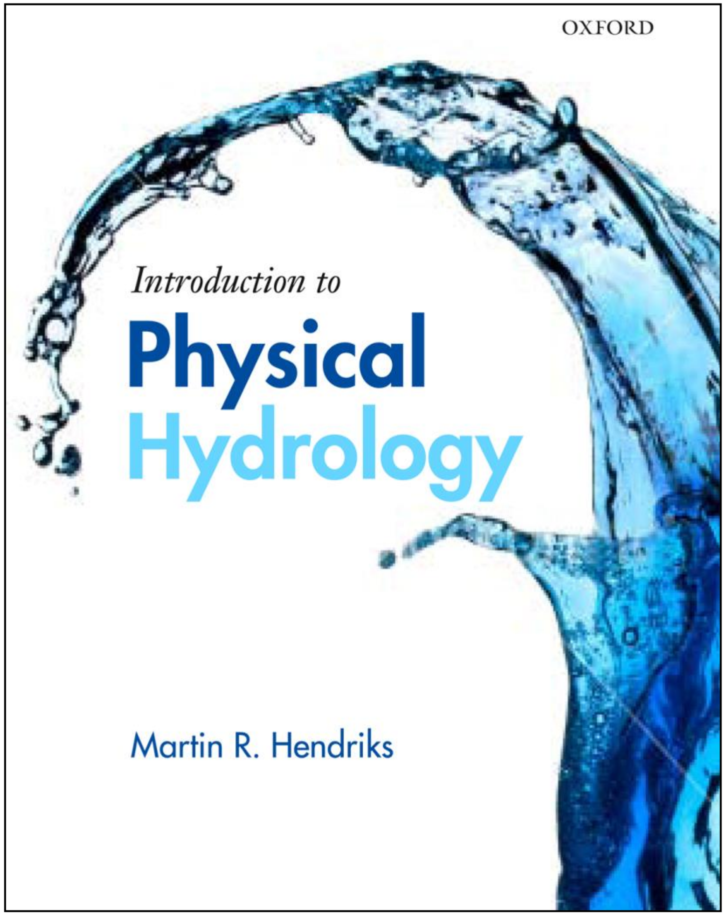
Soil water / Unsaturated zone hydrology



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

- Hydrological cycle
- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

4. Soil water

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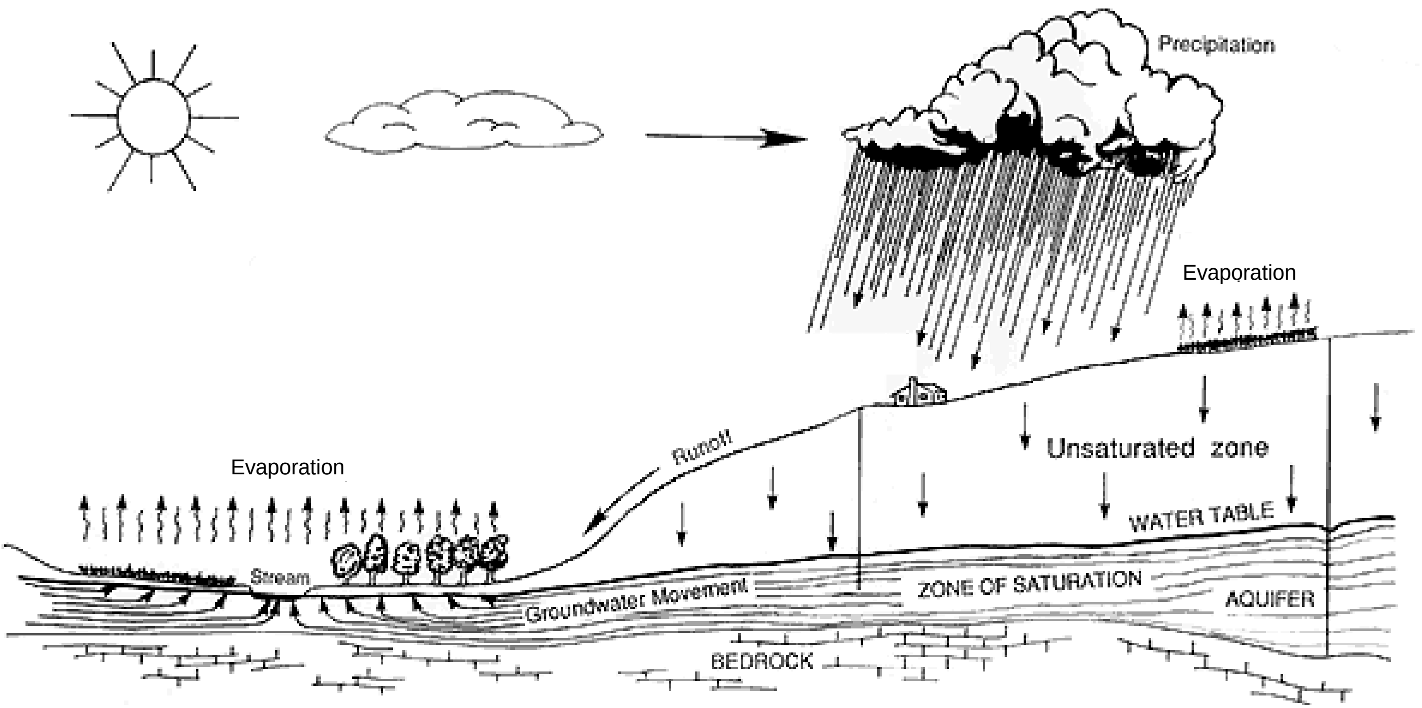
Soil water

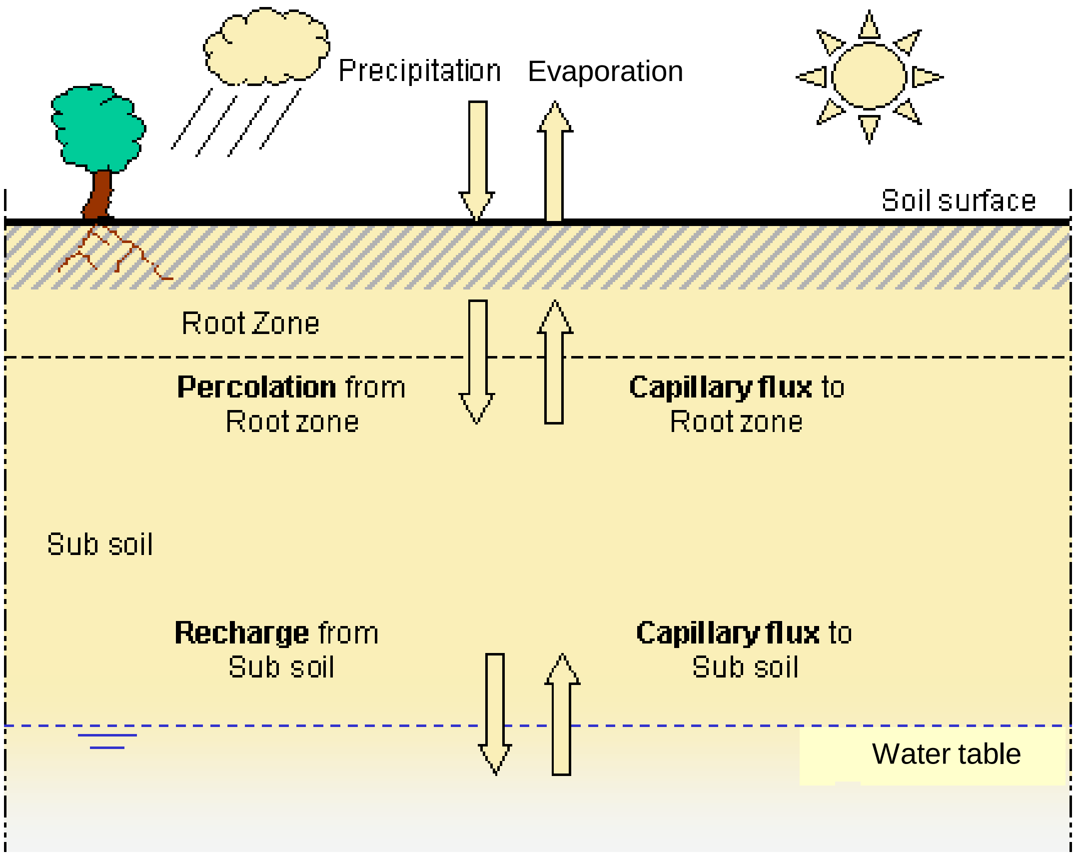


The unsaturated zone is part of the soil situated between the soil surface and the water table (phreatic level) where some of the spaces between the soil particles are filled with air.

Unsaturated zone

- Unsaturated zone (UZ)
- Vadose zone
- Root zone
- Percolation zone
- Capillary fringe

The UZ can be temporarily saturated but usually it is not.



Why study the unsatured zone?

The unsaturated zone is important for

- land degradation processes at the surface: overland flow, erosion
- land degradation processes below the surface: mass movement
- availability of moisture and growth of plants (natural vegetation, agriculture)
- groundwater recharge
- protecting groundwater from pathogenic bacteria and viruses

Soil components

- minerals
  - coarse sand (200 - 2000 µm)
  - fine sand (50 - 200 µm)
  - silt (2 - 50 µm)
  - clay (< 2 µm)
- organic matter
- water
- air

Proportions:

weather balloon = sand
basketball = silt
rice-grains = clay

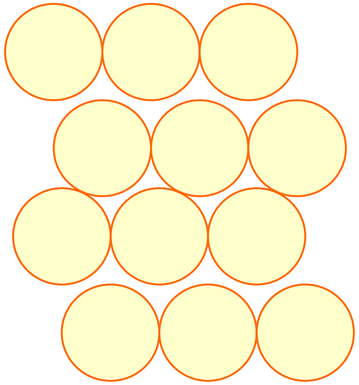
Porosity *n*

$n = \theta_s$ = volume pores / total volume (cm^3/cm^3)

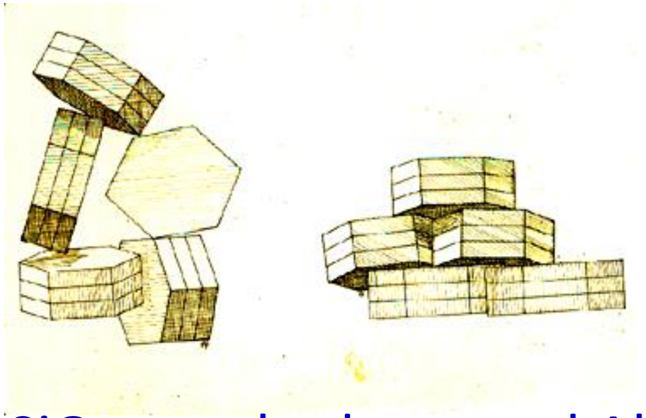
sandy soils	0.37 (0.30 - 0.56)
silty soils	0.45 (0.39 - 0.56)
loamy soils	0.50 (0.30 - 0.55)
clayey soils	0.53 (0.35 - 0.70)
peaty soils	0.80 - 0.85

Porosity *n* of sand and clay

n sand < *n* clay?



Sand: large grains; closely packed



Clay: small sheets of SiO_4 tetrahedrons and $Al(OH)_6$ octahedrons

Volumetric moisture content

- Measure the soil sample mass m_w
- Saturate the sample and measure the mass m_s
- Dry 24 hours in the oven at 105^0C
- Measure the sample mass again: m_d
- If V is the volume of the core sample ring:

$$\theta = \frac{m_\mathrm{w} - m_\mathrm{d}}{\rho_\mathrm{w} V}$$

$$\theta_\mathrm{s} = \frac{m_\mathrm{s} - m_\mathrm{d}}{\rho_\mathrm{w} V}$$

ρ_w = density of fresh water = 1000 kg m^{-3} = 1 g cm^{-3}

Photos soil core sample ring: Forschungszentrum Jülich GmbH

m_w, m_d and m_s: mass of core sample ring included

Moisture content

Volumetric moisture content θ

θ = volume water / total soil volume ($cm^3\ cm^{-3}$)

Gravimetric moisture content or wetness w

w = mass water / mass solid matter ($g\ g^{-1}$)

Relative moisture content or wetting phase saturation θ_E (0 – 1)

$\theta_E \approx \theta / n$

Dry bulk density ρ_d

ρ_d = mass of a dry soil / total soil volume ($g\ cm^{-3}$)

Calculations

Rainfall of 10 mm at a soil with $n_e = 0.4$ and $\theta = 0.3$ in first instance reaches a depth of:

$10 / (0.4 - 0.3) = 100$ mm

(and percolates afterwards under gravity).

A soil which due to compaction in volume of pores recedes from $n = 0.43$ to 0.37 loses in the upper 100 mm:

$(0.43 - 0.37) \times 100 = 6$ mm of storage capacity.

Hydrostatics

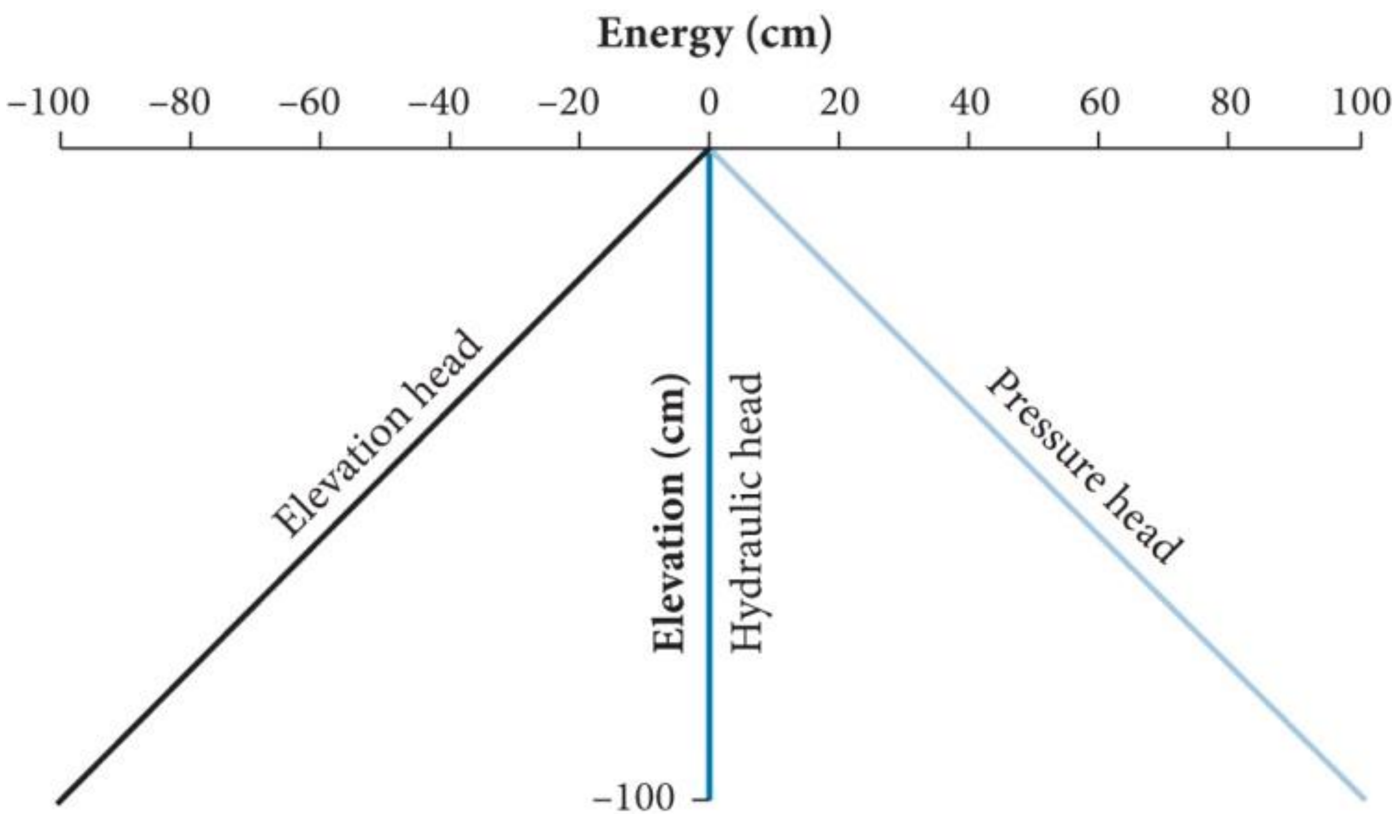
- Study of the forces in the soil-water system, when there is hydrostatic equilibrium
- All forces are in equilibrium: there is no water flow; the fluxes (*rates*) in the soil are zero; the moisture content (*state*) does not change
- The moisture content differs at different depths!

Forces in the soil:

- Gravity
- Capillary
- Adsorption
- Electrostatic
- ...

Groundwater at hydrostatic equilibrium

Potential diagram

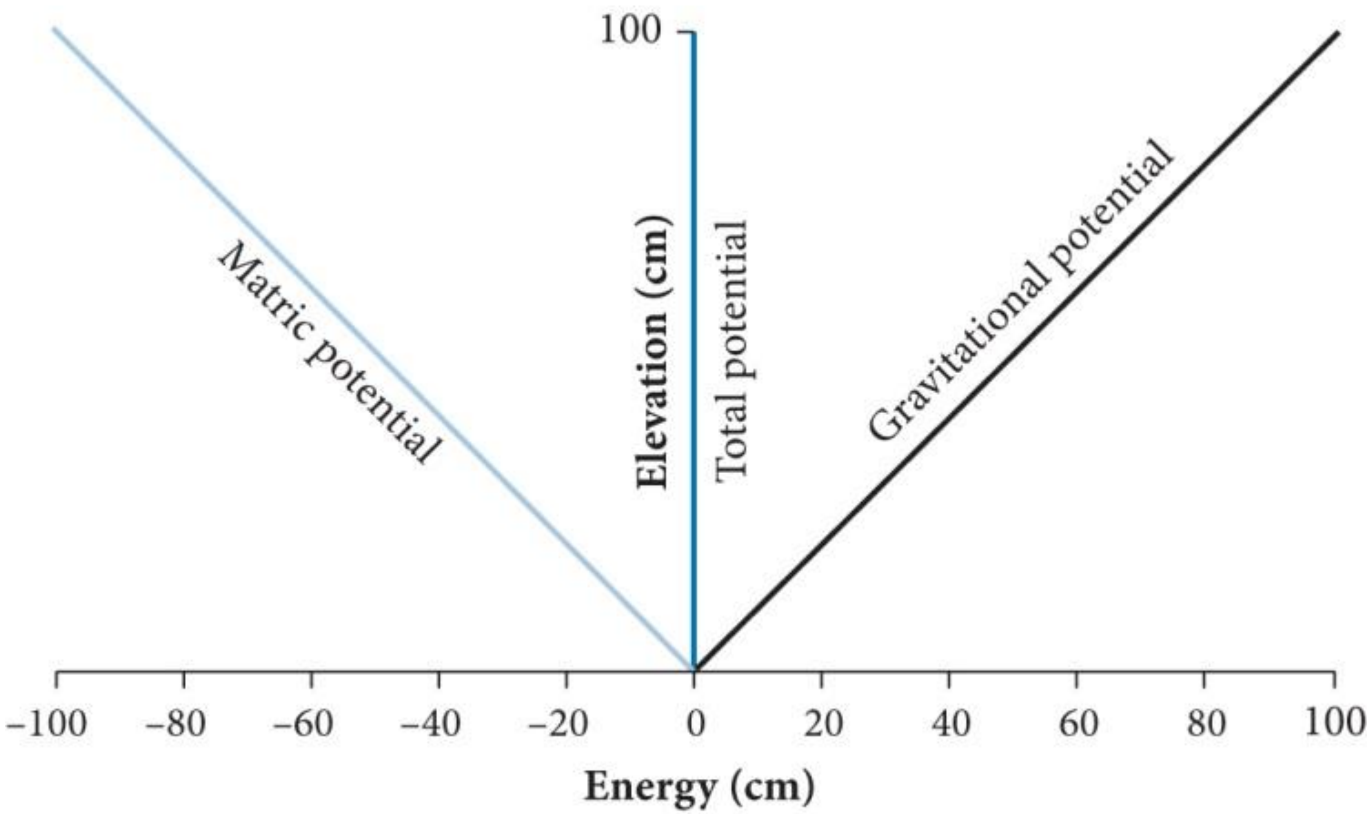


Bernoulli's law: $h = z + \frac{p}{\rho g}$

Soil water at hydrostatic equilibrium

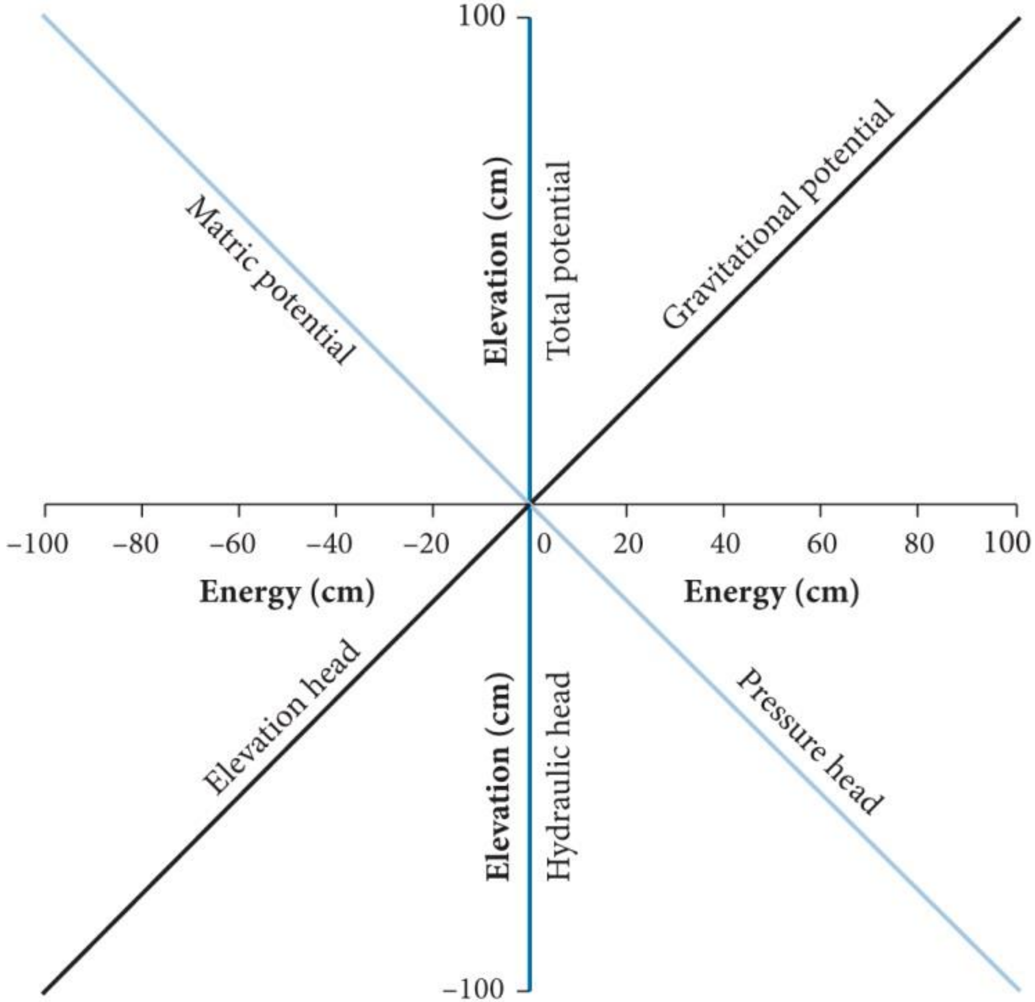
Potential diagram

Bernoulli's law: $h = z + \psi$



Subsurface water at hydrostatic equilibrium

Potential diagram



Terminology

Groundwater:

h = hydraulic head (m) = stijghoogte (m)

z = elevation head (m) = plaatshoogte (m)

$\frac{p}{\rho g}$ = pressure head (m) = drukhoogte (m)

Soil water:

h = total potential (cm) = hydraulische potentiaal (cm)

z = gravitational potential (cm) = zwaartekrachtspotentiaal (cm)

ψ = matric potential (cm) = matrixpotentiaal (cm) = vochtspanning (cm)

GEO4-4417 Unsaturated Zone Hydrology

GEO2-4203 Physical Hydrology:

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