Stability with perched water table

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Introduction

The objective of this example is to demonstrate how to use computed pore-water pressures from a water transfer analysis in a SLOPE/W stability analysis. This steady-state water transfer analysis creates a perched water table under long-term net infiltration of precipitation. This perched condition is properly handled by using the water transfer results from SEEP/W and applying them directly to the SLOPE/W analysis. This example illustrates a scenario where it is not possible to use a piezometric line to establish the in-situ pore-water pressures.

Numerical Simulation

The problem configuration is depicted in Figure 1. The slope includes a less permeable layer in the middle portion of the slope. A steady-state analysis was used to simulate the long-term pore-water pressure conditions in the slope created by infiltration into the upland. The infiltration is simulated using a unit flux (q) boundary condition of 3×10^{-5} m/day that is applied to the upland of the slope. The slope has a potential seepage face boundary condition applied, with a zero pressure boundary condition applied to the toe surface. An initial water table is applied to the domain along the elevation of the toe or 10 m. The specified boundary conditions, particularly the imposed infiltration, and the layer of material with low permeability can lead to the formation of a perched water table.

The hydraulic conductivity functions for each of the layers are shown in Figure 2. Both of the upper and lower layers are represented using the same hydraulic conductivity function with a saturated conductivity of 1×10^{-3} m/day. The middle, lower permeability layer is represented with a saturated conductivity of 1×10^{-5} m/day. Volumetric water content functions are not required since it is a steady-state analysis.

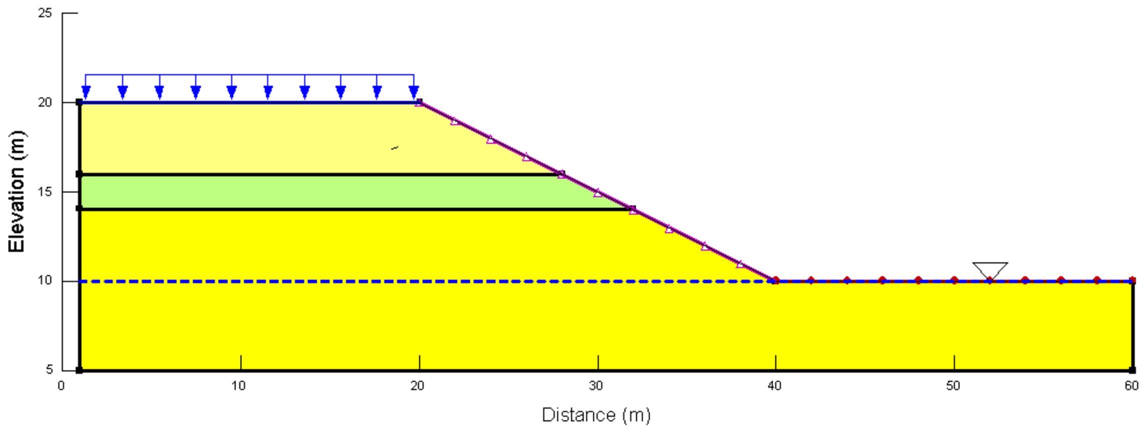

Figure 1. Problem configuration.

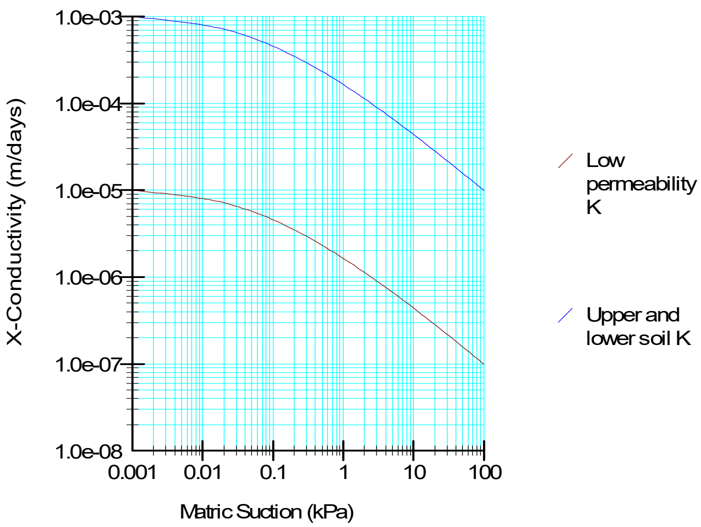

Figure 2. Hydraulic conductivity functions.

The resulting pore-water pressures can be used in a SLOPE/W stability analysis by making the SEEP/W water transfer analysis the parent of the SLOPE/W analysis and indicating that the pore-water pressure conditions should come from the Parent Analysis (Figure 3). The SLOPE/W analysis uses the Morgenstern-Price analysis method, with the slip surface regions defined using the entry-exit method in the left to right direction (Figure 4). The Mohr-Coulomb material model is used to define all three of the materials. Table 1 outlines the parameters used for each of the materials in the stability analysis.

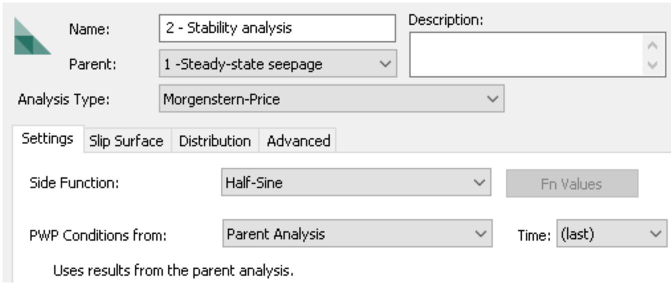

Figure 3. Using initial PWP conditions from the Parent water transfer analysis.

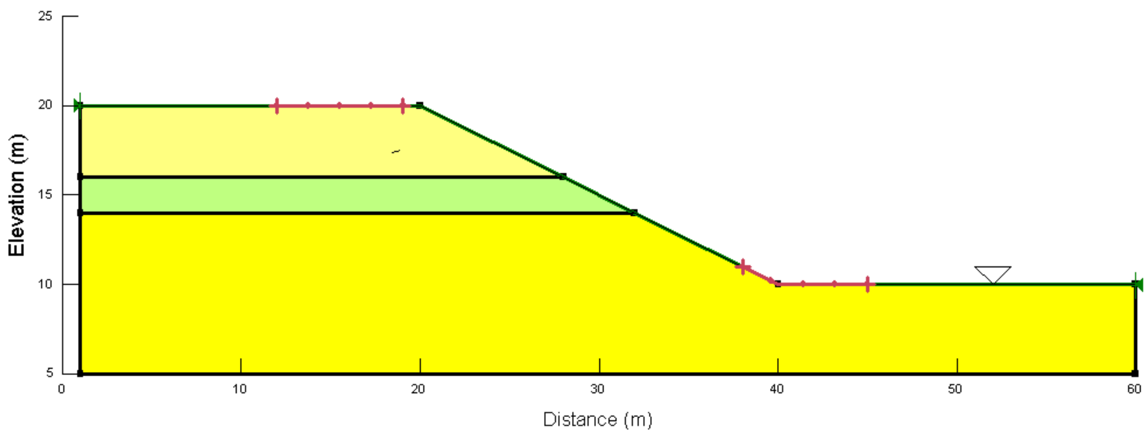

Figure 4. Entry-exit definition for the slope stability analysis.

Table 1. Mohr-Coulomb material properties for each of the layers.

Material	Soil unit weight (kN/m3)	Phi (degrees)	Cohesion (kPa)	Phi B (degrees)
Upper layer	18	25	5	15
Low permeable, middle layer	19	20	5	15
Lower layer	20	26	10	0

Results and Discussion

The resulting pore-water pressure conditions for the water transfer analysis are shown in Figure 5. The contours are drawn in such a way that only the zones with positive pore-water pressures are displayed, which clearly shows the perched water table zone.

The infiltration enters the slope through an unsaturated zone. Once it reaches the perched saturated zone, it migrates down and to the right. The water moves from the perched saturated layer by either passing through the underlying unsaturated zone to reach the regional groundwater, or by exiting the face of the slope. This example illustrates the influence of a natural slope's stratigraphy on the development of atypical pore water pressure conditions (e.g., perched water table) and exfiltration along the slope face.

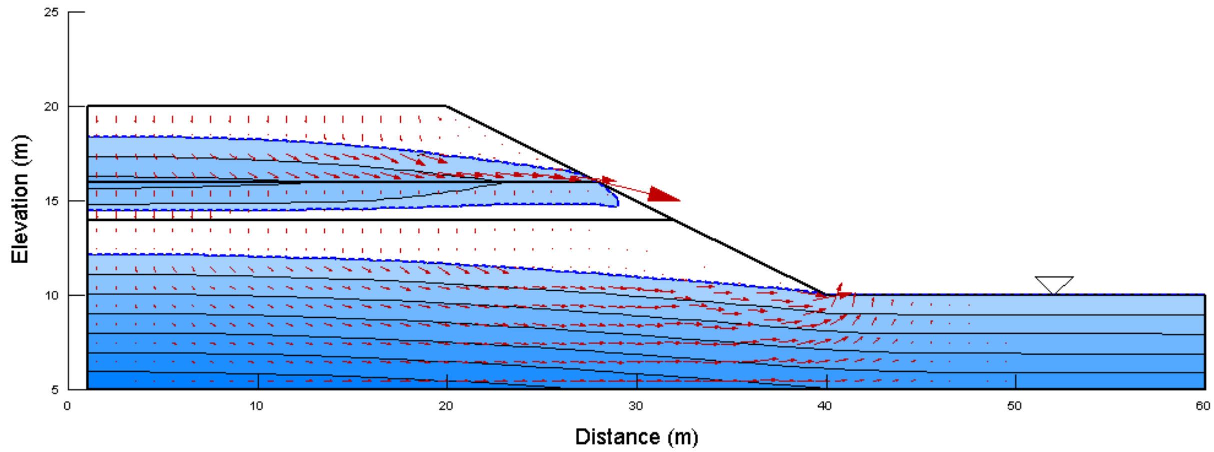

Figure 5. Perched positive ground water conditions.

The critical slip surface generated given these pore-water pressures is shown in Figure 6. The simulated slip surface crosses the zero pressure contour three times. The factor of safety for the most critical surface is 1.564.

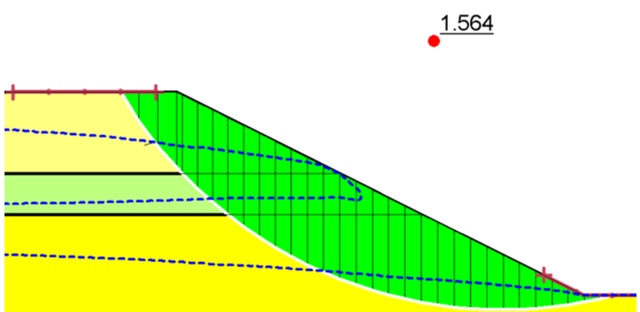

Figure 6. Slip surface crossing the zero-pressure contour three times.

A plot of pore-water pressure along the slip surface produces the graph in Figure 7. The pore-water pressure is negative at the crest of the slip surface, positive in the perched water table zone, negative below the perched water table zone, and positive when the slip surface enters the natural groundwater.

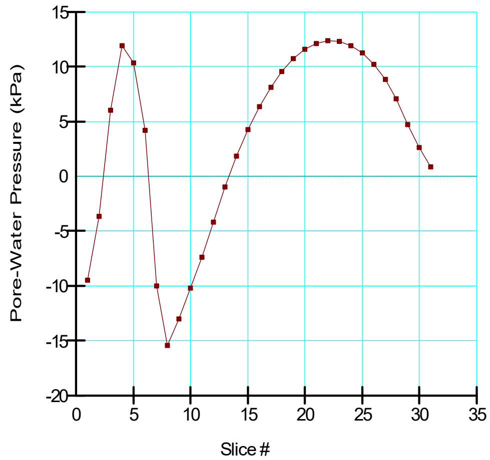

Figure 7. Pore-water pressure distribution along the slip surface.

Summary and Conclusions

This example illustrates the power of using computed pore-water pressure conditions from a steady-state SEEP/W water transfer analysis in a SLOPE/W stability analysis. The only other way of considering a perched water table, without using a water transfer analysis as the Parent Analysis, is to use a spatial pore-water pressure function in SLOPE/W to define the pressure head conditions at a series of points and then contour the data points. However, this is a more time consuming process.