1D Infiltration into Dry Soil: Benchmark

1 Introduction

Infiltration into unsaturated soil is a problem of great interest in the fields of hydrology, soil science, agricultural science, and geotechnical engineering. Some typical examples of practical problems include water movement in pavement sections, contaminant transport through the unsaturated zone, soil cover design, and irrigation and drainage studies. Interestingly, finite element solutions to infiltration problems involving dry soil can exhibit numerical problems (e.g. oscillation), mass balance errors, and can converge to the wrong solution. This deceptively simple problem is complicated by highly nonlinear hydraulic properties and relatively large pressure head gradients across the wetting front.

The objective of this example file is to benchmark SEEP/W against a semi-analytical solution for one-dimensional infiltration in unsaturated soil developed by Warrick et al. (1985). Details of the solution can be found in the original publication.

2 Boundary Conditions and Material Properties

The model domain comprises a 1 m high column that is 0.2 m wide and has an initial pressure head of – 8 m (Figure 1). The initial pore water pressure for the soil is established using the 'Activation PWP' feature under the KeyIn | Material properties dialogue box. This initial condition starts the soil from a dry state with a volumetric water content nearing residual (refer to the volumetric water content function). For the transient analysis, a zero pressure head is imposed at the top of the column, while the pressure head is maintained at – 8 m at the bottom. These boundary conditions simulate the infiltration condition as the negative pore water pressure at the top of the column is reduced to zero as soon as infiltration begins.

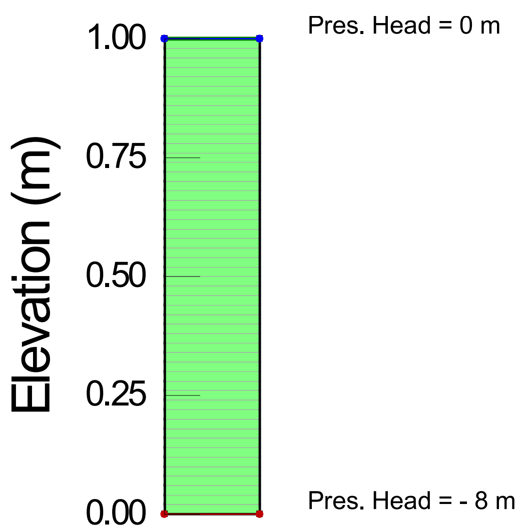

Figure 1 Model domain and boundary conditions.

The volumetric water content function for the soil used in the analysis was generated using the van Genuchten soil model. The key parameters are presented in Table 1 and are typical of a sandy clay loam. The hydraulic conductivity function was generated using the 'estimate' feature under KeyIn Hydraulic Conductivity Functions (see the book Seepage Modelling with SEEP/W 2007: An Engineering Methodology). The estimation of the function was completed using a K_{sat} of 1×10^{-6} m/s with the sandy clay loam volumetric water content function.

Table 1. Material properties used for soil.

Parameter	Value	Units
Saturated volumetric water content (θ_s)	0.363	
Residual volumetric water content (θ_r)	0.186	
α	9.81	1/kPa
n	1.53	
Sat. Hydraulic Conductivity (K_{sat})	1×10^{-6}	m/s

The problem was modeled using both coarse discretization and fine discretization. In the first case, the mesh comprised twenty elements in the vertical direction (i.e. Δ y = 0.05 m) and a total of 10 time steps. The fine discretization case used a vertical spacing of 0.02 m and 100 time steps. The total time duration for the analysis was 46,800 seconds.

3 Convergence Settings

Figure 2 presents the convergence settings for the analysis.

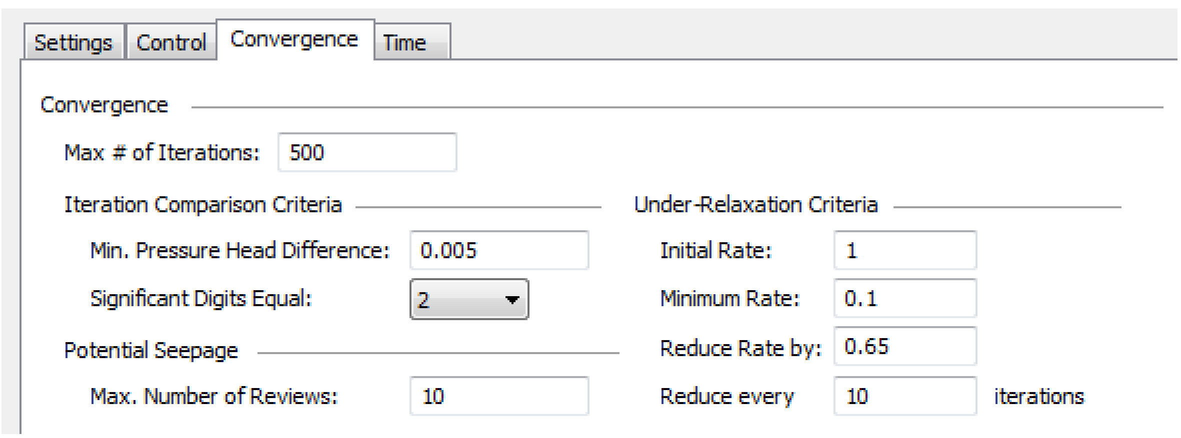

Figure 2 Convergence settings for analysis.

Figure 3 compares the actual K used at each Gauss integration point with the corresponding K from the specified K function. The two are the same indicating convergence was achieved.

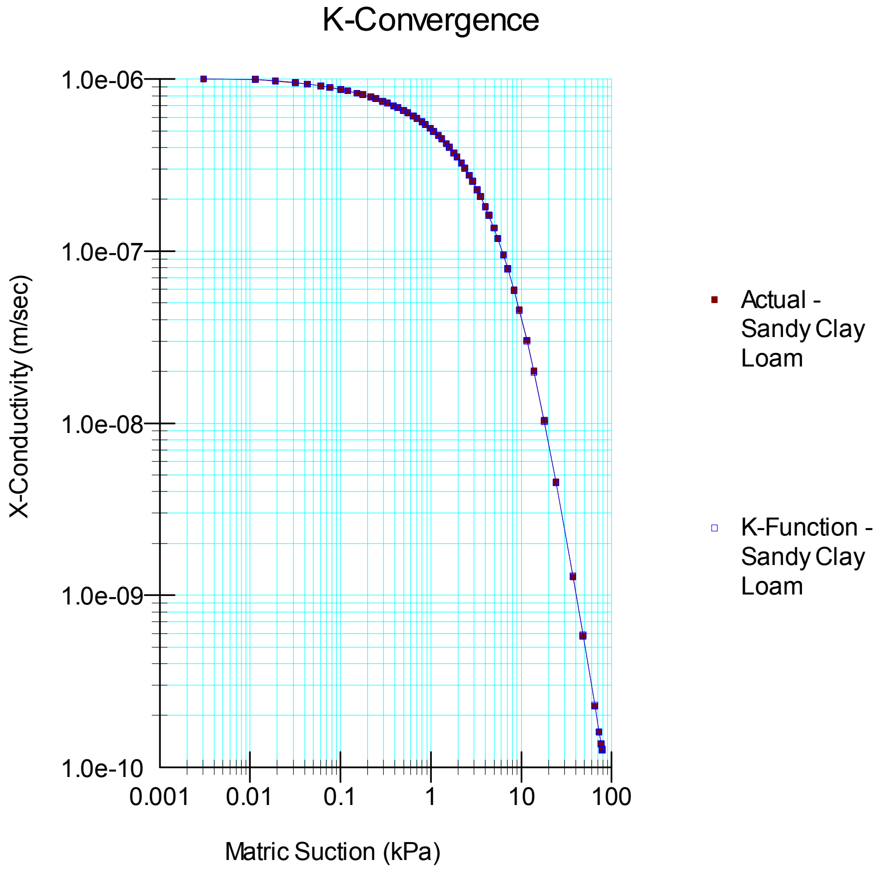

Figure 3   Actual K compared with the function K

4 Results and Discussion

Figure 4 presents the modeled results using fine and coarse discretization along with the semi-analytical solution from Warrick et al. (1985). Both levels of discretization yield a correct solution, although the coarse discretization produces a wetting front that is more diffuse than the actual solution. Additional mesh and time step refinement cause the wetting front to rotate about the correct elevation.

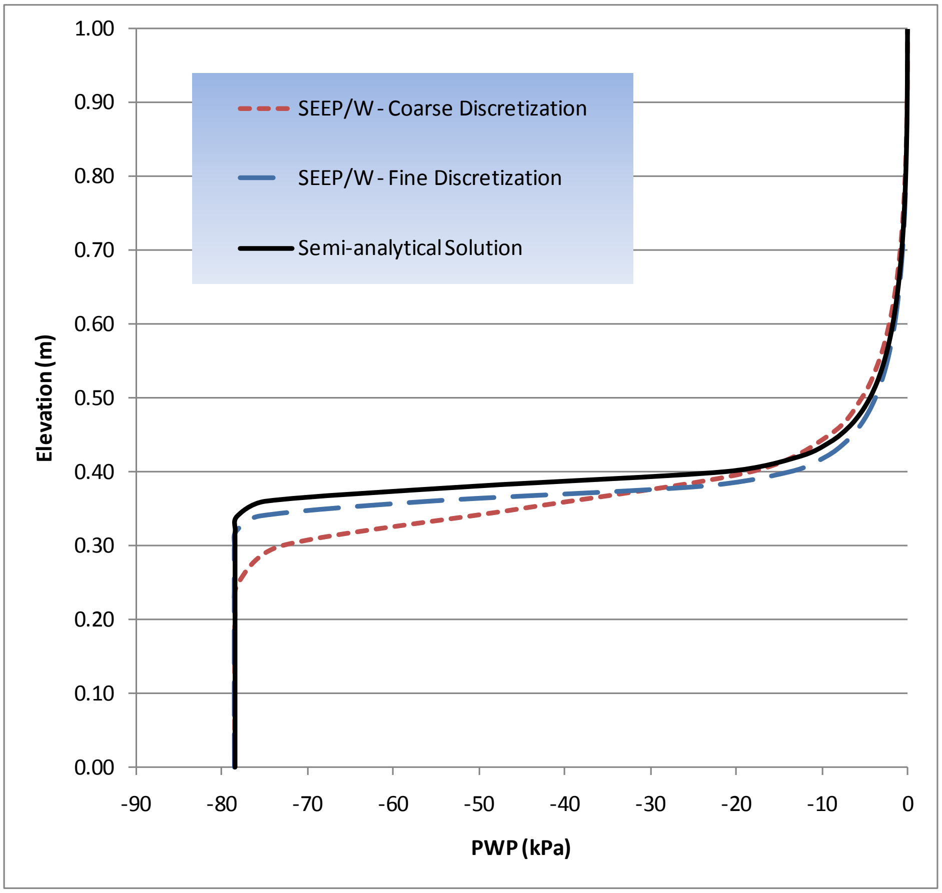

Figure 4 Vertical profiles of pore water pressure.

5 Concluding Remarks

SEEP/W is capable of modeling infiltration into a dry soil, which can be a challenging problem due to non-linearity in the hydraulic functions and steep hydraulic gradients at the edge of the wetting front. The results demonstrate that a correct solution is produced even with fairly coarse discretization (spatial and temporal), although the accuracy of the wetting front elevation is improved with mesh and time step refinement.

6 References

Warrick, A.W., Lomen, D.O., and Yates, S.R. 1985. A generalized solution to infiltration. Soil Science Society of America Journal, 49: 34 – 38.