Slope Stability

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Exercise 5

SEEPAGE AND STABILITY ANALYSES
GEOSTUDIO SEEP/W AND GEOSTUDIO SLOPE/W

The goal of this exercise is: a) to perform a seepage analysis of a slope, under given hydraulic boundary conditions, by adopting the SEEP/W module of the commercial software GeoStudio (*student license version*); b) to assess the stability of the slope by using the SLOPE/W module of the same software. A tutorial is presented in order to guide the student through the basic steps of the application.

1.1 Exercise description

The slope considered in this exercise is characterized by the same geometry and material properties considered in exercise 4a (see Figure 1 and Table 1). However, different from the previous exercise where the slope was considered to be submerged, the one analyzed in this exercise is characterized by the water table level depicted in Figure 1. Seepage is hence expected to occur.

Table 1 provides also the volumetric saturated water content (θ_{sat}=$V_{w,sat}$/V with $V_{w,sat}$ volume of water when the soil is saturated and V total volume), the AEV (air entry value of the soil= negative relative pore water pressure starting from which the degree of saturation decreases) and the saturatad hydraulic conductivity k_{sat} (=the hydraulic conductivity of the saturated soil).

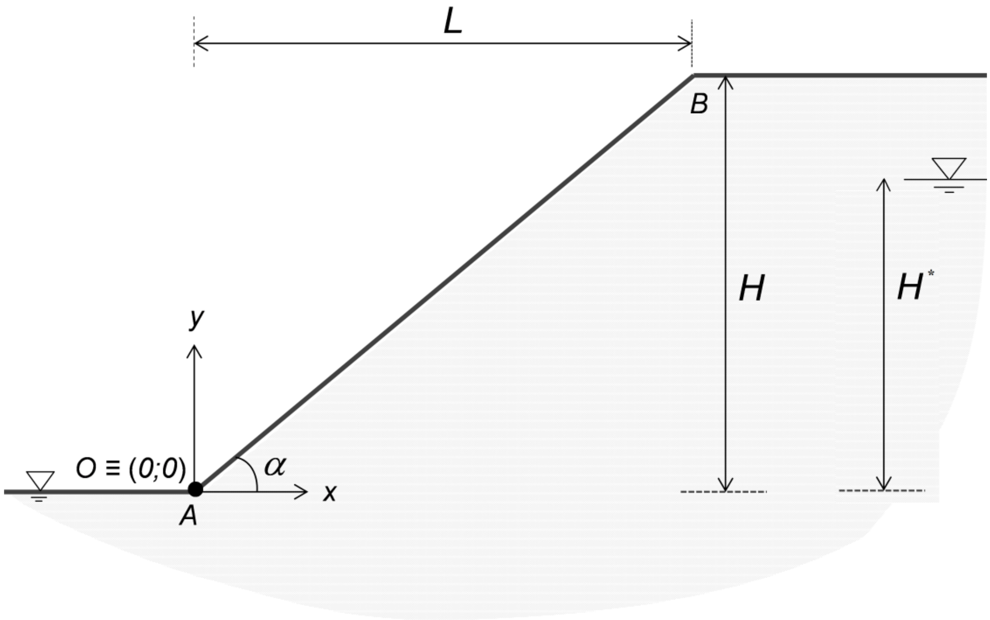

Figure 1: slope geometry.

Table 1: geometry and soil properties of the slope reported in Figure 1.

γ_{sat} (kN/m^3)	θ_{sat} (-)	*AEV (kPa)*	k_{sat} (m/s)	α (°)	*H* (m)	*H** (m)	*L* (m)	φ' (°)	*c'* (kPa)
21.0	0.35	100	10^{-7}	30.0	8.0	5	13.9	22.0	5.0

Perform a seepage analysis of the considered slope in steady state conditions and focus on the quantitative evaluation of *(i)* pore water pressure and *(ii)* total head within the considered domain. Consider the material above the water table as saturated by capillarity and verify the correctness of this assumption by analyzing the pore water pressure values in the domain of interest and comparing them with the air entry value (AEV) provided in Table 1.

Finally, perform a slope stability analysis according to the simplified Bishop method and compare the obtained results with those in the context of exercise 4a (slope in dry and submerged conditions).

1.2 Strategy for the resolution of the exercise

The suggested strategy for solving the proposed exercise consists of the following steps:

I. Resolution of the hydraulic problem (GeoStudio SEEP/W). After drawing the slope and assigning the boundary condition of the hydraulic problem (see Figure 1), the seepage problem is solved and the distribution of water pressure in the slope of interest is thus obtained;

II. Resolution of the mechanical problem (GeoStudio SLOPE/W). Once the distribution of water pressure in the slope of interest is known, the limit equilibrium method is applied for identifying the critical slip surface.

To solve the mechanical problem, remember and pay attention to the following concepts:

- when a seepage flow is expected to exist (i.e. not hydrostatic condition), the equilibrium of a generic slice could be evaluated by using two possible approaches: a) effective stress and seepage forces; b) total stress and resultant forces due to the water pressure acting in the sides of the slice. GeoStudio, for computational reasons, adopts the b) approach. As a consequence, if the slope is saturated, the saturated unit weight of the material must be used.
- it would be good to verify that the pressure along the considered slip surface is consistent with what is expected from the hydrogeological knowledge of the site of interest.

1.2 GeoStudio SEEP/W tutorial

In the following sections a step-by-step tutorial is presented to solve the proposed exercise. Three different steps must be followed:

1. a pre-processing step, in which all the input data are introduced (geometry, material properties, ...);
2. a processing step, in which the problem is solved with the Finite Element Method;
3. a post-processing step, in which the obtained results are displayed and analyzed.

Creation of a new project, basic settings and saving

For creating a new project select the option SEEP/W as shown in Figure 2.

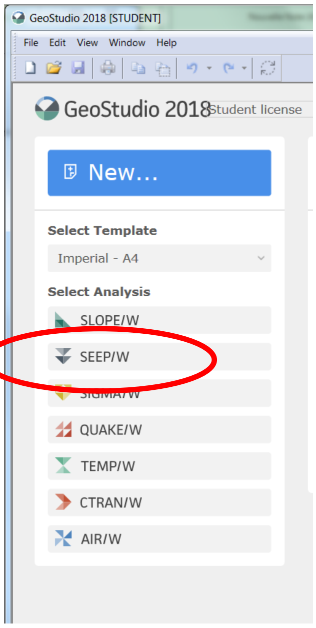

Figure 2: GeoStudio 2018 starting interface.

It is suggested to choose the basic units of measurements: 'View→ Units' (Figure 3).

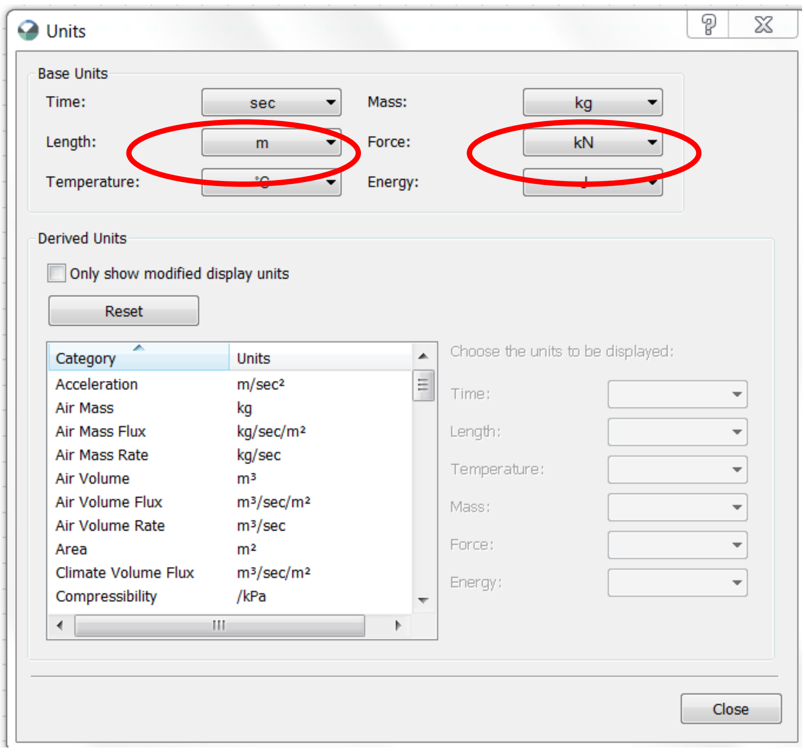

Figure 3: Units window.

The Grid spacing can be changed by using the command 'View→ Grid' (Figure 4).

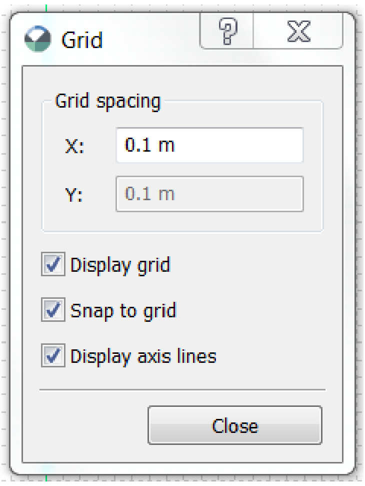

Figure 4: Grid window.

Afterwards, save the project in your working folder: *namefile*.gsz, as a GeoStudio file (*.gsz). Remember to save regularly your project (File→Save).

<u>Pre-processing step</u>

Define geometry

The command 'Draw→Regions→Polygonal' allows the geometry to be defined manually (Figure 5). Then, the 'Enter coordinate' cell in the bottom left can be used for this purpose. Starting from the origin *O*, referring to the given geometry (Figure 1), the following points must be added: (0;0), (13.9;8), (40;8), (40;-15), (-25;-15), (-25;0) (0;0). The last point needs to be connected to the origin.

Afterwards, the axes of the reference system can be displayed by setting their minimum and maximum values of interest (Figure 6): ‘Sketch→Axes’.

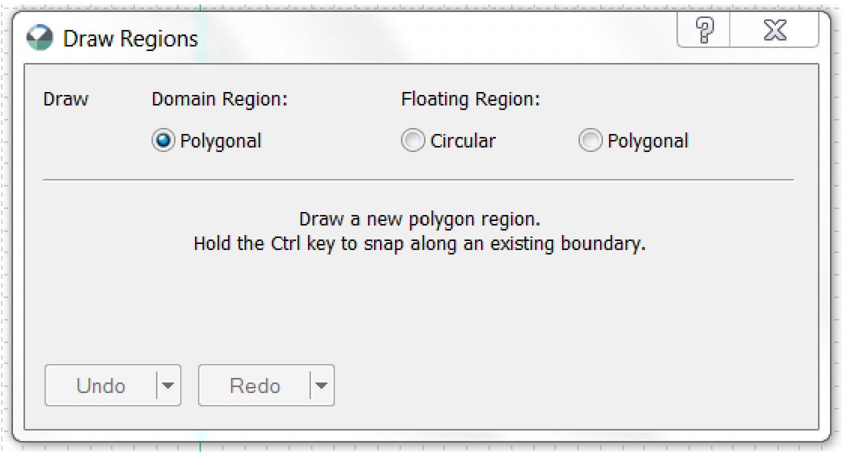

Figure 5: *Draw regions* window.

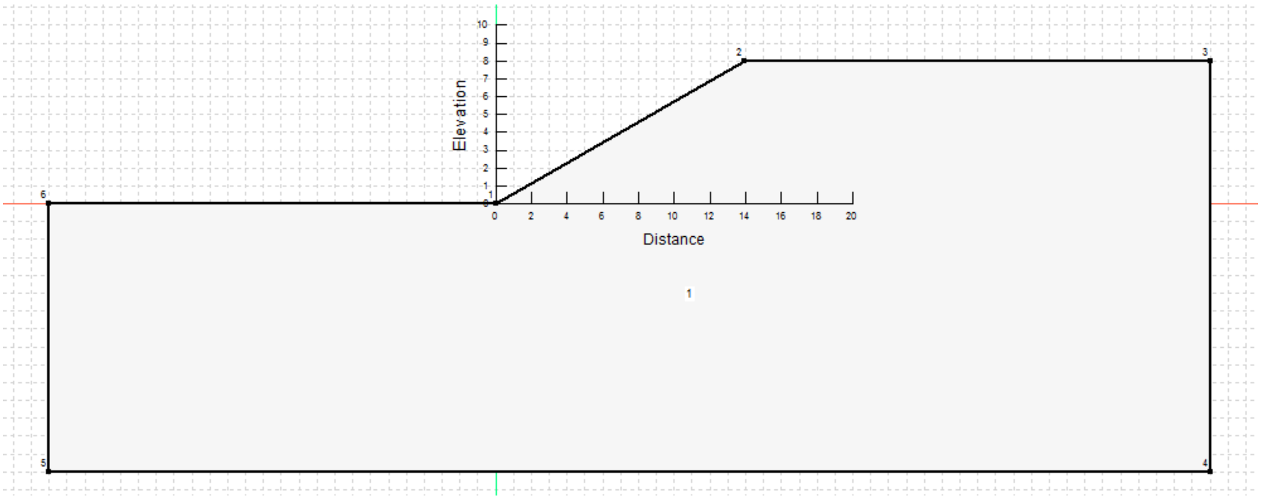

Figure 6: Geometry according to Figure 1 and Table 1.

Define material (hydraulic properties)

The command ‘Define→Materials’ allows to create a new material. A “Sandy silt” material is created and a material model of the type “Saturated” is selected (Figure 7).

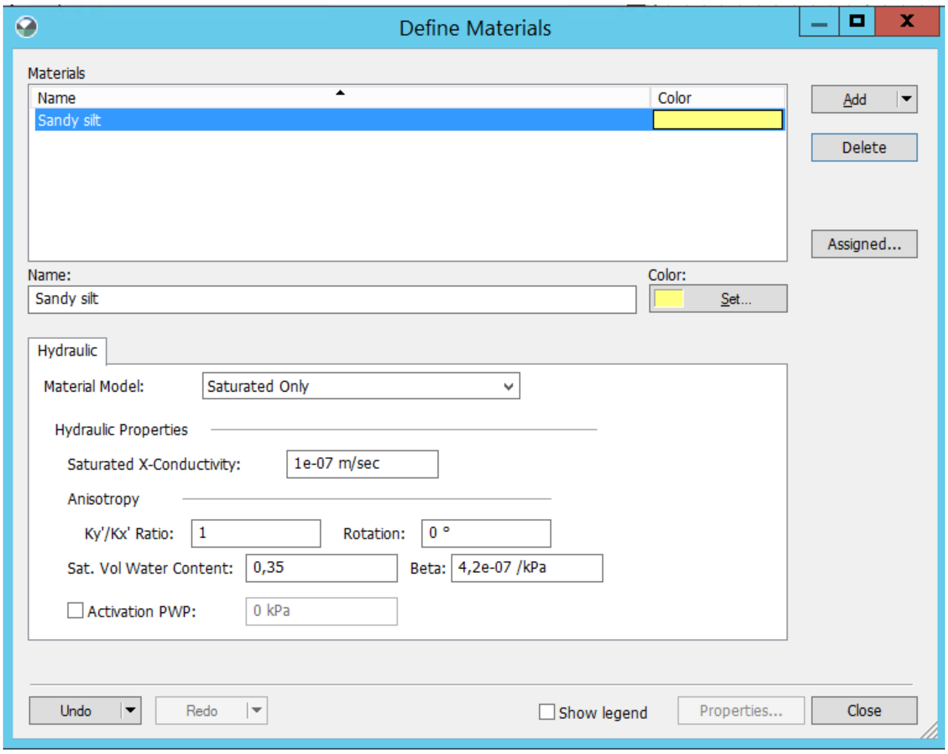

Figure 7: Define material (hydraulic properties)

The hydraulic properties of the material are defined in terms of:

- saturated hydraulic conductivity,
- saturated volumetric water content

thanks to the values provided in Table 1.

Assign the material

Assign the material to the region by selecting: 'Draw→Materials'. If the material is correctly assigned, the color of the slope will change (Figure 8).

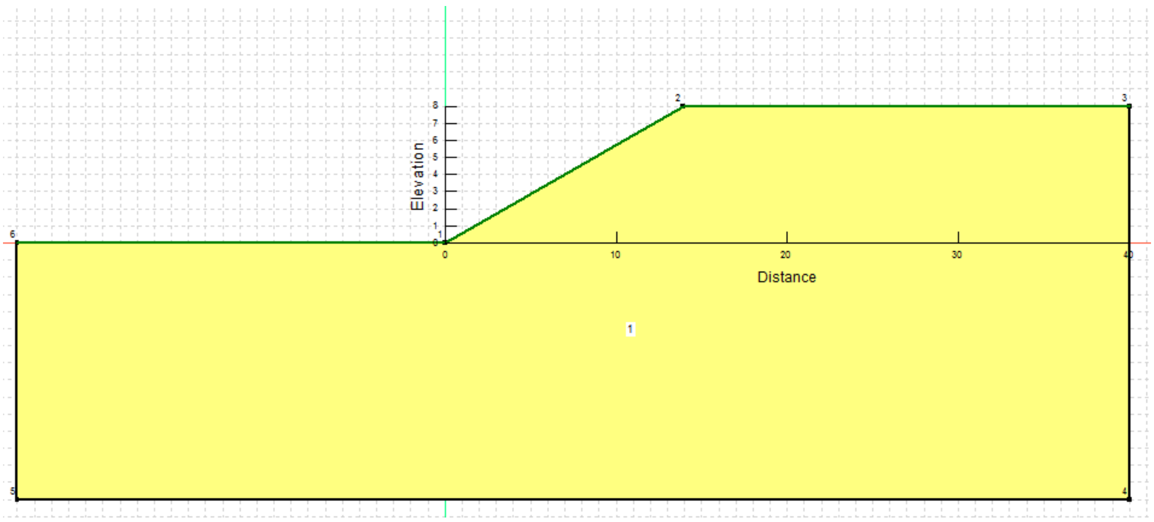

Figure 8: The material is assigned to the region of interest.

Define and assign the boundary conditions

Create the boundary conditions (BC). To do so click: "Define→Boundary Conditions" and follow the suggestions given in Figure 9.

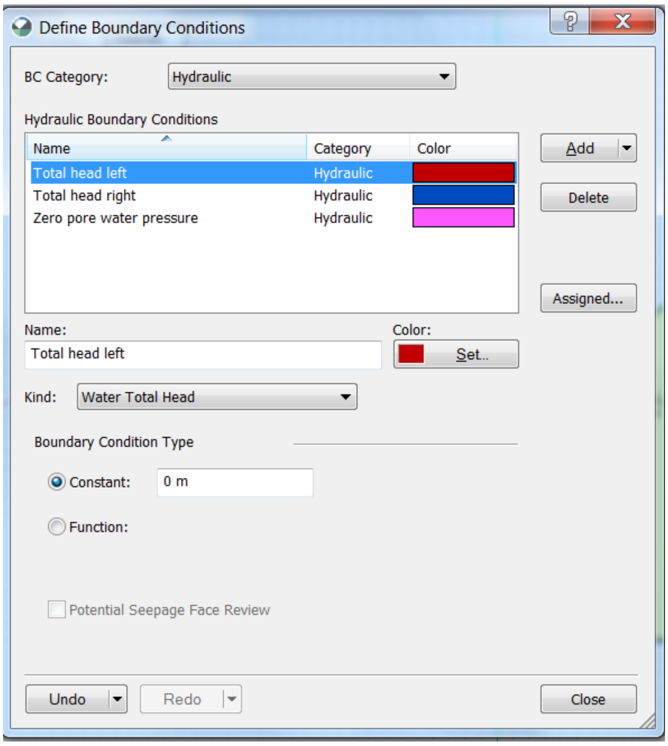

Figure 9: Define boundary conditions window.

The BCs can be assigned by selecting: "Draw→Boundary Conditions". If the BCs are correctly assigned, the color of the corresponding lines will change (Figure 10).

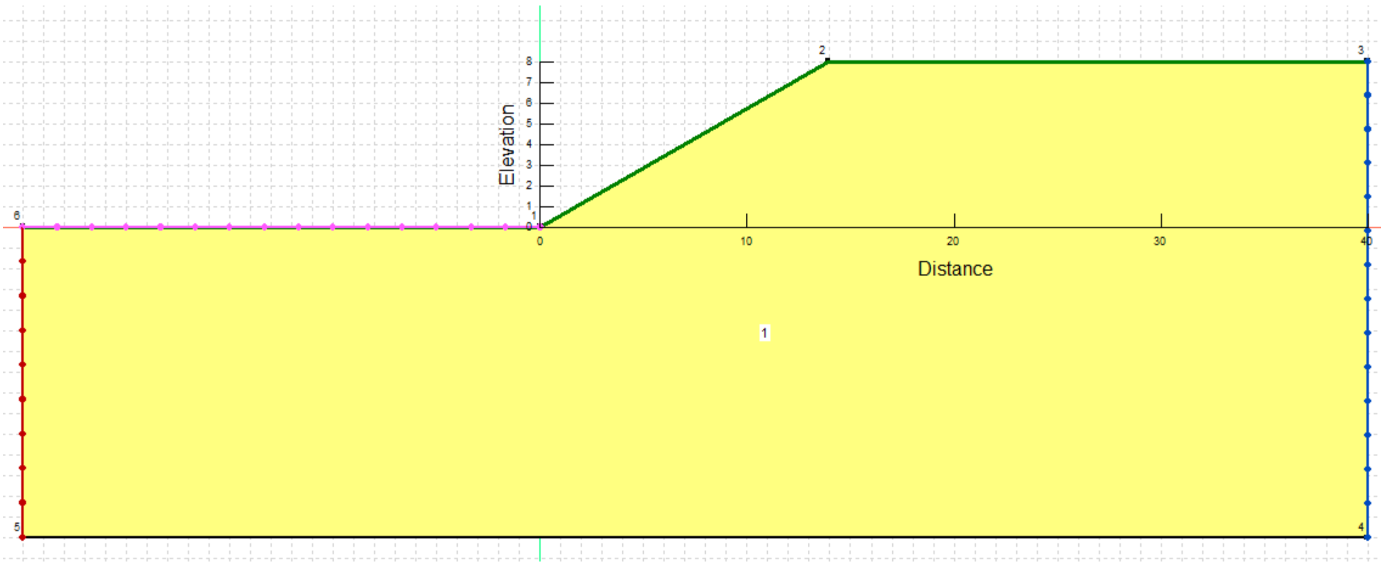

Figure 10: The boundary conditions are assigned to the problem of interest.

Draw the mesh

Draw the mesh by clicking on “Draw→Mesh”. Specify an “Approximate global Element Size” of around 2 m (to note: the student version limit the number of elements to 500. Choose the element size in order to have less than 500 elements) (Figure 11).

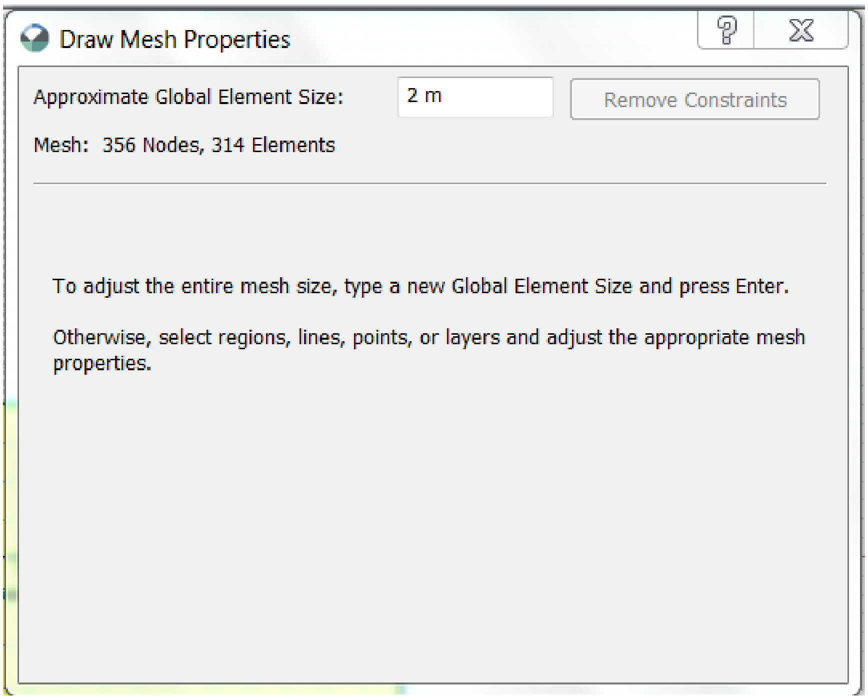

Figure 11: Draw mesh window for solving the hydraulic problem.

<u>Processing step</u>

Run the numerical simulation. To do so go in the “Solve Manager” window (left of the screen) and click on “Start” (Figure 12). The simulations will run.

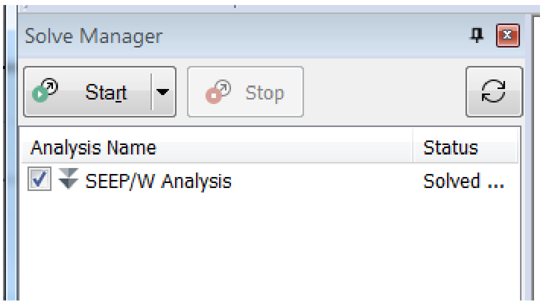

Figure 12: The “Solve Manager” window.

<u>Post-processing step</u>

To see the results, click “Draw→Contours” and select the quantities of interest.

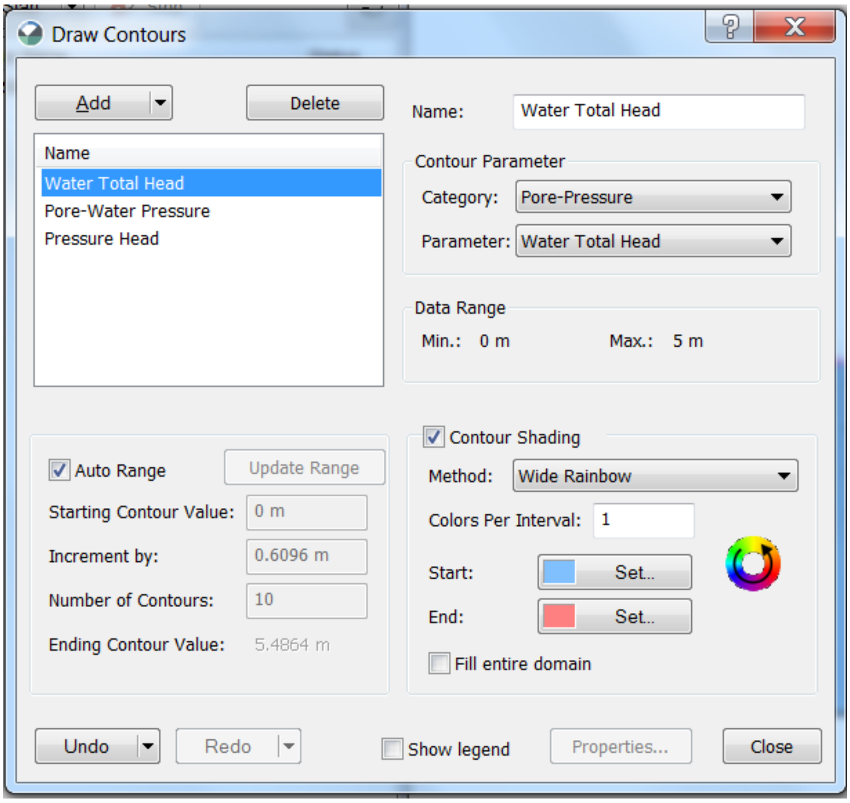

Figure 13: The “Draw Contours” window.

1.3 GeoStudio SLOPE/W tutorial

Once the distribution of pore water pressure is known from the seepage analysis we proceed to calculate the mechanical problem. In the analysis explorer window (left side of the main screen) we choose the option ‘Define analyses’, and window as follows will appear. We choose the SEEP/W analysis as a parent model. In the analysis type we choose Bishop, then select PWP conditions that will be imported from the parent analysis.

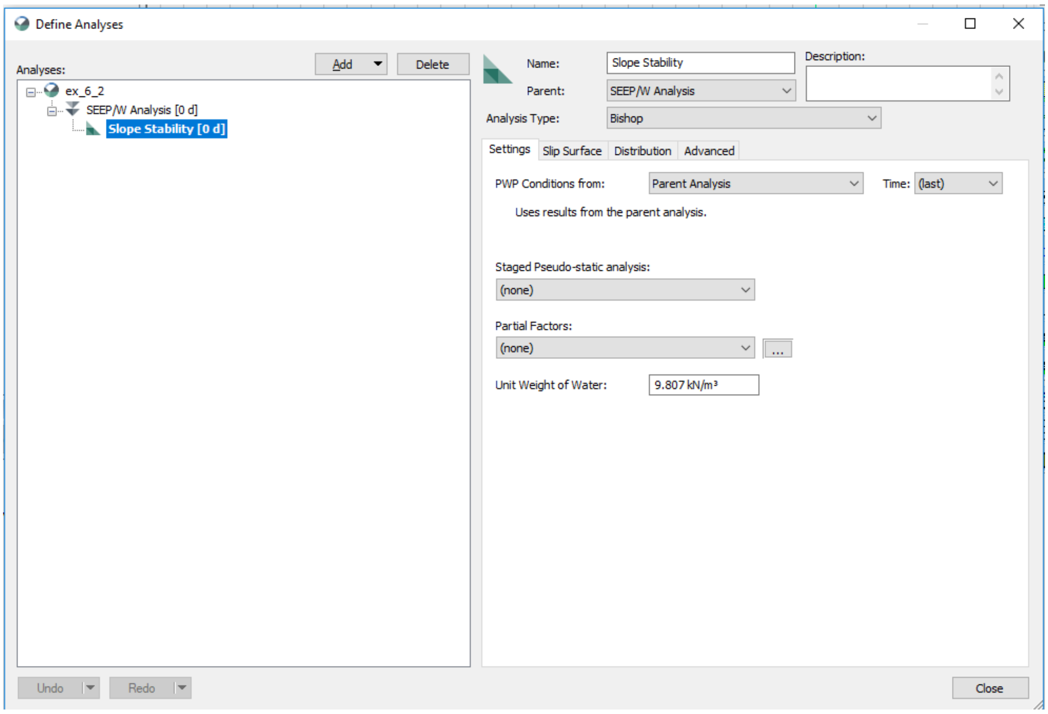

Figure 14: The “Define Analyses” window.

Next we define the slip surface options as shown in the following figure. We check the option ‘Grid and Radius’ so that we can specify the grid of central points and the grid of tangent points. Movement direction must be set to ‘from right to left’

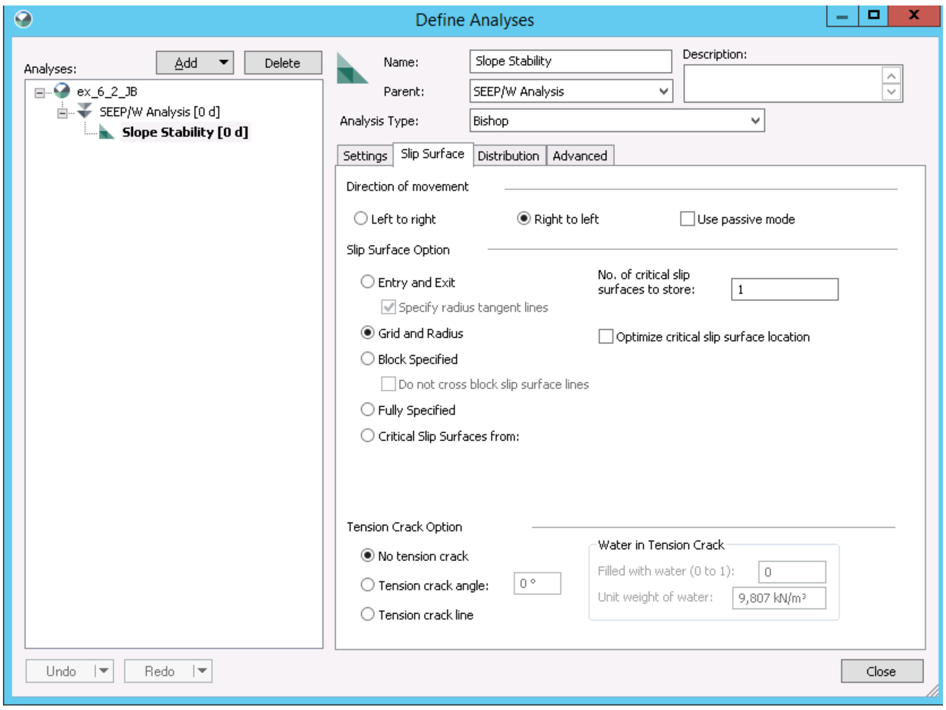

Figure 15: The “Define Analyses – Slip surface” window.

In the ‘Advanced’ tab we will choose 40 as a ‘number of slices’.

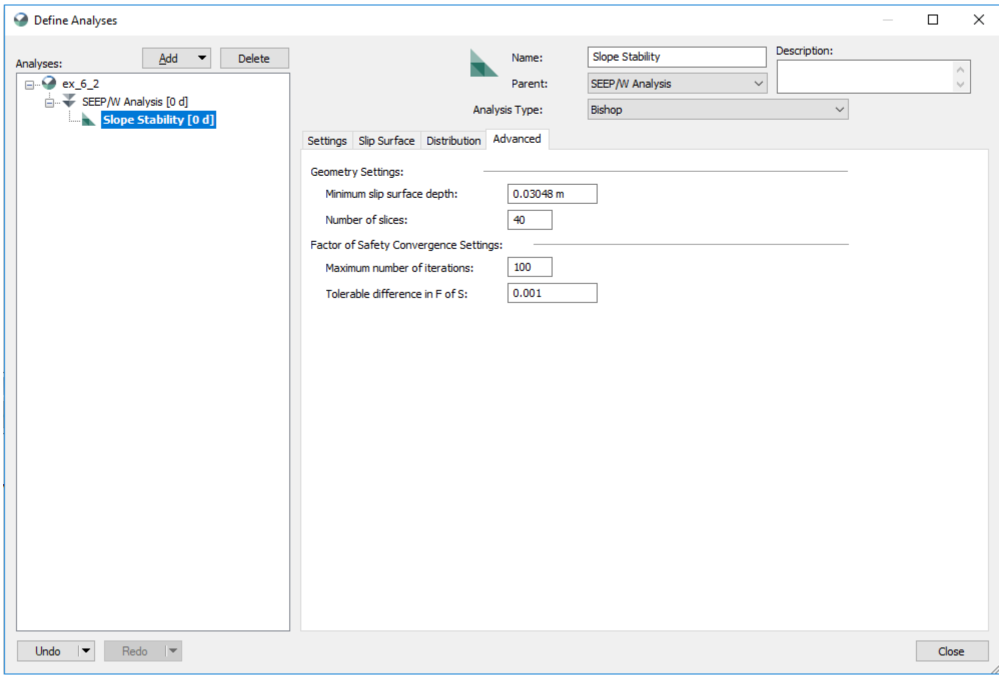

Figure 16: The "Define Analyses – Advanced" window.

Now we close the 'Define analyses' window and we go to 'Define – define materials' menu. Here we will select the Sandy silt material already defined in the previous analysis. Now we choose the 'Mohr Coulomb' as a 'Material Model'. We assign the parameters as given in Table 1.

The material is defined according to the given data (see Table 1 and Fig. 17).

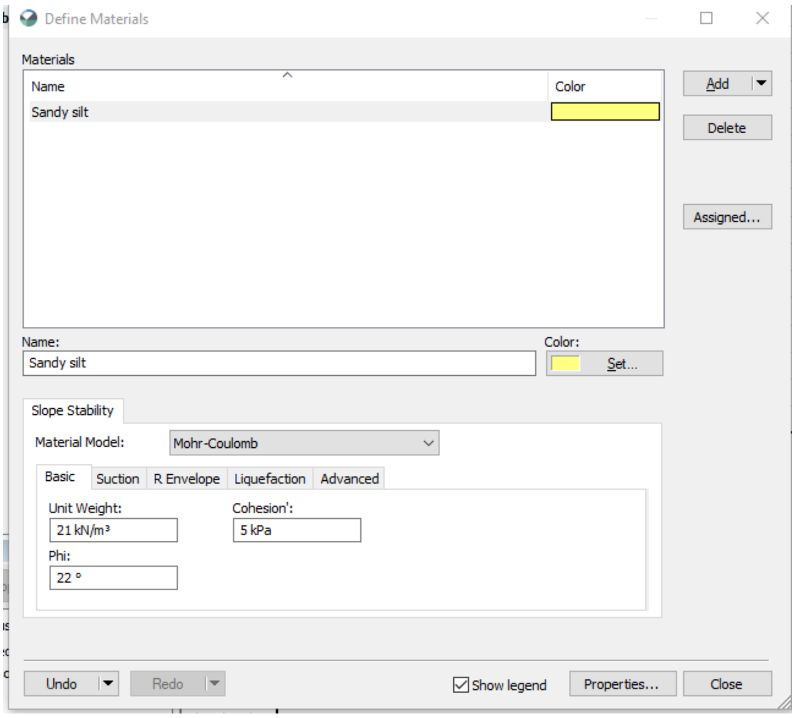

Figure 17: The "Define Materials" window.

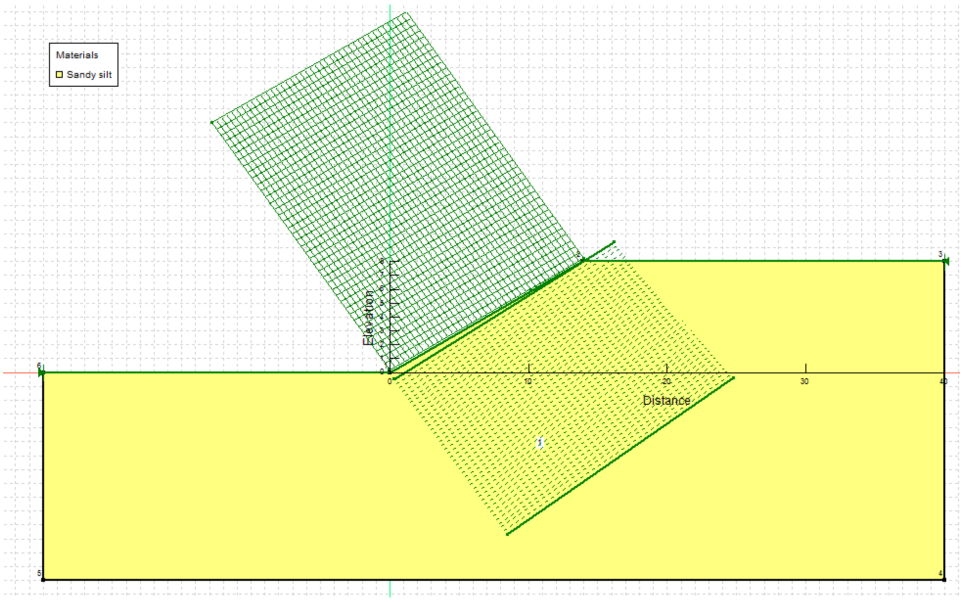

Figure 18: Sketch of the model

Processing step

Now the program is ready to start the computations. We check both the seepage analysis and the slope analysis boxes and we click the ‘start’ button in order to begin the calculations.

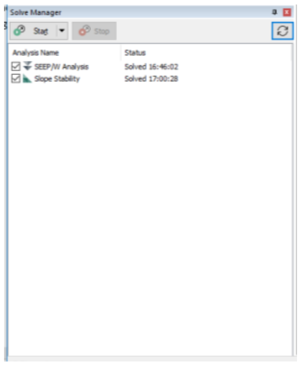

Figure 19: The “Solve Manager” window.

Post-processing step

After the program finishes the calculation process, the results can be visualized.