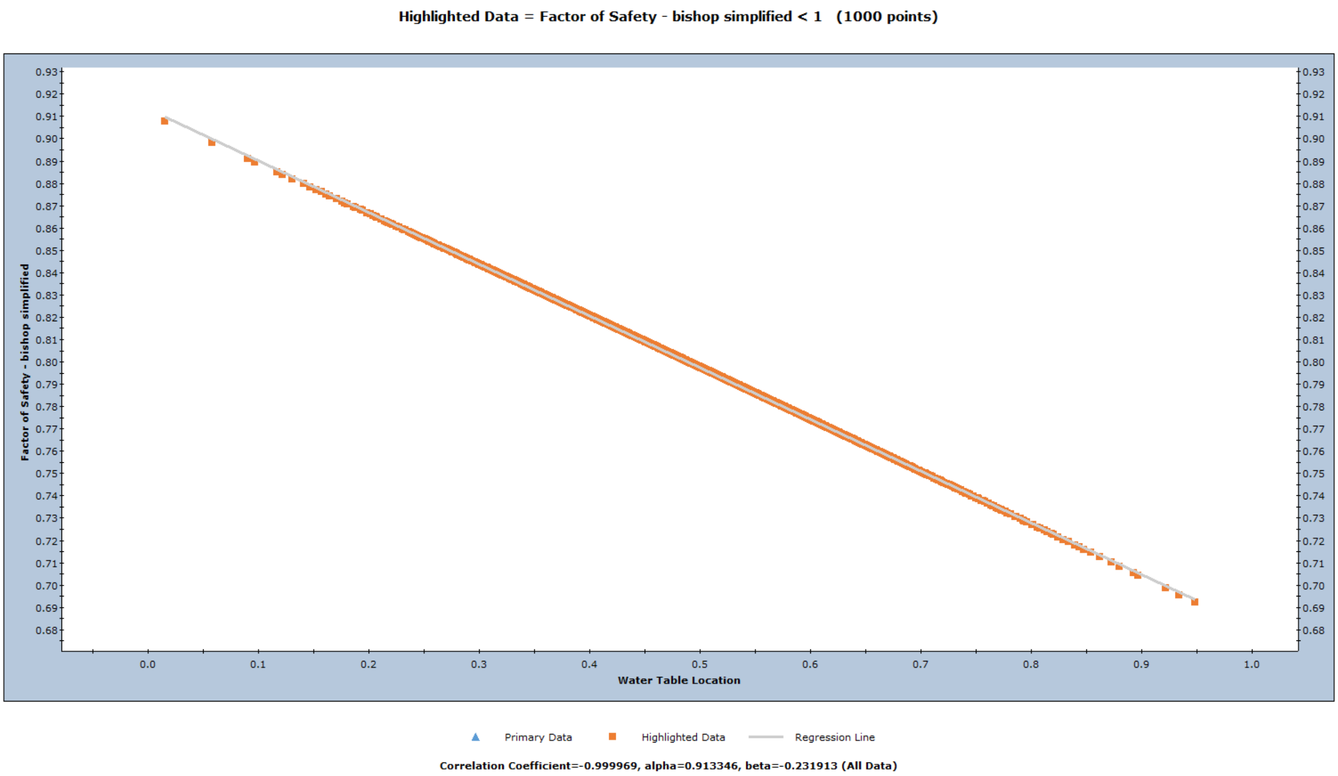
As you can see, the Water Table random variable has a possible range of 0 to 1. A Normal distribution of samples has been generated, around the mean value of 0.5.

For each iteration of the Probabilistic Analysis, the value of the Water Table random variable determines the elevation of the Water Table between the Minimum and Maximum Water Table boundaries. In this way, the elevation of the Water Table is controlled by a single random variable, which makes it very simple to model a probabilistic Water Table in Slide2.

Let’s view a Scatter Plot.

Select **Statistics > Scatter Plot**

In the Scatter Plot dialog, select Water Table Location versus Factor of Safety – Bishop. Select Plot.



Water Table elevation versus Safety Factor

For this model, there is a direct, linear correlation between the Water Table elevation and the Factor of Safety of the Global Minimum slip surface.

Because there are no other random variables involved in this analysis, there is no scatter of data in the above plot. If we included other random variables in the analysis, then you would see a scatter of the data points on this plot.

Note

If you generate a Sensitivity Plot of the Water Table elevation, it will be essentially the same plot as the Scatter Plot shown above. Again, this is because our Probabilistic

Analysis only involved ONE random variable (the Water Table elevation).

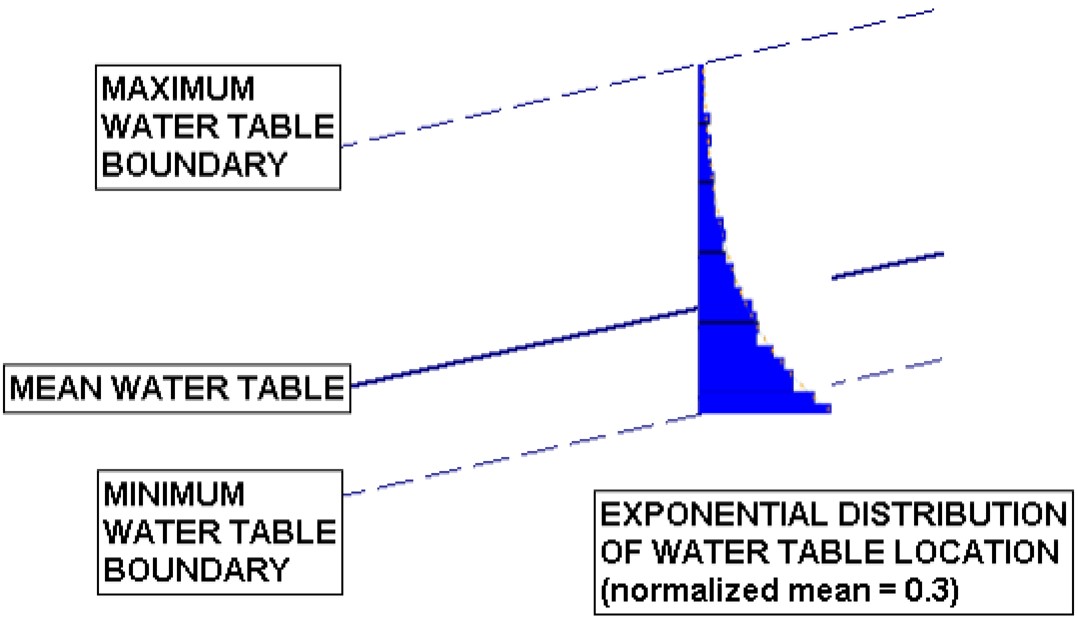
7.0 Additional Exercises

Here are some additional features to consider, related to probabilistic Water Table analysis.

EXPONENTIAL DISTRIBUTION

For this analysis, we used a Normal Distribution of the Water Table elevation random variable.

It should be noted that an Exponential Distribution can also be useful for modelling the elevation of a Water Table. An Exponential Distribution could be used to simulate the infrequent occurrence of high water tables and introduce a time dimension to the probabilistic analysis.



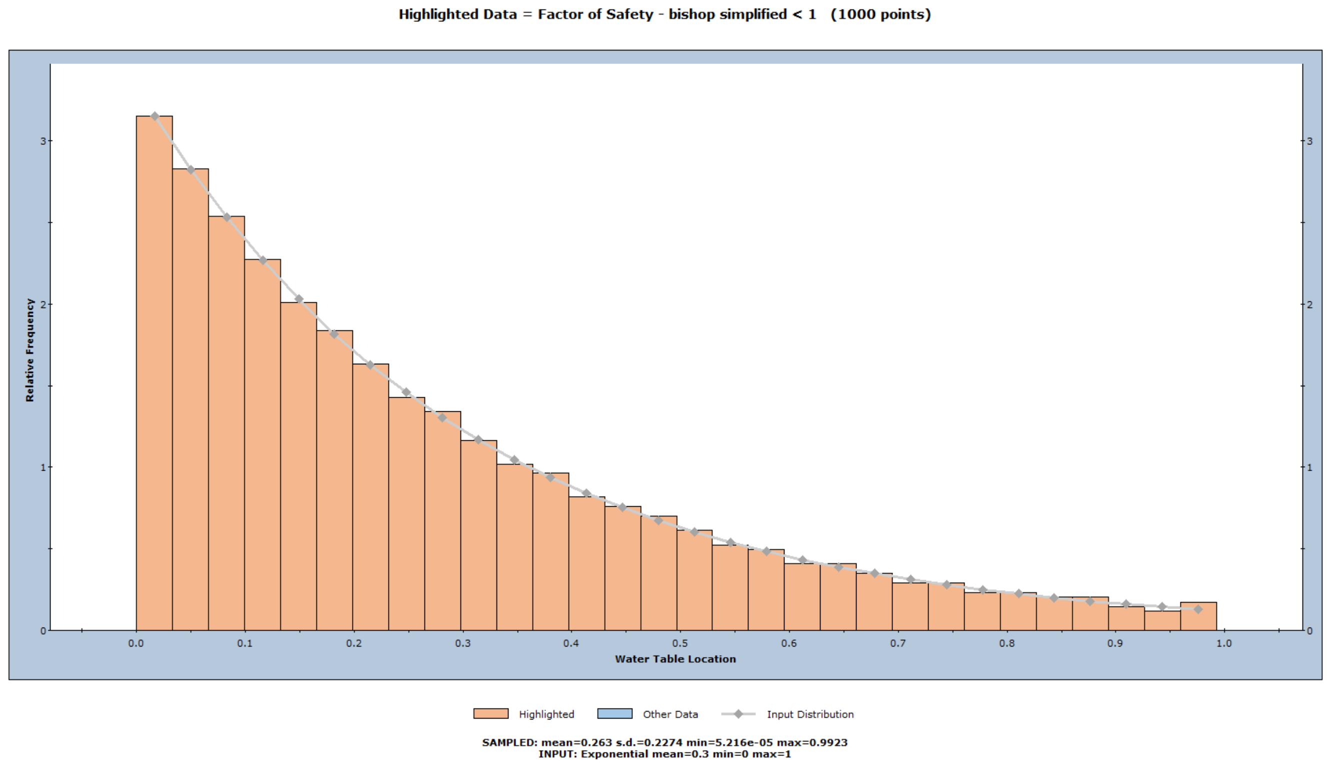
Exponential Distribution of Water Table elevation

Re-run the analysis, using an Exponential Distribution for the Water Table random variable, and a Normalized Mean = 0.3.

Note

A Standard Deviation is not entered for an Exponential Distribution, because by definition, the Standard Deviation = the Mean for an Exponential Distribution.

Because the Normalized Mean = 0.3, you will notice that the Minimum Water Table which is automatically generated, is now closer to the Mean Water Table, compared to the previous analysis with Normalized Mean = 0.5.



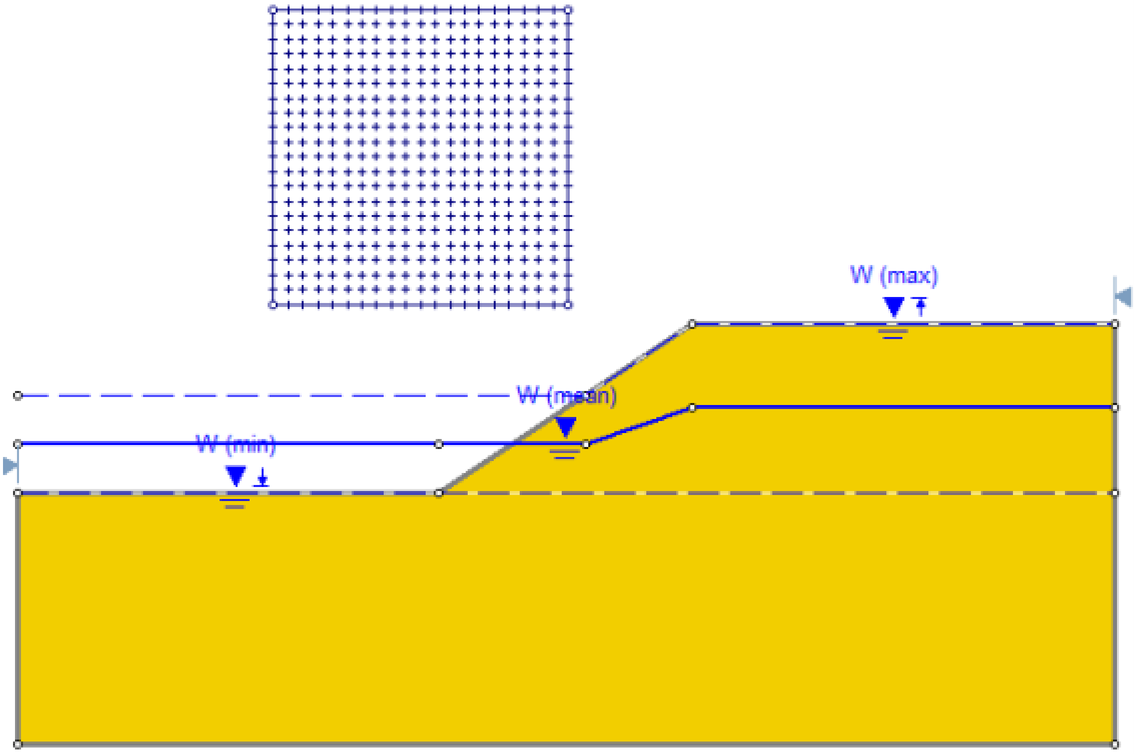
Histogram of samples generated by Exponential Distribution.

The exponential distribution simply implies that most of the Water Tables which are generated during the Probabilistic Analysis, will be towards the lower elevations, and relatively few samples will be generated at the higher elevations.

PONDED WATER / DRAWDOWN ANALYSIS

A variable height of Ponded Water above a slope can also be modelled in a Sensitivity or Probabilistic Water Table analysis with Slide2.

If the Maximum Water Table boundary is located ABOVE the slope at any location, then Ponded water will be automatically created, as necessary, between the Water Table and the slope, in exactly the same manner, as for a regular (Deterministic) Water Table.



Variable ponded water elevation.

Note

To ensure that the (variable) ponded water surface remains horizontal, for all possible water tables which are generated, the Minimum Water Table boundary should include a horizontal segment which has the same lateral extents as the ponded water surface of the Maximum Water Table.

Using a Sensitivity Analysis, a drawdown scenario could be quickly analyzed in this manner.

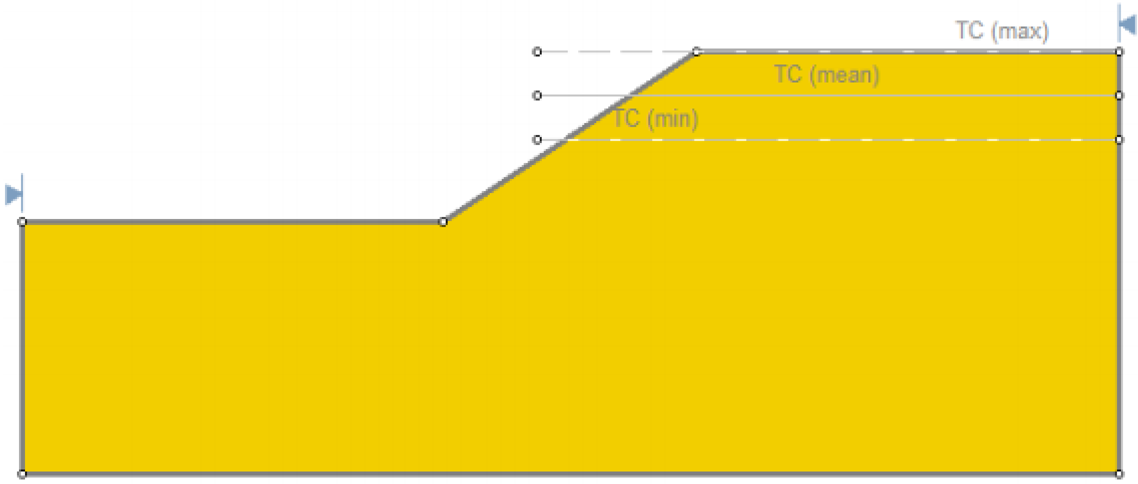
Note

When you define probabilistic Water Table boundaries above a slope, Ponded Water is NOT graphically displayed on the model. Ponded water will be automatically created and taken into account during the analysis, whenever necessary, but it will not be visible on the model.

TENSION CRACK STATISTICS

Finally, we will note that the statistical analysis of a variable Tension Crack boundary, is carried out in exactly the same way as for a Water Table, as described in this tutorial.

In addition, the water level in the Tension Crack can also be specified as a random variable. This is left as an optional exercise for the user to experiment with.



Variable tension crack elevation

See the Slide2 Help system for more information about Water Table and Tension Crack statistics.