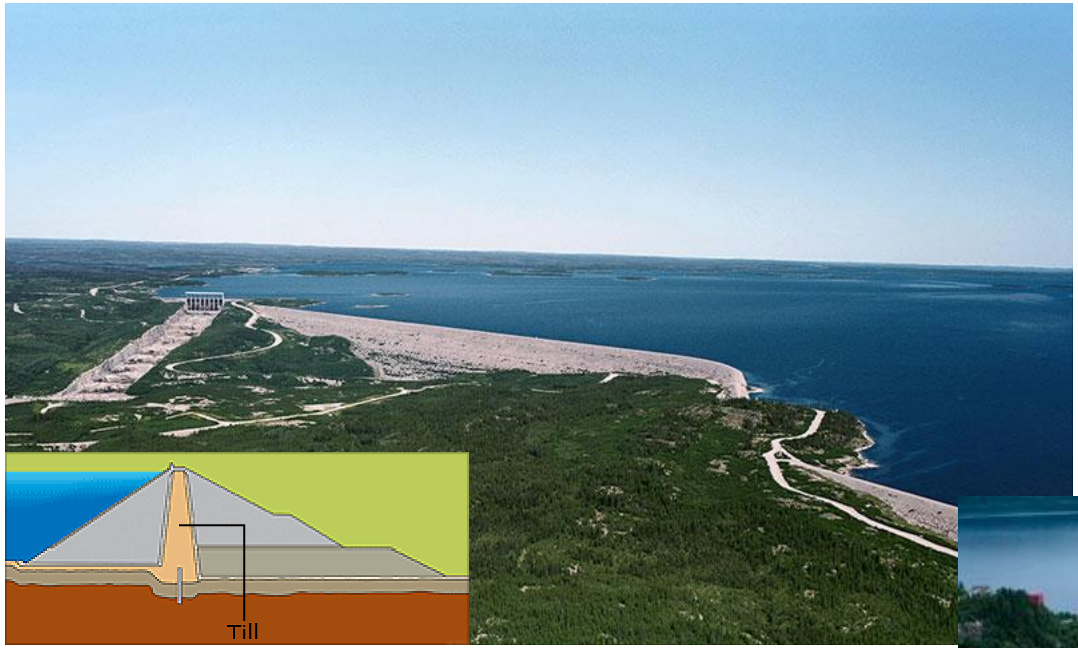
Dr. Khalil Qatu

ENCE 331: Seepage

Seepage flow



Seepage flow

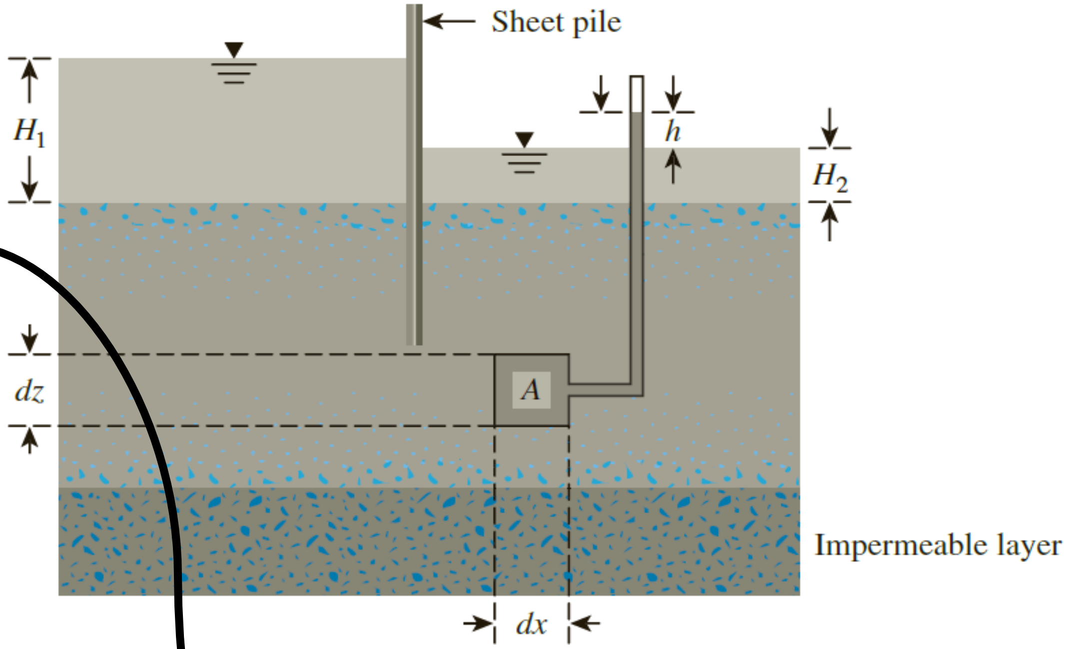
$$\left[\left(v_x + \frac{\partial v_x}{\partial x}dx\right)dz\,dy + \left(v_z + \frac{\partial v_z}{\partial z}dz\right)dx\,dy\right] - [v_x\,dz\,dy + v_z\,dx\,dy] = 0$$

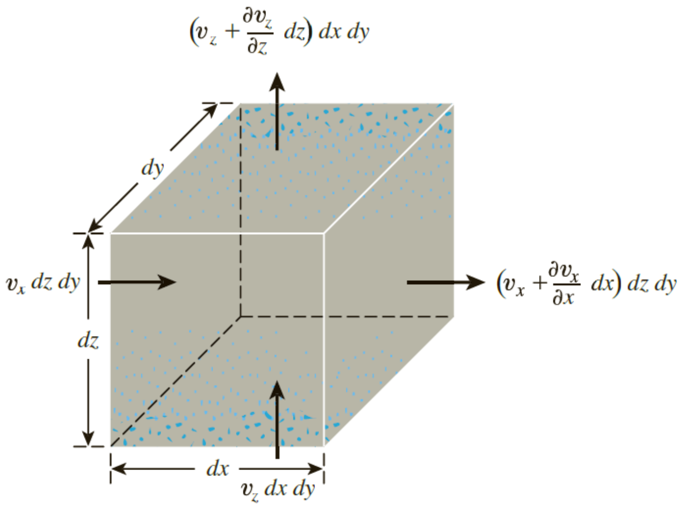
$$\frac{\partial v_x}{\partial x} + \frac{\partial v_z}{\partial z} = 0$$

$$v_x = k_x i_x = k_x \frac{\partial h}{\partial x}$$

$$v_z = k_z i_z = k_z \frac{\partial h}{\partial z}$$

$$k_x \frac{\partial^2 h}{\partial x^2} + k_z \frac{\partial^2 h}{\partial z^2} = 0 \longrightarrow \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

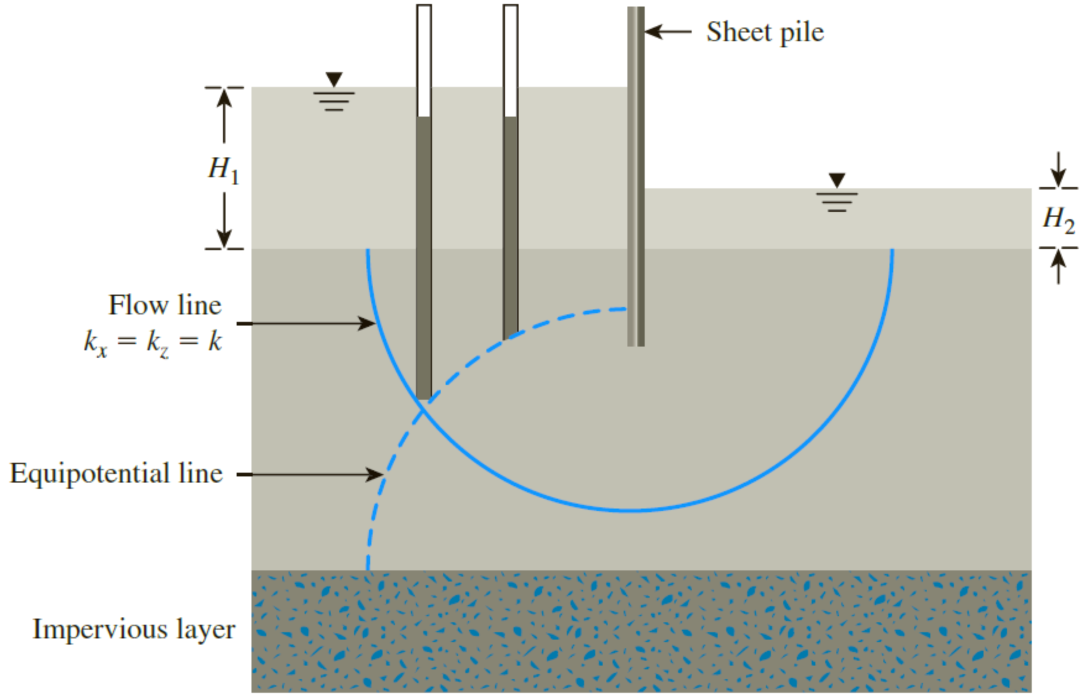




Laplace continuity Equation

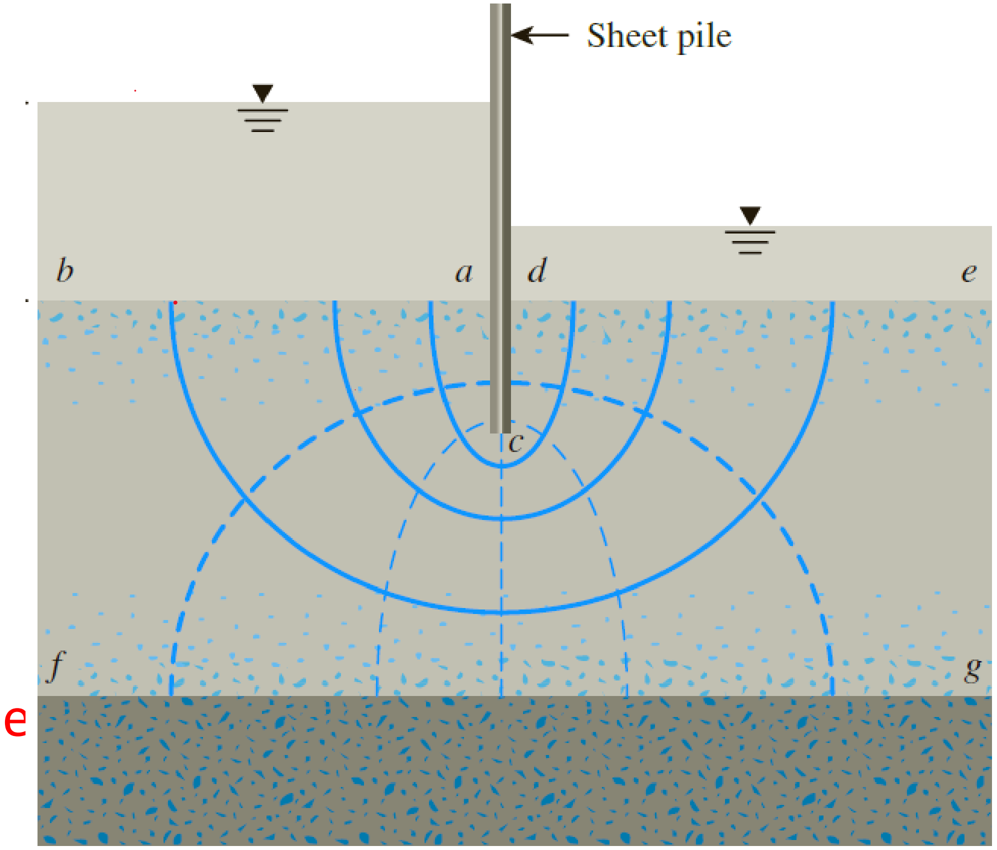
$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

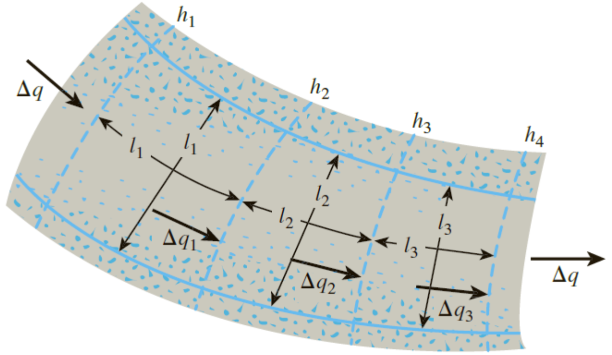
- Two-dimensional Second order differential equation
- The solution for this equation is divided into two orthogonal family of curves:
  - Equipotential curves: a line represents the points that have the same total energy
  - Flow line: a line along which a water particle will travel from upstream to downstream



Flow nets

- The equipotential lines intersect the flow lines at right angles.
- The flow elements formed are approximate squares.
- The area between flow lines is called a flow channel (flow rate in all channels are the same)
- The difference in total head between two adjacent equipotential lines is called Potential drop
- Flow lines and equipotential lines must agree with B.C.
  - The upstream and downstream surfaces of the permeable layer (lines ab and de) are equipotential line
  - Because ab and de are equipotential lines, all the flow lines intersect them at right angles.
  - The boundary of the impervious layer—that is, line fg—is a flow line, and so is the surface of the impervious sheet pile, line acd.
  - The equipotential lines intersect acd and fg at right angles.





Why flow nets ??

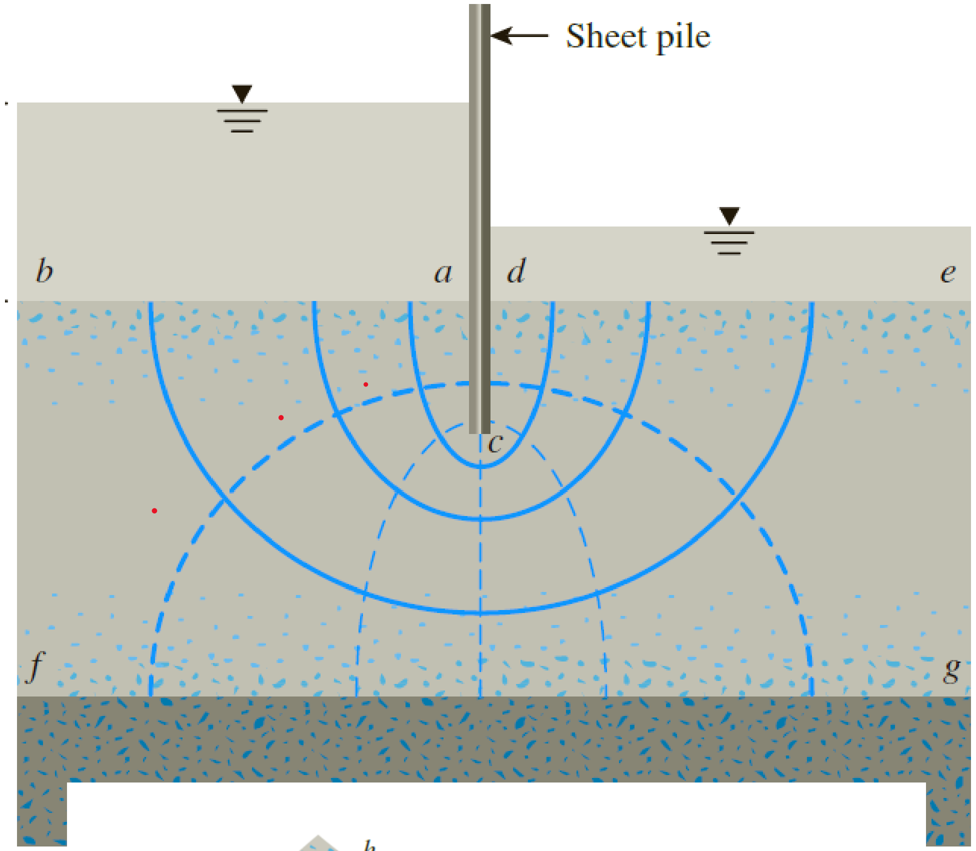
- Head distribution

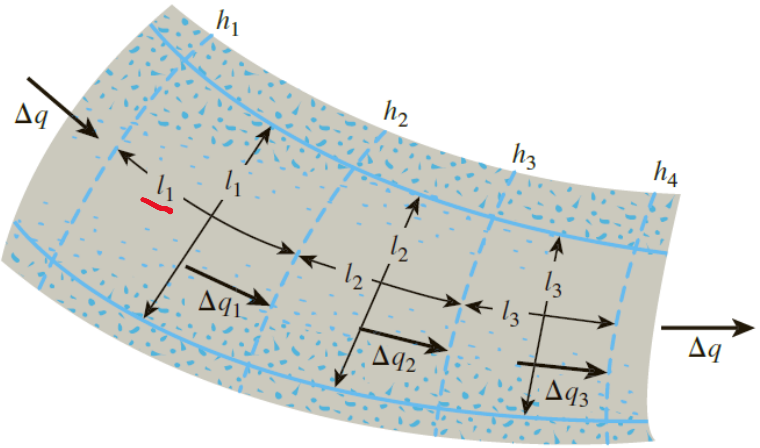
  (N_d) , (N_f) → ?? $h_1 - h_2 \rightarrow \frac{H}{N_d}$

- Flow rate

  $\Delta q = k \cdot \frac{h_1 - h_2}{l_1} \cdot l_1$ $q = kiA \rightarrow q = k\frac{H}{N_d}N_f$

- Gradient distribution
- Discharge velocity
- Pore water pressure

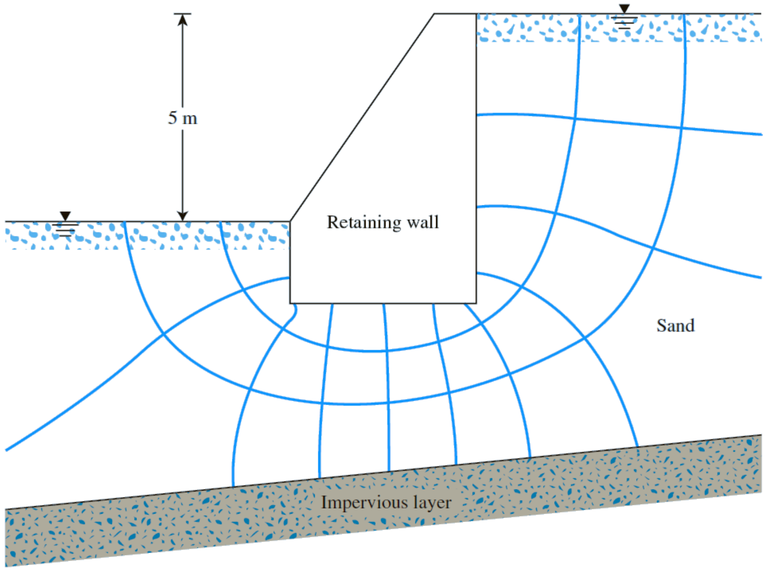




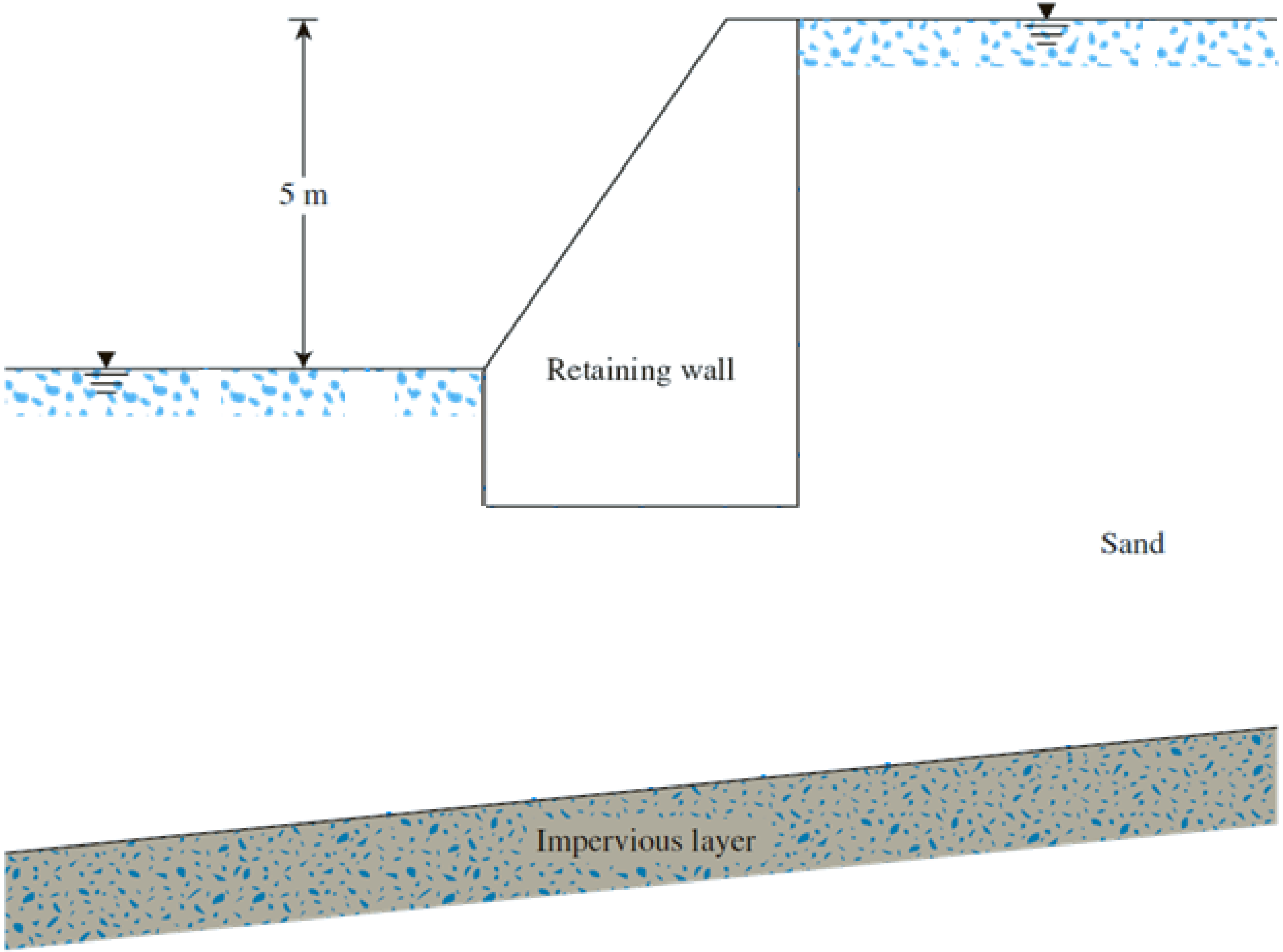
How to draw a good flow net

- Use pencil and draw to scale
- Start by marking B.C.s in ink
- Drawing is an iteration process (sketch then correct mistakes)
- Draw flow lines first (3-5 flow channels are usually sufficient)
- Draw equipotential lines (take symmetry into account).
- You can get partial head drops or partial flow channel
- Don’t over complicate it.

Examples

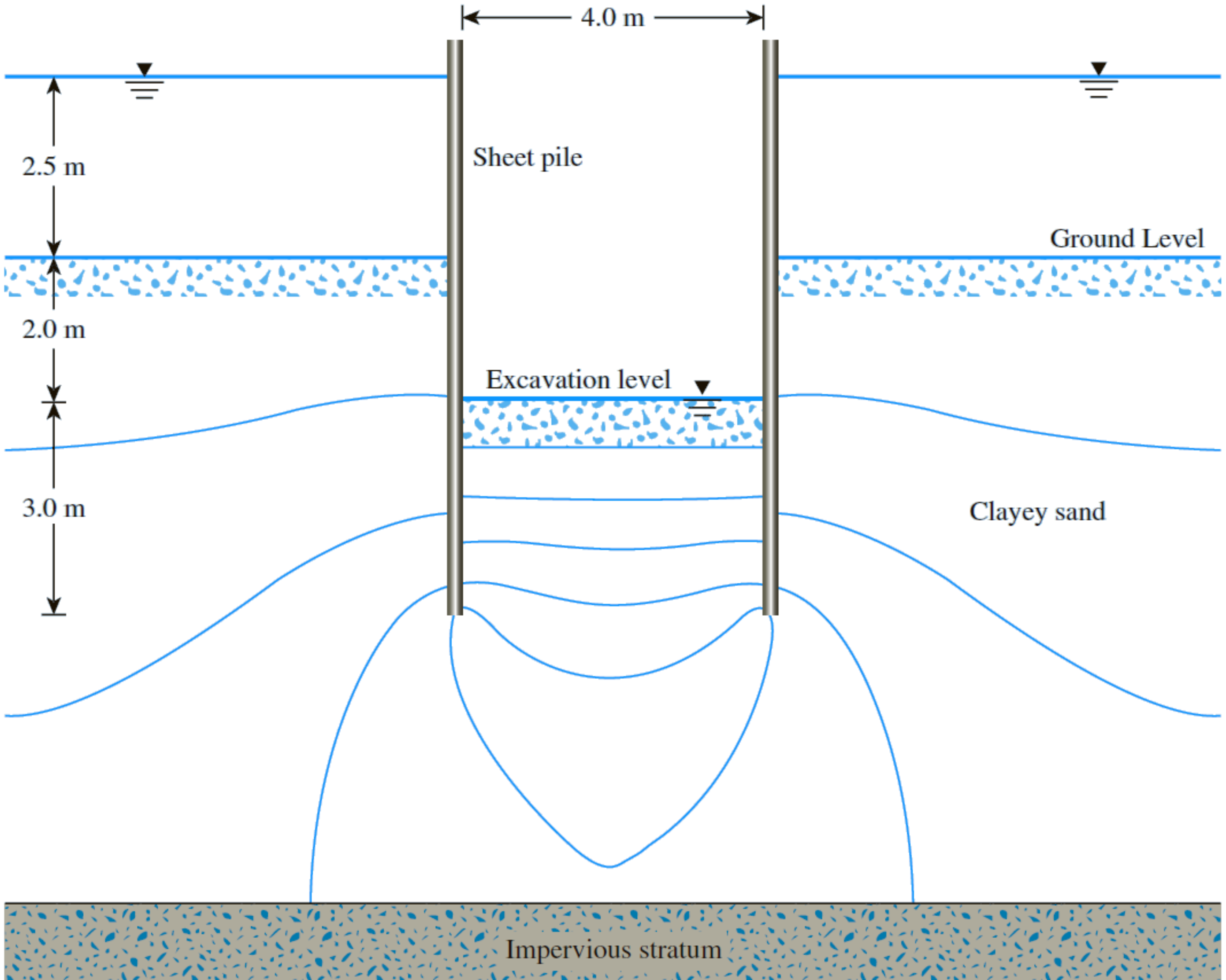


5 m
Retaining wall
Sand
Impervious layer



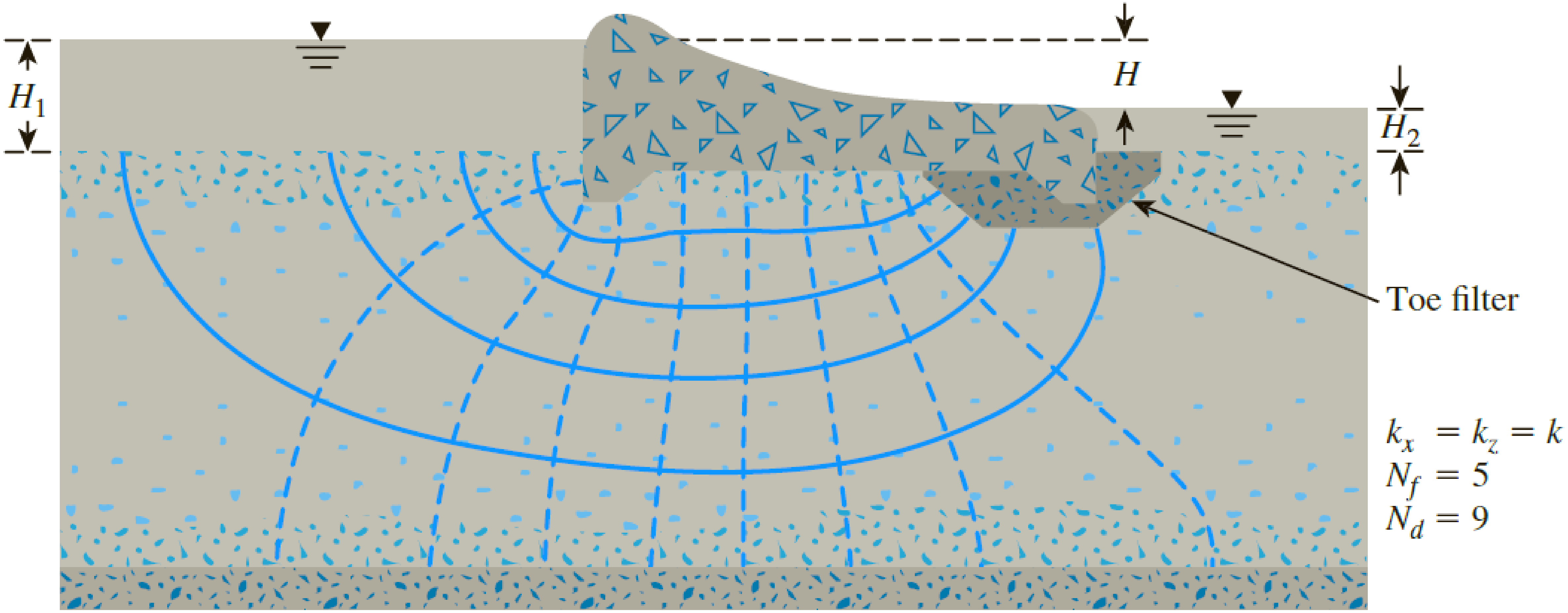
5 m
Retaining wall
Sand
Impervious layer

Examples

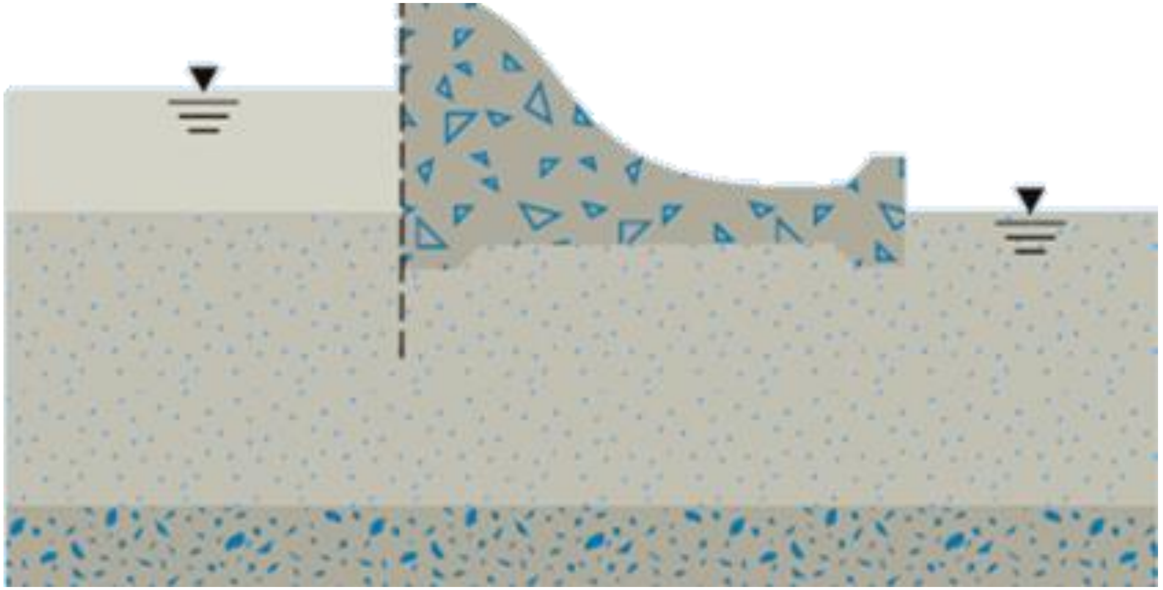


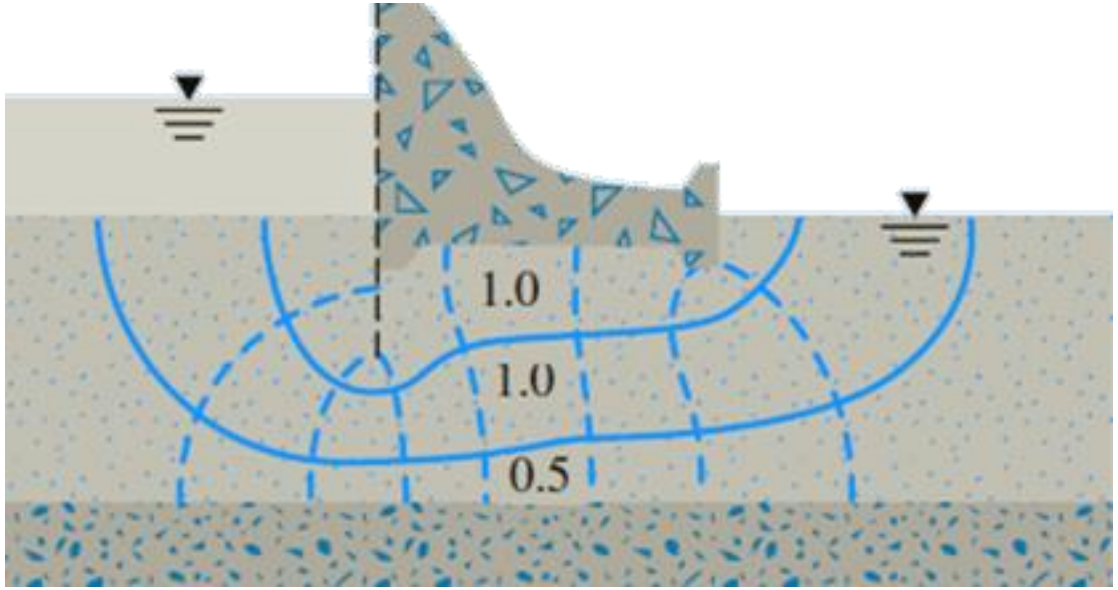
4.0 m
2.5 m
Sheet pile
Ground Level
2.0 m
Excavation level
3.0 m
Clayey sand
Impervious stratum

Examples



Examples

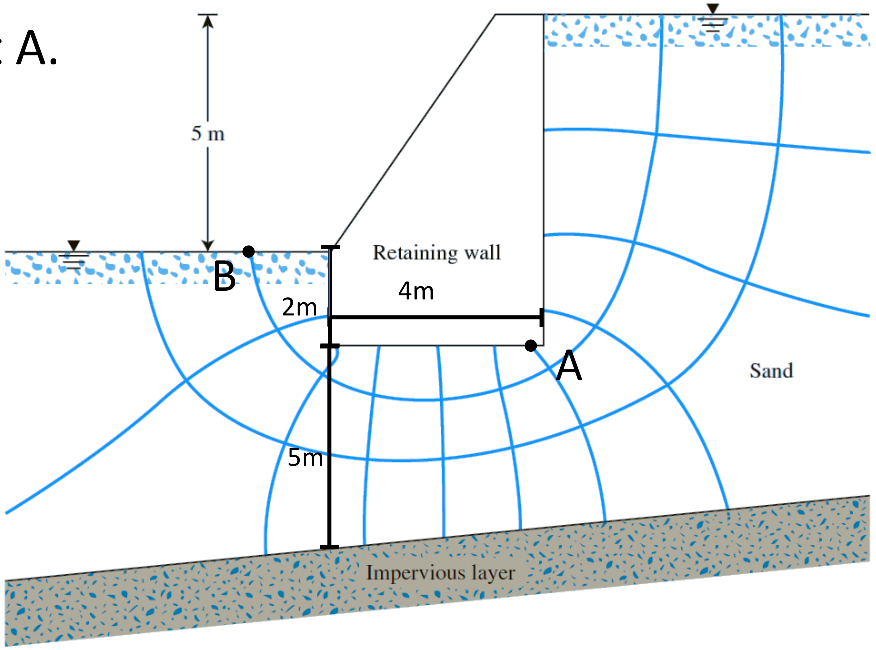




Example

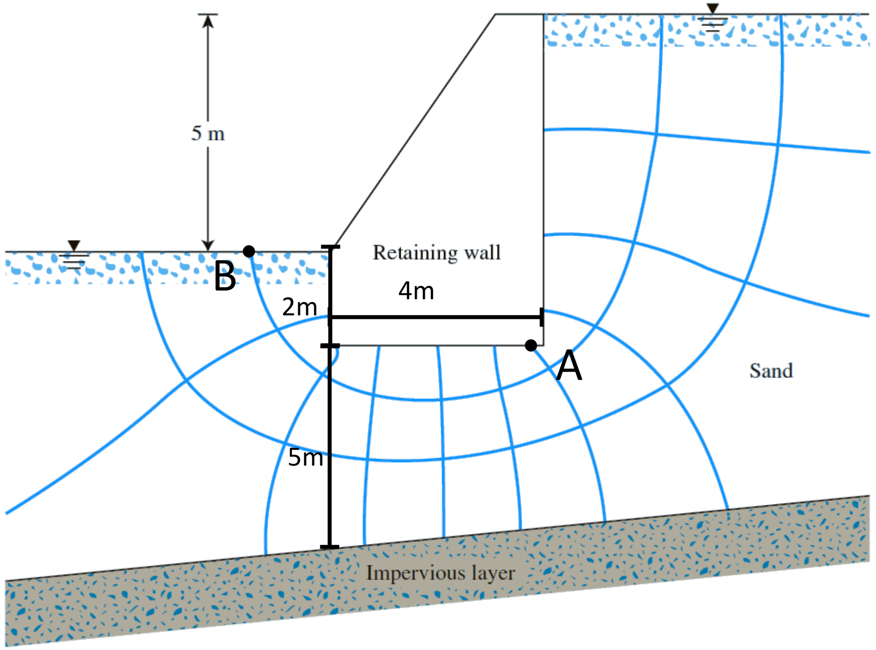
The hydraulic conductivity of the sand is 1.5×10^{-5} cm/s. The retaining wall is 50 m long. Determine:

- The quantity of seepage across the entire wall per day.
- The total head, elevation head, and pressure head at point A.
- The total uplift force on the retaining wall
- The exit gradient at point B.



Example

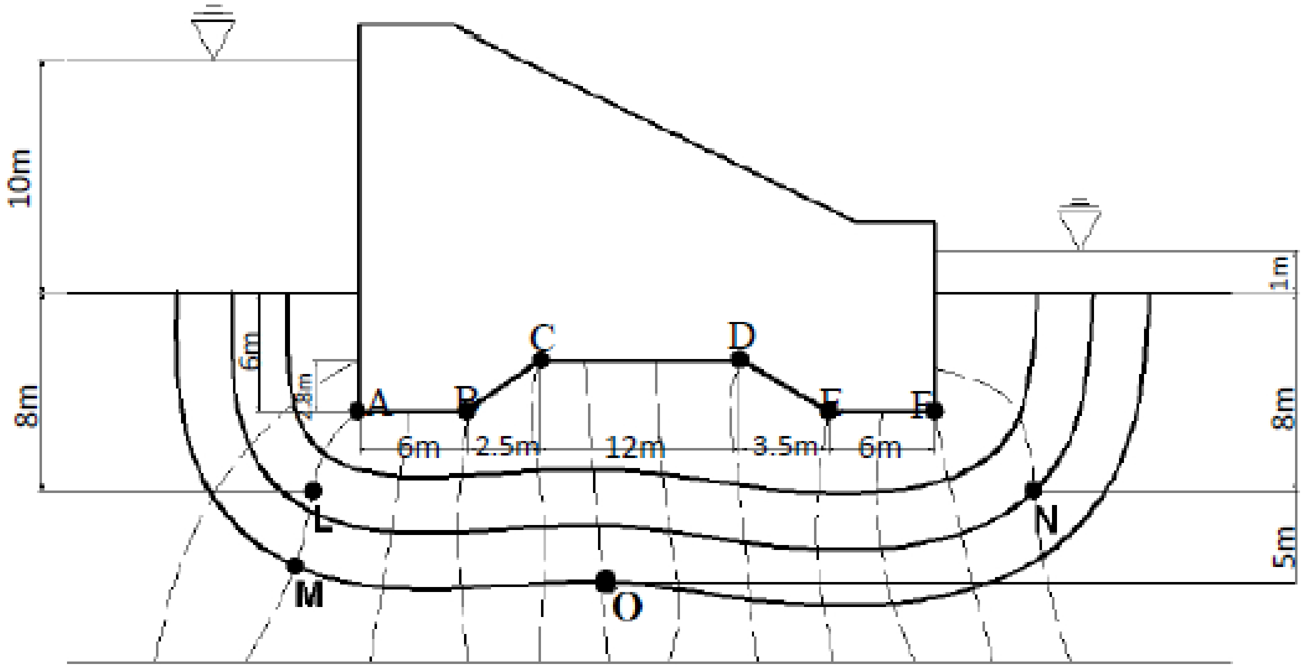
The hydraulic conductivity of the sand is 1.5 x 10^{-5} cm/s. The retaining wall is 50 m long. Determine:



Example

The hydraulic conductivity of the soil below the dam is 5.3×10^{-5} cm/s. Determine:

- The quantity of seepage across the entire wall per day.
- The total head, elevation head, and pressure head at point A.
- The total uplift force on the dam
- The exit gradient at point B.



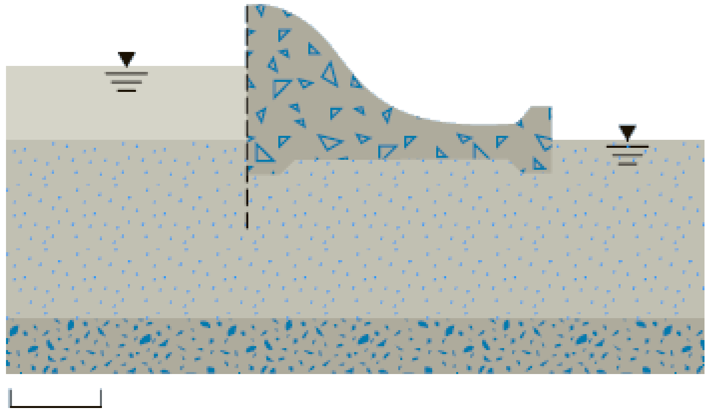
Anisotropic soil

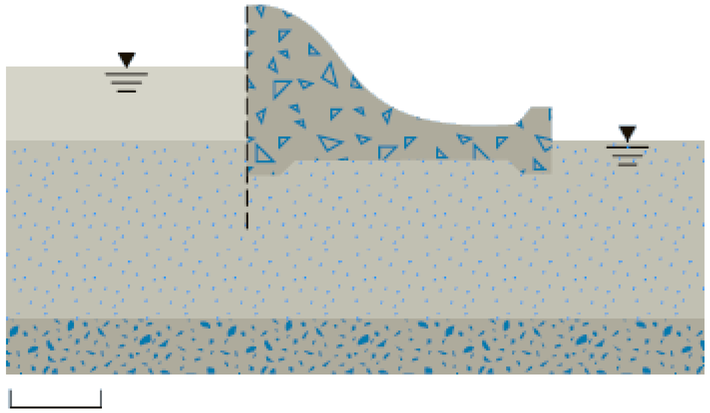
$$k_x \frac{\partial^2 h}{\partial x^2} + k_z \frac{\partial^2 h}{\partial z^2} = 0$$

$$\frac{\partial^2 h}{(k_z/k_x)\,\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

$$x' = \sqrt{k_z/k_x}\,x$$

$$q = \sqrt{k_x k_z}\,\frac{H N_f}{N_d}$$





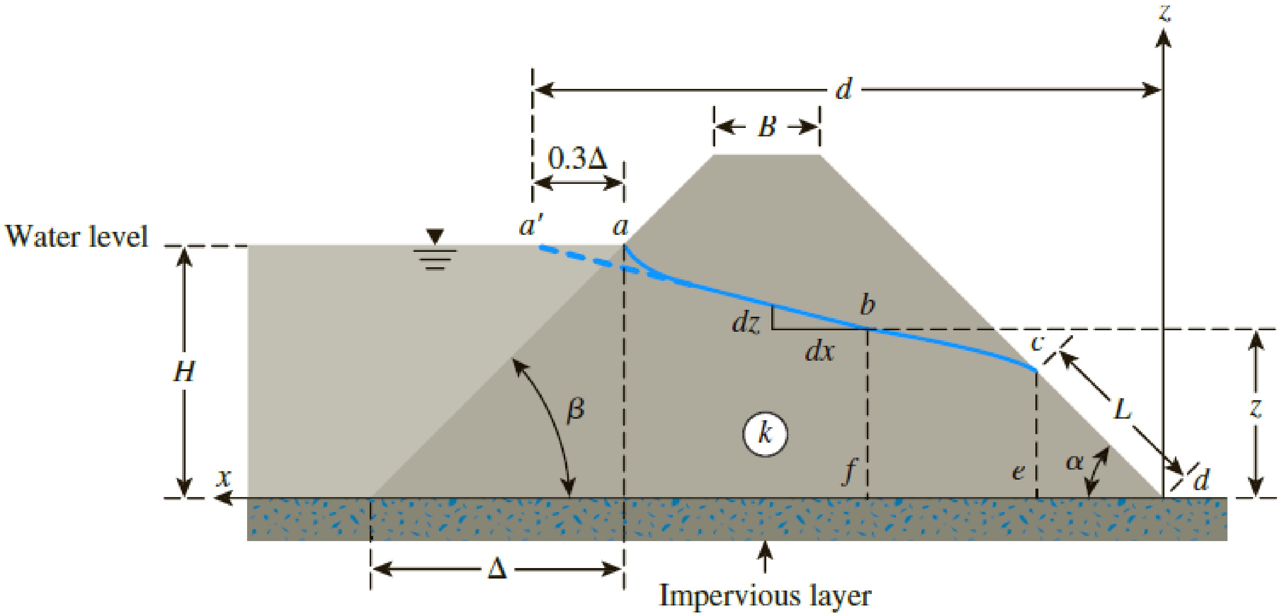
Earthen Dam on impervious soil

$$q = k\, L \sin\alpha \tan\alpha$$

$$L = \frac{d}{\cos\alpha} - \sqrt{\frac{d^2}{\cos^2\alpha} - \frac{H^2}{\sin^2\alpha}}$$

Step 1. Obtain α.
Step 2. Calculate Δ (see Figure 8.15) and then 0.3Δ.
Step 3. Calculate d.
Step 4. With known values of α, H and d, calculate L
Step 5. With known value of L, calculate q

Schaffernak's Solution
$\alpha < 30^o$



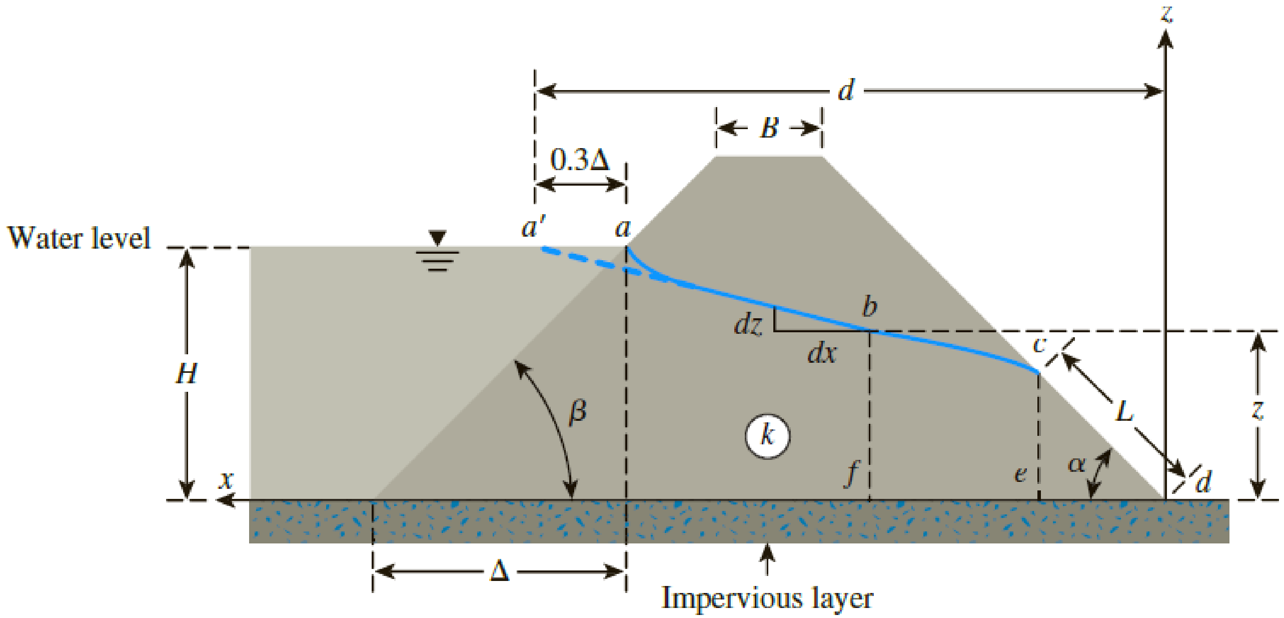
Earthen Dam on impervious soil

$$q = k\,L\sin^2\alpha$$

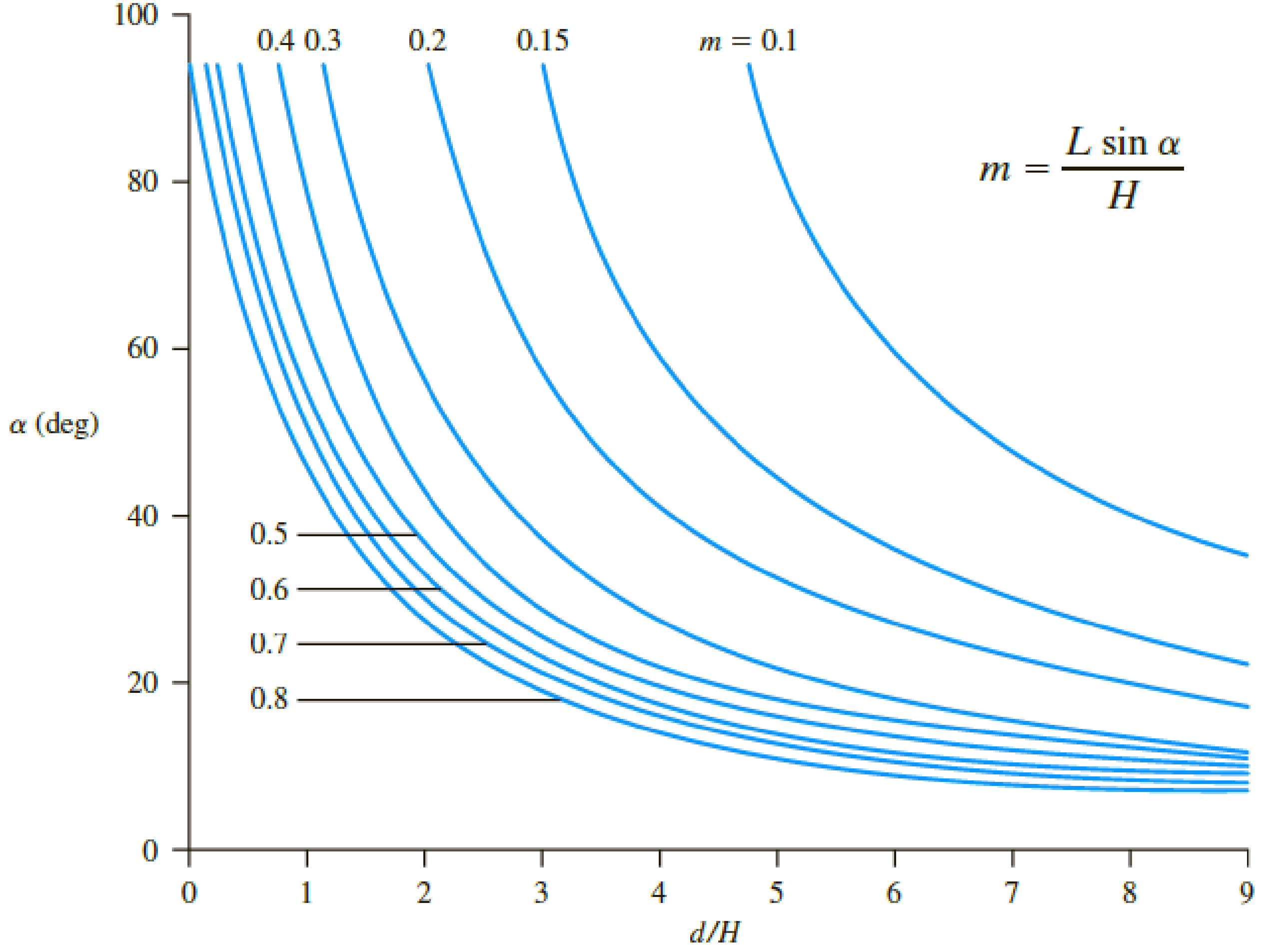
$$L = \sqrt{d^2 + H^2} - \sqrt{d^2 - H^2\cot^2\alpha}$$

Step 1. Obtain α.
Step 2. Calculate Δ (see Figure 8.15) and then 0.3Δ.
Step 3. Calculate d.
Step 4. With known values of α, H and d, calculate L
Step 5. With known value of L, calculate q

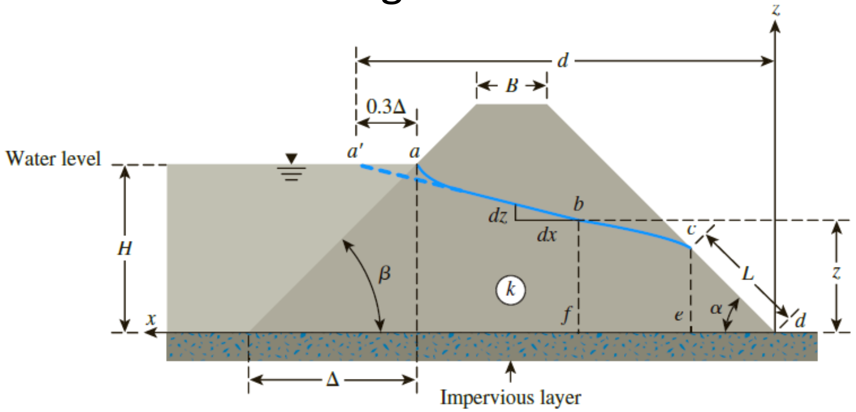
Casagrande's Solution



Earthen Dam on impervious soil



Casagrande's Solution



Step 1. Determine d/H.

Step 2. For a given d/H and α, determine m.

Step 3. Calculate $L = \dfrac{mH}{\sin \alpha}$.

Step 4. Calculate $q = kL \sin^2 \alpha$.