Unsaturated Flow Example

Unsaturated flow below tailings or liquid waste impoundments.

Cross-section definition sketch — Estimate the seepage rate from impoundment.

A. Saturated flow region — flow through layered soils

\[ q = \frac{K \Delta H}{\Delta x} = \frac{K}{l} \left( h_0 + h_1 + h_2 \right) \]

where \( h_f = h_0 \) at the liner-foundation boundary

\[ K = \frac{L}{K_1 + K_2 + K_3} \]

substituting then:

\[ L = K_1 + K_2 + K_3 \]

Unfortunately \( h_f \) is unknown

B. Assumption — for large times (weeks to years) \( q \to K(\theta_f) \)

(unsat flow) because during infiltration at long times, the gravitational force is the primary driving force,

(in other words, \( \Delta H \to 0 \)). Therefore, from the B-C Eqs:

\[ K = K_f \left( \frac{h_f}{h_f^*} \right) \]

and \( q \neq K \), rearranging:

\[ h_f = h_d \left( \frac{K_f}{q} \right)^{\frac{1}{\gamma}} \]

C. Substitute and solve implicitly for \( q \) using trial & error beginning

with \( q = K_f \), or \( h_f = h_d \)

\[ q = \frac{(a + l) - h_f \left( \frac{K_f}{q} \right)^{\frac{1}{\gamma}}} {K_1 + K_2 + K_3} \]

D. The foundation soil water content is given by

\[ \theta_f = (\theta_{m} - \theta_i) \left( \frac{q}{K_f} \right)^{\frac{1}{\gamma}} + \theta_i \]

where \( \theta_i = \theta_r \)

E. The time required for the seepage water to contact the groundwater is given by

\[ t = \frac{-l}{q} (\theta_f - \theta_i) \]