GeoStudio Example File
Settlement due to Pumping

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Introduction

A powerful and flexible feature in SIGMA/W is the ability to compute the volume change arising from an independently computed change in pore-water pressure. The pore-water pressure change could, for example, come from a water transfer analysis. This example illustrates how to compute settlement due to pumping using a load-deformation analysis. The results are then compared to a fully coupled SIGMA/W consolidation analysis.

Numerical Simulation

The geometry and initial conditions for the model domain are as shown in Figure 1. The initial water table is defined at 2 m below the ground surface. There are four analyses in the GeoStudio Project (Figure 2). An In situ analysis using the Gravity Activation procedure is used to establish the initial stresses and pore-water pressures in the ground. This analysis is set as the Parent for the subsequent three analyses.

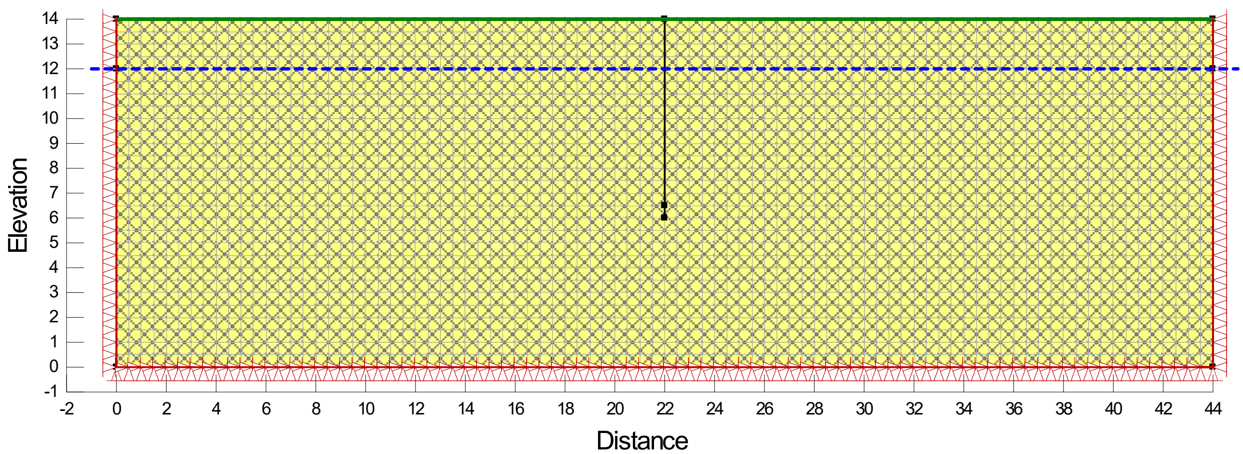

Figure 1. Problem configuration.

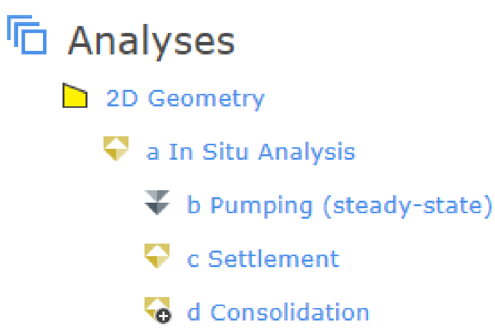

Figure 2. Analysis Tree for the GeoStudio Project.

The effect of the pumping is analyzed using a steady-state water transfer analysis with SEEP/W. Constant head boundary conditions are applied on the left and right boundaries so that the water level remains at the initial water table height of 12 m. The top elevation of the well screen is 6.5 m. We will make the assumption that the pumping will be controlled, so that the water level in the well will not drop below the top of the screen. This can be specified with an total head boundary condition equal to 6.5 m. This means the water pressure will be zero at the top of the well screen and increase hydrostatically with depth within the well screen.

Settlement due to pumping is modeling using a load deformation analysis (Analysis c). The initial stresses and pore-water pressures are defined from the Parent analysis (Analysis a). The final pore-water pressure conditions is set to the last time step of the SEEP/W analysis (Analysis b). Pore-water pressure changes specified in a Load-Deformation analysis are accommodated by means of an automatic nodal force boundary condition. The change in stress is converted into an equivalent nodal force via formal numerical integration over the volume of an element. Changes within the unsaturated zone are weighted by the Effective Degree of Saturation since a volumetric water content function is defined for the material (see SIGMA/W Reference Book).

Analysis d computes settlement due to pumping using a SIGMA/W consolidation analysis type. A consolidation analysis solves the coupled stress-strain and groundwater flow equation, thereby calculating time-dependent deformation. Although Analysis d will provide a more accurate depiction of settlement, the results should be similar to Analysis c.

Results and Discussion

The resulting long-term (steady-state) pore-water pressure conditions in the water transfer analysis for the pumping phase are shown in Figure 3. Notice that the zero-pressure contour is above the well screen even though a zero-pressure was specified at the top of the well screen. This is the correct numerical solution, but perhaps not representative of actual field conditions. This response comes about in part due to the close proximity of the specified head conditions at the left and right boundaries. Physically, this means the end boundary conditions can supply sufficient water to create this situation. For actual field problems, the left and right boundaries should be further away. The results are, however, adequate for this illustrative example.

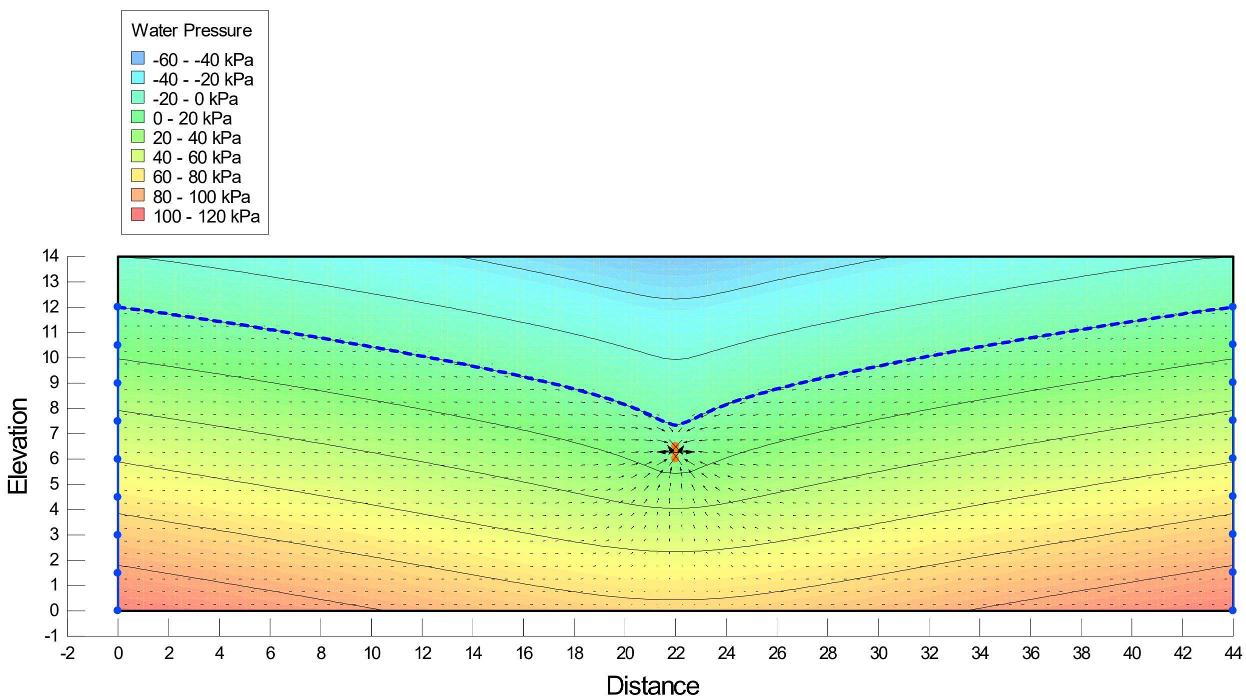

Figure 3. Steady state pore-water pressure contours for the pumping phase analysis.

Ground surface settlements for Analysis c and d are presented in Figure 4 and Figure 5, respectively. The consolidation analysis produced slightly less deformation because volume change in the unsaturated zone is more accurately captured by modeling the transient behaviour, verses imposing a single (and large) pore-water pressure decrement in a single load-step. Regardless, the results are equivalent for practical purposes.

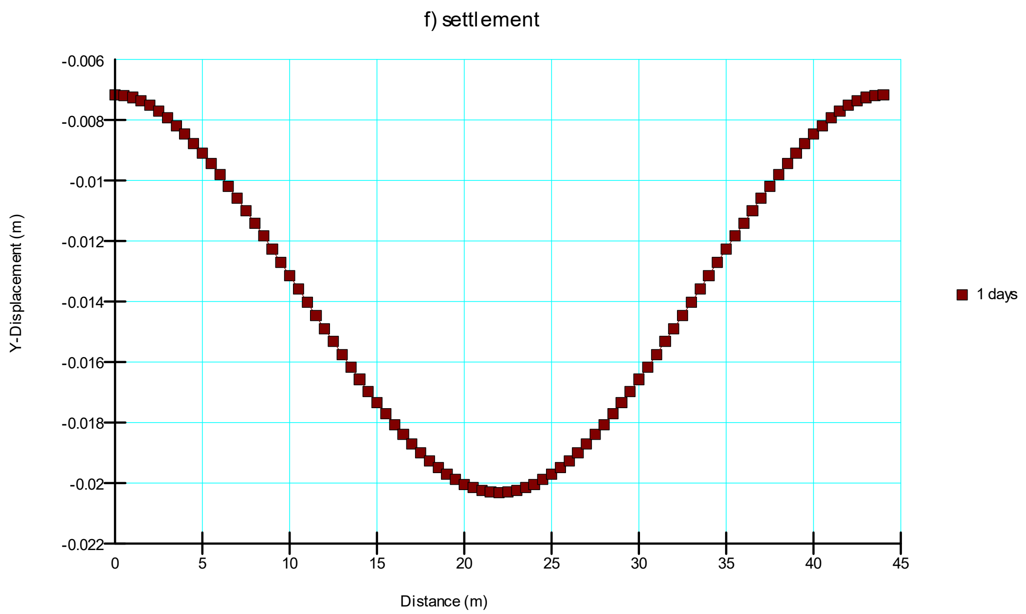

Figure 4. Settlement due to pumping for Analysis c.

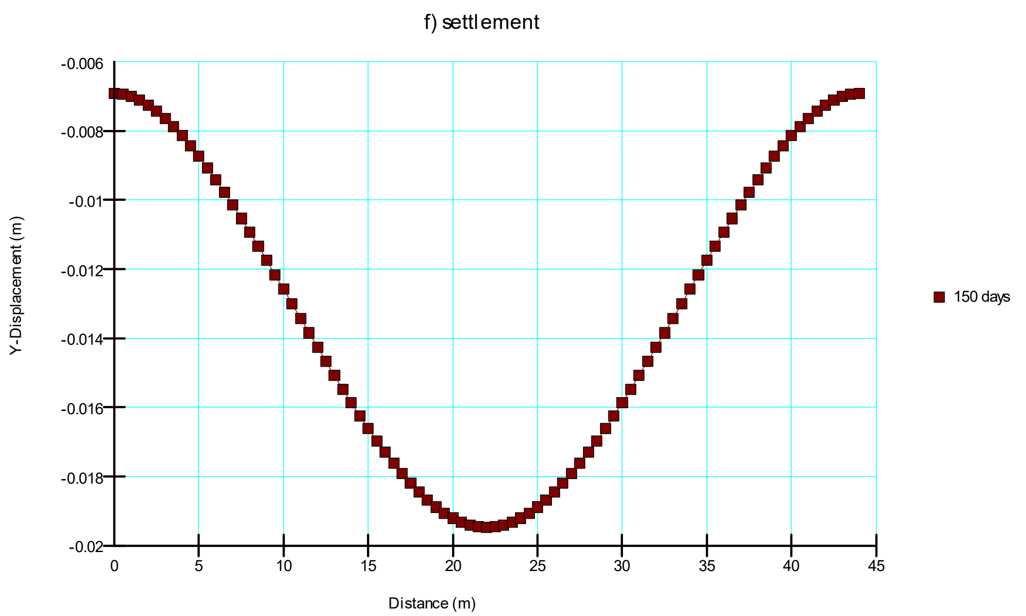

Figure 5. Settlement due to pumping for Analysis d.

Summary and Conclusions

This simple example illustrates a very powerful feature in SIGMA/W. A load-deformation analysis can be used to study the deformation due to changing pore-water pressure conditions separately from a consolidation analysis. This is particularly useful for complex saturated-unsaturated flow systems. It can lead to an understanding of the issues involved in a project in steps, rather than trying to do everything in one step.