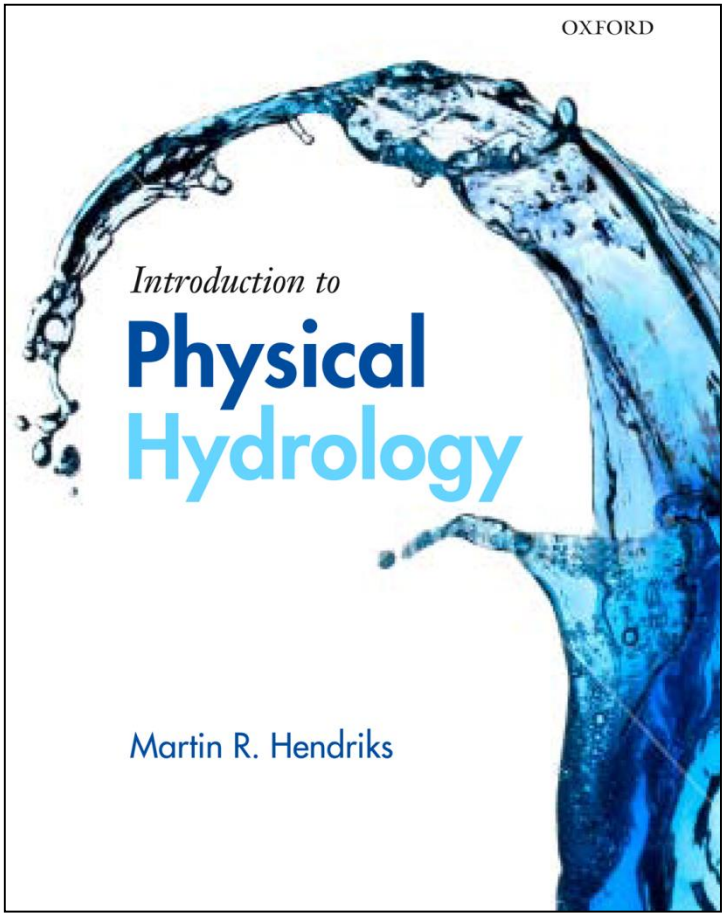
Groundwater



Paperback | 351 pages
Follow the book's didactic concept!

- Hydrological cycle
- Drainage basin
- Water balance

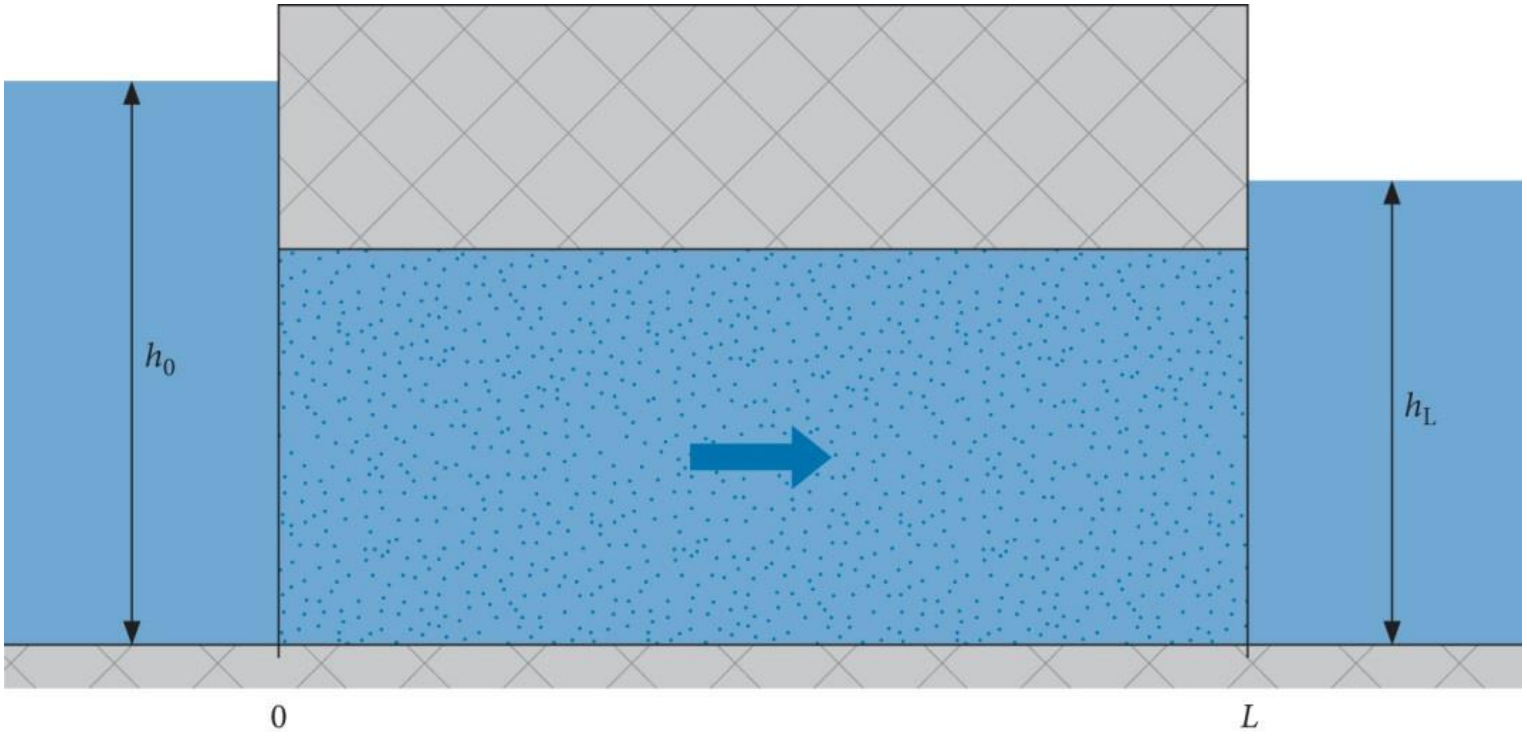
- Energy equation
- Flow equation
- Continuity equation

1. Introduction
2. Atmospheric water
3. **Groundwater**
4. Soil water
5. Surface water

Exercises

Confined groundwater

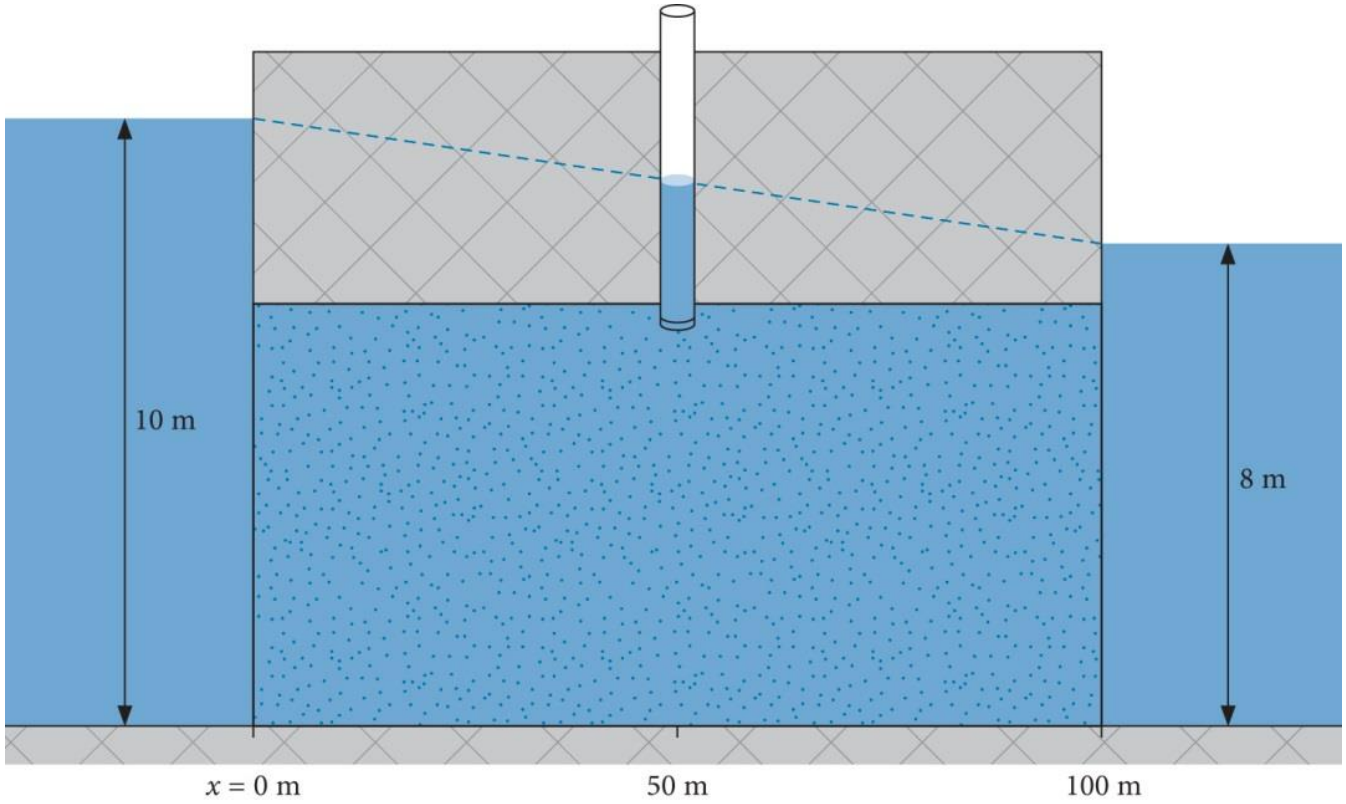
Horizontal groundwater flow



$$Q = -KA\frac{h_L - h_0}{L} \qquad Q = -KA\frac{\Delta h}{\Delta x} \qquad Q = -KA\frac{dh}{dx} \qquad Q = -KDW\frac{dh}{dx} \qquad Q' = \frac{Q}{W} = -KD\frac{dh}{dx}$$

Confined groundwater

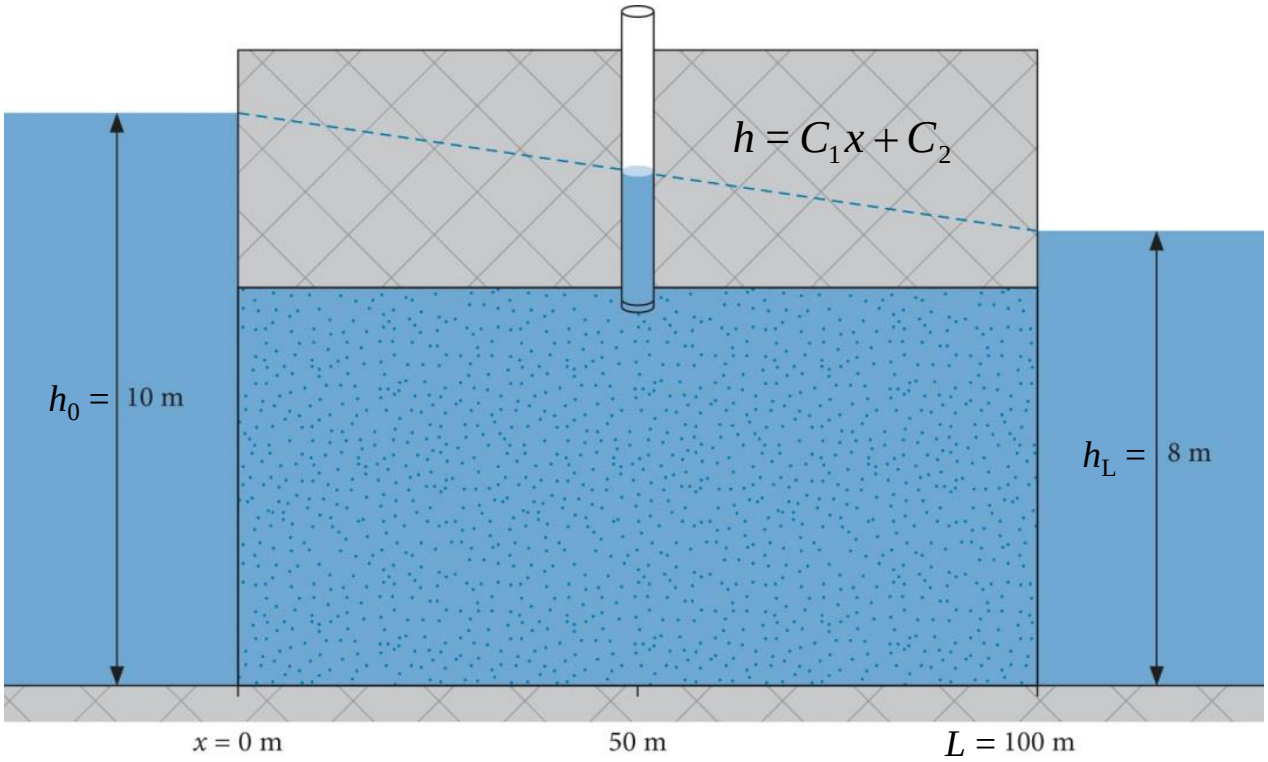
$$Q' = -KD\frac{dh}{dx}$$



$$Q' = \text{constant} \Rightarrow -KD\frac{dh}{dx} = \text{constant}$$

$$\frac{dh}{dx} = \text{constant} = C_1 \Rightarrow h = C_1 x + C_2$$

Confined groundwater

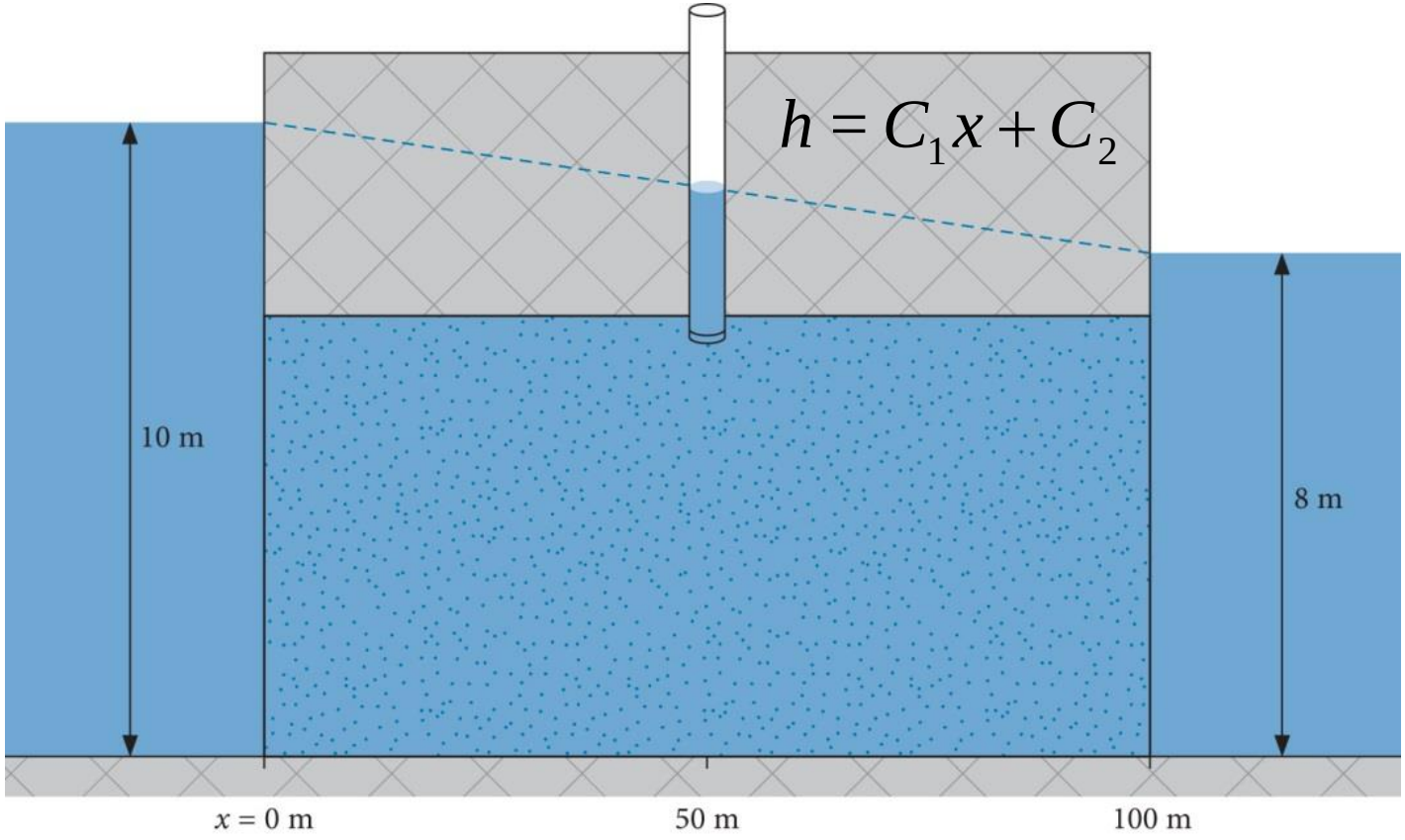


When $x = 0$, then $h = h_0 \Rightarrow h_0 = C_1 \times 0 + C_2 \quad h_0 = C_2 \quad C_2 = h_0$

When $x = L$, then $h = h_L \Rightarrow h_L = C_1 \times L + C_2 = C_1 L + h_0 \quad C_1 = \dfrac{h_L - h_0}{L}$

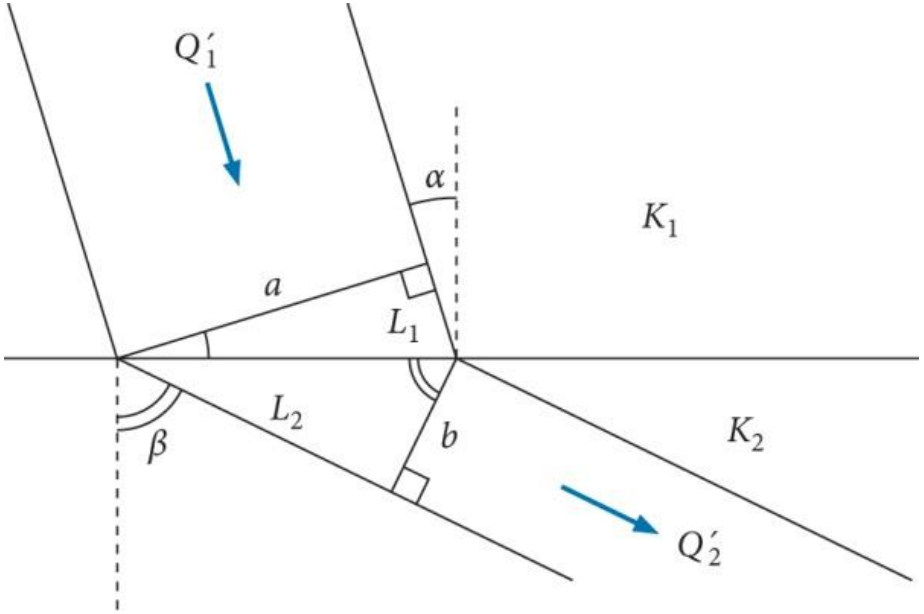
Inserting the values found for C_1 and C_2 in $h = C_1 x + C_2$ gives: $h = \dfrac{h_L - h_0}{L} x + h_0$

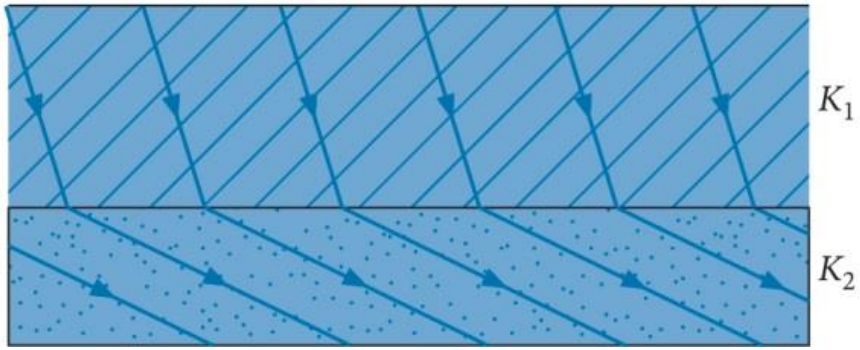
Confined groundwater



$$h = \frac{h_L - h_0}{L} x + h_0 \qquad h = \frac{8-10}{100} x + 10$$

Refracting the water





$$Q_1^{'} = Q_2^{'}$$

$$Q_1^{'} = -K_1\, a\, \frac{\Delta h_1}{L_1}$$

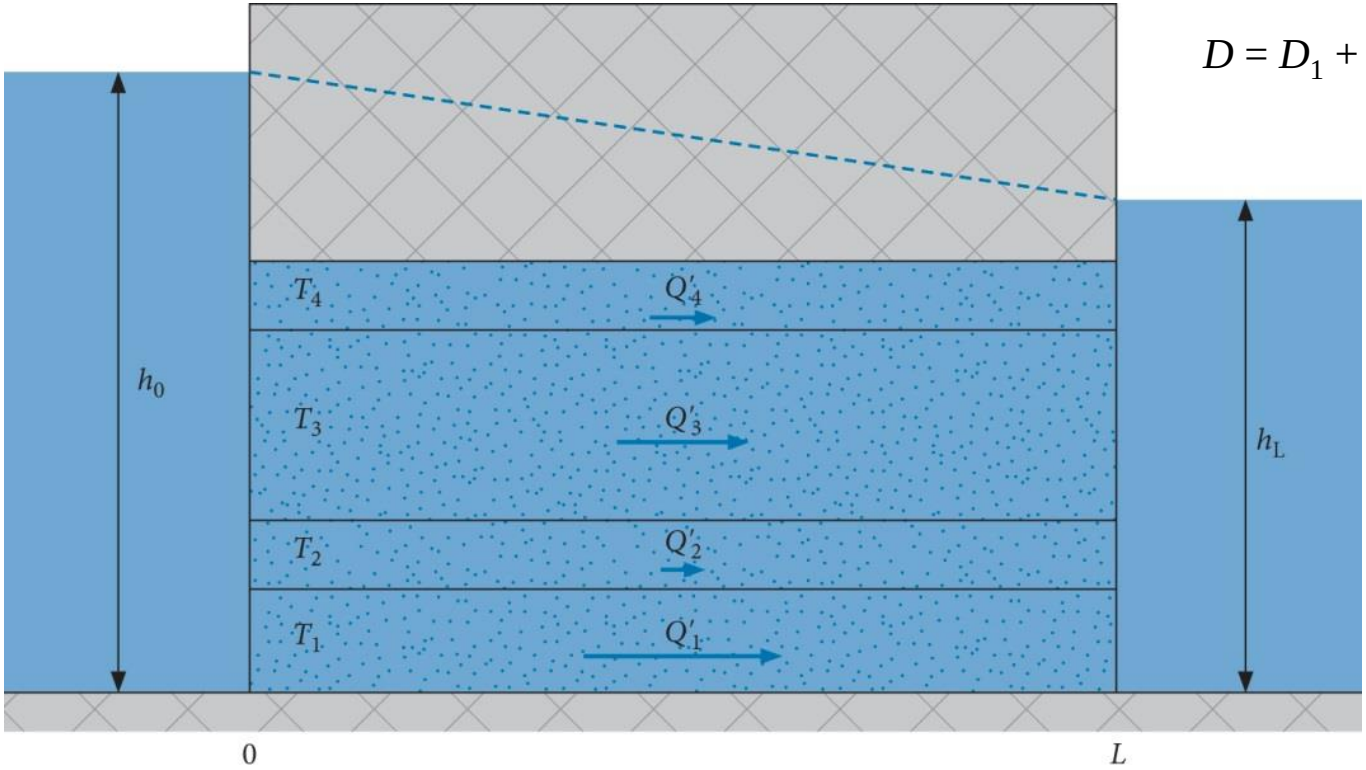
$$Q_2^{'} = -K_2\, b\, \frac{\Delta h_2}{L_2}$$

$$\Delta h = \Delta h_1 = \Delta h_2$$

$$K_1 \frac{a}{L_1} = K_2 \frac{b}{L_2}$$

$$\frac{K_1}{K_2} = \frac{\tan\alpha}{\tan\beta}$$

Horizontal groundwater flow



$$D = D_1 + D_2 + D_3 + D_4$$

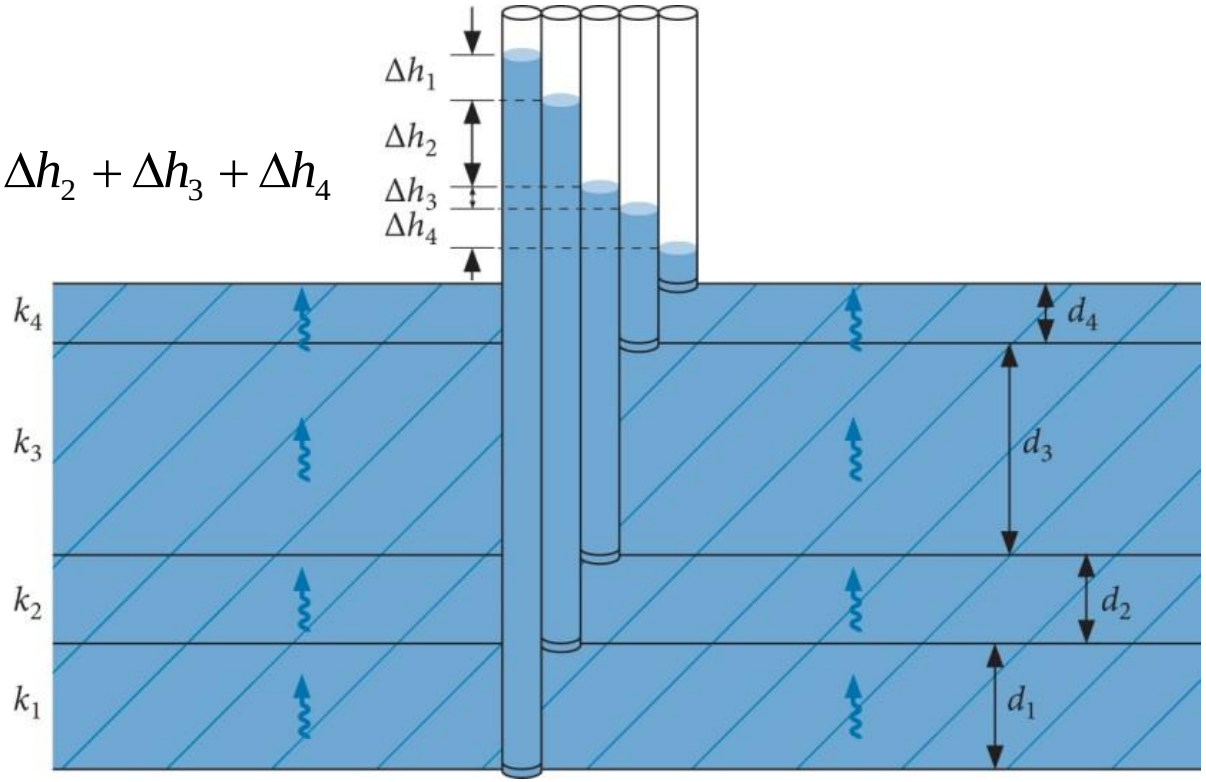
$$Q' = Q'_1 + Q'_2 + Q'_3 + Q'_4$$

$$-KDi = -K_1 D_1 i - K_2 D_2 i - K_3 D_3 i - K_4 D_4 i$$

$$KD = K_1 D_1 + K_2 D_2 + K_3 D_3 + K_4 D_4$$

Vertical groundwater flow

$$\Delta h = \Delta h_1 + \Delta h_2 + \Delta h_3 + \Delta h_4$$



$$d = d_1 + d_2 + d_3 + d_4$$

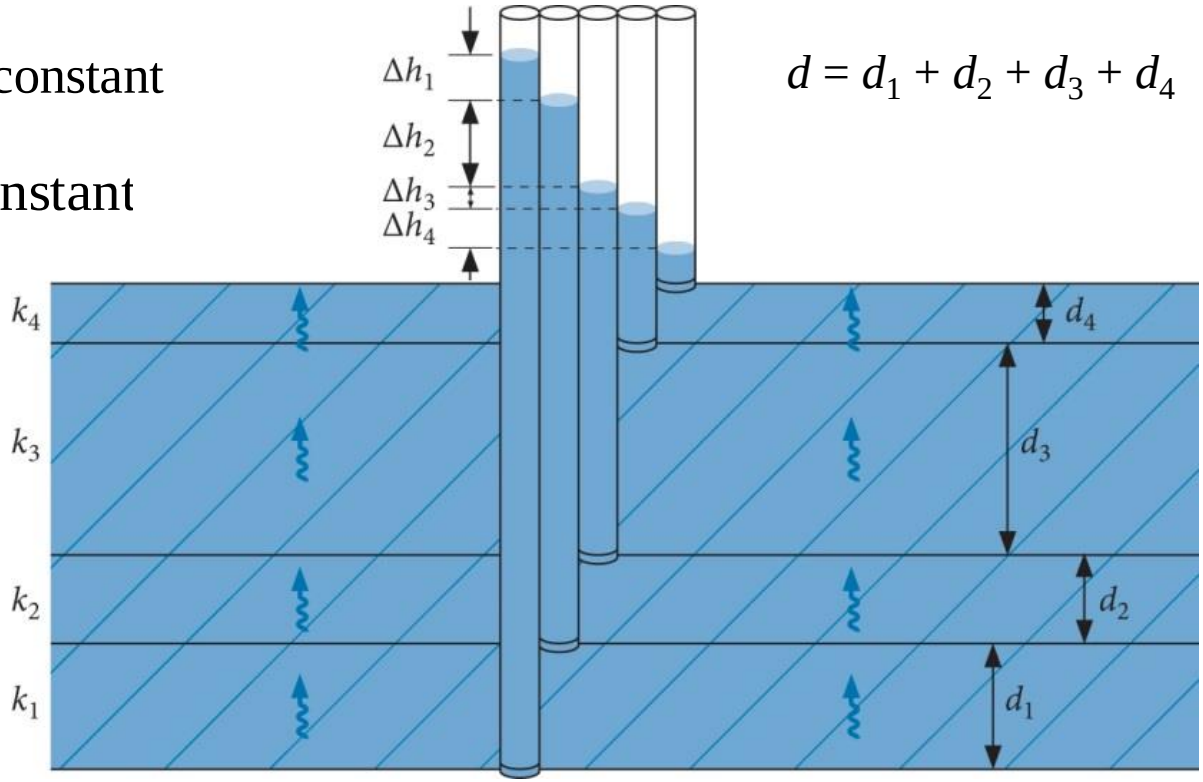
Continuity equation: $Q = Q_1 = Q_2 = Q_3 = Q_4$

Vertical groundwater flow

$$\frac{Q}{A} = \frac{Q_1}{A} = \frac{Q_2}{A} = \frac{Q_3}{A} = \frac{Q_4}{A} = \text{constant}$$

$$q = q_1 = q_2 = q_3 = q_4 = \text{constant}$$

$$d = d_1 + d_2 + d_3 + d_4$$



$$\Delta h = \Delta h_1 + \Delta h_2 + \Delta h_3 + \Delta h_4$$

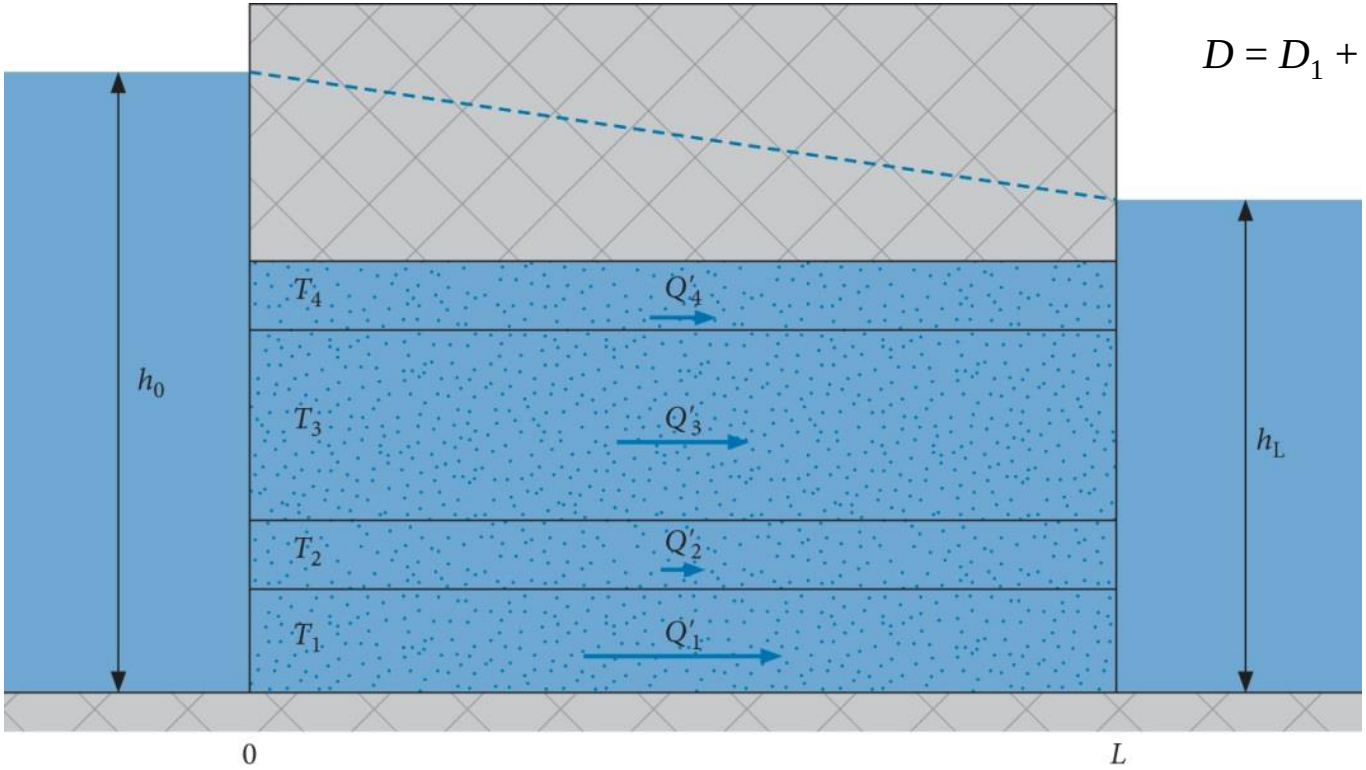
$$\frac{\Delta h}{q} = \frac{\Delta h_1}{q_1} + \frac{\Delta h_2}{q_2} + \frac{\Delta h_3}{q_3} + \frac{\Delta h_4}{q_4}$$

$$q = -k\frac{\Delta h}{d} = q_1 = -k_1\frac{\Delta h_1}{d_1} = q_2 = -k_2\frac{\Delta h_2}{d_2} = -k_3\frac{\Delta h_3}{d_3} = -k_4\frac{\Delta h_4}{d_4}$$

$$\frac{d}{k} = \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_3}{k_3} + \frac{d_4}{k_4}$$

$$c = c_1 + c_2 + c_3 + c_4$$

Horizontal groundwater flow

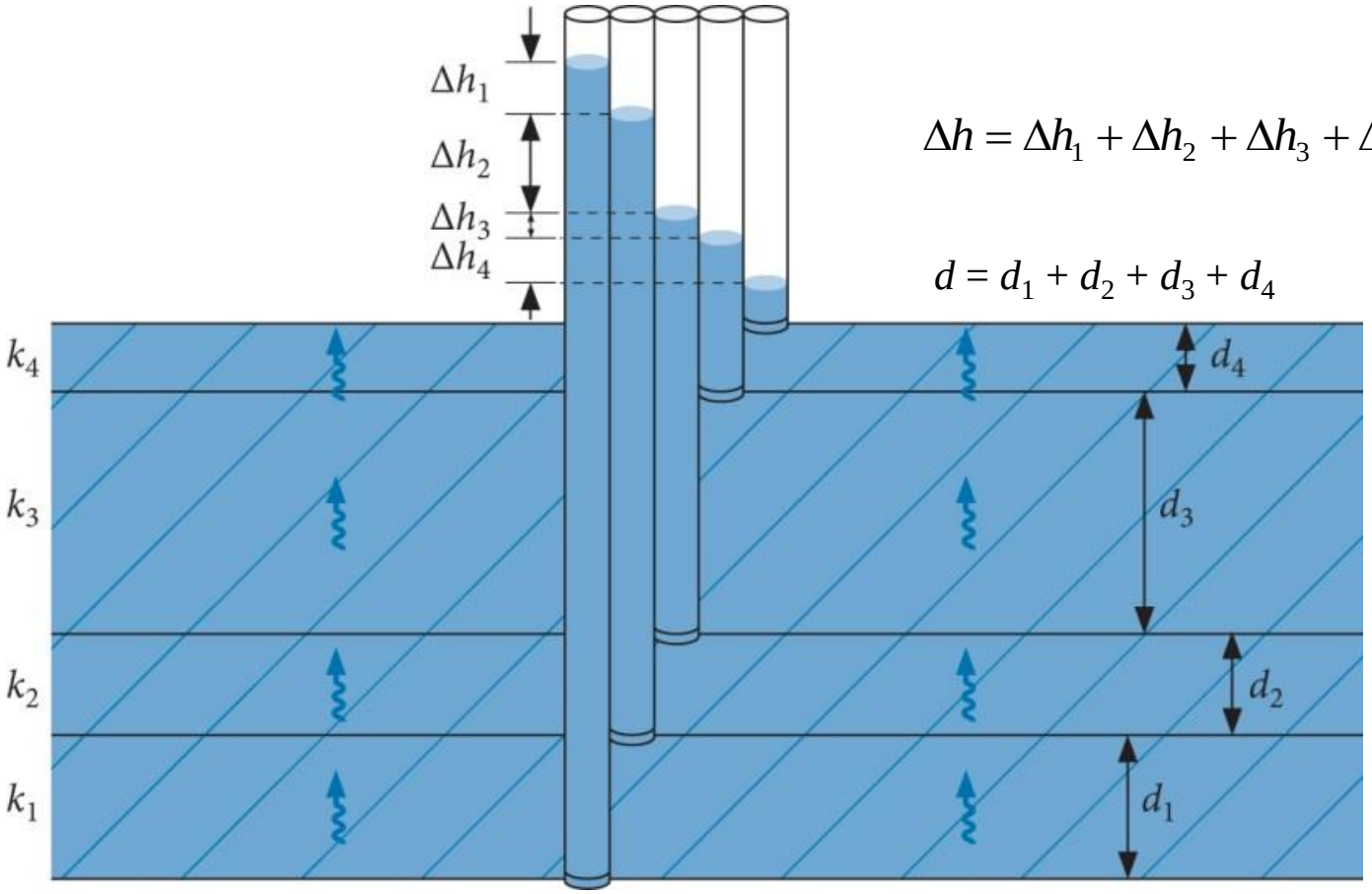


$$D = D_1 + D_2 + D_3 + D_4$$

$$Q' = Q'_1 + Q'_2 + Q'_3 + Q'_4$$

$$KD = K_1 D_1 + K_2 D_2 + K_3 D_3 + K_4 D_4$$

Vertical groundwater flow



$$\Delta h = \Delta h_1 + \Delta h_2 + \Delta h_3 + \Delta h_4$$

$$d = d_1 + d_2 + d_3 + d_4$$

$$q = q_1 = q_2 = q_3 = q_4$$

$$\frac{d}{k} = \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_3}{k_3} + \frac{d_4}{k_4}$$

$$c = c_1 + c_2 + c_3 + c_4$$

Horizontal and vertical groundwater flow

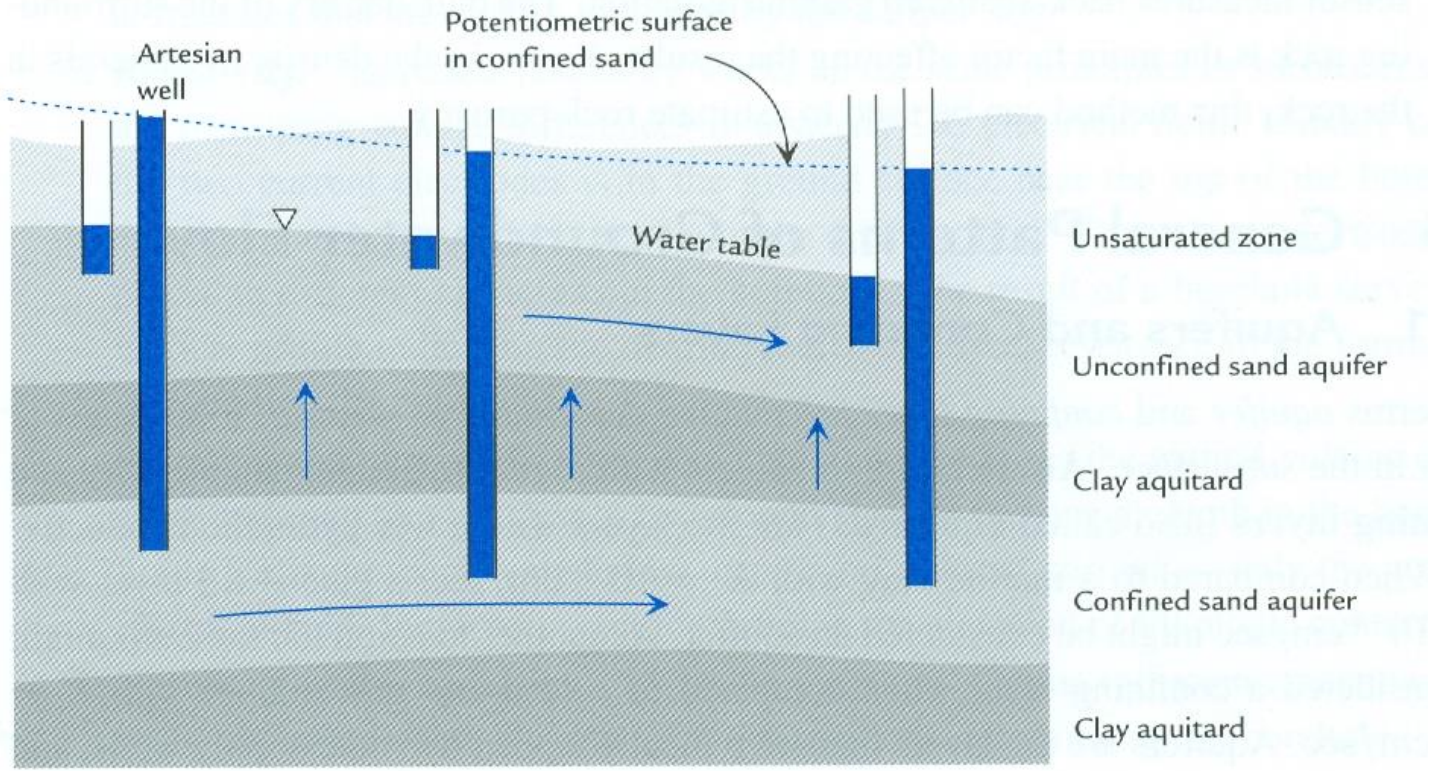


Figure 4.13 Vertical cross-section through an unconfined aquifer and a confined aquifer, with a confining layer separating the two. An artesian well is one where the water level rises above the ground surface.

Source: Fitts (2002)

References

Fitts, C.R. (2002). Groundwater Science. Academic Press, Elsevier Science.

Hendriks, M.R. (2010). Introduction to Physical Hydrology. Oxford University Press.