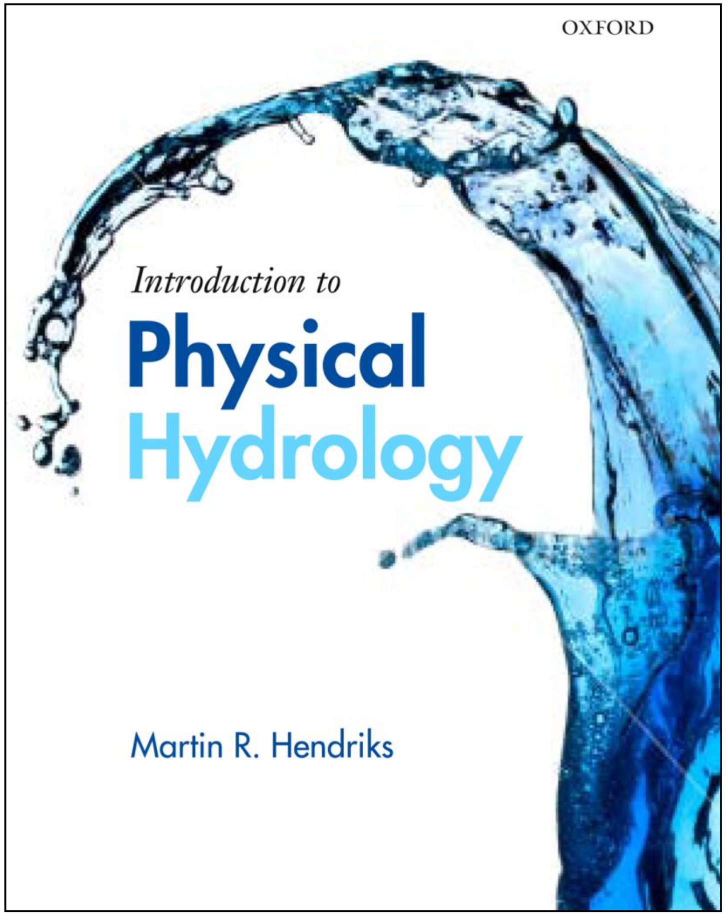
Groundwater



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

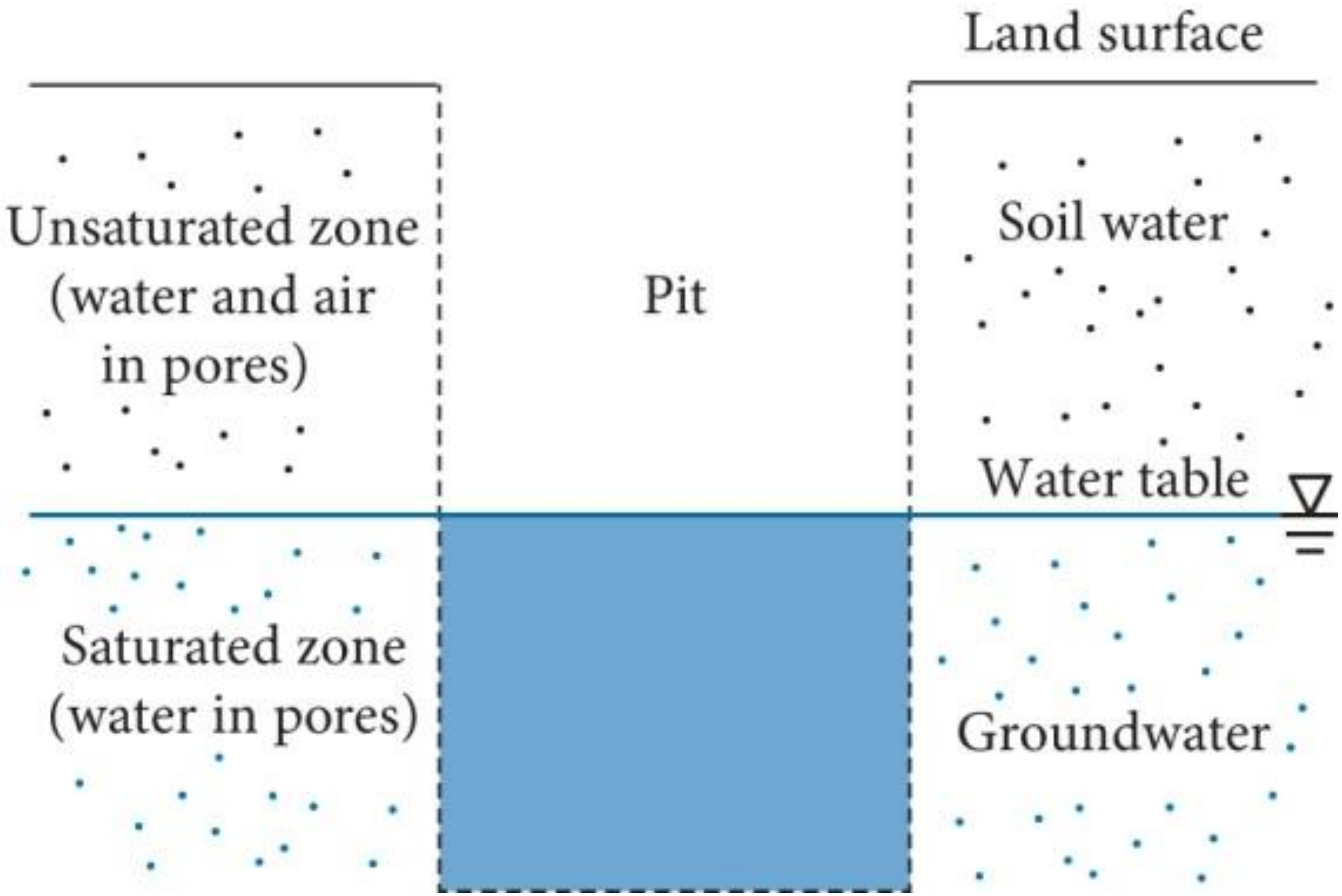
- Hydrological cycle
- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

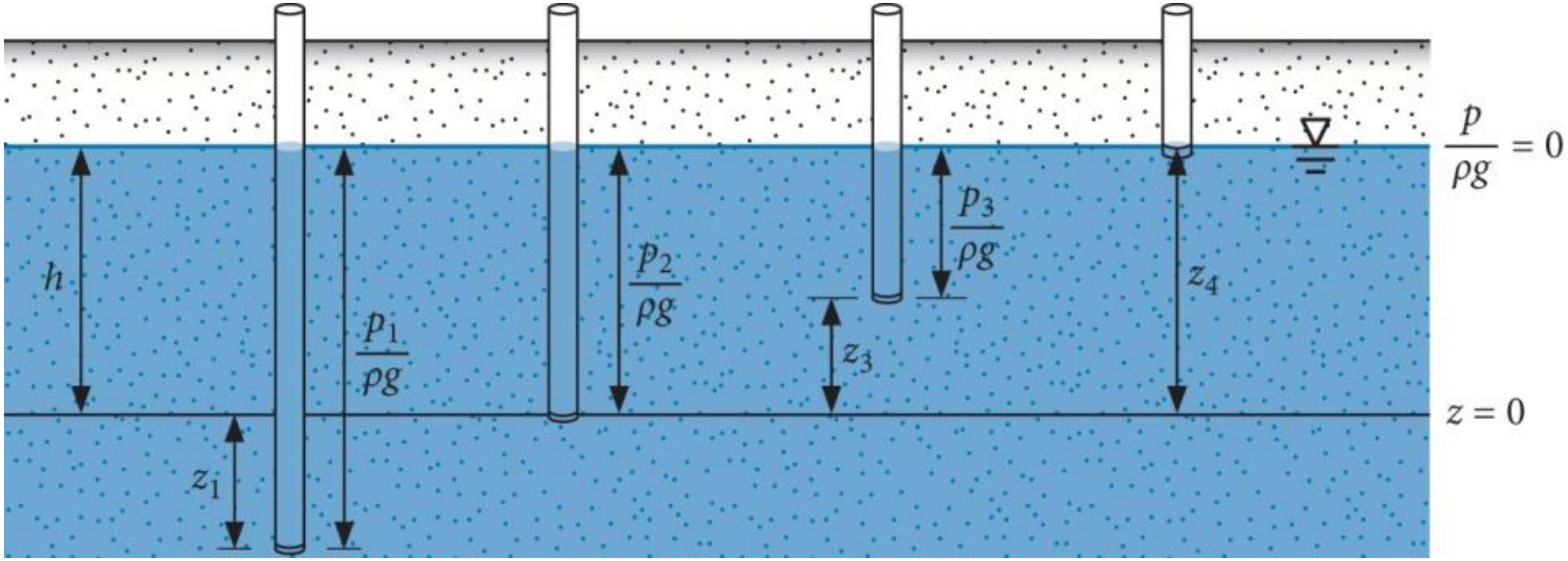
1. Introduction
2. Atmospheric water
3. **Groundwater**
4. Soil water
5. Surface water

Exercises

Water table

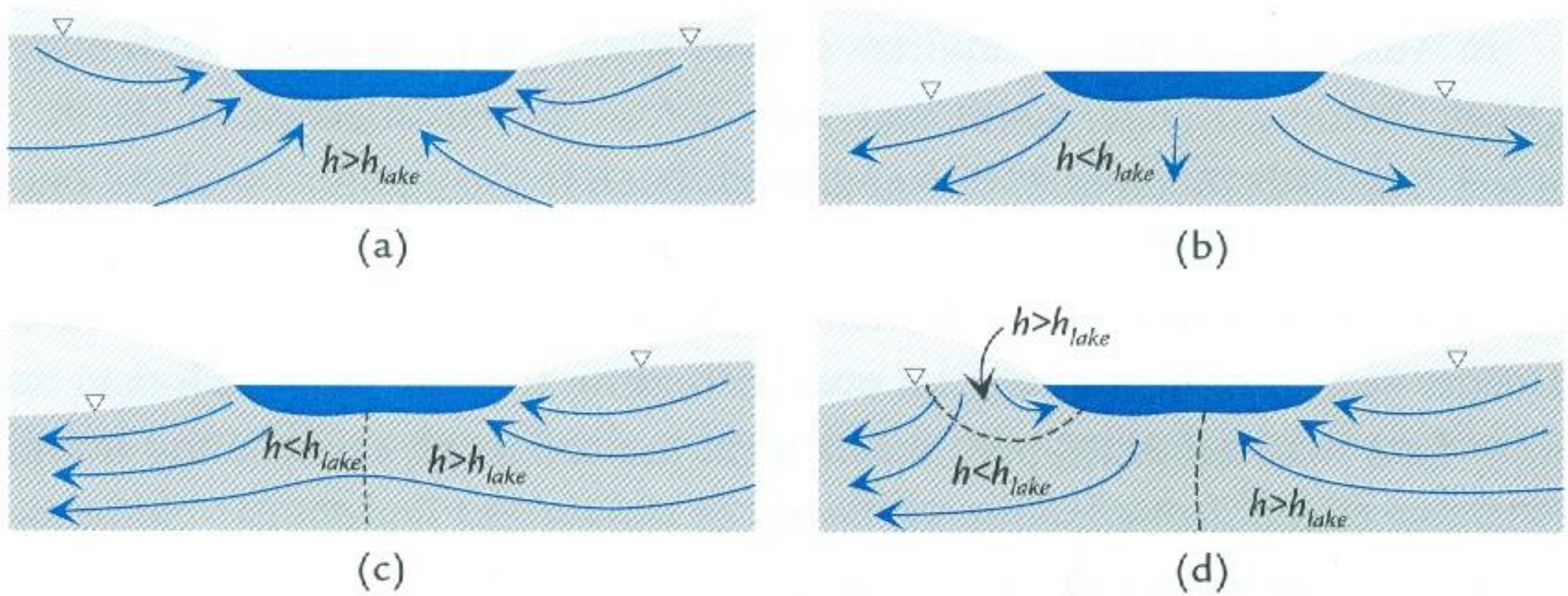

Land surface
Unsaturated zone
(water and air
in pores)
Pit
Soil water
Water table
Saturated zone
(water in pores)
Groundwater

Hydrostatic equilibrium



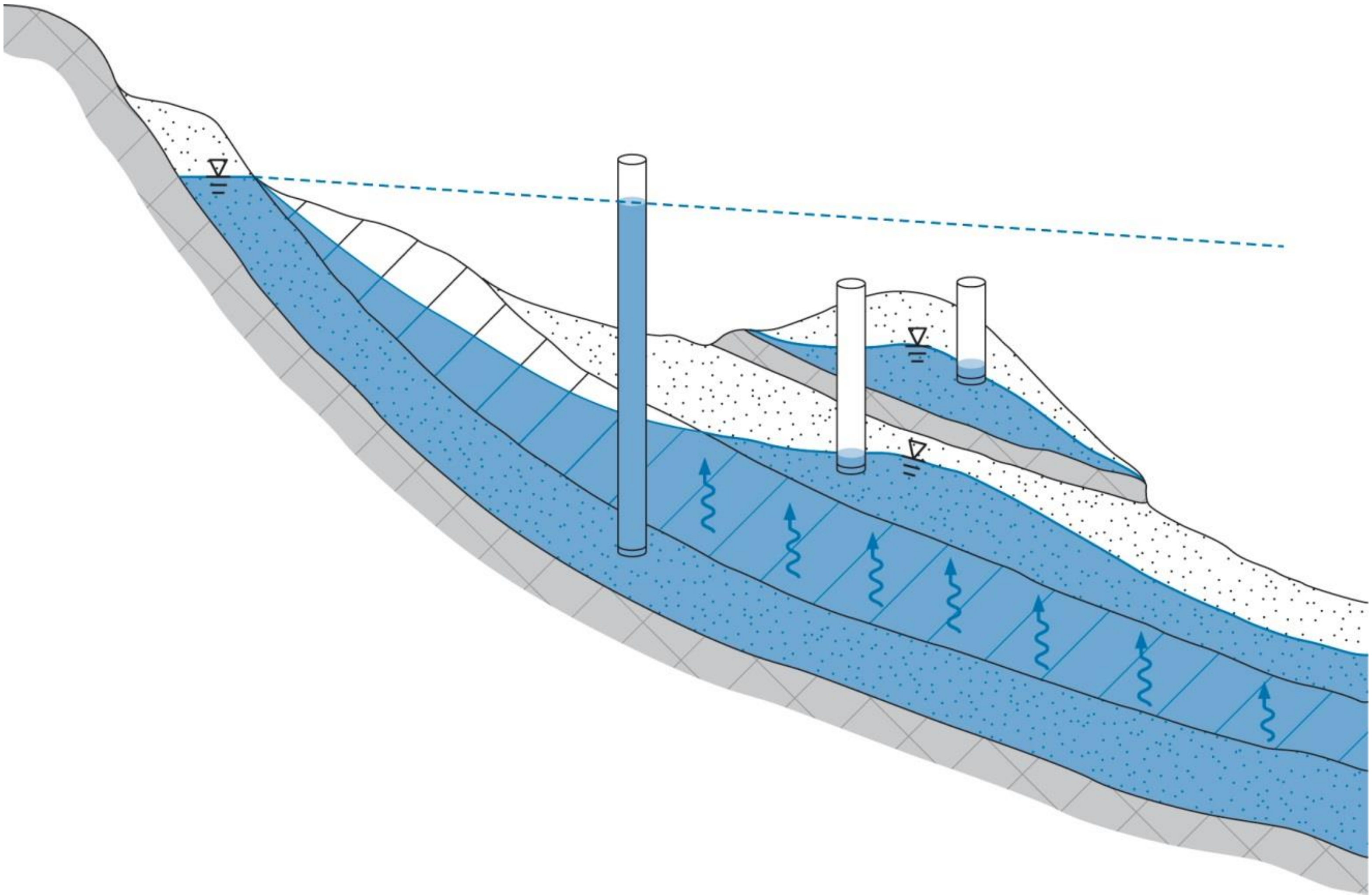
$$h = z_1 + \frac{p_1}{\rho g} = 0 + \frac{p_2}{\rho g} = z_3 + \frac{p_3}{\rho g} = z_4 + 0$$

Flow patterns beneath lakes



Source: Fitts (2002)

Aqui...



Lagen in de ondergrond

aquifer = watervoerende laag

unconfined aquifer = phreatic aquifer = freatisch watervoerende laag

confined aquifer = afgesloten watervoerende laag

semi-confined aquifer = leaky aquifer = gedeeltelijk afgesloten watervoerende laag

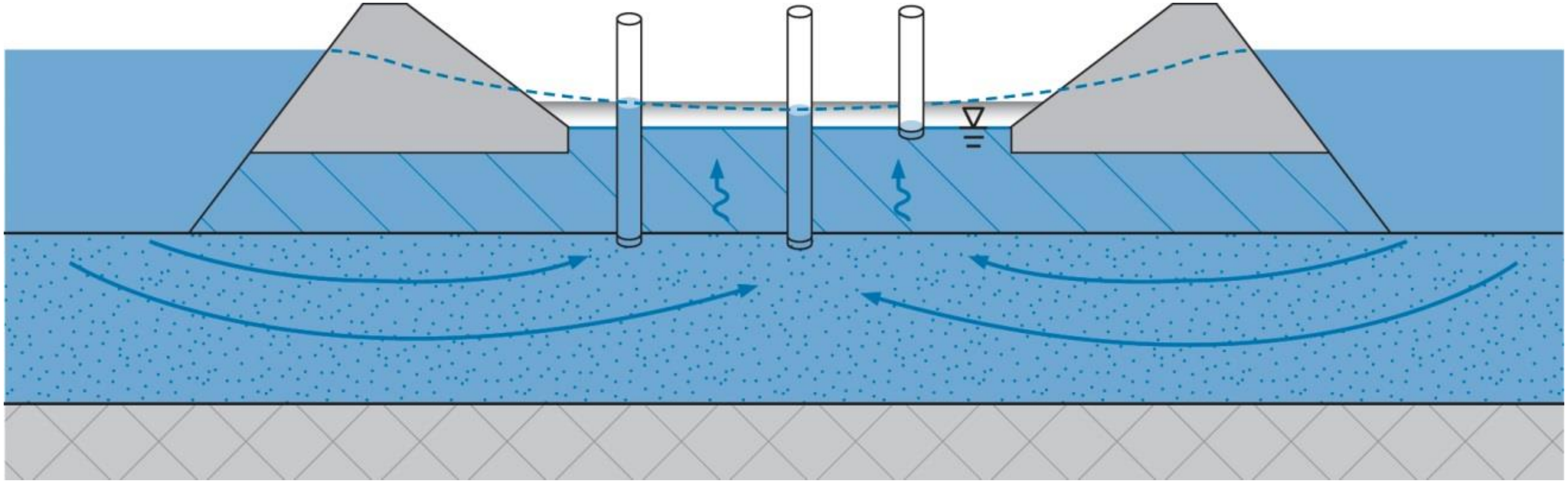
confining layer = afsluitende laag

impermeable layer = aquifuge = ondoorlatende laag

semi-permeable layer = aquitard = slecht-doorlatende laag

leaky confining layer = aquitard = gedeeltelijk afsluitende laag

Seepage in a polder area



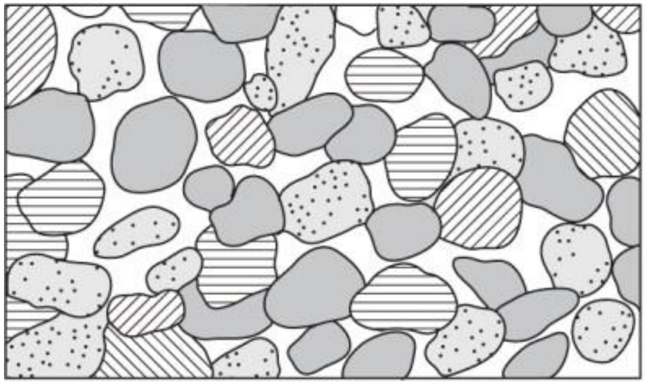
Land van Maas en Waal

Upward seepage behind dyke

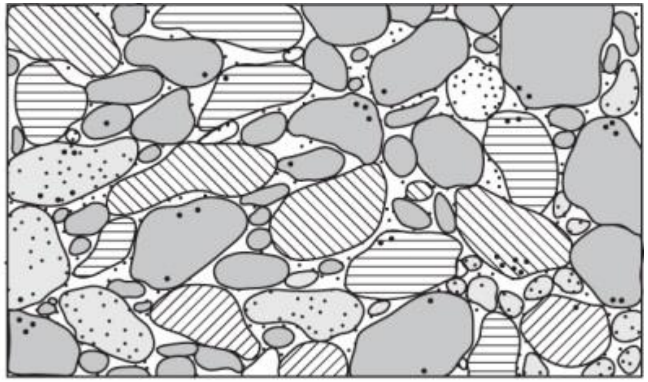
Photo taken by P.C. Beukenkamp

Porosity

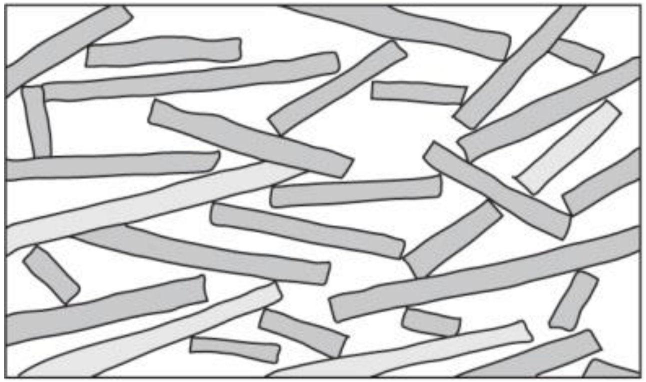
After De Vries and Cortel (1990)



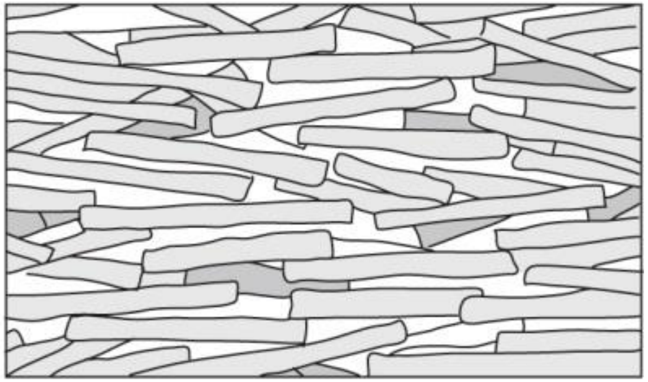
Well-sorted, rounded, porous sand; porosity $n \approx 0.4$



Poorly sorted, partly cemented sand with smaller grains in the interstices; porosity $n \approx 0.2$



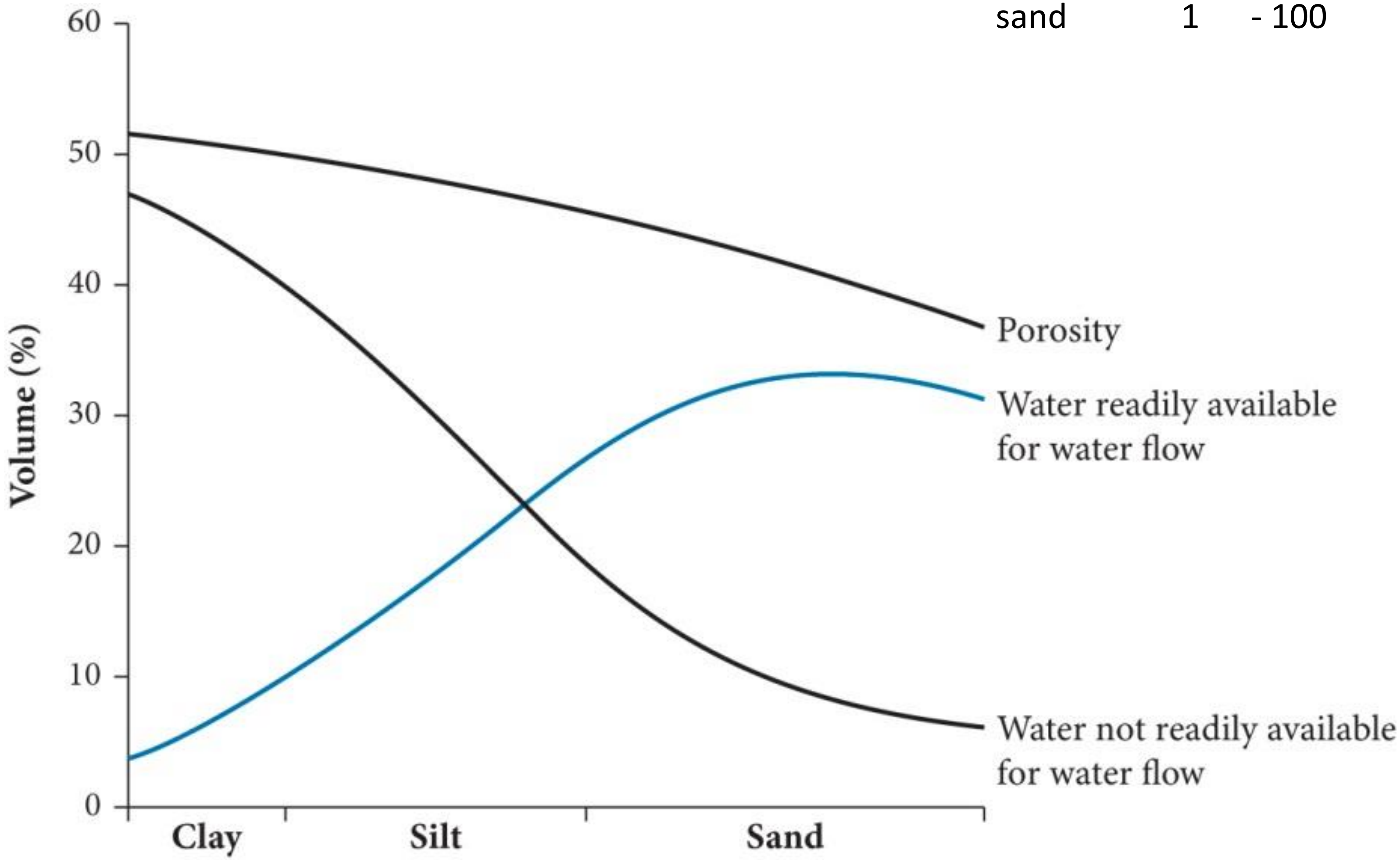
Very porous, loosely packed clay; porosity $n \approx 0.7$



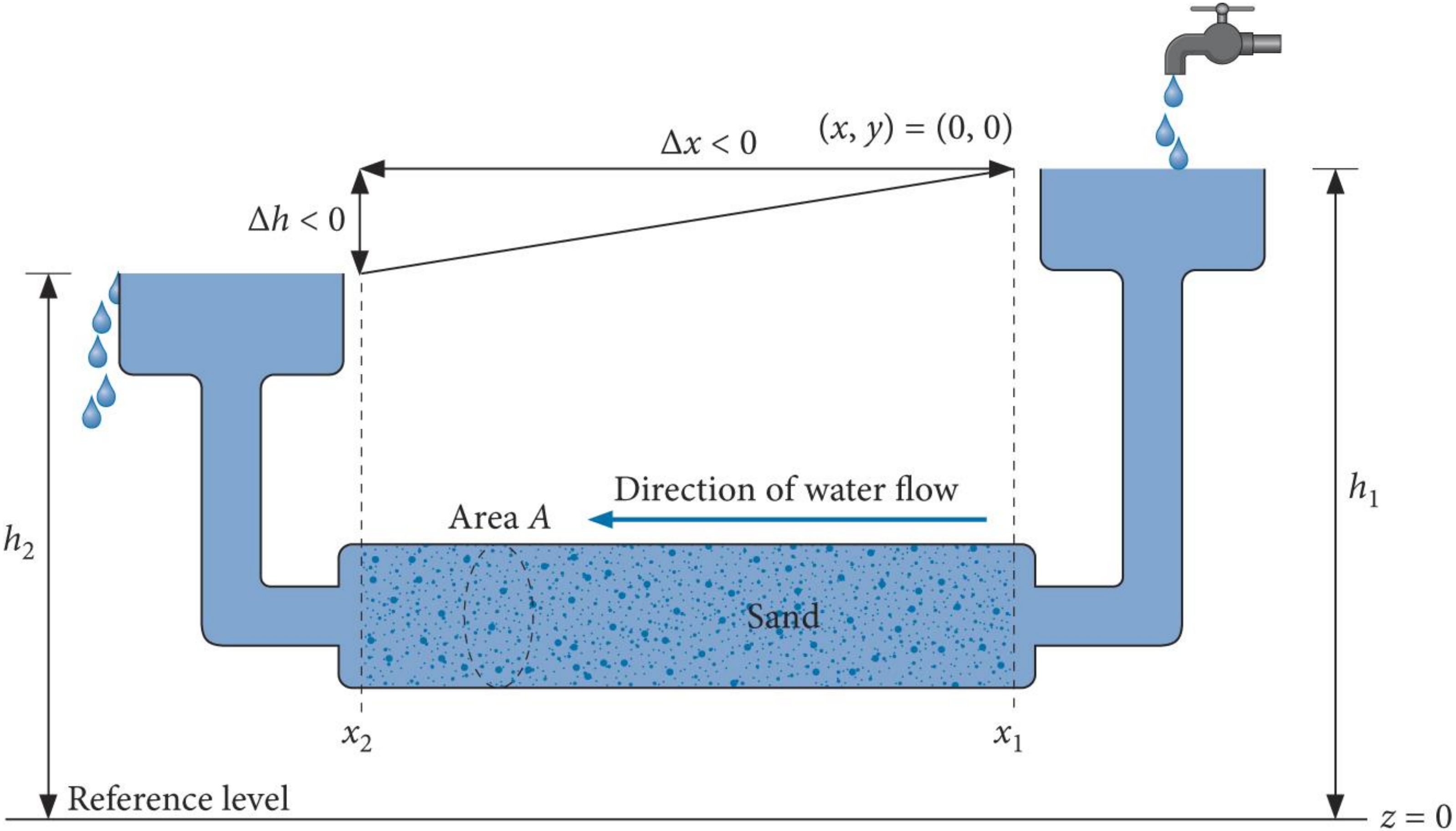
Slightly compacted, porous clay; porosity $n \approx 0.5$

Do NOT confuse these!

Table 3.1 Porosity *n* (-)	clay	0.4 - 0.7
	sand	0.25 - 0.4
Table 3.2 Hydraulic conductivity *K* (m day^{-1})	clay	≈0 - 0.2
	sand	1 - 100



Darcy's law



$\Delta x < 0$
$(x, y) = (0, 0)$
$\Delta h < 0$
Direction of water flow
Area A
Sand
h_2
h_1
x_2
x_1
Reference level
$z = 0$

Homogeneity and isotropy

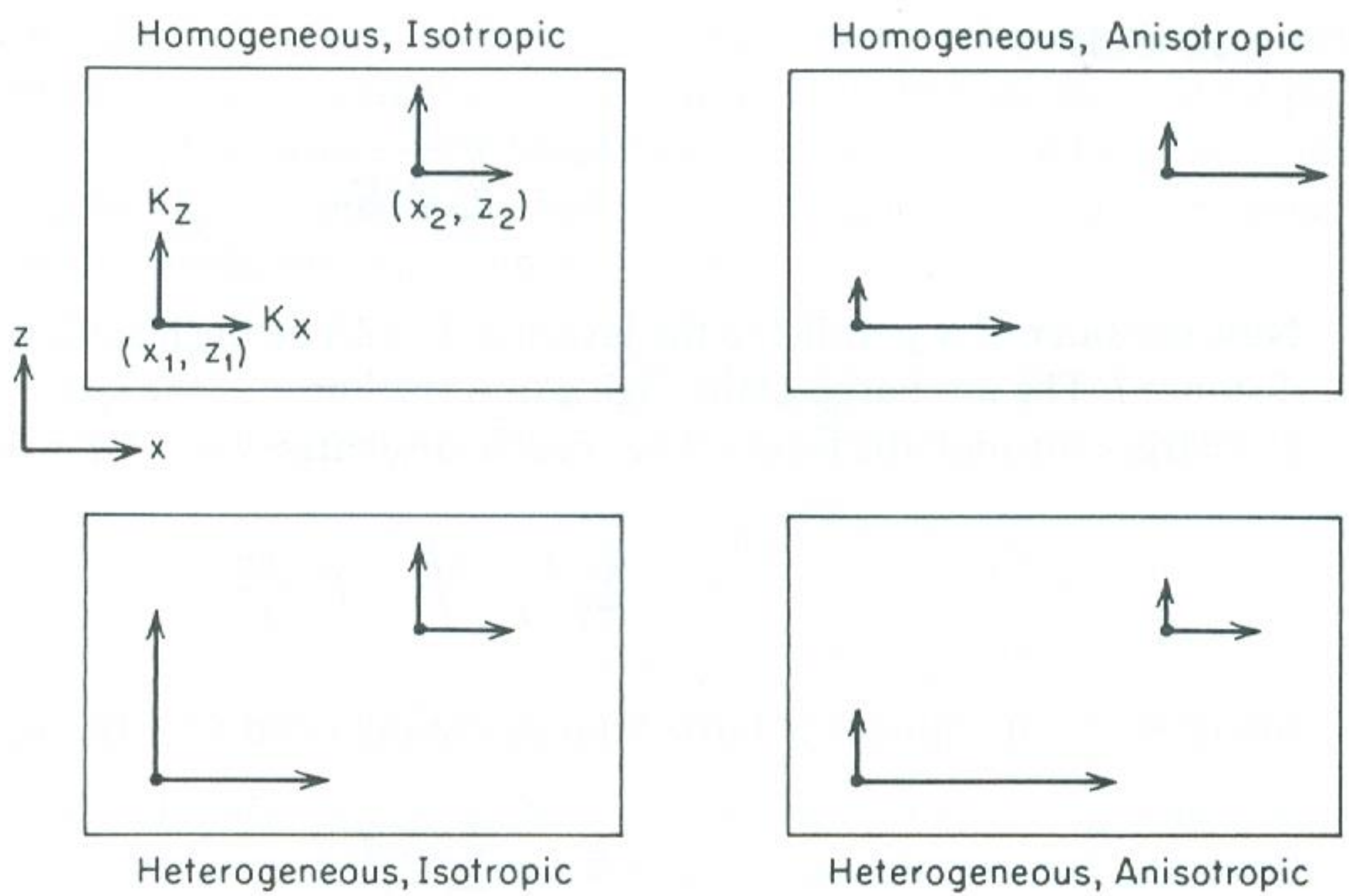
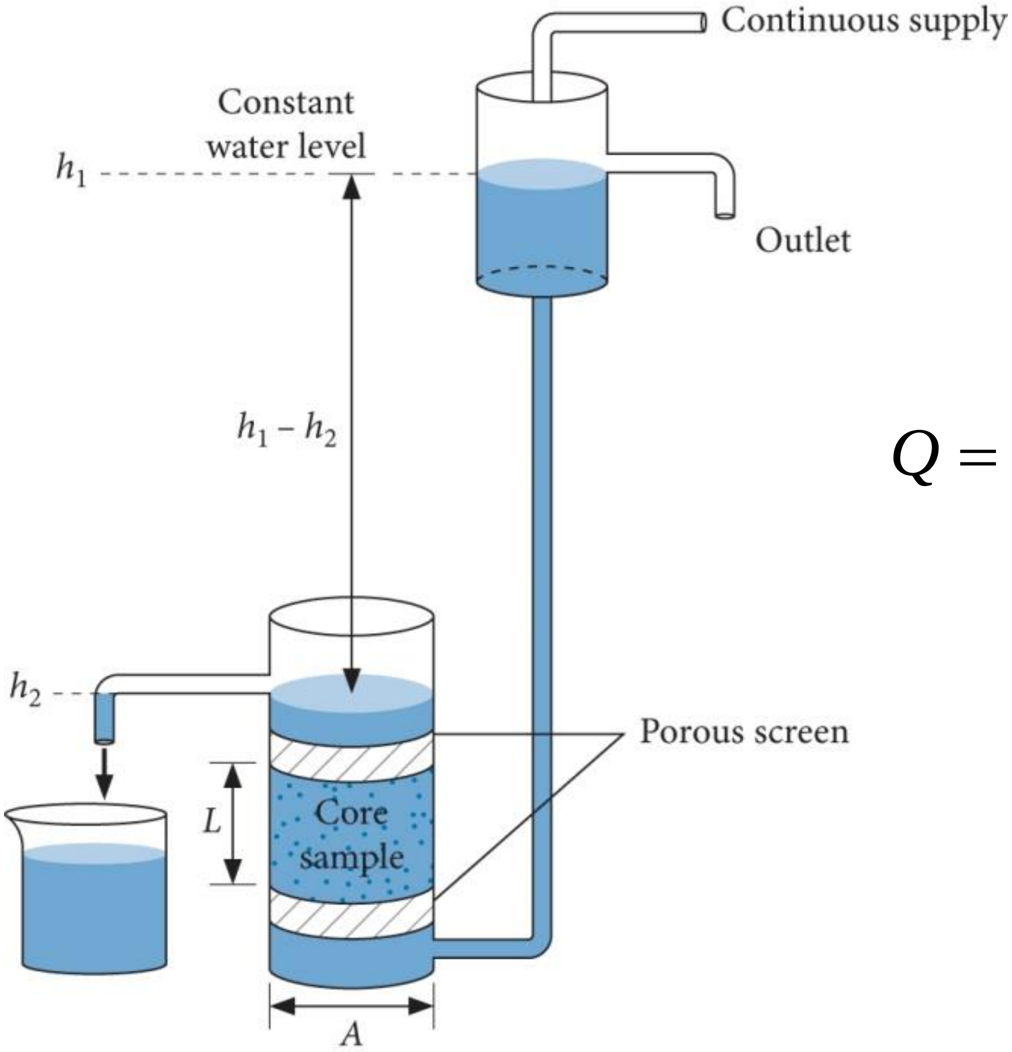


Figure 2.8 Four possible combinations of heterogeneity and anisotropy.

Source: Freeze and Cherry (1979)

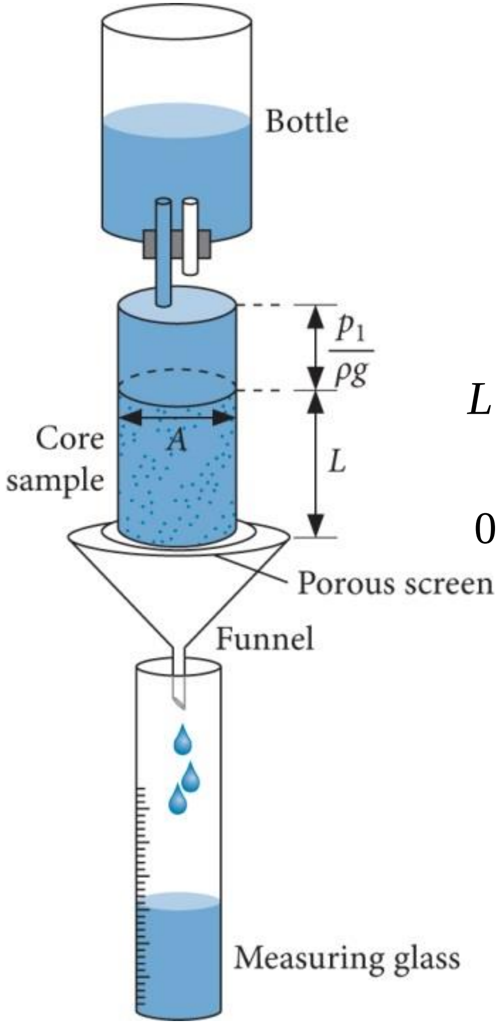
Constant-head permeameter



$$Q = -K\,A\,\frac{\Delta h}{L}$$

Constant-head permeameter

Kopecki field method



$$L + \frac{p_1}{\rho g}$$

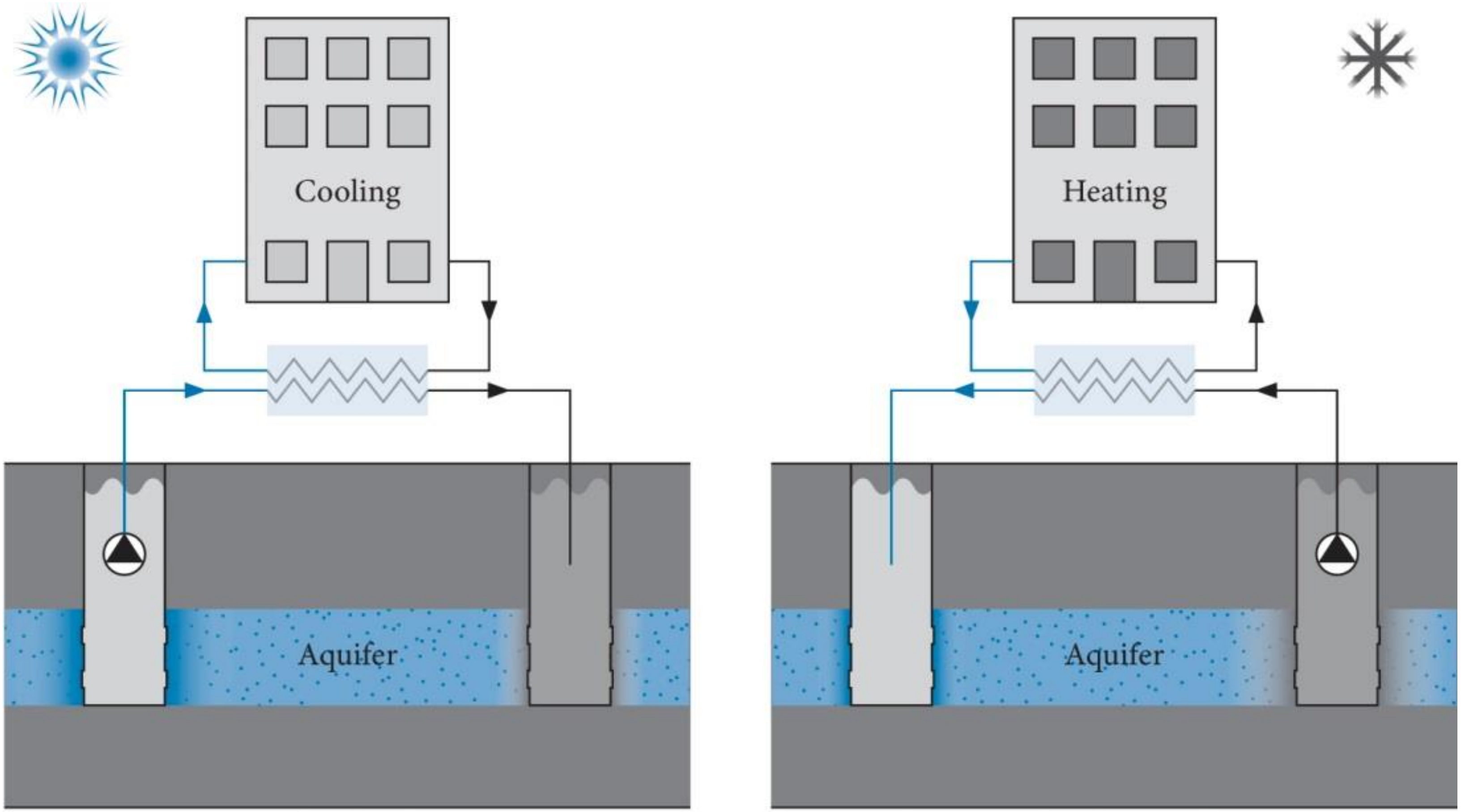
$$0 + 0$$

$$Q = -KA\frac{L + \frac{p_1}{\rho g}}{L} \quad (Q < 0)$$

Kopecki field method

Kopecki field method

Aquifer thermal energy storage



Summer: cooling of office buildings

Winter: heating of office buildings

Source: IF Technology B.V., Arnhem, The Netherlands

References

De Vries, J.J. and Cortel, E.A. (1990). Introduction to Hydrogeology. Lecture notes. Institute of Earth Sciences, VU University Amsterdam, The Netherlands.

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

Freeze, R.A. and Cherry, J.A. (1979). Groundwater. Prentice Hall, Inc. / Pearson Education, Inc.: http://hydrogeologistswithoutborders.org/wordpress/1979-english/preface/

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