Earth dam – transient flow analysis

Program: FEM – Water Flow

File: Demo_manual_33.gmk

Introduction

This example illustrates the application of the GEO5 FEM – Water Flow module to analyze transient (time dependent) seepage through a homogeneous earth dam. The geometry and material parameters are the same as in the engineering manual No. 32. In this case, however, we shall search for the evolution of phreatic line in time. The analysis provides the location and shape of the phreatic line, distribution of pore pressure, water flow velocities and total fluxes at model boundaries at specified times instances.

Task input

Consider an earth dam described in the engineering manual No. 32. Determine the location and shape of the phreatic line at the following time instances: 1 hour, 1 day, 7 days, 3 months and 1 year after a sudden increase of water table in the reservoir from 2 to 9 m. Determine the time needed to reach the steady state flow.

Analysis – entering input data

When defining the geometry and material parameters we proceed in the footsteps of the Demo_manual_32.gmk example and choose the *Transient water flow* analysis in the Topo->Settings regime. We also check the *Allow for inputting water in the 1st stage by performing Steady state water flow analysis* option.

Calculation stage No. 1 – initial water table at 2 m above the reservoir bottom

Unlike the steady state water flow analysis, we are interested in the evolution of a certain variable in time starting from a given initial state. This state must be defined first prior to running the actual transient analysis. Choosing the *Allow for inputting water in the 1st stage by performing Steady state water flow analysis* option provides us with the distribution of initial pore pressure obtained by performing standard steady state water flow analysis in the 1st calculation stage both below (pore pressure) and above (suction) the current phreatic line.

Boundary conditions in the 1st calculation stage – steady state flow analysis

Boundary conditions as well as the analysis results in the 1st calculation stage are the same as in the 1st calculation stage of the Demo_manual_32.gmk example. The initial distributions of pore pressure and suction are plotted in the following two figures.
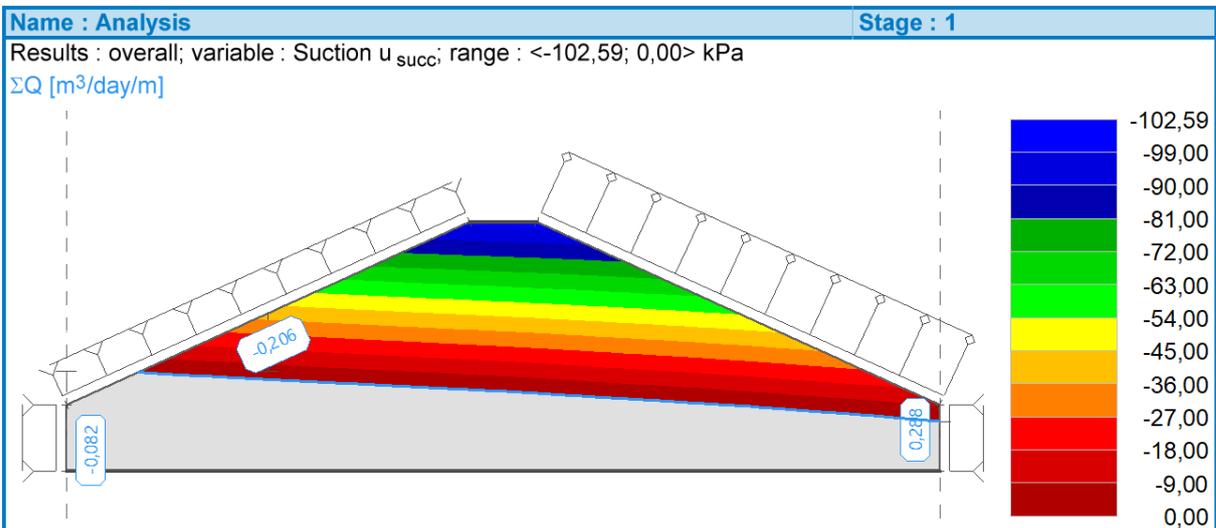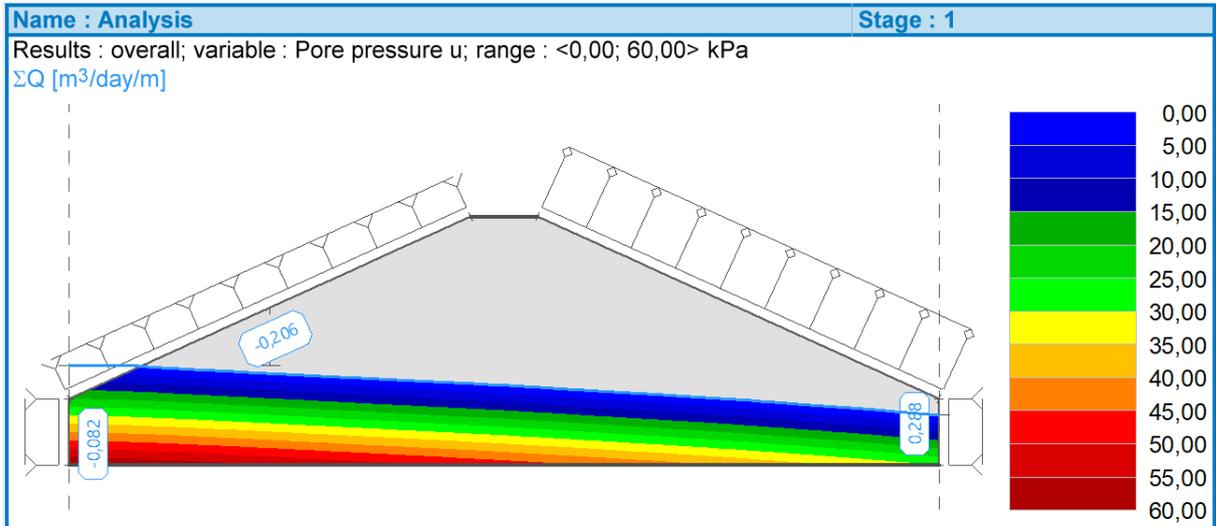
Distribution of pore pressure and suction (pore pressure above the phreatic line) in the 1st calculation stage – the initial steady state

Calculation stage No. 2 - water table raised to 9 m above the reservoir bottom

In the 2nd calculation stage, we consider a sudden rise of water table in the reservoir up to 9m. The types of boundary conditions remain the same. We only adjust the height of water table on the lines corresponding to upstream face from initial 2 m to final 9 m

Time step setting

Before running the Transient flow analysis, it is necessary to specify the *Time of stage duration* and the way the water flow boundary conditions should be introduced into the analysis. For the present analysis we set the *Initial time* step *t* = 1 hour = 0.04167 day (see the Analysis-Settings). The boundary conditions are *introduced at the beginning of stage.*

Note: The GEO5 FEM – Water Flow program allows for introducing the boundary conditions either instantly at the beginning of stage or they can be linearly increased during the course of a given stage

analysis. In this example we adopted the first option corresponding to a sudden increase of water table in the reservoir.

Results – 2nd calculation stage

It is evident from the figure below that during such a short time of analysis the steady state of flow has not been reached yet. Instead, the waterfront, identified by the current phreatic line, has progressed 1 m into the domain only. The difference between the inflow (1.05 + 44.89 m^3/den/m) and outflow (0.29 m^3/den/m) suggests high infiltration rate.
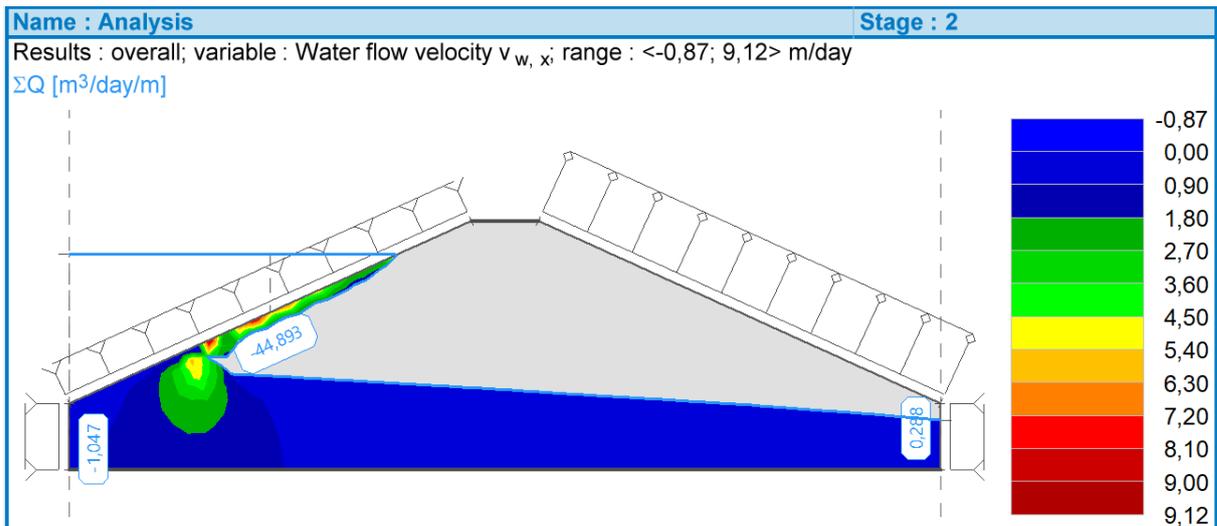
Distribution of the horizontal component of velocity after 1h from a sudden rise of water table in the reservoir

Subsequent calculation stages

In subsequent calculation stages we keep the boundary conditions unchanged. In stages 3 – 7 we wish to obtain the results at 1 day, 7 days, 28 days, 90 days and 365 days. The time at the end of a given stage corresponds to the sum of time intervals assigned to all preceding stages. The time duration of the 3rd stage is thus set equal to 0.9583 days, 4th stage to 6 days, 5th stage to 21 days, 6th stage to 62 days. The last 7th stage lasts 275 days. The variations of the phreatic lines at the end of individual stages display the following figures.

Results : overall; variable : Water flow velocity $v_{w, x}$; range : <0,00; 2,40> m/day

ΣQ [m³/day/m]

Results : overall; variable : Water flow velocity $v_{w, x}$; range : <-0,01; 1,08> m/day

ΣQ [m³/day/m]

Results : overall; variable : Water flow velocity $v_{w, x}$; range : <-0,10; 1,44> m/day

ΣQ [m³/day/m]

4
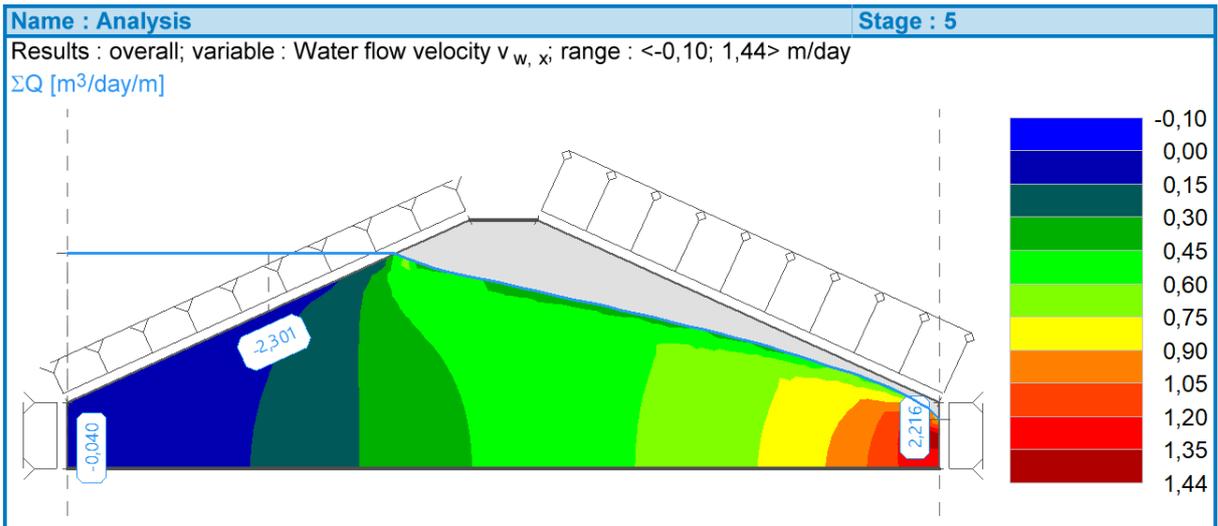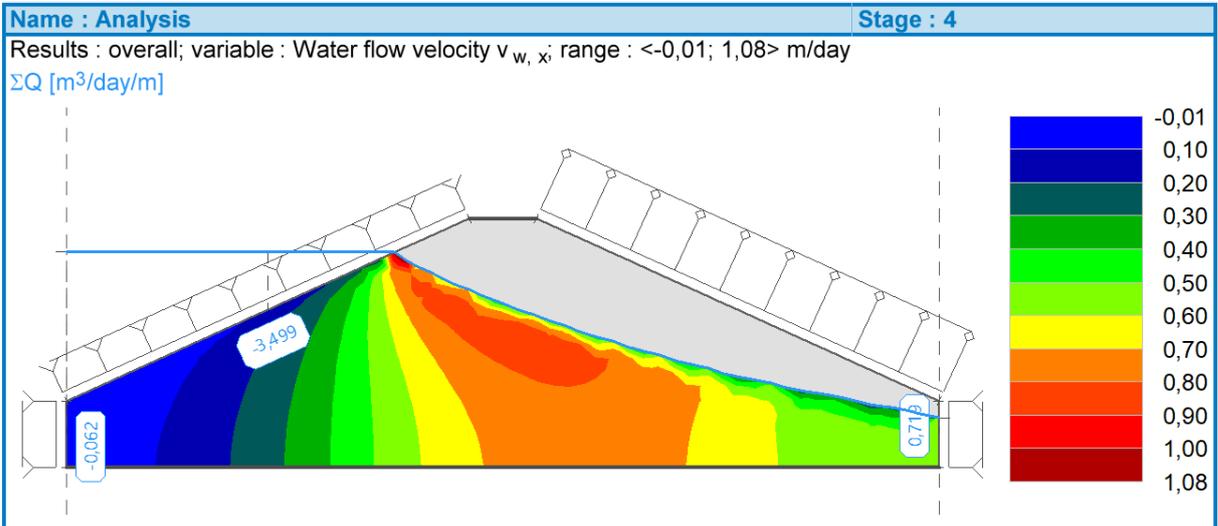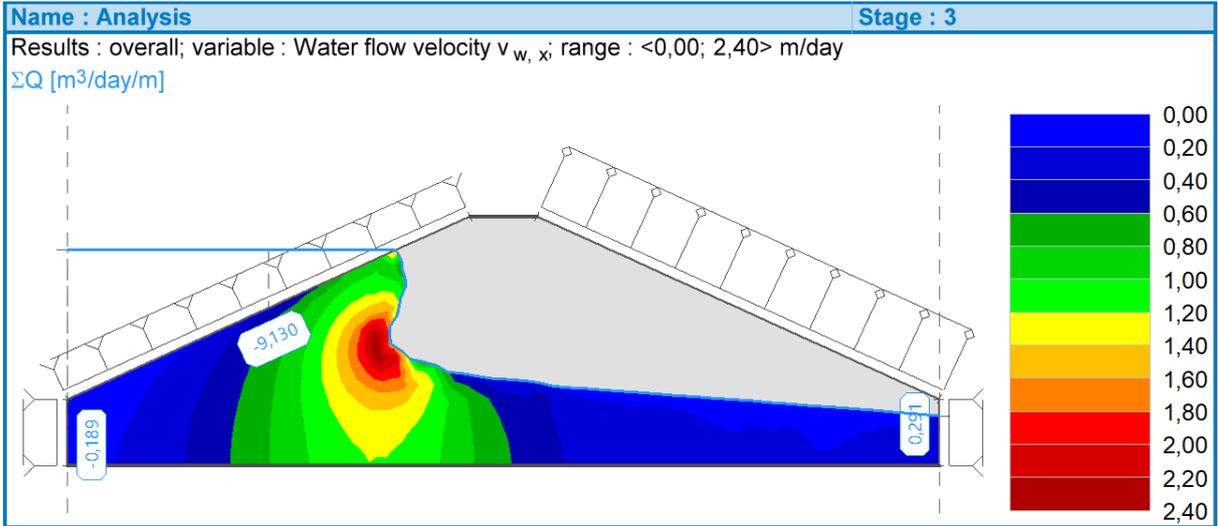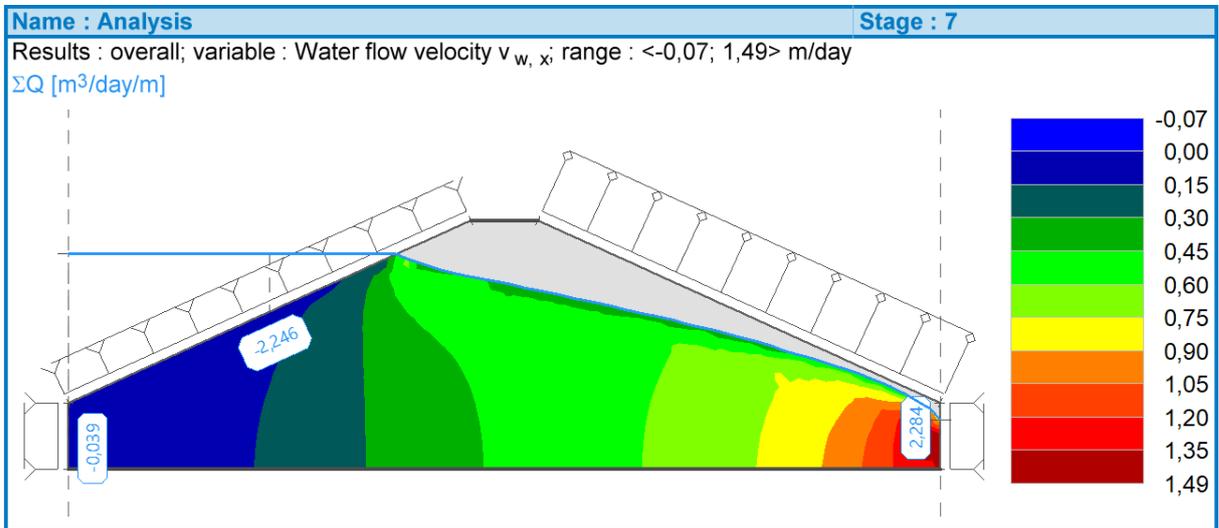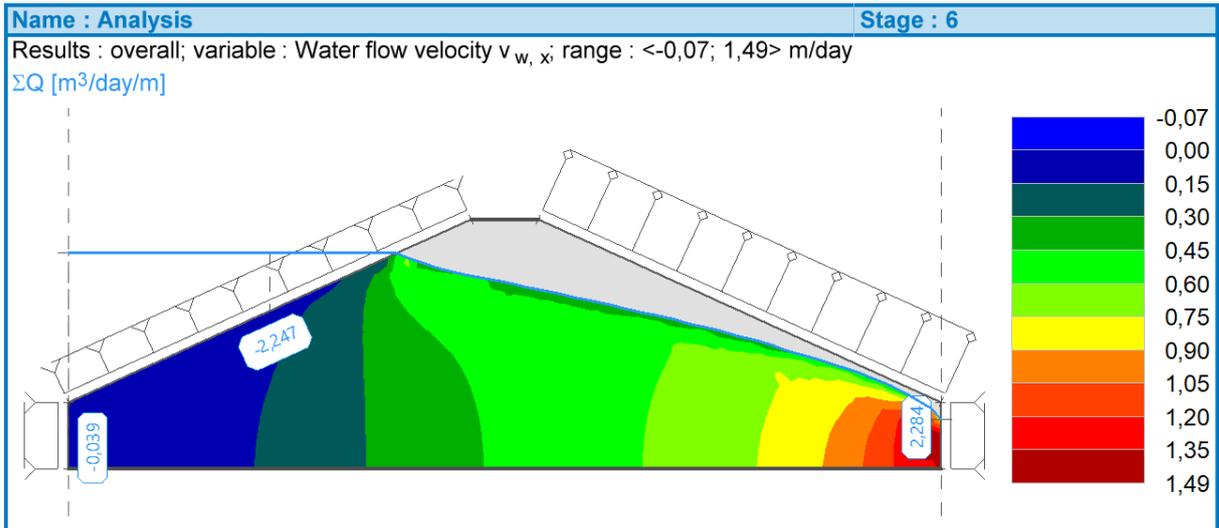
The shape of phreatic line and distribution of horizontal velocity in stages 3 – 7

It is clearly seen that no essential evolution of the phreatic line takes place during the last three calculation stages and that its location and shape practically correspond to the steady state conditions. This is supported also by comparing the amount of water entering and exiting the domain. The following table shows that during the initial stages of calculation the water infiltration is relatively fast and that the equilibrium between inflow and outflow (the steady state conditions) is achieved in the interval of 28 to 90 days after raising the water table in the reservoir.

Amount of water entering and exiting the domain for a particular duration of infiltration

Time	Inflow [m^3/day/m]	Outflow [m^3/day/m]	Difference [m^3/day/m]
1 hour	45.94	0.288	45.652
1 day	9.319	0.291	9.028
7 days	3.561	0.719	2.842
28 days	2.341	2.216	0.125
90 days	2.286	2.284	0.002

365 days	2.285	2.284	0.001

Note: The results corresponding to the last two calculation stages can be assumed to represent the steady state conditions and as such are identical to the results derived in the engineering manual No. 32. Here, the total flux into the domain equals 2.284 m^3/day/m and is exactly the same as the total flux out of the domain.

Conclusion

The steady conditions are reached after 90 days of infiltration. From practical point of view such conditions are reached already after 28 days, because after that the location and shape of the phreatic line are changed only marginally.