rocscience

Rapid Drawdown Tutorial

1. Introduction

The concept of excess pore pressure using the B-bar method can also be applied to unloading scenarios. If a load is removed quickly from a low permeability material, a "negative excess pore pressure" can be induced.

The change in pore pressure is given by:

$$\Delta u = \bar{B} \Delta \sigma_v \qquad \text{Equation 1}$$

where B (B-bar) is the overall pore pressure coefficient for a material. In Slide2, this can be used to simulate the pore pressure changes due to rapid drawdown of ponded water in earth dams.

In the **Slide2** Rapid Drawdown (B-bar method) analysis:

1. An initial water table is defined. This defines the initial pore pressure distribution and the initial weight of ponded water.

2. For a complete drawdown scenario, it is assumed that all ponded water is removed from the model. The change in pore pressure for undrained materials is calculated due to the removal (unloading) of the ponded water according to Equation 1. The final pore pressure at any point is the sum of the initial pore pressure and the (negative) excess pore pressure.

3. For a partial drawdown scenario, a drawdown water table is also defined. In this case, the unloading is due to the removal of ponded water to the drawdown level. This determines the change in pore pressure for undrained materials. The pore pressure in drained materials will be calculated from the drawdown water table.

This tutorial will demonstrate rapid drawdown analysis using the B-bar method in Slide2. The following scenarios will be analyzed: full reservoir, complete drawdown, partial drawdown.

The finished file can be found in **File > Recent Folders > Tutorials Folder >** ***Tutorial 13 Rapid Drawdown.slmd***.

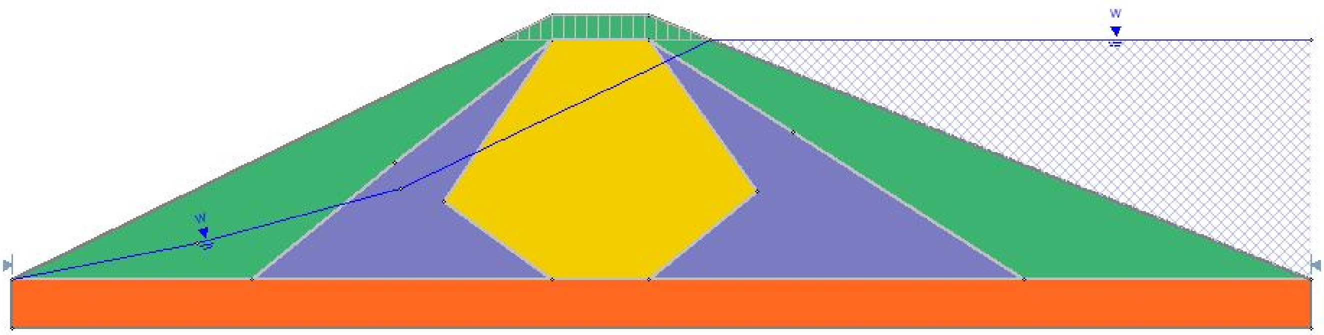
OTHER DRAWDOWN METHODS

See Tutorial 17 for other rapid drawdown methods available in Slide2: • Duncan and Wright 3-stage (1990) • Army Corps 2-stage (1970) • Lowe and Karafiath (1960)

2. Full Reservoir - Steady State

First, we will analyze a dam with a full reservoir.

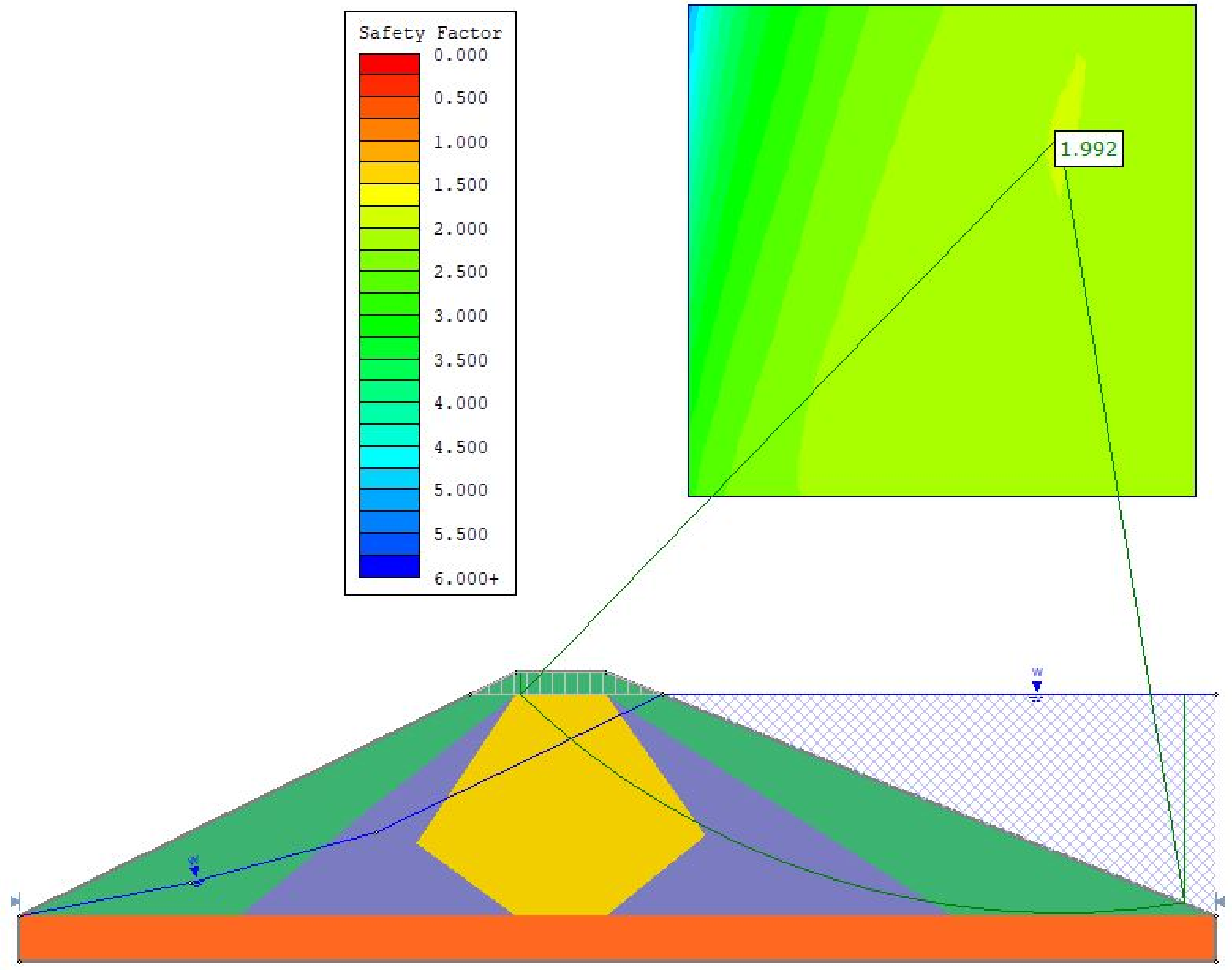
From the Slide2 main menu, select **File > Recent Folders > Tutorials Folder** and read in the *Tutorial 13 Drawdown1.slmd* file. You can rename Group 1 to “Full Reservoir Steady State”.



Dam with full reservoir

The model represents a dam with a clay core, a transition zone, and a granular fill outer layer.

Run Compute and then view the results in Interpret. The critical slip circle has a safety factor = 1.99. Select the Show Slices option to highlight the sliding region.



Critical slip circle with full reservoir

3. Rapid Drawdown of Entire Reservoir

Go back to the Modeler. Duplicate the “Full Reservoir Steady State” group and name the new group “Rapid Drawdown (Entire)”.

In this group, we will simulate a complete drawdown of the reservoir.

PROJECT SETTINGS

1. Select **Project Settings > Groundwater**

2. Check the Advanced checkbox and specify Rapid Drawdown Method = Effective Stress using B-bar. The change in pore pressure due to removal of the ponded water will be calculated using the B-bar method.

3. Click **OK** to save the settings.

Note

The water table is labelled as “initial” and no ponded water is displayed. This is to indicate that a complete drawdown state exists, i.e. the ponded water will be removed for the final stage of the analysis (i.e. the safety factor calculation).

MATERIAL PROPERTIES

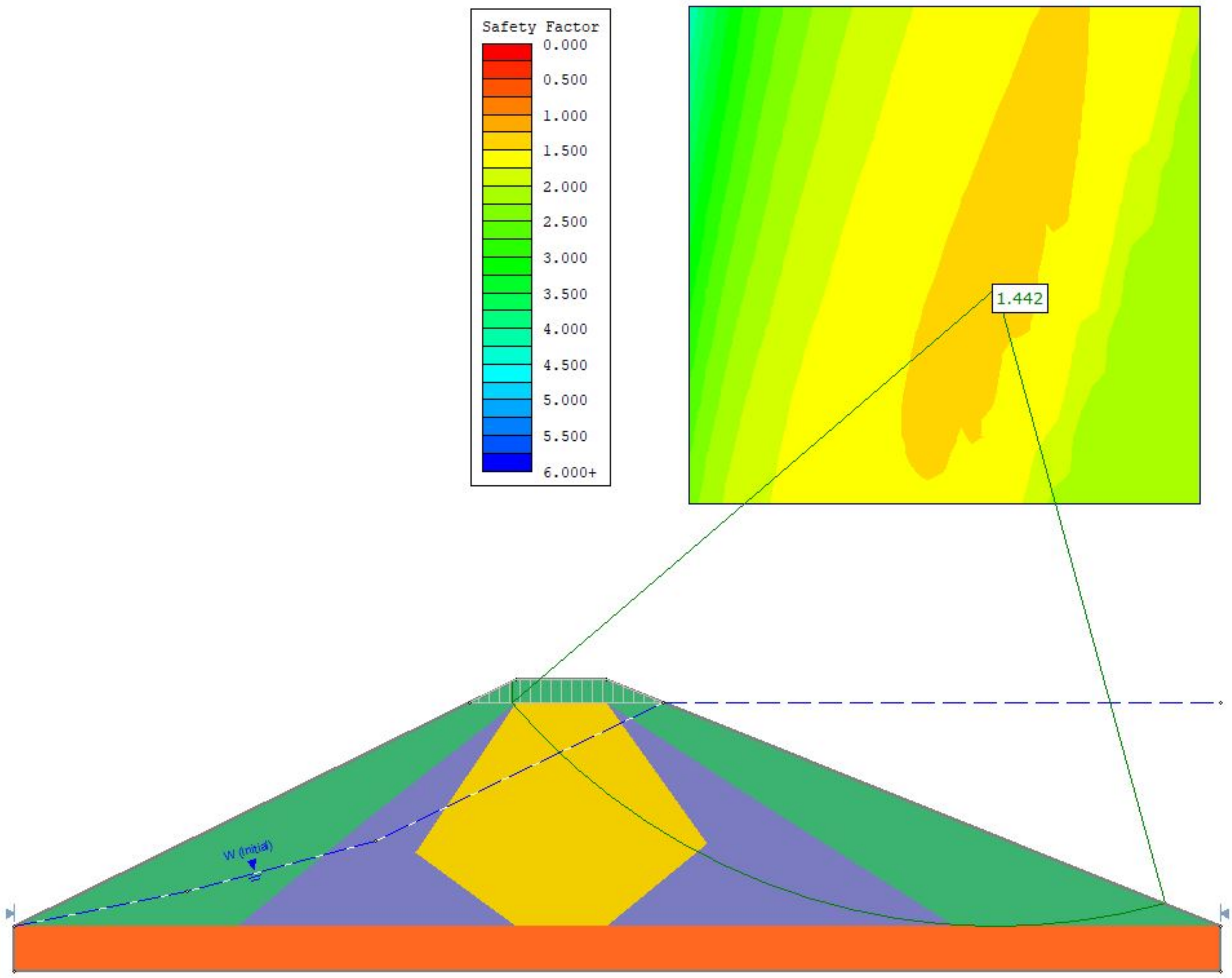
1. Select **Properties > Define Materials**.

2. For the “clay core”, “transition” and “hard bottom” materials click the Undrained Behaviour checkbox and enter B-bar = 1. This will result in a negative pore pressure change for any of these materials which is located beneath the ponded water, calculated according to Equation 1.

3. The “granular fill” is assumed to be free-draining, so the “undrained” checkbox is NOT selected. For a complete drawdown scenario, this will result in zero final pore pressure for this material.

4. Click **OK** to save the changes.

Run **Compute**, and view the results in Interpret. You should see the following critical slip surface (FS = 1.44). Select the Show Slices option

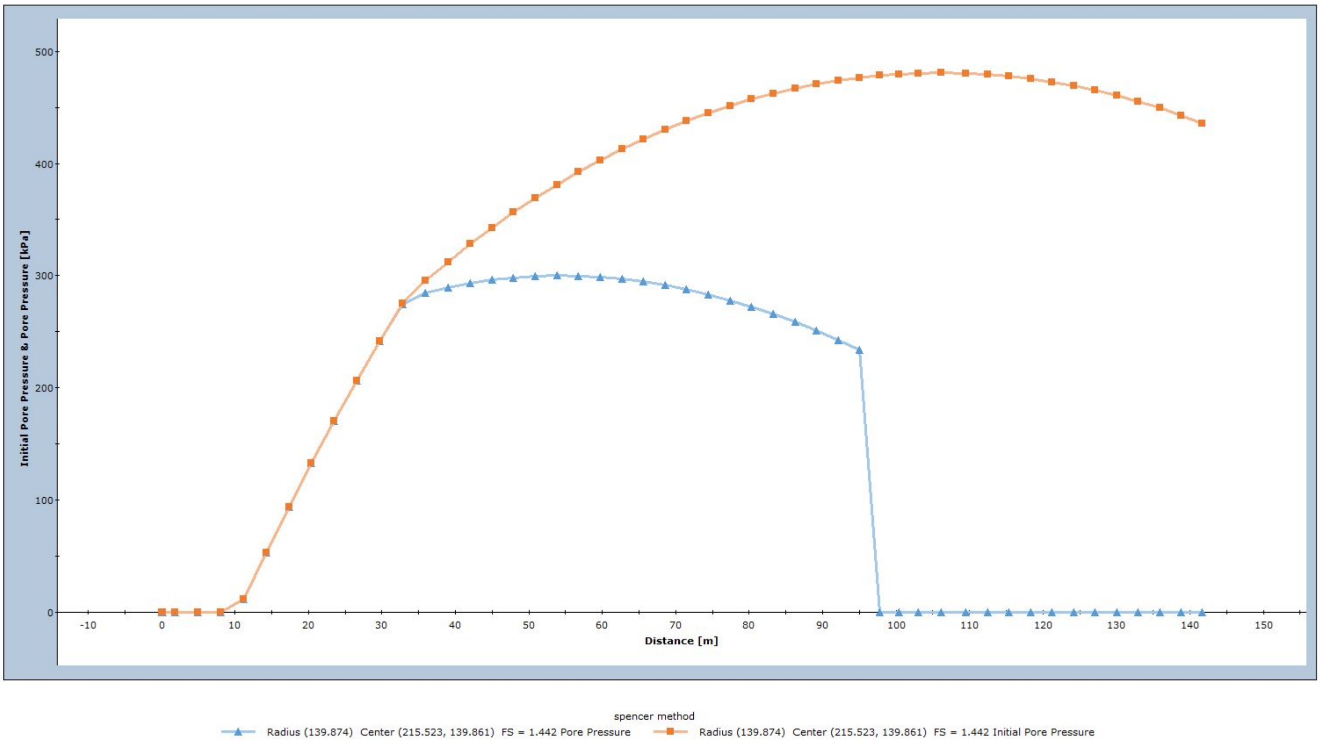


Critical slip surface after rapid drawdown

The critical safety factor after rapid drawdown is significantly lower than the safety factor of the full reservoir, as we would expect, due to the removal of the support provided by the ponded water against the slope. For this example, the critical slip circles, before and after drawdown, are quite similar (i.e. large, deep-seated surfaces passing through the core of the dam).

Let's examine the pore pressure along this slip surface. Select Graph Query from the toolbar.

Select Pore Pressure as the primary data, and Initial Pore pressure as the secondary data, and select Create Plot. You should see the following plots.



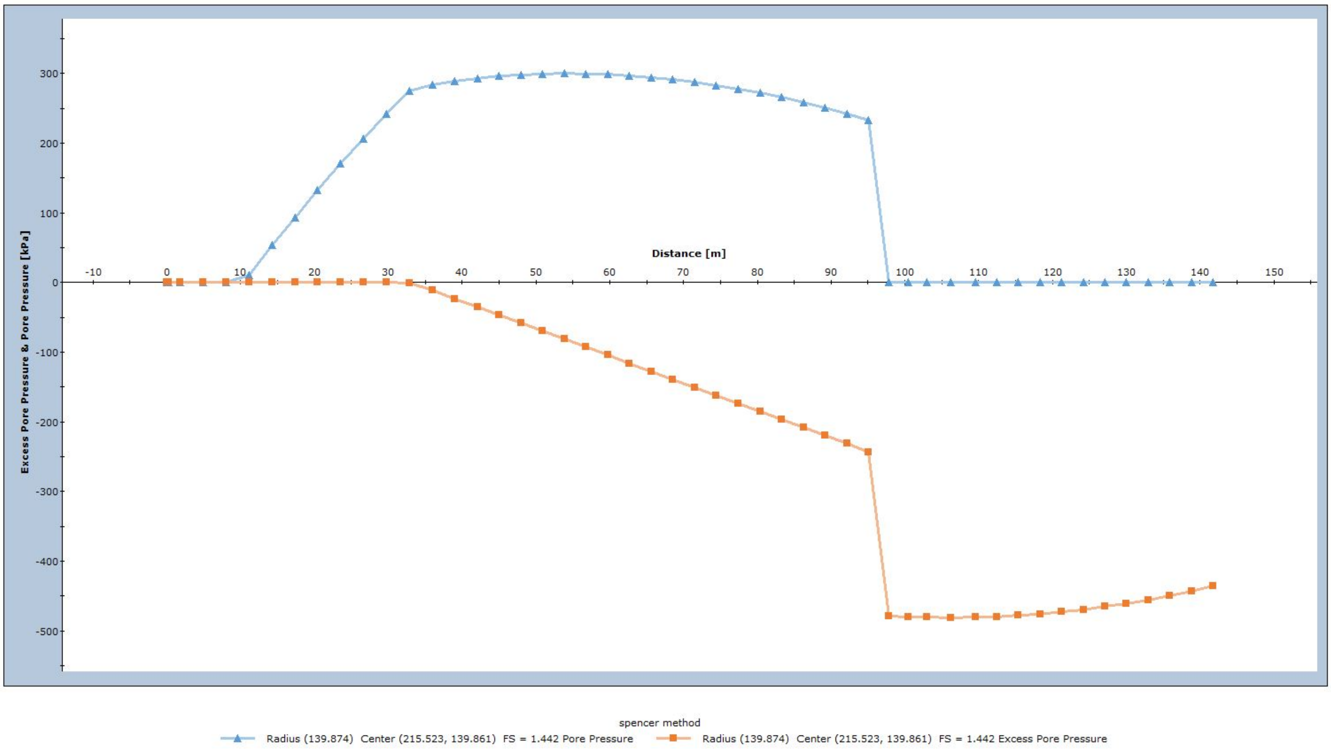
Initial Pore Pressure and Final Pore pressure

Notice that the (final) Pore Pressure is lower than the Initial Pore Pressure for most of the slip surface.

• For the portion of the slip surface within the "transition" material (B-bar = 1) this is due to the negative change in pore pressure due to removal of the ponded water load.

• For the portion of the slip surface within the "granular fill" material (free draining) the final pore pressure is zero due to the complete drainage of the fill material.

Let's plot the Excess Pore pressure. Right-click on the graph, and select "Change Plot Data" from the popup menu. Select Excess Pore Pressure as the secondary data, and select Create Plot. You should see the following plot.



Final pore pressure and excess pore pressure, rapid drawdown analysis

The negative excess pore pressure is clearly visible on the plot.

• For the portion of the slip surface within the “transition” material (B-bar = 1) this is due to the negative change in pore pressure due to removal of the ponded water load.

• For the “granular fill” material, the “negative excess pore pressure” is actually the change in pore pressure due to the lowering of the water table. Since the granular fill is free draining, the negative excess pore pressure is NOT due to the B-bar unloading effect but is simply the difference between the initial and final pore pressure.

4. Rapid Drawdown to Specified Level

Finally, let’s demonstrate how we can model rapid drawdown to a specified water level, rather than a full drawdown. Duplicate the “Rapid Drawdown (Entire)” group and name the new group “Rapid Drawdown (Specific Level)”. We will be editing this group.

1. Select **Boundaries > Add Drawdown Line.**

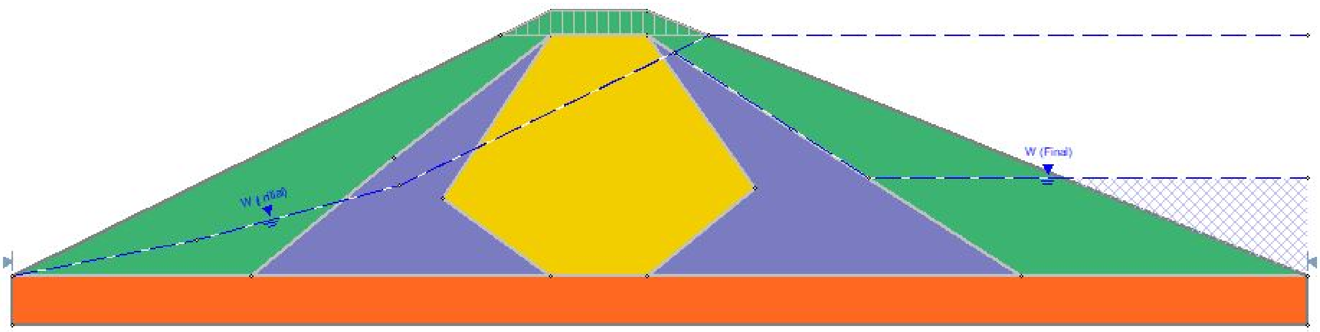
2. In the prompt line enter **t** then **Enter.**

3. In the Coordinate Table that appears, copy and paste the following coordinates, then click OK.

X-Coordinate	Y-Coordinate
0	0

37.8530642196367	7.3830662547644
79.292	18.543
135.398610454628	45.5376610208739
175.1	20
265	20

4. Hit Enter to complete entering the water line.

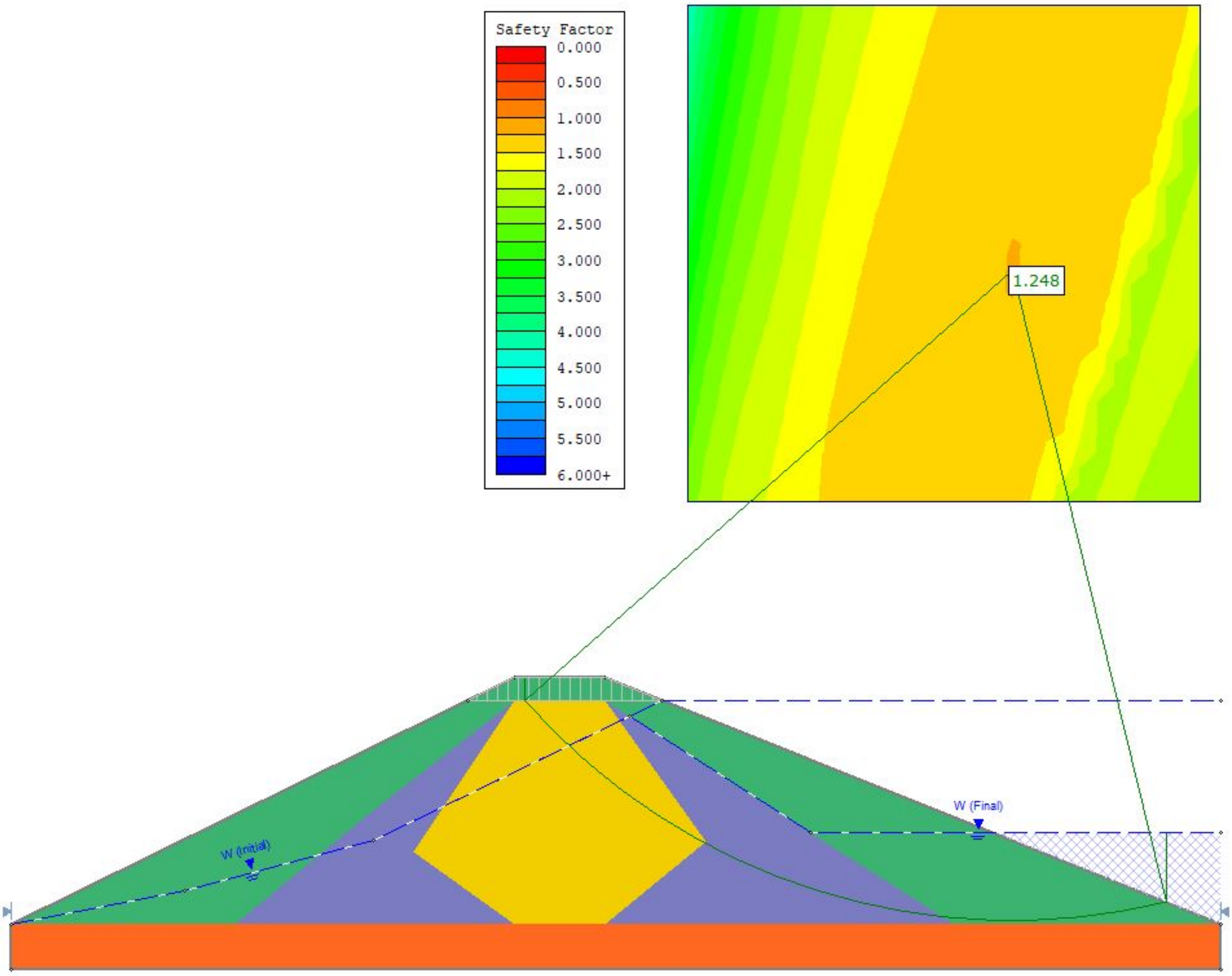


Partial drawdown of reservoir

Note

Ponded water is defined where the drawdown water level is above the slope. In this case, the change in loading is due to the difference in the weight of ponded water between the initial and final water tables. This unloading creates a negative change in pore pressure for undrained materials.

Run **Compute**, and view the results in **Interpret.**



For this example, the minimum safety factor at partial drawdown (FS = 1.24) is lower than the minimum safety factor at full drawdown. This is due to the material properties and geometry of the slope – e.g. complete drainage (zero pore pressure), assumed for the granular material for the complete drawdown state. At partial drawdown, the drawdown water table creates significant pore pressure in the granular material, towards the toe of the slope, and this leads to the lower safety factor. For this particular model, a minimum safety factor, therefore, exists at some intermediate drawdown level.