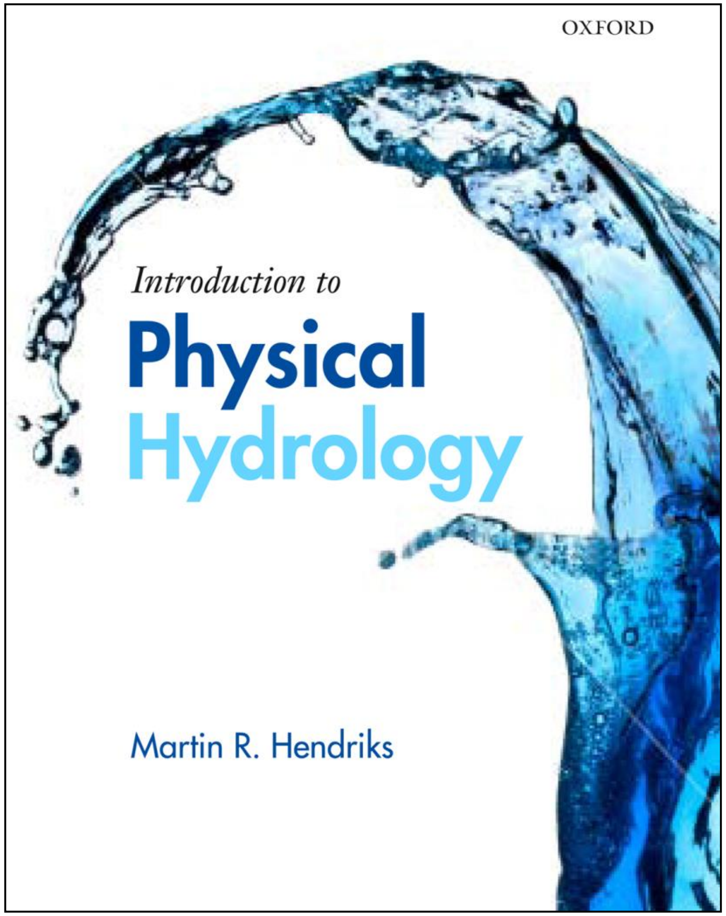
Soil water / Unsaturated Zone Hydrology



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

- Hydrological cycle
- Drainage basin
- Water balance

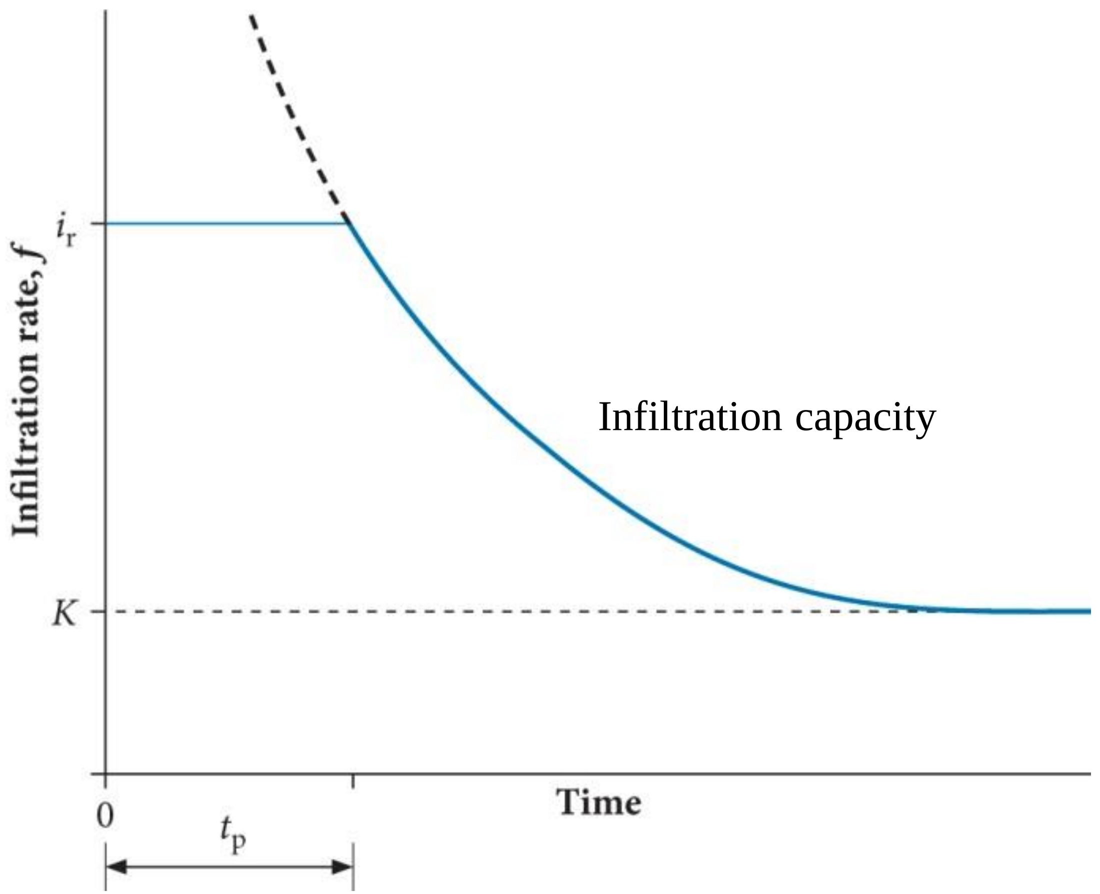
- Energy equation
- Flow equation
- Continuity equation

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

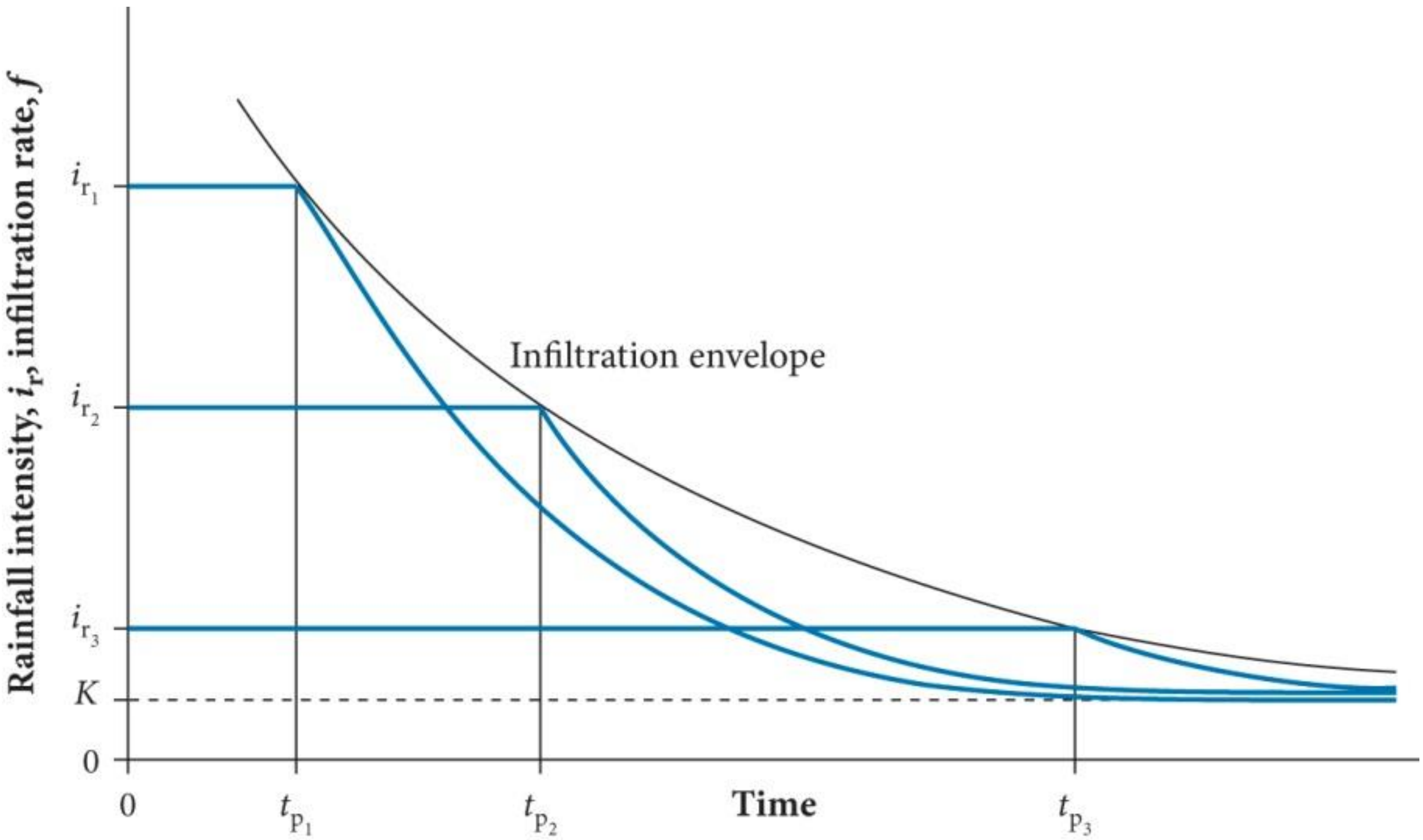
Exercises

Infiltration capacity

Ponded infiltration



Infiltration envelope



Horton equation

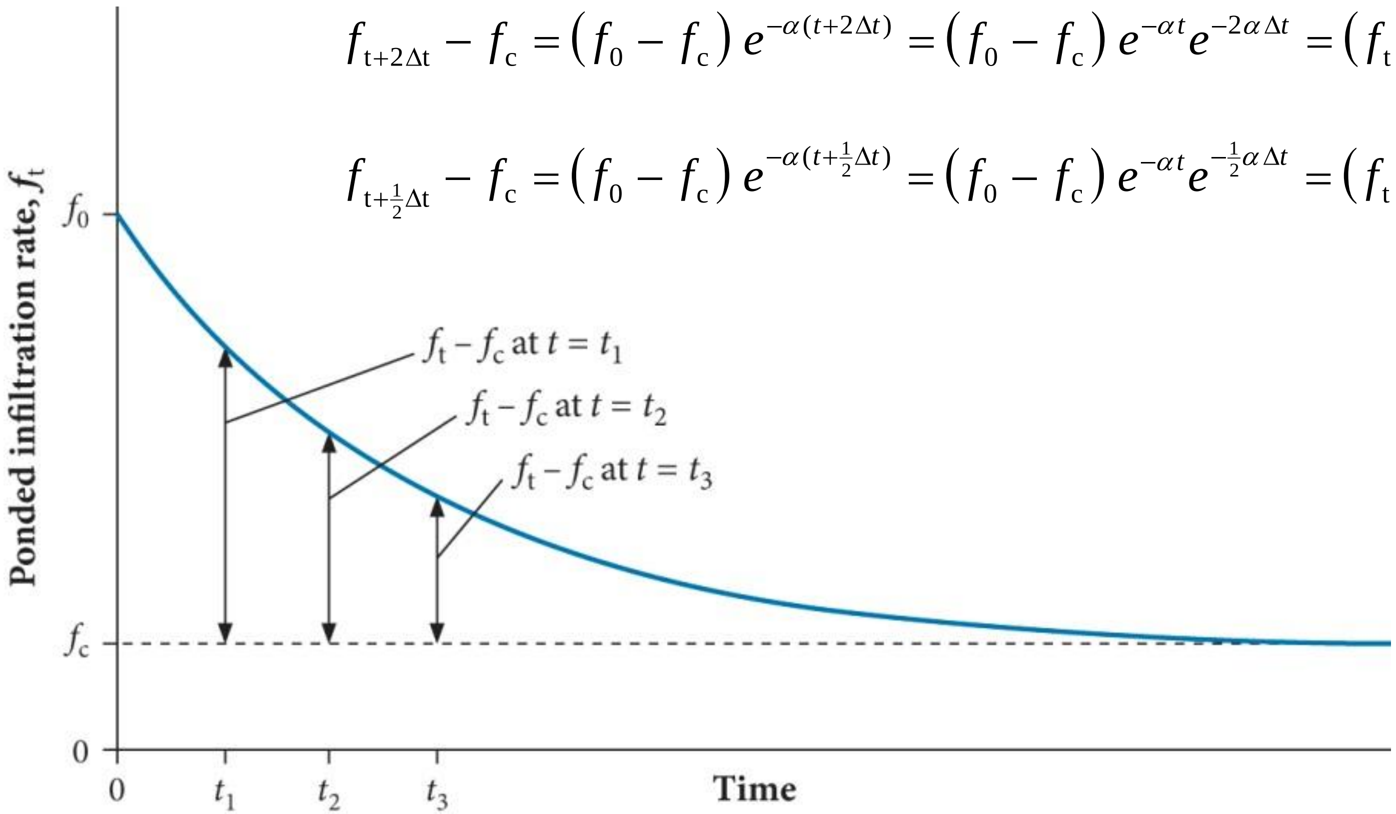
Ponded infiltration

$$f_t = f_c + (f_0 - f_c)\, e^{-\alpha t}\,;\; f_t - f_c = (f_0 - f_c)\, e^{-\alpha t}$$

$$f_{t+\Delta t} - f_c = (f_0 - f_c)\, e^{-\alpha (t+\Delta t)} = (f_0 - f_c)\, e^{-\alpha t} e^{-\alpha \Delta t} = (f_t - f_c) e^{-\alpha \Delta t}$$

$$f_{t+2\Delta t} - f_c = (f_0 - f_c)\, e^{-\alpha (t+2\Delta t)} = (f_0 - f_c)\, e^{-\alpha t} e^{-2\alpha \Delta t} = (f_t - f_c)\left(e^{-\alpha \Delta t}\right)^2$$

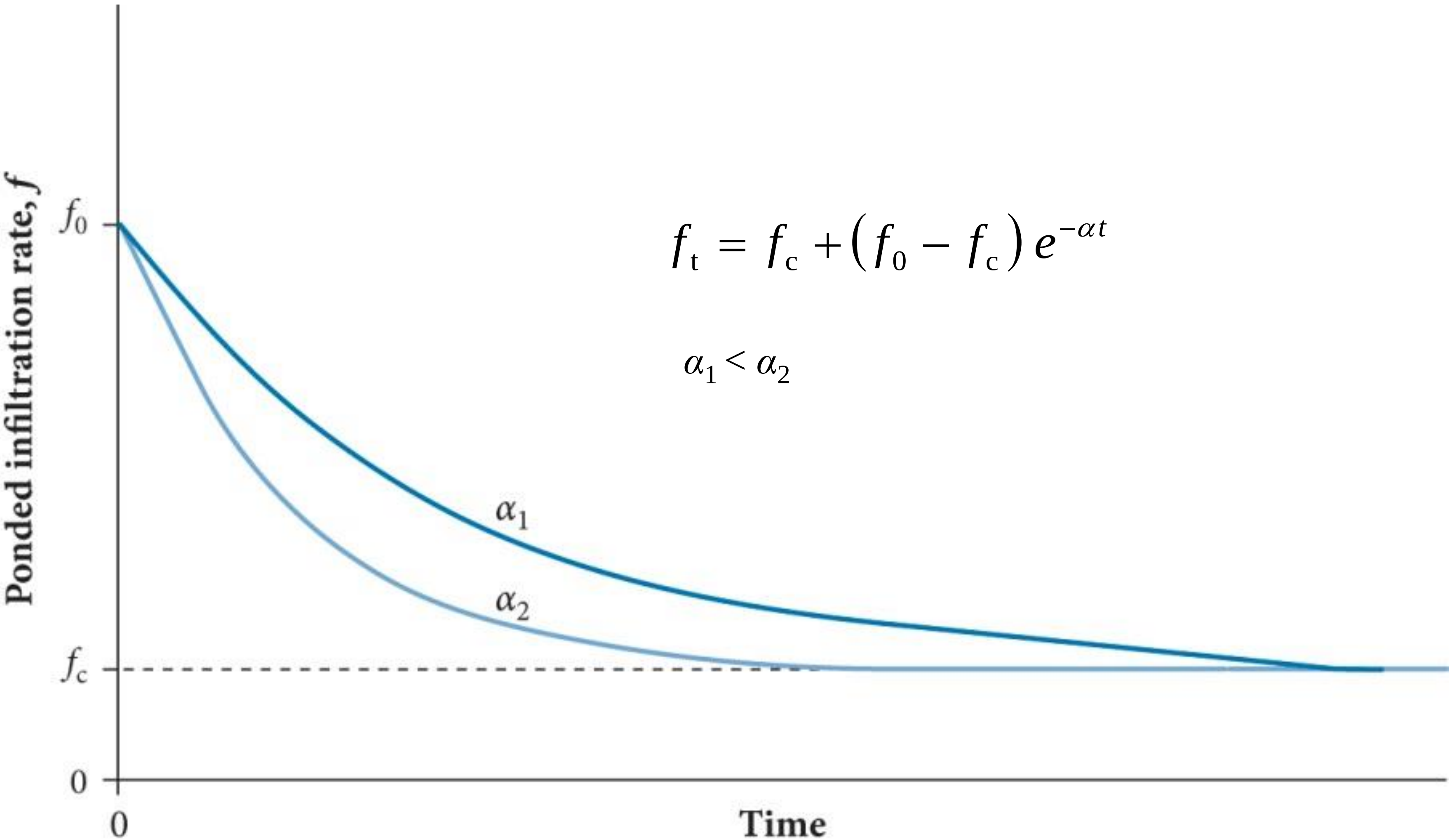
$$f_{t+\frac{1}{2}\Delta t} - f_c = (f_0 - f_c)\, e^{-\alpha (t+\frac{1}{2}\Delta t)} = (f_0 - f_c)\, e^{-\alpha t} e^{-\frac{1}{2}\alpha \Delta t} = (f_t - f_c)\left(e^{-\alpha \Delta t}\right)^{\frac{1}{2}}$$



After Horton (1939)

Two different values of α

Ponded infiltration

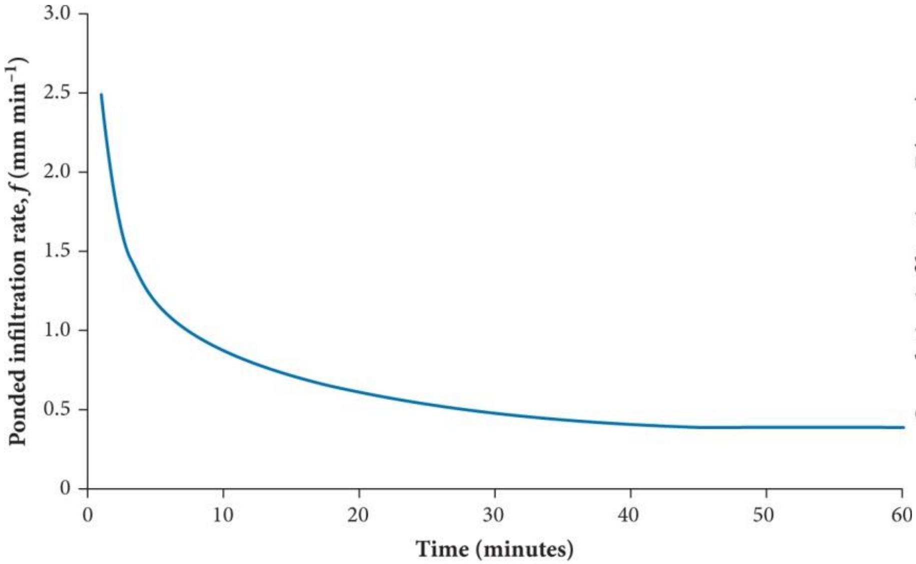


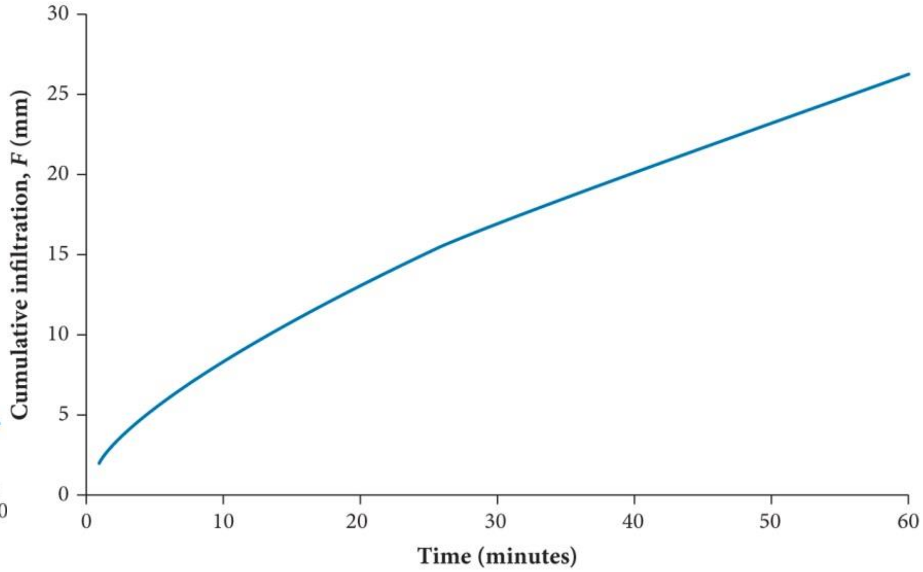
$$f_t = f_c + \left(f_0 - f_c\right) e^{-\alpha t}$$

$\alpha_1 < \alpha_2$

Philip equation

Ponded infiltration





$$f = \tfrac{1}{2} S t^{-\frac{1}{2}} + K$$

K = asymptotic end value of f

For t = 1 minute: $f = \tfrac{1}{2} S + K$

$$F = S t^{\frac{1}{2}} + K t$$

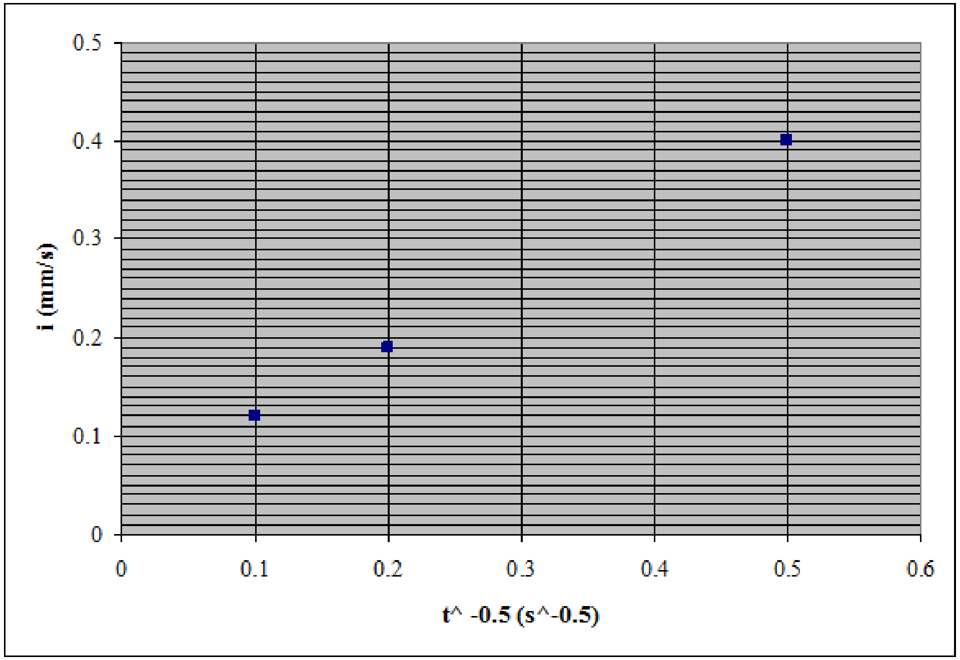
K = slope of straight part of curve

For t = 1 minute: $F = S + K$

Philip equation

Estimate the values of S and K_s

$$i = \tfrac{1}{2} S t^{-0.5} + A$$



$\frac{0.40 - 0.12}{0.5 - 0.1} = \frac{0.28}{0.4} = 0.7$ mm s$^{-0.5}$; the slope = $\tfrac{1}{2} S$

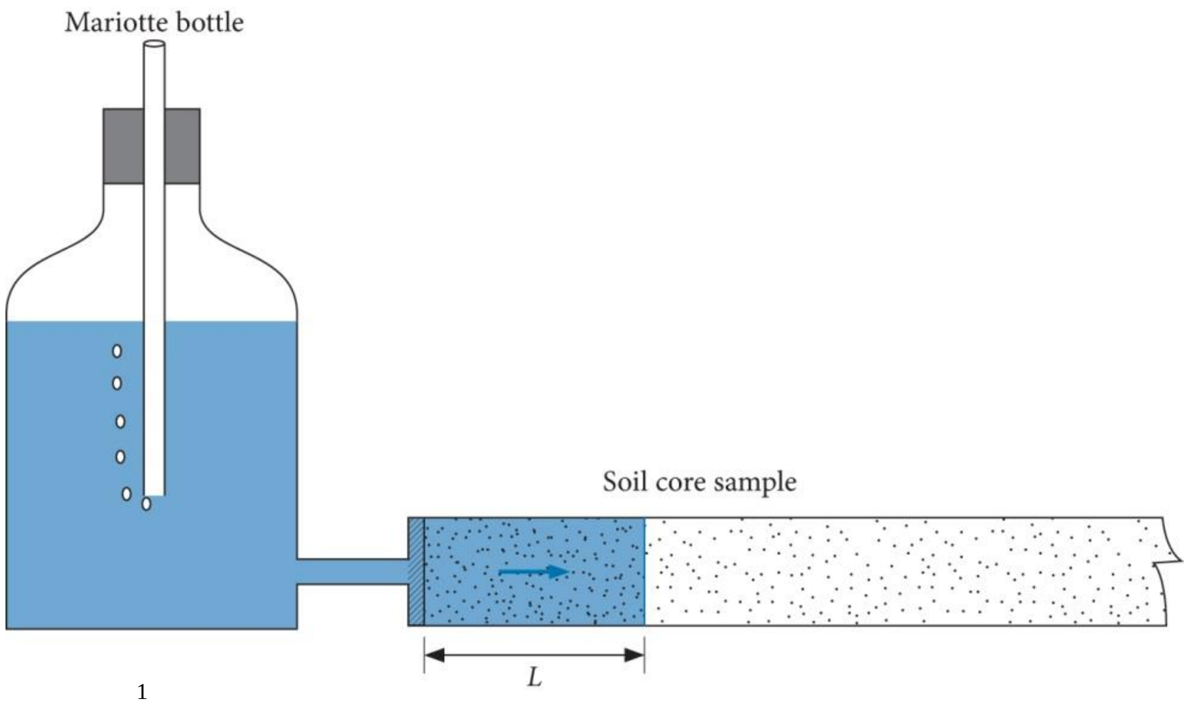
S is twice the slope = 1.4 mm s$^{-0.5}$

Intercept with the i-axis: 0.05 mm s^{-1}

$K_s = \tfrac{3}{2} A = 0.075$mm s^{-1} = 6.48 m day^{-1}

Texture: sand

Estimation of the sorptivity S



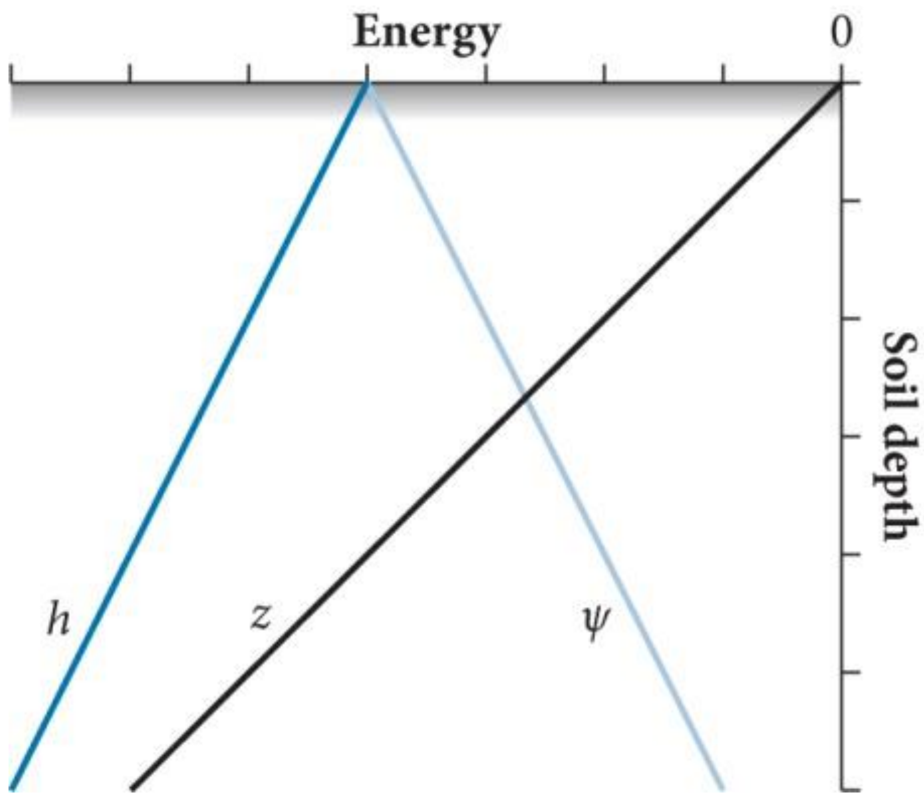
$$F = St^{\frac{1}{2}} + Kt$$

The horizontal water flow is mainly controlled by capillary action!

$F = S\sqrt{t}$ and $F = L(\theta_s - \theta_i)$

Non-ponding infiltration

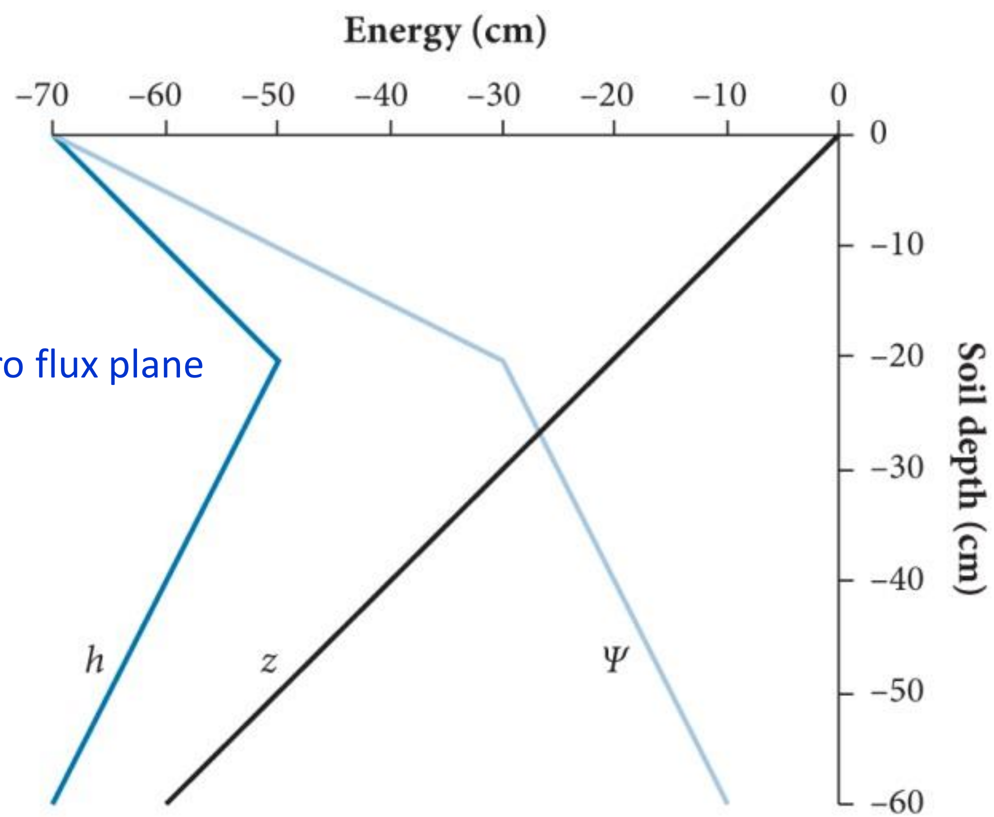
Potential diagram



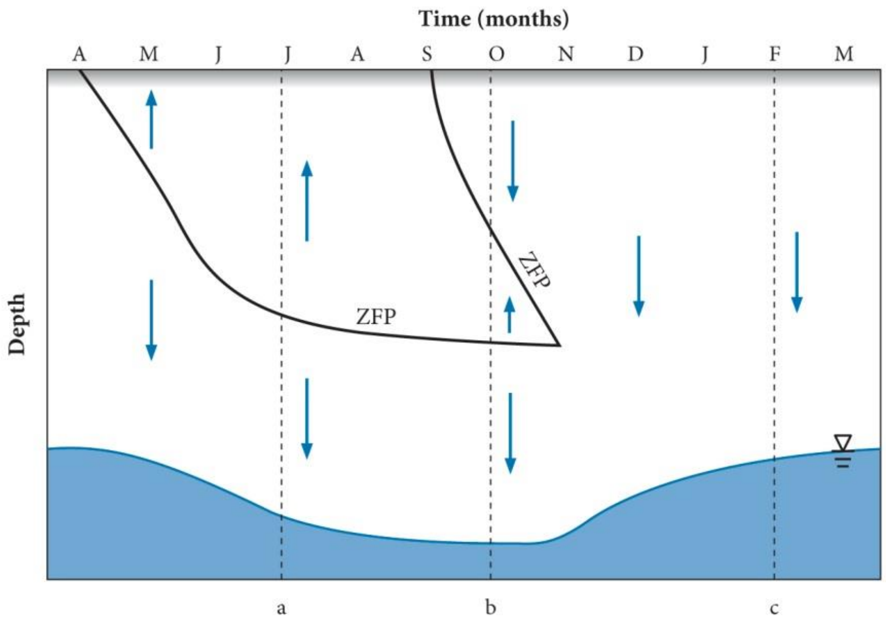
Evaporation and percolation

Potential diagram

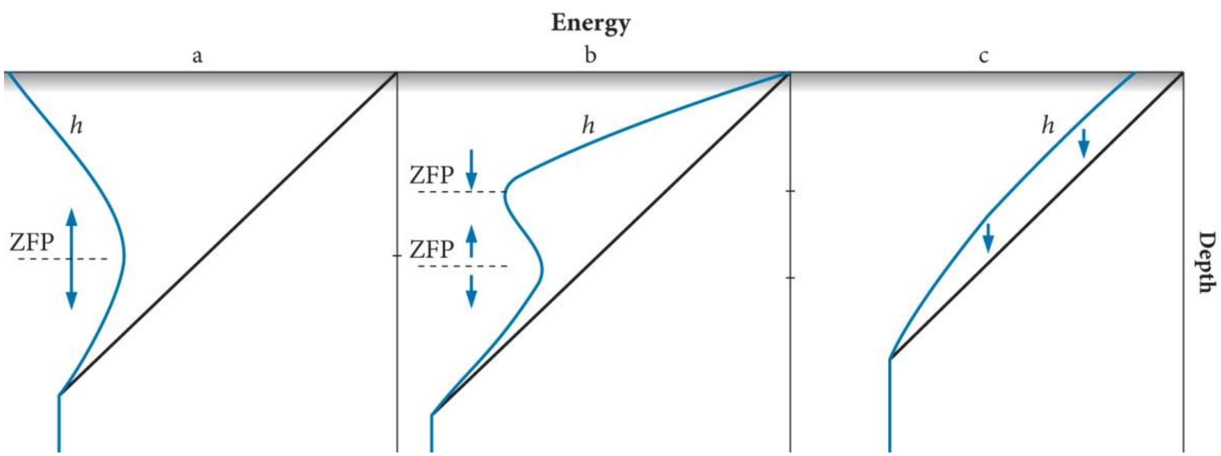
Zero flux plane



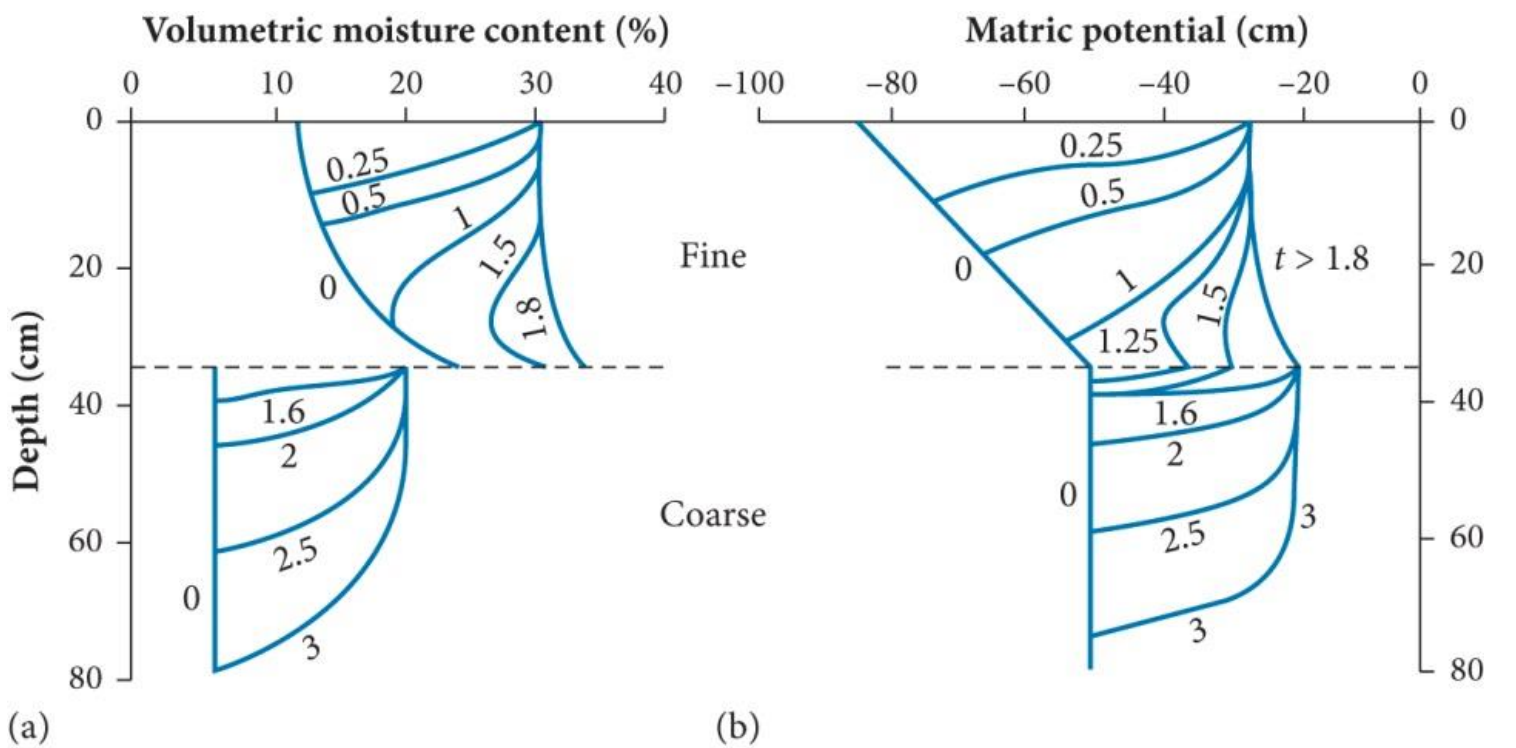
Development of zero flux planes



Adapted from Wellings and Bell (1982)



Effect of soil layering on percolation



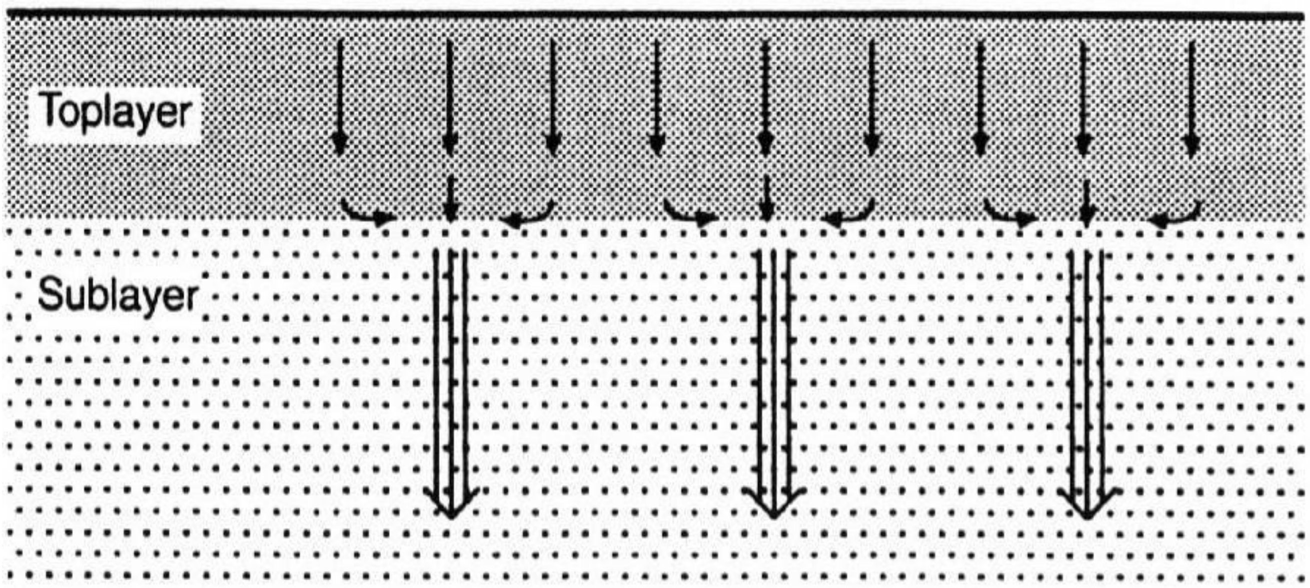
Profiles of the change with time (hours) of volumetric moisture content (a) and matric potential (b) during a constant rate of water application to a layered soil (after Vachaud et al. 1973)

Fingered flow due to soil heterogeneity

toplayer fine soil ⇔ sublayer coarse soil

high capillary suction ⇔ low capillary suction

low conductivity ⇔ high conductivity



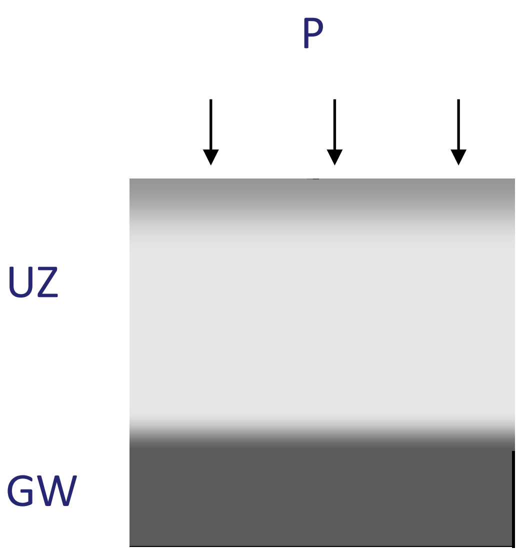
Fingered flow due to soil heterogeneity

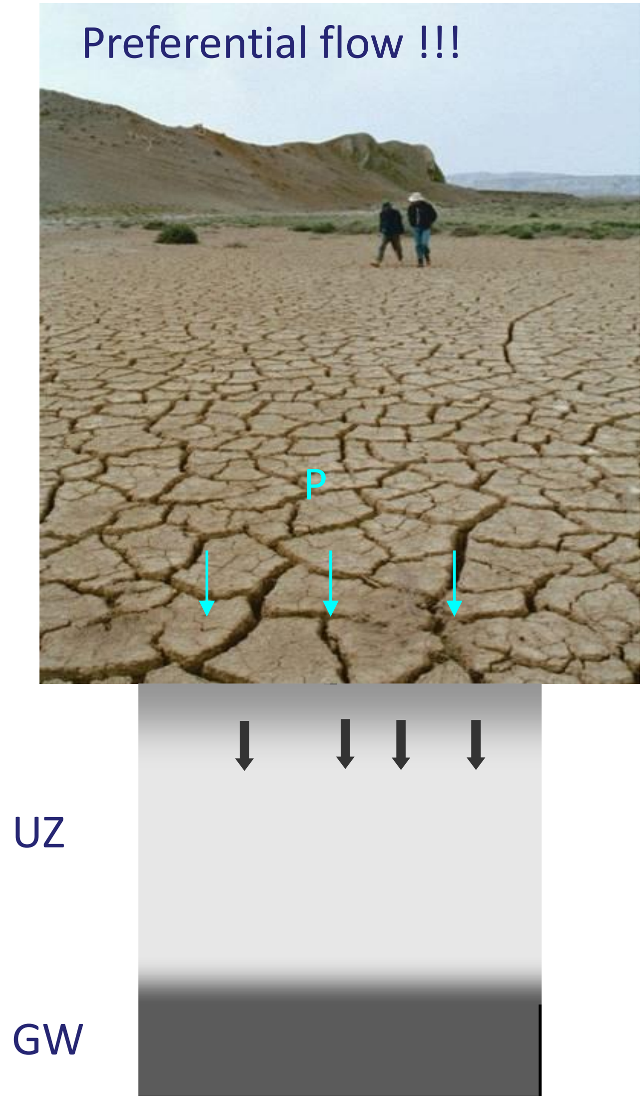
Photo taken by Dr L. van Schaik

Unsaturated flow

Traditionally :

- uniform
- vertical flow
- Richards equation





Preferential flow

Macropore flow

Fingered flow

Funnel flow

Source: Cornell University Soil and Water Laboratory

Exercise 4.9

Taking the soil as homogeneous can lead to a strong underestimation of the maximum depth of infiltration under high rainfall intensities!

References

Cornell University Soil and Water Laboratory: http://soilandwater.bee.cornell.edu/Research/pfweb/

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

Horton R.E. (1939). Analysis of runoff-plot experiments with varying infiltration capacity. Transactions, American Geophysical Union, 20, 693–711.

Vachaud, G., Vauclin, M., Khanji, D. and Wakil, M. (1973). Effects of air pressure on water flow in an unsaturated stratified vertical column of soil. Water Resources Research, 9, 160-173.

Wellings, S.R. and Bell, J.P. (1982). Physical controls of water movement in the unsaturated zone. Quarterly Journal of Engineering Geology, 15(3), 235-241.