rocscience

Seismic Analysis with Newmark Method

1. Introduction

This tutorial will demonstrate how to model a multi-material slope with seismic loading in a multiple scenario model. We will demonstrate three different seismic analysis options including displacement analysis using the Newmark method.

The finished product of this tutorial can be found in the *Tutorial 28 Seismic Analysis.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. Model 1 - No Seismic Loading

From the Slide2 main menu, select **File > Recent Folders > Tutorials Folder** and read in the *Tutorial 28 Seismic (initial).slmd file*. This model is based on the non-homogeneous, three-layer slope found in Slide2 Verification Problem #4.

Notice the child scenario is named “No Seismic.” We will run this scenario first.

MATERIAL PROPERTIES

Let’s examine the material properties of the model. Select **Define Material** from the toolbar or the **Properties** menu.

Select **Properties > Define Materials**

Click through the first three materials and review the properties defined.

Select **Cancel** to close the Define Material Properties dialog when finished.

3. Compute

Before you analyze your model, save it as a file called Seismic Tutorial.slmd.

Select **File > Save**

Use the Save As dialog to save the file. You are now ready to run the analysis.

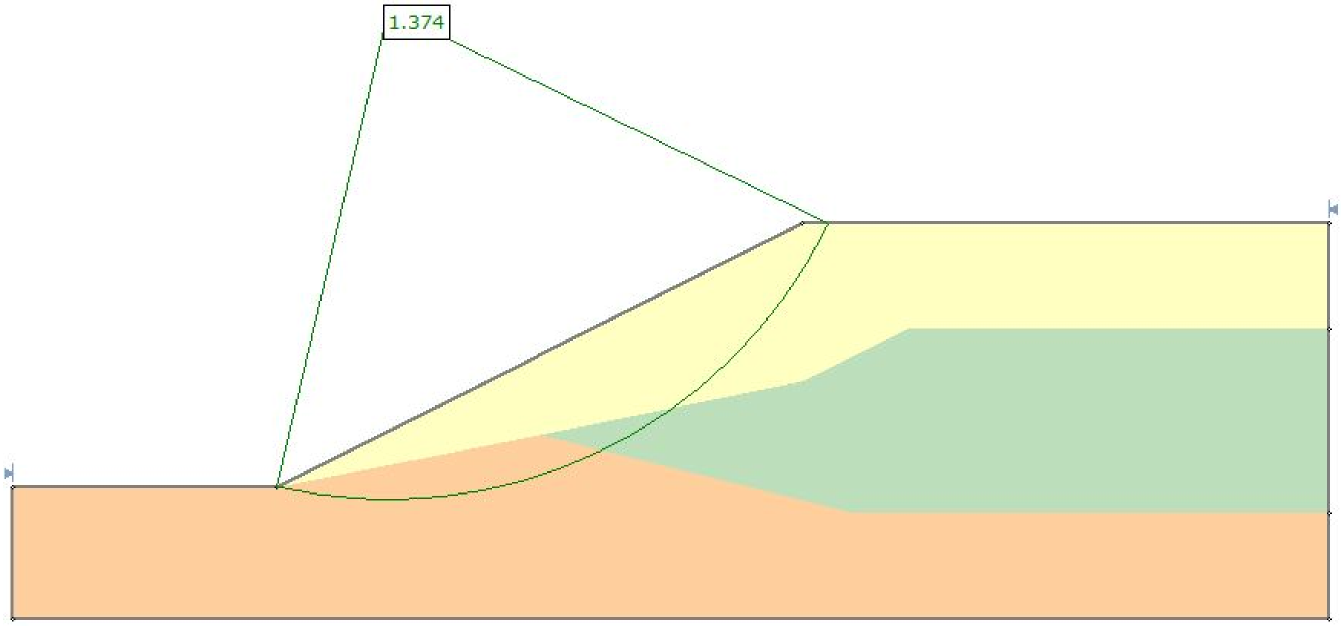
Select **Analysis > Compute**

4. Interpret

To view the results of the analysis:

Select **Analysis > Interpret**

This will start the Slide2 Interpret program. You should see the following critical slip surface with FS = 1.374.



5. Model 2 - Pseudostatic Seismic Loading

We will now duplicate the scenario, add a pseudostatic seismic load to the new model and re-run the analysis to determine its effect on the Safety Factor.

1. Return to the Slide2 Model program.
2. In the **Document Viewer**, right-click on **No Seismic** and select **Duplicate Scenario.**
3. Right-click on this new scenario and select **Rename**.
4. Enter **Seismic = 0.15** as the scenario name.
5. Click **Save** and Close.

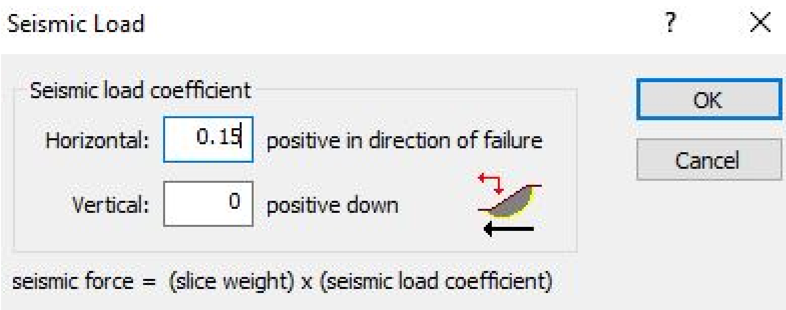
Note

Since we created the second scenario by duplicating the first scenario, all settings in the second scenario are initially the same as the first scenario by default. However, any subsequent changes made to a scenario will only apply to that scenario, unless Link Scenarios is activated. Only changes made to the geometry (External Boundary and Material Boundary) of one scenario or changes in the Master Scenario are automatically applied to all scenarios within that group.

PSEUDO-STATIC SEISMIC LOAD

In Slide2, pseudo-static seismic loads can be applied in the horizontal and vertical directions by specifying the corresponding Seismic load coefficient. The Seismic load coefficient is used to determine the seismic force applied to the slope. Ensure you have clicked on the Seismic = 0.15 scenario.

Select **Loading > Seismic Load**

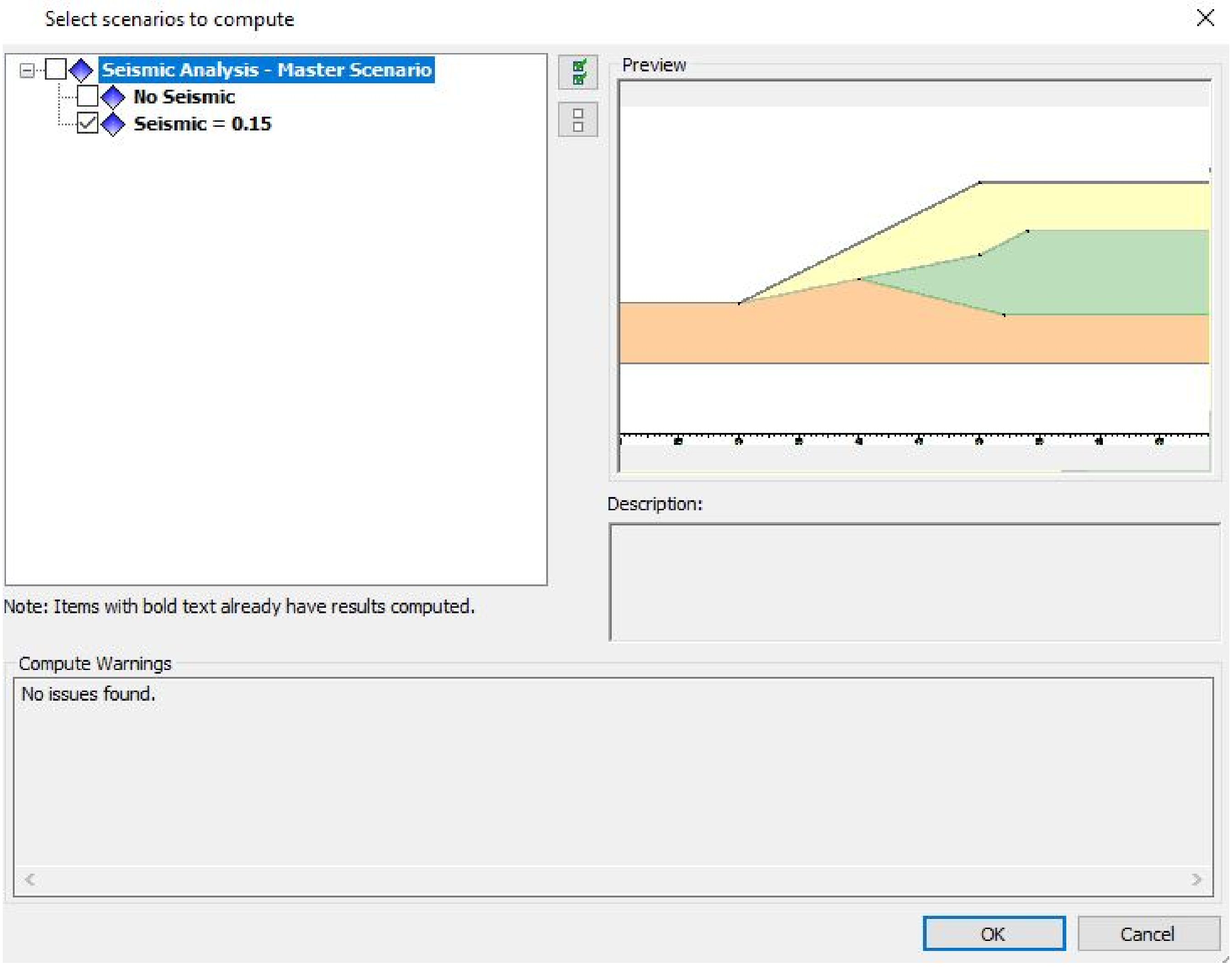


In the dialog, enter a **Horizontal Seismic load coefficient = 0.15**. Notice that this value is positive in the direction of failure. Select **OK** when finished.

We are now finished creating this scenario and can proceed to run the analysis and interpret the results.

6. Compute

Select **Analysis > Compute**



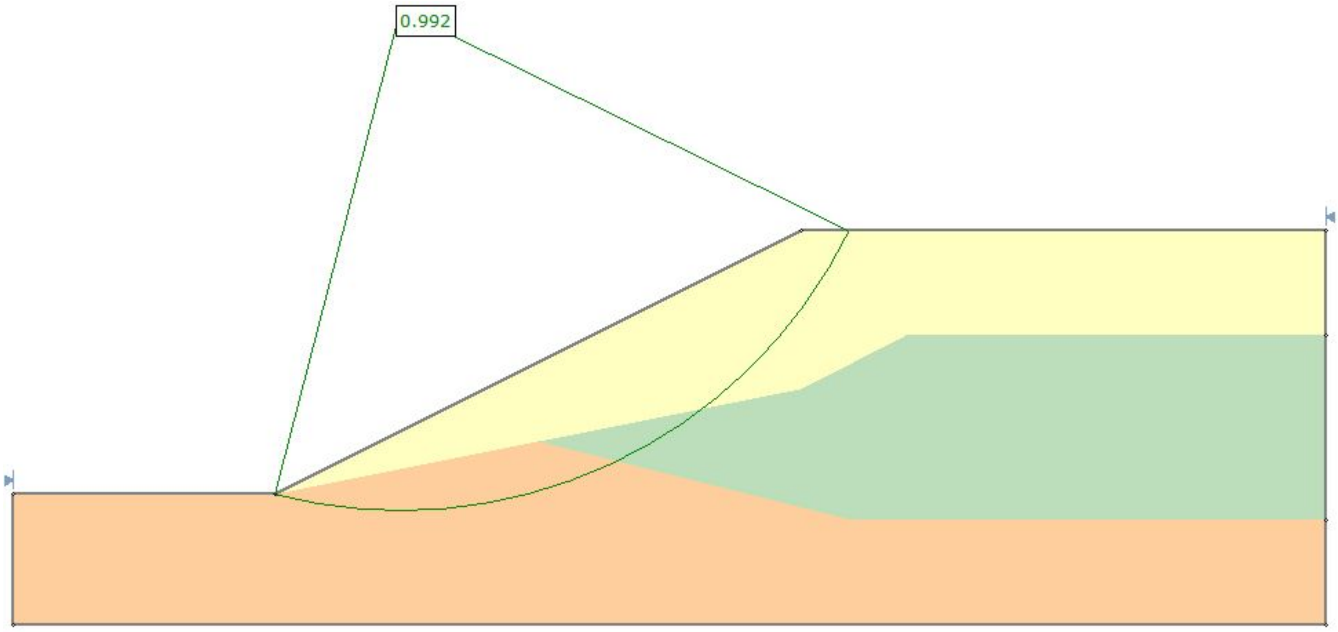
Notice the scenario without results, Seismic = 0.15, is automatically selected to Compute. Select **OK**. The Slide2 Compute engine will proceed in running the analysis. When completed, you are ready to view the results in Interpret.

7. Interpret

To view the results of the analysis:

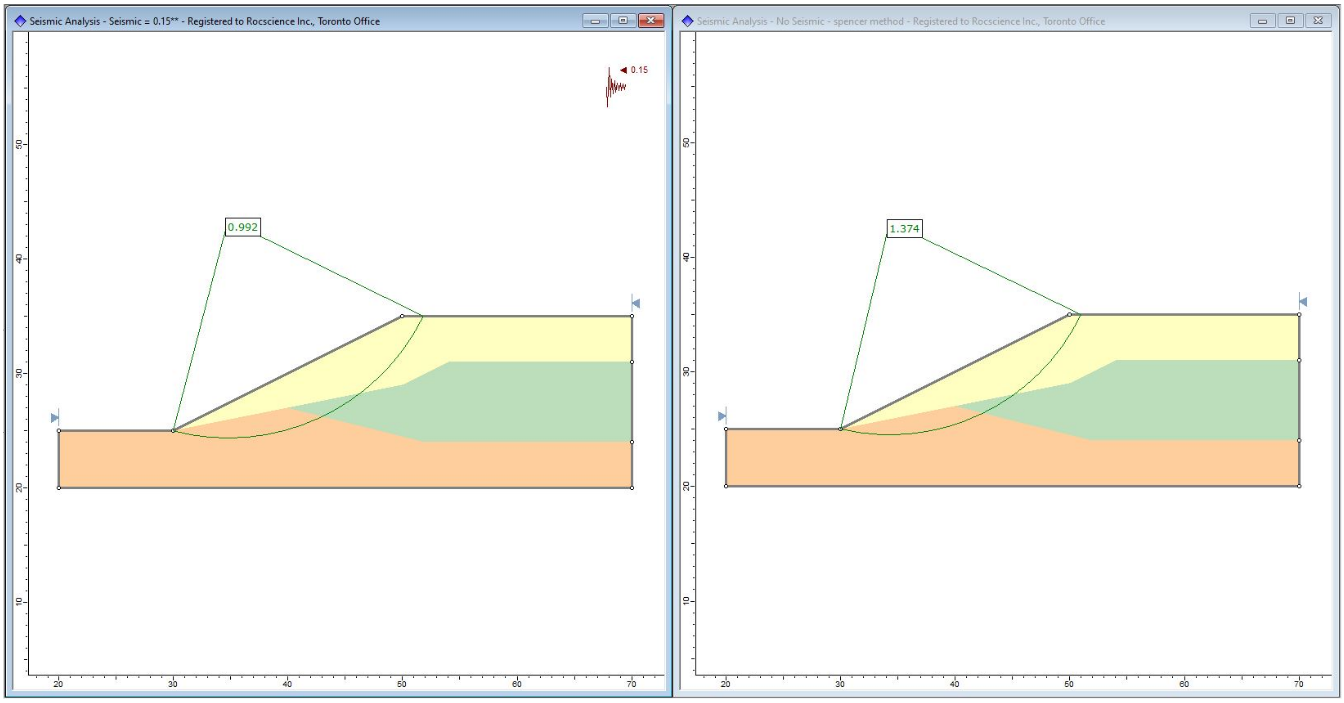
Select **Analysis > Interpret**

This will start the Slide2 Interpret program. For the Seismic = 0.15 scenario, you should see the following critical slip surface with FS = 0.992.

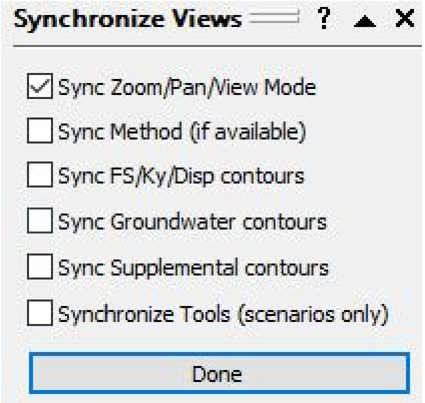


With the addition of horizontal seismic loading, the Global Minimum safety factor is now 0.992 compared to 1.374 before adding the seismic load. The seismic load has destabilized the slope. You may find it useful to tile the views, to view the results of both scenarios together. Minimize the master scenario to better compare.

Select **Window > Tile Vertically**



Above the Document Viewer pane, select Synchronize Views. Select the “Sync Zoom/Pan/View Mode” checkbox. Select Done.



Once activated, this feature allows you to apply the zoom and pan settings used in one scenario across all scenarios. Use the Zoom options as necessary to achieve the desired view of the slopes.

8. Model 3 - Critical Seismic Coefficient (kc) Analysis

In this tutorial, we have so far considered the effect of a pseudostatic seismic load on the minimum safety factor, by specifying a horizontal seismic load coefficient. In Slide2, we can also perform advanced seismic analysis to determine the critical seismic coefficient (kc) that results in a destabilized slope with FS = 1.

Return to the Slide2 Model program.

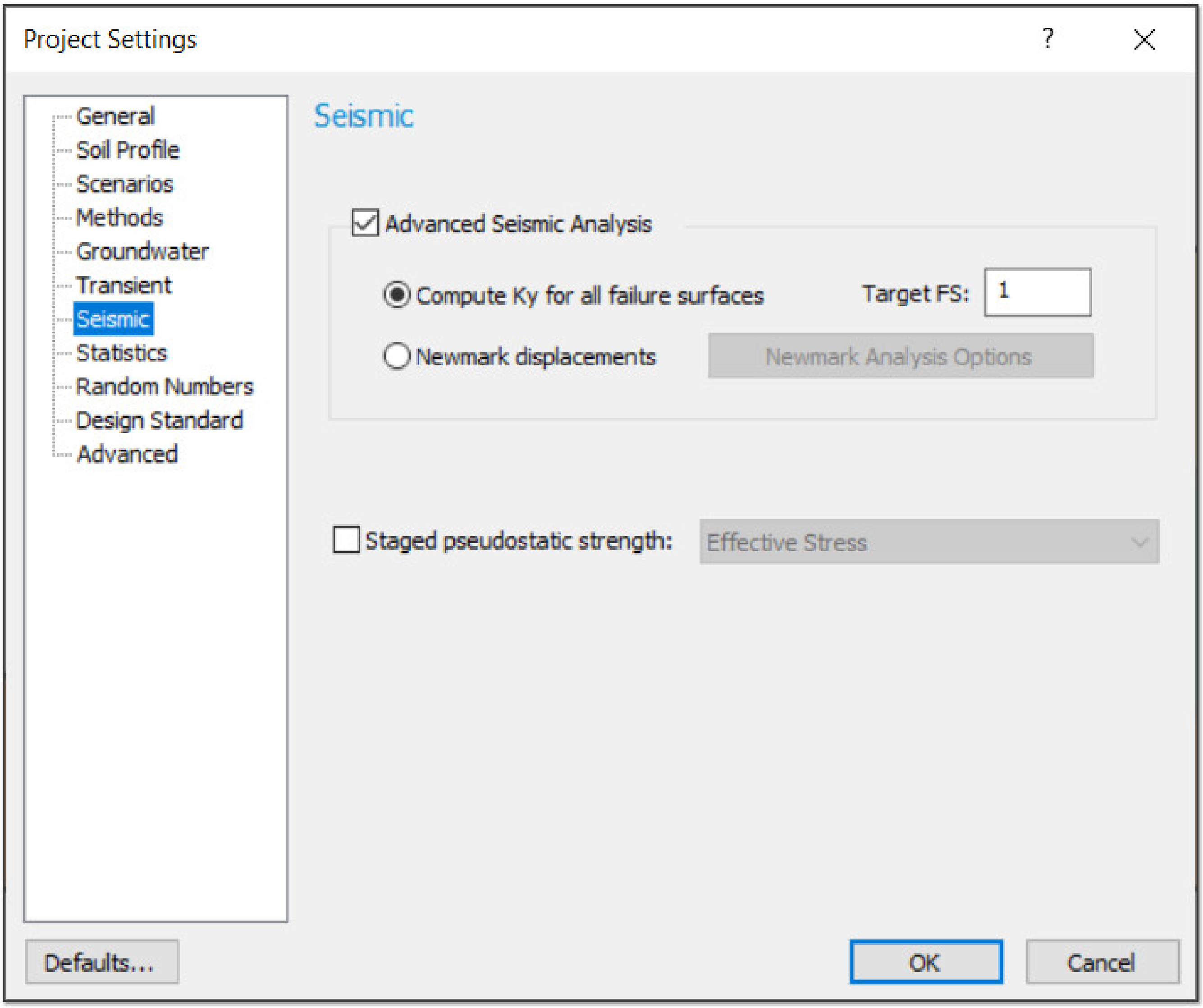
In the **Document Viewer**, right-click on **No Seismic** and select **Duplicate Scenario**. Rename the scenario **Critical Acceleration**.

PROJECT SETTINGS

For the **Critical Acceleration** scenario, we will change the Project Settings in order to determine the critical seismic coefficient. Ensure you have this scenario selected.

Select **Analysis > Project Settings**

Select the **Seismic** page from the list at the left of the dialog.



Select the "**Advanced Seismic Analysis**" checkbox. Notice that the "Compute Ky for all failure surfaces" option is selected. This option must be selected in order to compute ky for all failure surfaces. Select **OK**.

9. Compute

Select **Analysis > Compute**

The new scenario, Critical Acceleration, is automatically selected to Compute. Select **OK**.

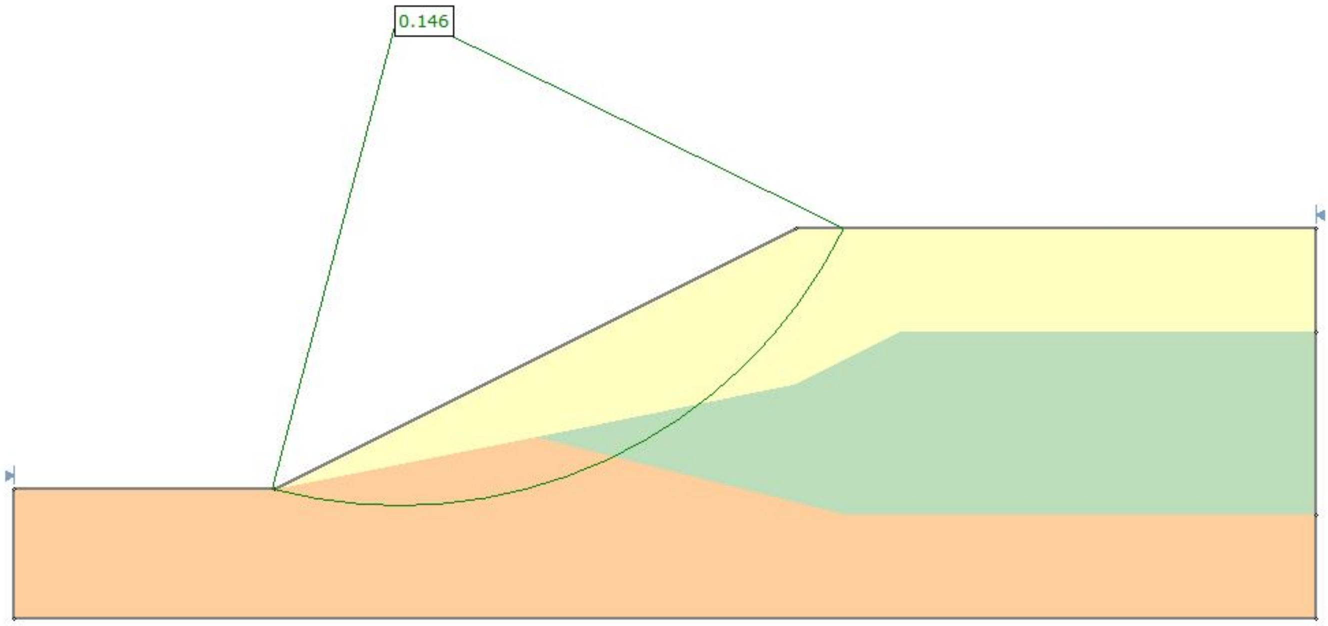
The Slide2 Compute engine will proceed in running the analysis. When completed, you are ready to view the results in Interpret.

10. Interpret

To view the results of the analysis:

Select **Analysis > Interpret**

You should see the following critical slip surface with the critical seismic coefficient displayed (ky = 0.146).



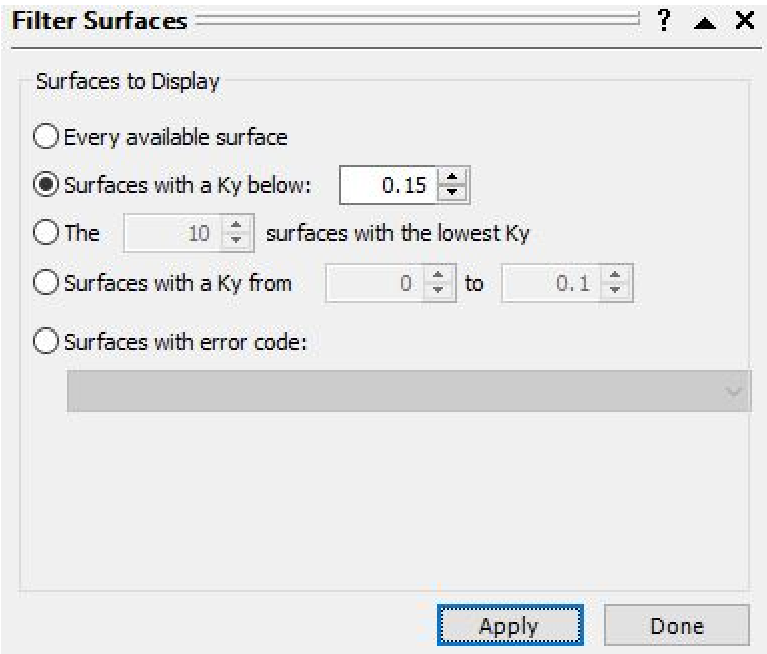
Now select the **All Surfaces** option to view all circles generated by the analysis:

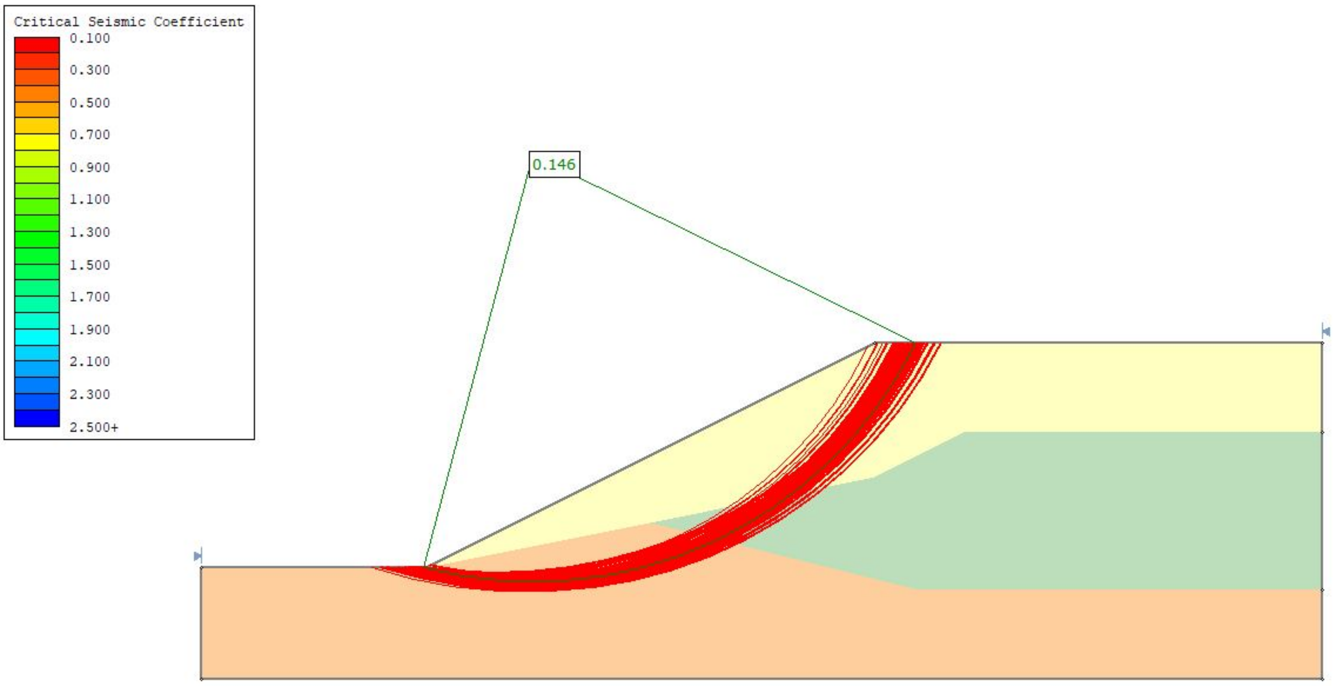
Select **Data > All Surfaces**

Let's use the **Filter Surfaces** option, to display only surfaces with a critical seismic coefficient (Ky) below 0.15, the value we specified in the previous scenario Seismic = 0.15.

Select **Data > Filter Surfaces**

In the Filter Surfaces dialog, select the "**Surfaces with a Ky below**" option, enter a value of 0.15, and select **Done**.





As you can see, there are a number of unstable surfaces for this model, wherein a seismic coefficient less than 0.15 would result in a destabilized slope. This makes sense, since the Global Minimum factor of safety for the Seismic = 0.15 scenario, is 0.992 (i.e. just below one).

11. Model 4 - Newmark Displacement Analysis

We will now perform a **Newmark displacement analysis** to determine the critical Newmark displacement that results from seismic loading.

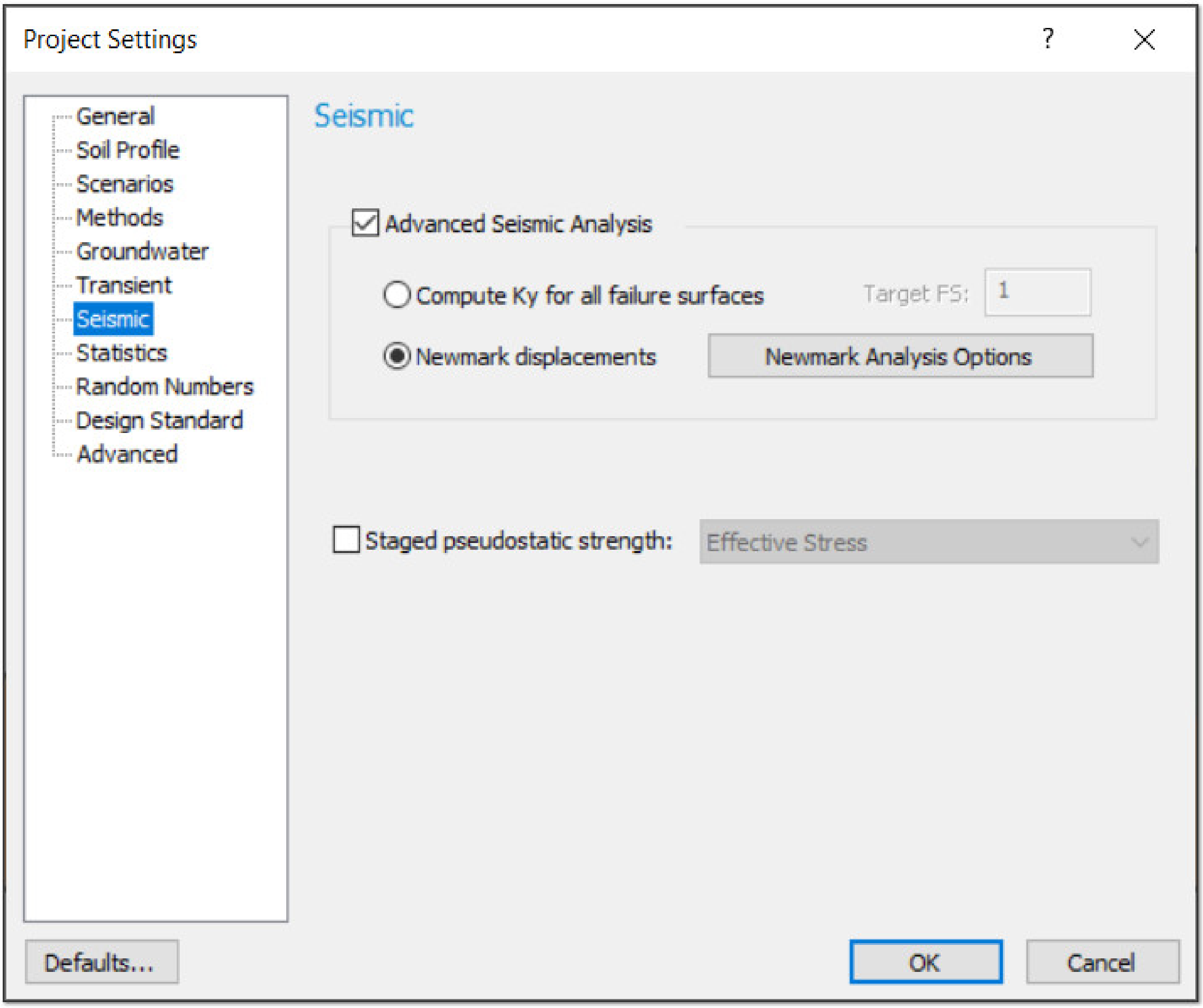
Return to the Modeler. In the **Document Viewer**, right-click on the **Critical Acceleration** scenario and select **Duplicate Scenario**. Rename it **Newmark Displacement.**

PROJECT SETTINGS

We will now change the Project Settings for the new scenario in order to determine the Newmark displacements.

Select **Analysis > Project Settings**

Select the **Seismic** page from the list at the left of the dialog.

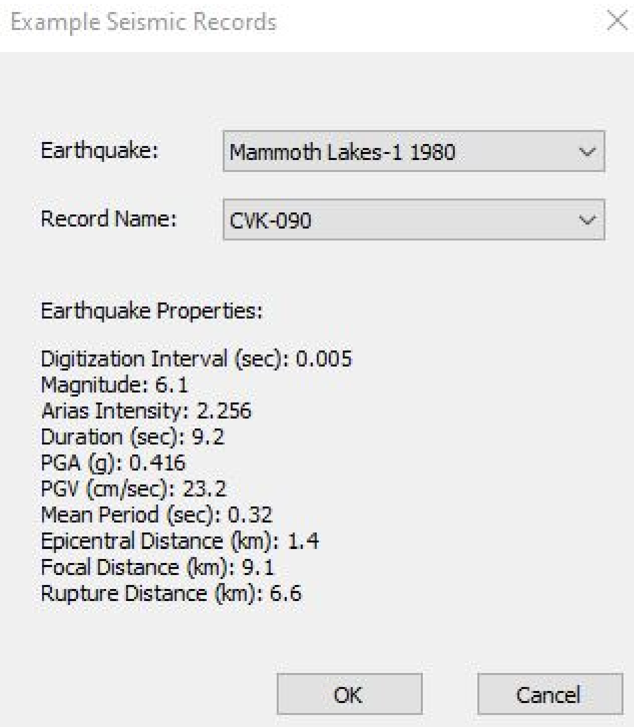


Notice that the "**Advanced Seismic Analysis**" checkbox is selected, as it was in the Critical Acceleration scenario. This option must be selected in order to compute Newmark displacements. The Newmark analysis in Slide2 is based on the program SLAMMER, developed by the U.S. Geological Survey. The permission to use the SLAMMER code by Dr. Jibson and Dr. Rathje in Slide2 is gratefully acknowledged.

Select **Newmark Analysis Options** and **Define Seismic Record**.

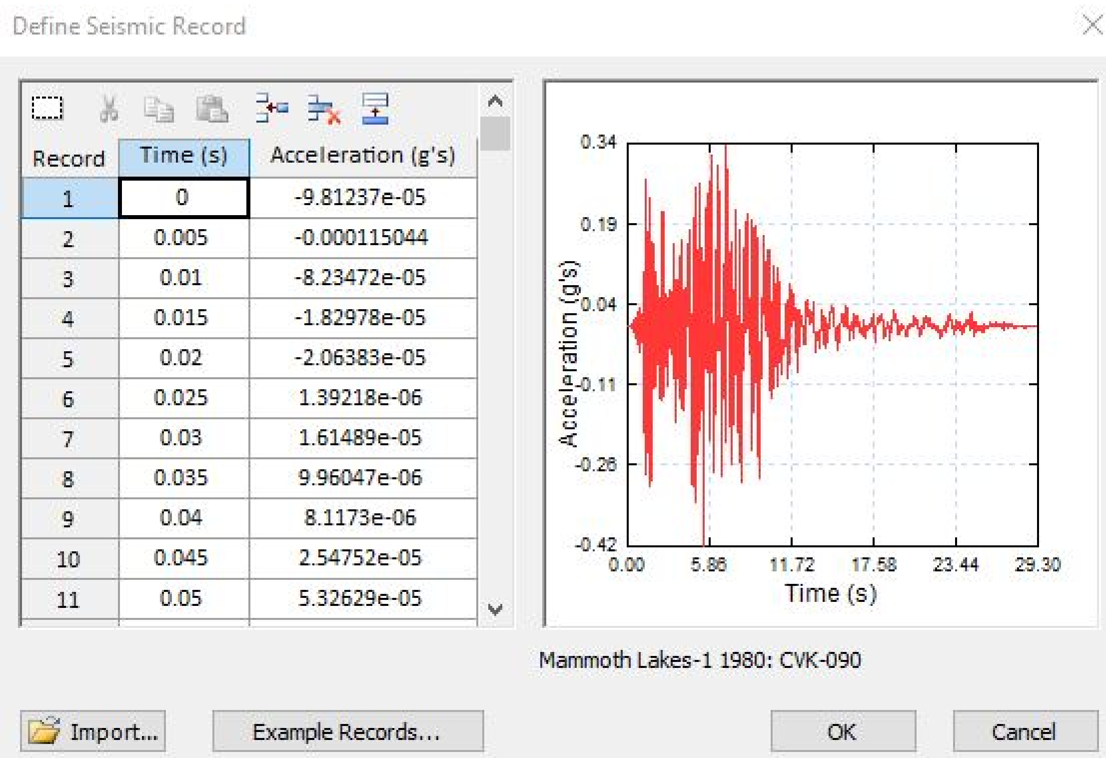
Notice that in Slide2 there are a number of ways the seismic record can be entered. Time and acceleration data points can be manually entered into each cell or copied in from a table. Alternatively, the seismic record can be imported from a Slammer or Slide2 (.ssr) file, or chosen from a list of Example Records containing historical data from a selection of earthquakes.

For this tutorial, we will use data from the Example Record of Mammoth Lakes-1 1980, CVK090 with a peak ground acceleration (PGA) of 0.416 g. Select **Example Record** and set **Earthquake = Mammoth Lakes-1 1980** and **Record Name = CVK-090**.



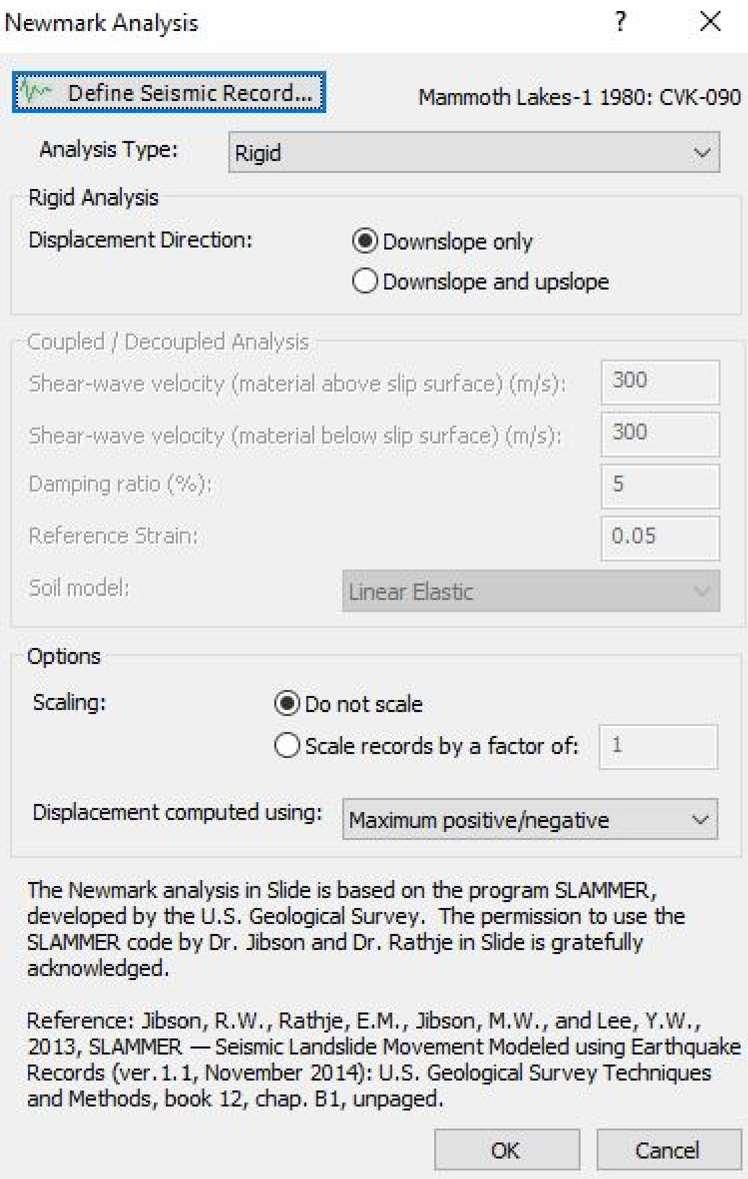
Notice that a summary of the Earthquake Properties, which includes the PGA and PGV of the selected record, is displayed.

Select **OK** to close the Example Seismic Records dialog.



Notice that once the time and acceleration data points have been entered, the acceleration vs. time plot is generated in the **Define Seismic Record** dialog.

Select **OK** to close the **Define Seismic Record** dialog when finished reviewing the seismic record data.



In the Newmark Analysis dialog, notice the Newmark Analysis Type option. In Slide2, we are able to define the Newmark Analysis Type as either Rigid, Coupled, or Decoupled. We can also run all three at once. Also, notice that the displacement can be computed by examining the Positive Accelerations, Negative Accelerations, Mean Accelerations, or the Maximum positive/negative accelerations of the seismic record. We can also run all these displacement options at once.

For this tutorial, we will set **Newmark Analysis Type = Rigid** and **Displacement computed using = Maximum positive/negative acceleration.**

Select **OK** to close the Newmark Analysis dialog.

Select **OK** in the Project Settings dialog.

12.Compute

Select **Analysis > Compute**

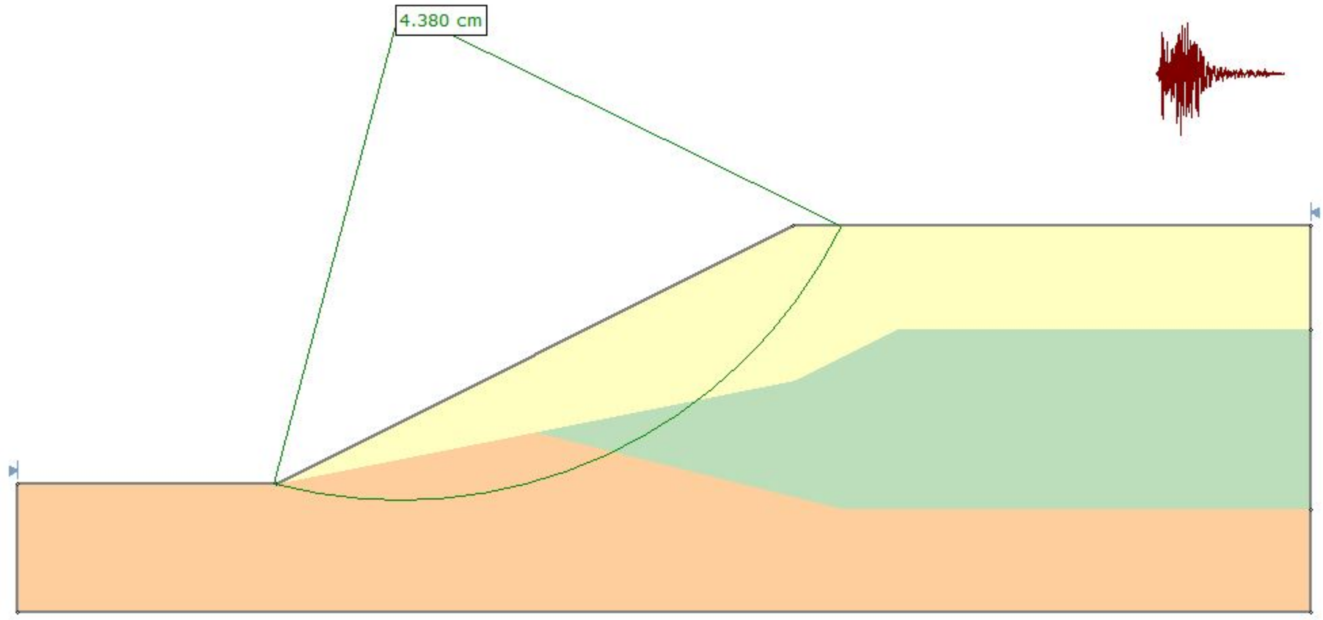
The Slide2 Compute engine will proceed in running the analysis. When completed, you are ready to view the results in Interpret.

13. Interpret

To view the results of the analysis:

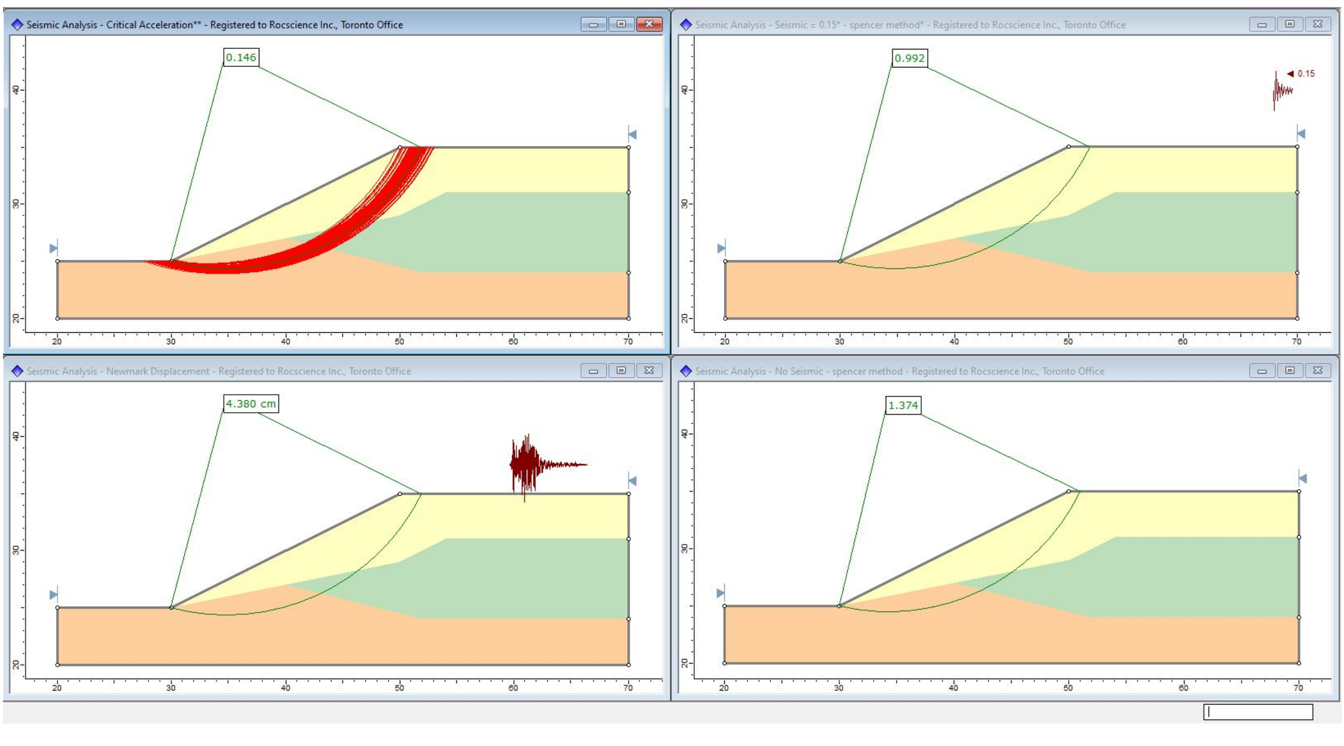
Select **Analysis > Interpret**

You should see the following critical slip surface with the critical Newmark displacement displayed = 4.380 cm.



Select **Window > Tile Vertically**

This allows us to view all the different scenarios at once.



This concludes the seismic analysis tutorial.

References

Jobson, R.W., Rathje, E.M., Jibson, M.W., and Lee, Y.W., 2013, SLAMMER – *Seismic LandSlide2 Movement Modeled using Eatherquake Records* (ver.1.1, November 2014): U.S. Geological Survey Techniques and Methods, book 12, chap. B1, unpaged