

# Seepage through a dam embankment

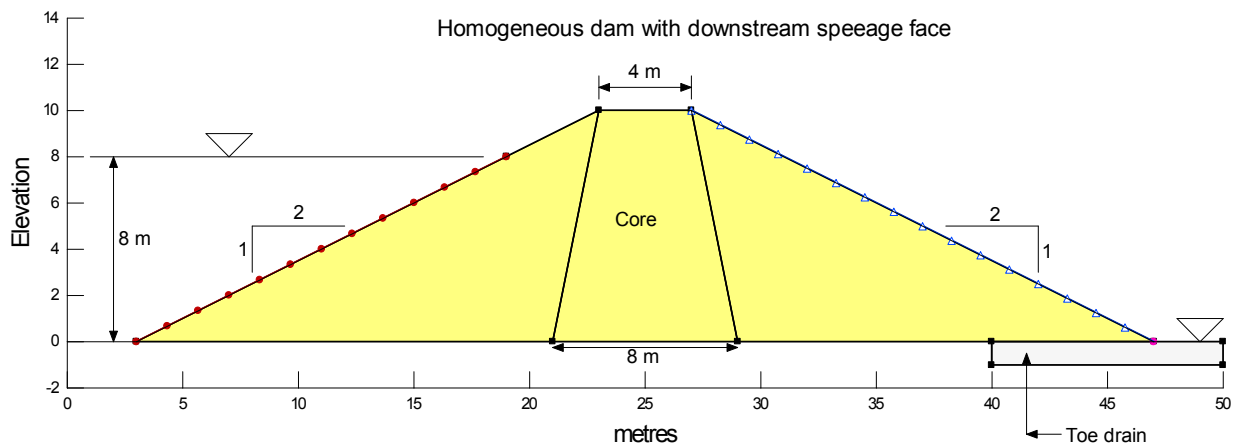
## 1 Introduction

The objective of this example is look at a rather simple case of flow through an embankment dam. One of the reasons for presenting this case is that it appears in most text books on seepage and consequently most SEEP/W users will have a good idea as to what the solution should look like.

The example illustrates how easy it is to find the downstream seepage face when the dam is all one material. Other features included are the inclusion of a toe under-drain and a central core with hydraulic conductivities lower than the shells of the dam.

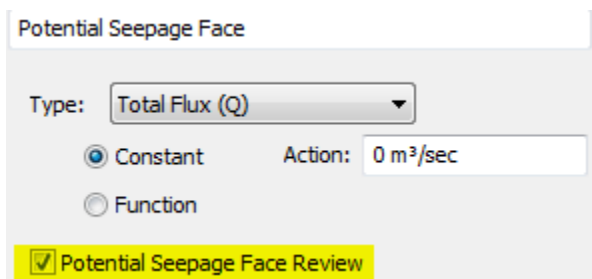
## 2 Geometry and boundary conditions

The problem geometry and boundary conditions are illustrated below, in Figure 1. To begin with we'll look at the homogeneous case. Regions have been created for a toe under-drain and a core but they will be assigned materials in a later analysis.



**Figure 1 Problem configuration**

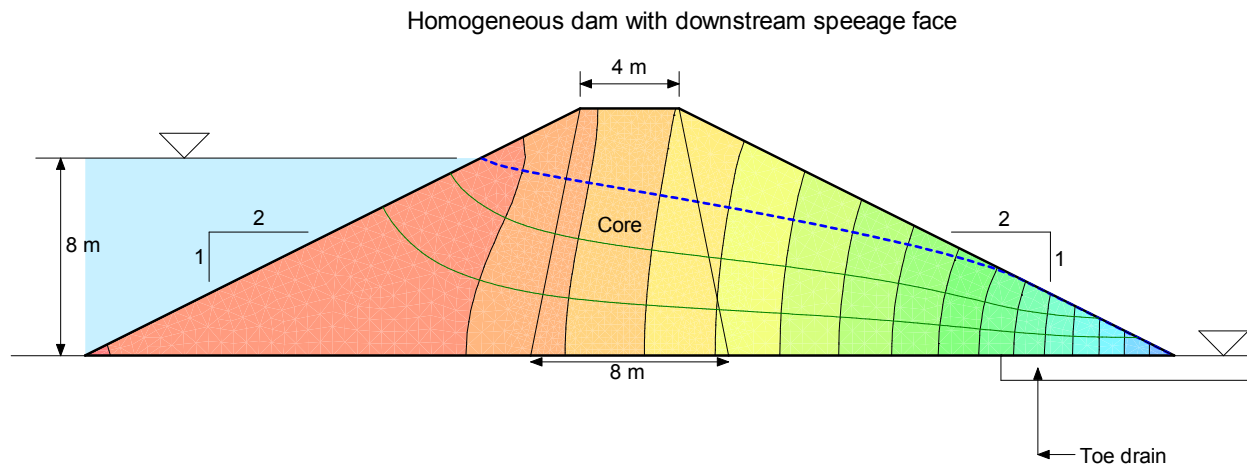
The upstream boundary nodes are designated as head boundaries with total head equal to the water level in the reservoir (8 m). The downstream toe is assigned a total head of 0.0 m ( $H = \text{elevation}$ ). The downstream slope is assigned a Potential Seepage Face type of boundary condition. A Potential Seepage Face Review boundary is a  $Q = \text{zero}$  boundary with the Potential Seepage Face Review option checked.



The material is considered to be silt. The GeoStudio VWC sample function for silt is used. The VWC function is not required for a steady-state analysis, but is used here to estimate a hydraulic conductivity function with a saturated  $K = 1 \times 10^{-5}$  m/sec.

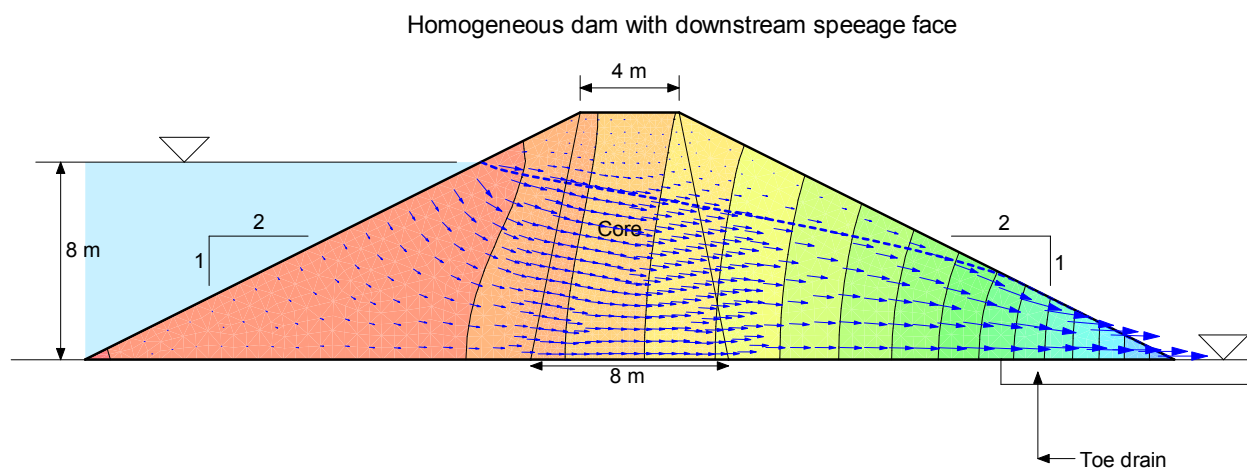
### 3 Homogeneous case

Figure 2 shows the results when the dam is all the same material and there is no under-drain. Shown are total head contours (or equipotential lines), and flow lines in the saturated zone. Placing the flow lines carefully makes it look like a flow net but it is important to remember this is not a true flow-net. The equipotential lines are as in a flow-net but the flow lines are only a pictorial representation of the path that a droplet of water would take from the reservoir to the downstream face. Stated in another way, the spaces between the flow paths are not strictly speaking flow channels as in a flow net. Notice the development of the seepage face on the downstream side.



**Figure 2 Steady-state seepage flow through a homogeneous embankment dam**

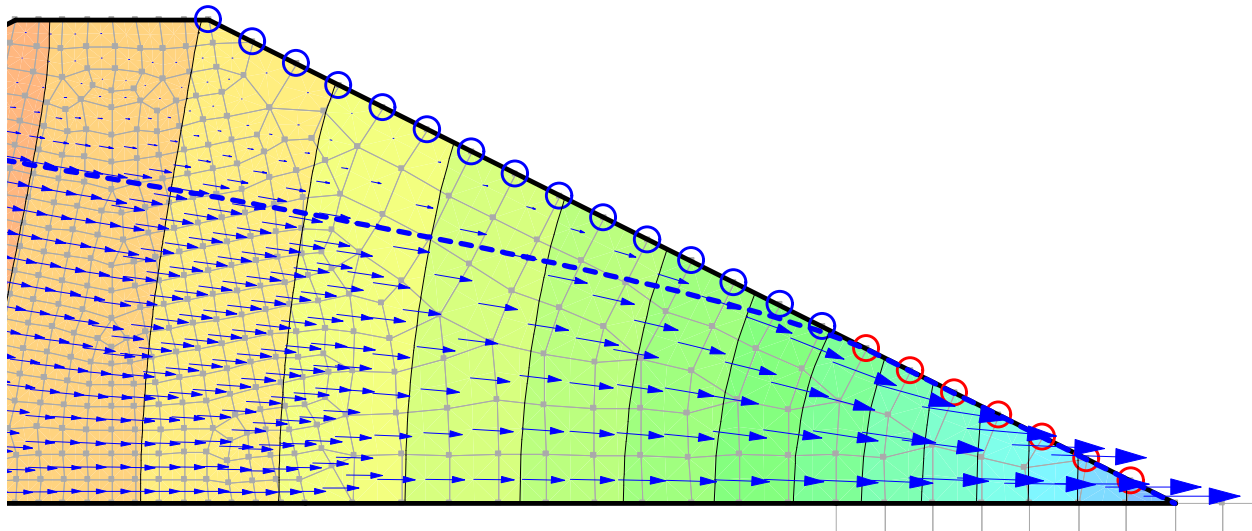
Figure 3 shows the flow as velocity vectors. Notice the flow in the capillary zone above the blue dashed zero-pressure contour.



**Figure 3 Flow represented by vectors**

The next diagram (Figure 4) shows the Potential Seepage Face Review nodes. The ones with a blue circle are Q nodes and the ones with a red circle are H nodes. The review process makes  $H = Y$  so that the pressure is zero.

SEEP/W always computes Q where H is specified. So seepage exits the dam at the nodes with the red circles.

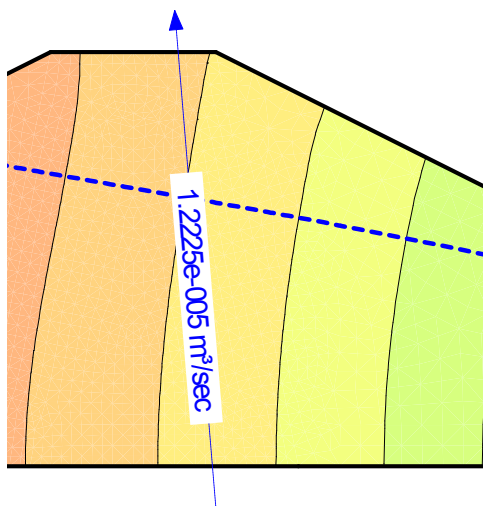


**Figure 4 Seepage face review nodes**

Using the Review Results Information command and clicking on one of the nodes with a red circle reveals the flux at the node as illustrated in the following list. The negative means flow out of the system.

Total Head (m)	3.1818182
Pore-Water Pressure (kPa)	0
Pressure Head (m)	0
Water Flux (m <sup>3</sup> /sec)	-1.4231084e-007
Cumulative Water Flux (m <sup>3</sup> )	0

The total seepage flow through the embankment can be determined with a flux section such shown below (Figure 5). This is the total flow per unit distance into the section.



**Figure 5 Total flux through embankment computed on a flux section**

#### 4 Embankment with a toe under-drain

There are several different ways to model the effect of a toe under-drain. First of all the toe drain material usually has a much high conductivity than the embankment and therefore likely makes no contribution to dissipating the potential energy of the reservoir. Consequently, the effect of the toe drain could be modeled by simply specifying a pressure-equal-zero boundary condition where the drain is in contact with the embankment material.

Intuitively, it is more desirable to include the drain. This can be done but an  $H = 0.0$  boundary condition is then applied to the entire region representing the drain. This is the approach used in this illustrative example.

No boundary condition is now required on the downstream face as the under-drain will prevent the seepage from exiting on the downstream face.

Figure 6 shows the result and indeed now there is no seepage exiting on the downstream slope. Notice in Figure 7 how flow enters the drain through the tensions saturated capillary zone above the blue dashed zero-pressure contour line.

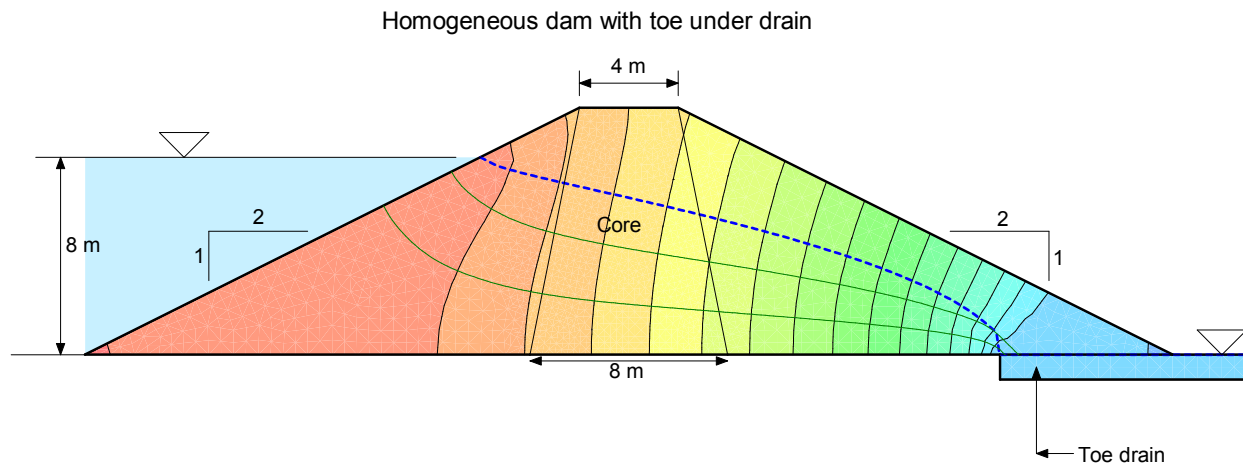


Figure 6 Seepage flow with a toe under-drain

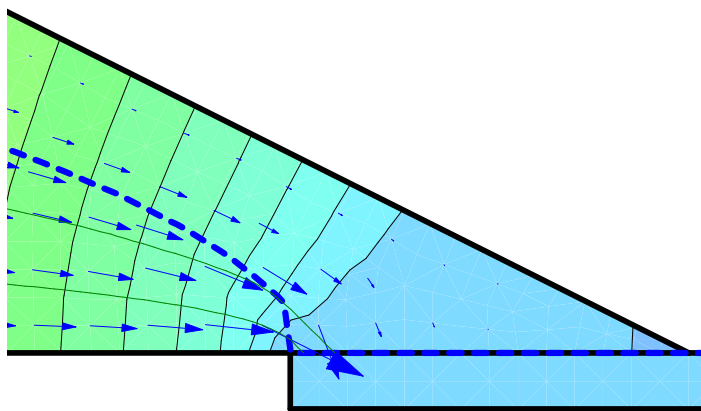


Figure 7 Flow entering the drain through the tension saturated capillary zone

## 5 Effect of a central core

We are now going to look at the effect of a clay core. We'll look at two cases – one where the  $K_{sat}$  is 10x less than the shell material and a second case where the  $K_{sat}$  is 100x less than the core material.

This can be conveniently done by creating (cloning) two new materials and two new conductivity functions.

The conductivity functions can be easily cloned from the one used for the shell material and then shift down by simply entering a new value in the K-Saturation edit box. This results in the three functions shown in Figure 8. They all have the same shape but are shifted vertically by an order of magnitude.

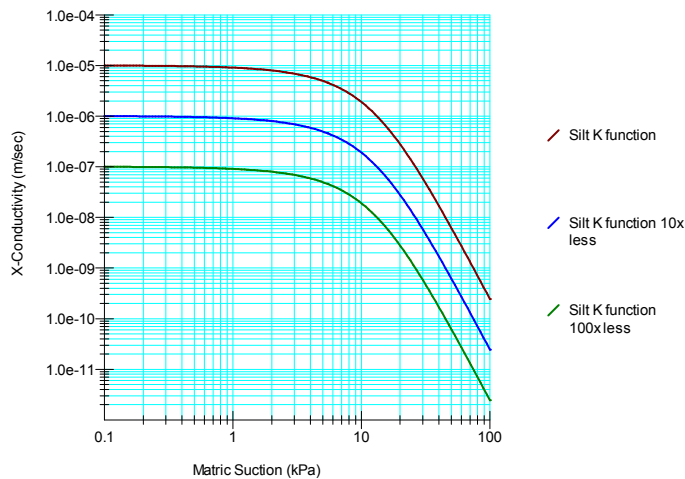


Figure 8 Hydraulic conductivity functions for the shell and the core materials

### 5.1 With core conductivity 10x less than shell

Making the conductivity just 10x less in the core than in the shell has a dramatic effect on the flow regime as is evident in Figure 9. A good portion of the reservoir potential energy or total head is now lost in the core.

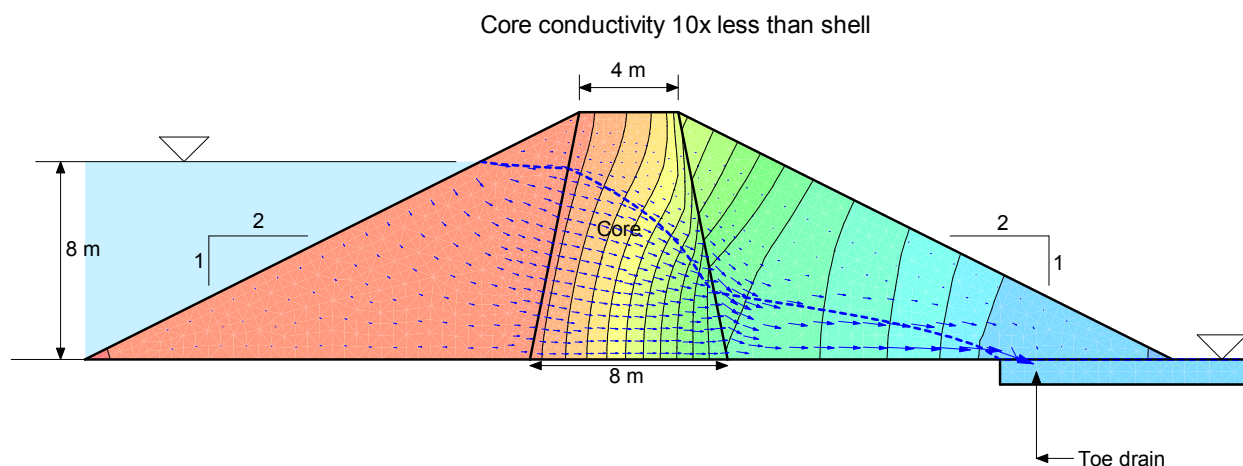
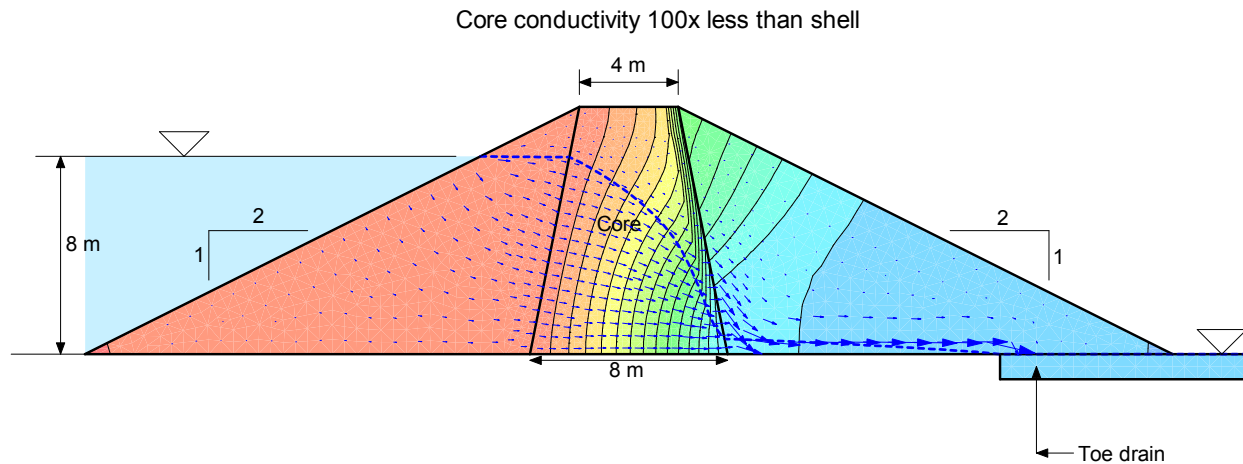


Figure 9 Flow regime with the core conductivity 10x less than the shell

## 5.2 With core conductivity 100x less than shell

As can be seen in Figure 10, when the conductivity of the core material is 100x less than that of the shell material almost all the head is lost in the core.



**Figure 10** Flow regime with the core conductivity 100x less than the shell

## 6 Commentary

There is an important lesson here. Making the contrast in conductivity even larger will not significantly alter the pore-pressure distribution. The distribution of total head contours will remain almost the same. The total seepage loss may decrease somewhat but the pressure distribution will not change significantly.

Making the conductivity contrast too high can lead to numerical convergence difficulties. The above observation can be used to mitigate the numerical convergence issue and yet get realistic results.