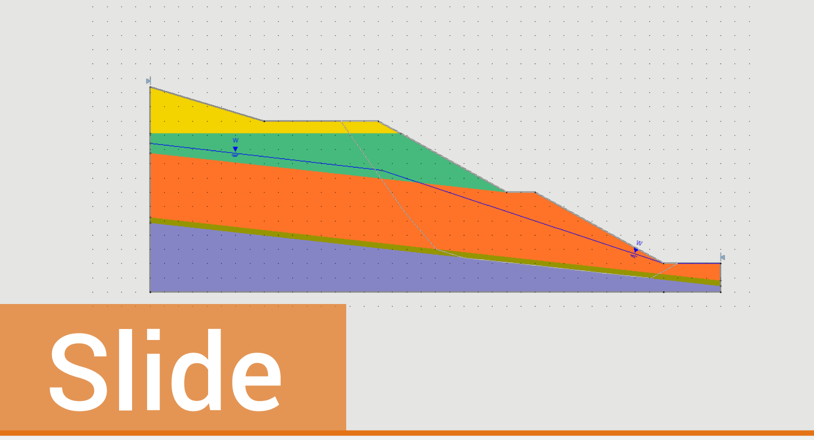
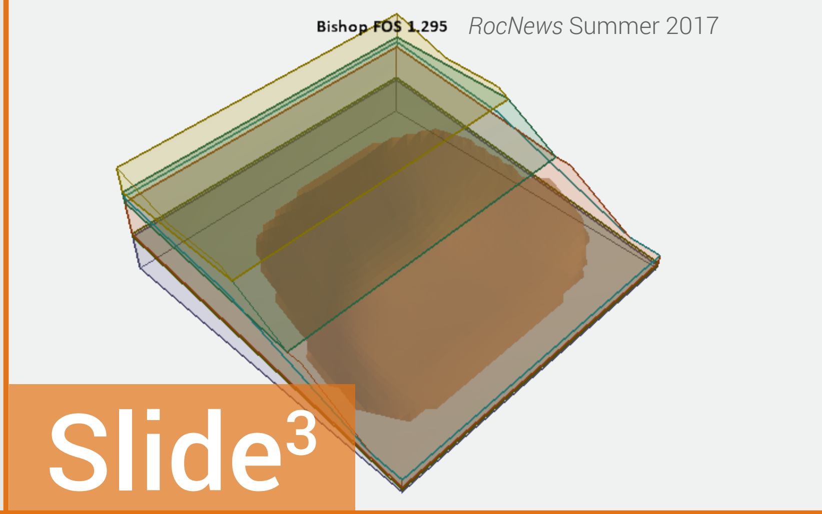
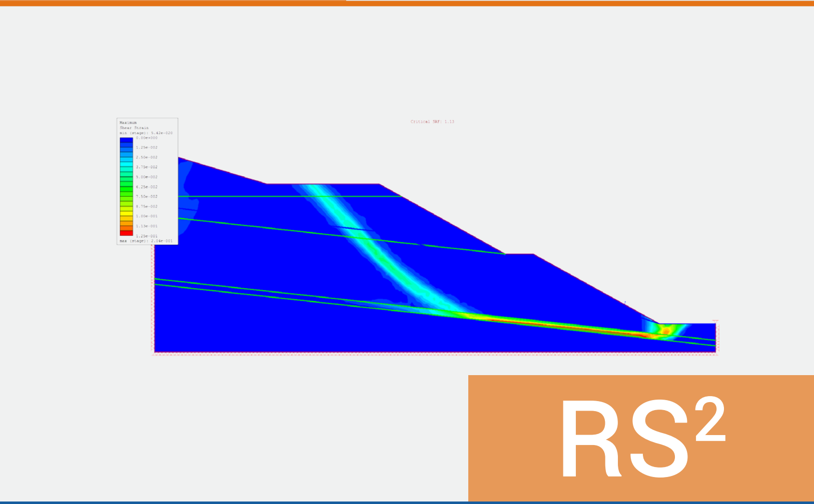
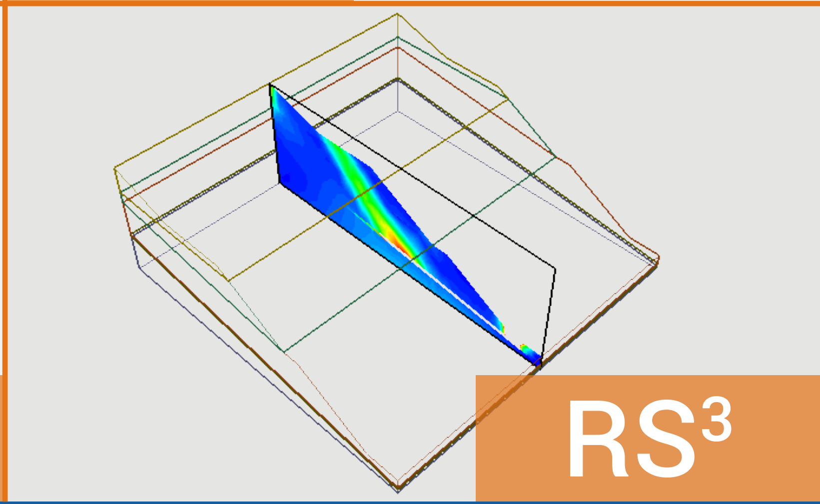








Limit Equilibrium, and Shear Strength Reduction, and 3D, oh my!

Four different approaches to slope stability.

With the recent addition of *Slide*³ to our slope stability suite, we are often asked:

1. How are the results different between 2D and 3D?
2. How are the results different between limit equilibrium (LE) and shear strength reduction (SSR)?

In this article, we review three slope stability examples from literature, and analyze them with four different approaches: 2D LE (*Slide*), 3D LE (*Slide*³), 2D SSR (*RS*²), and 3D SSR (*RS*³).

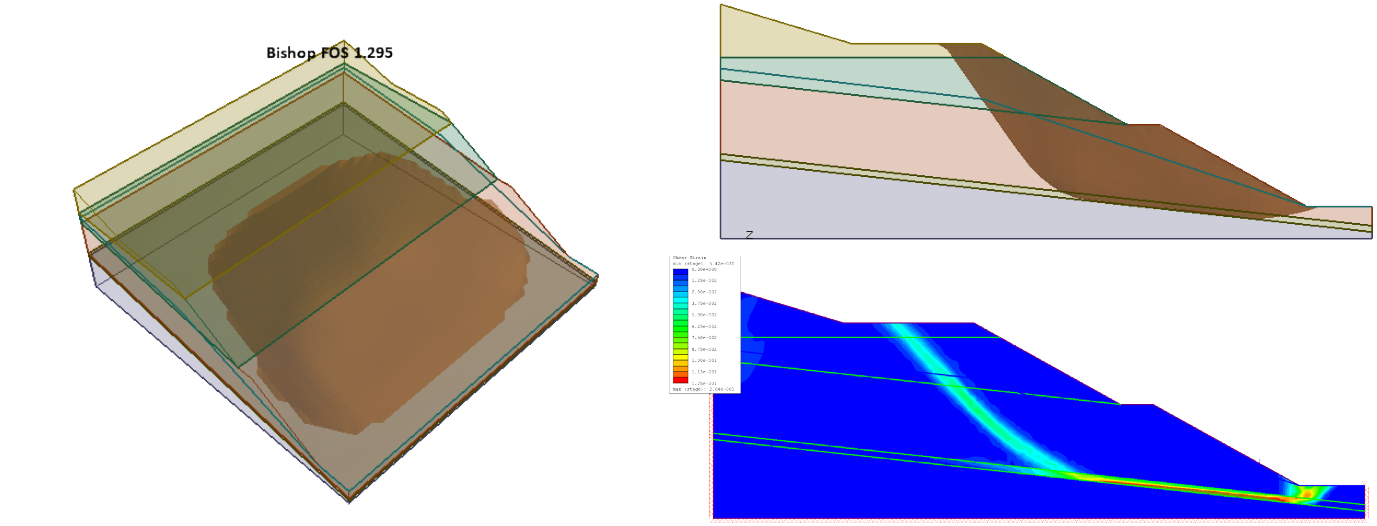
Example 1

This problem is taken from Wang et al. (2015). It is a non-homogeneous extruded slope with a water table and a thin weak layer. The non-circular slip surface and corresponding safety factor is required. The material properties for all four soil layers, as well as the weak layer, can be found in Table 1.1.

Table 1.1 Material Properties for Example 1.

	c′ (kN/m²)	φ′ (deg.)	γ (kN/m³)
Soil 1	9.8	30	22
Soil 2	58.8	25	24
Soil 3	49.8	30	26
Soil 4	64	35	27
Weak Layer	9.8	20	20

The results of *Slide*³ and *RS*² are displayed below, along with a summary table of the different approaches.



Example 1: Slide³ *solution using Bishop method (left; top right).* RS² *maximum shear strain contours at critical SRF (bottom right).*

Table 1.2 Factor of safety results for Example 1.

Method	Slide	Slide³	RS²	RS³
Bishop	1.076	1.295	1.13	1.23
GLE	1.104	1.333		
Janbu	1.026	1.259		
Spencer	1.125	1.445		

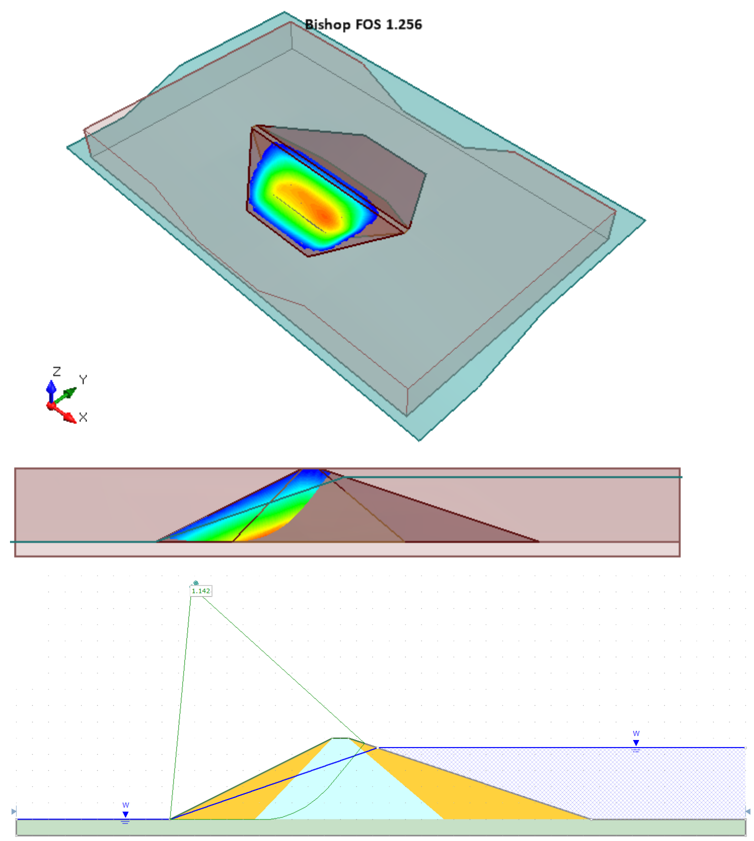
Example 2

This example is a model of a 3D valley with a water table. There is a dam extending across the middle of the valley, to regulate the height of the water table on either side of it. The non-circular slip surface and corresponding safety factor of the dam is required. Material properties are shown in Table 2.1.

Table 2.1 Material Properties for Example 2.

	c′ (kN/m²)	φ′ (deg.)	γ (kN/m³)
Material 1 (Drained)	35	35	18.15
Material 2	150	45	21.58
Material 3	35	15	18.15
Material 4	10	35	18.15
Material 1 (Undrained)	70	0	18.15

The results of *Slide³* and *Slide* are displayed, along with a summary table of the different approaches.



Example 2: Slide³ *normal stress contour on slip surface found using Bishop method (top first; top second).* Slide *solution using Bishop method (bottom).*

Table 2.2 Factor of safety results for Example 2.

Method	Slide	Slide³	RS²	RS³
Bishop	1.142	1.256	1.18	1.34
GLE	1.243	1.397		
Janbu	1.081	1.227		
Spencer	1.232	1.429		

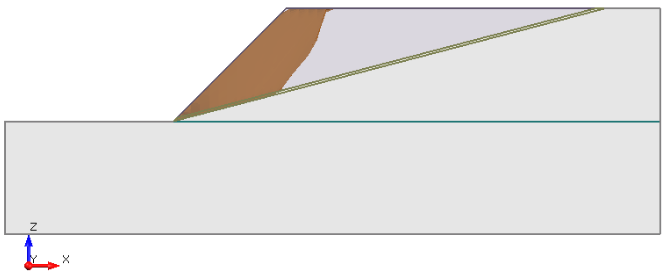
Example 3

Huang, Fan and Wang (2016) analyzed a slope with a weak layer and a changing water table. This example is case 1, where the water table is at the toe of the slope. Table 3.1 shows the material properties of the slope and the weak layer. The base is of infinite strength, which forces the slip surface to go through the weak layer, instead of the base, which is more accurate to real conditions and will lower the safety factor. Pore water pressures are caused by the water table, which is also shown.

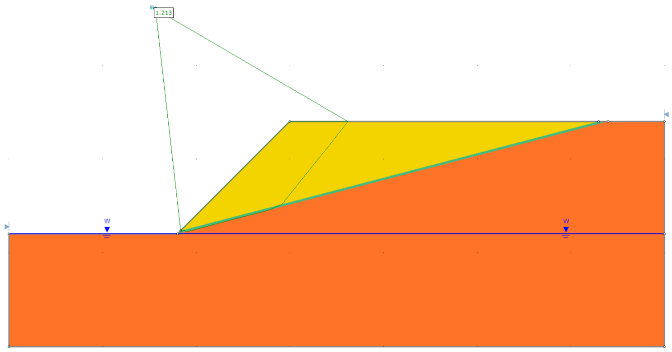
Table 3.1 Material Properties for Example 3.

	c' (kN/m²)	φ' (deg.)	γ (kN/m³)
Soil	20	15	20
Weak Layer	10	10	20

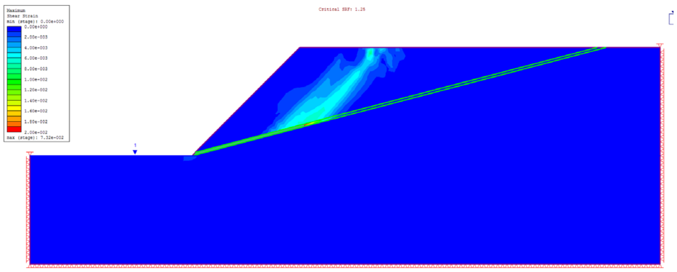
The results of *Slide*³, *Slide, RS*², and *RS*³ are displayed, along with a summary table of the different approaches.



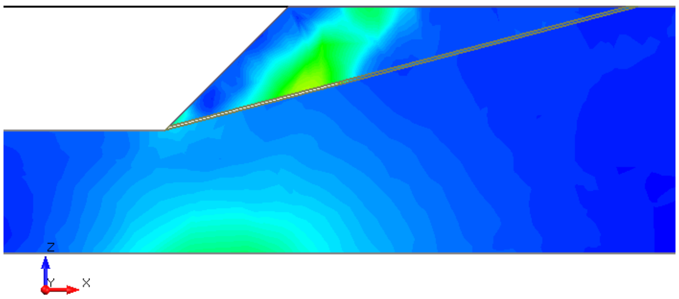
Example 3: Slide³ *solution using Bishop method.*

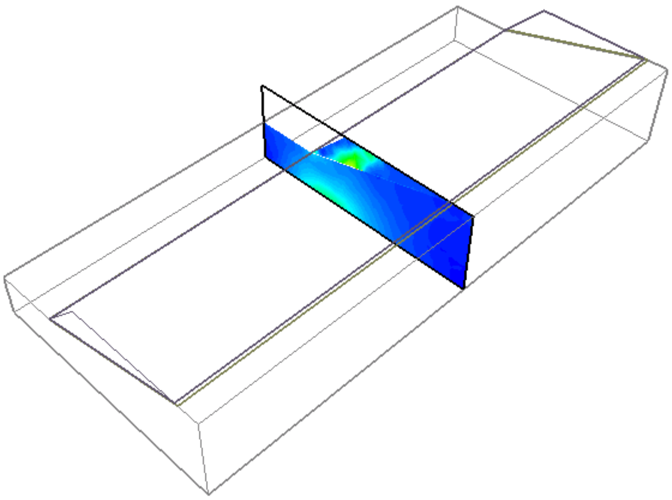


Example 3: Slide *solution using Bishop method.*



Example 3: RS² *maximum shear strain contours at critical SRF.*





Example 3: RS³ *base maximum shear strain contours*

Table 3.2 Factor of safety results for Example 3.

Method	Slide	Slide³	RS²	RS³
Bishop	1.213	1.204	1.25	1.20
GLE	1.342	1.203		
Janbu	1.240	1.202		
Spencer	1.307	1.203		

References

[1] Wang, L., Xie, M., Xu, B., & Esaki, T. (2015). A study on locating critical slip surface of slopes. International Journal of Geotechnical Engineering, 9(3), 265-278.

[2] Huang, M., Fan, X., & Wang, H. (2017). Three-dimensional upper bound stability analysis of slopes with weak interlayer based on rotational-translational mechanisms. Engineering Geology, 223, 82-91.