Unsaturated zone hydrology (second exam: 60% of grade) total points: 50

1. (10 points) In semi-arid areas it is always difficult to estimate groundwater recharge directly from precipitation and evaporation. Total yearly potential evaporation is usually much larger than total yearly precipitation and recharge thus occurs during a small number of large precipitation events. However, we could estimate the long-time average groundwater recharge, even though it is small, from the soil moisture content at sufficient depth below the surface and the soil physical properties. To this end we collect a soil sample from 10 m below the surface. We determine the volumetric soil moisture content θ in the laboratory and find that it is: $\theta = 0.12$. We also determine the soil-moisture retention relationship ($\theta(h)$) and the unsaturated hydraulic conductivity relationship ($K(h)$ in m/day) and find for these:

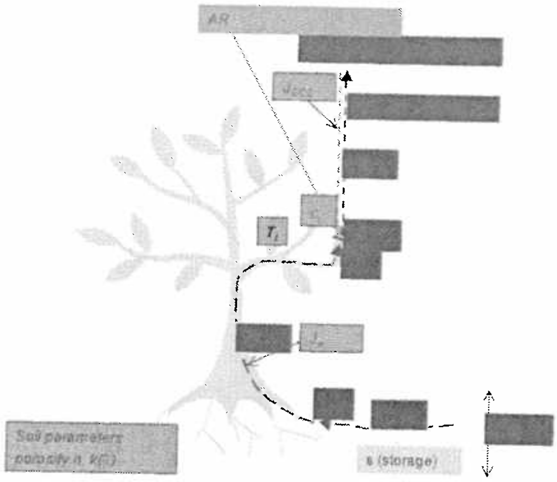
$$\theta(h) = 0.39e^{0.5h}$$
$$K(h) = 1.3e^{5h}$$

   where h is matric head ($h<0$) (in m). At 10 m we can assume that soil water flow is driven by gravity only. Given this assumption, determine the long-time average soil water flux, which is a good estimate of the long-time groundwater recharge?

2. (10 points) Hydrus1D offers the option of an "atmospheric boundary condition" at the top. Under this option, Hydrus will decide whether and how much rain will infiltrate, pond or run off. Now lets assume that you only have an older version of Hydrus1D for which the "atmospheric boundary condition" is not available.
   a. What boundary condition(s) would you then choose under the following circumstances:
      Soil: silty clay loam
      Saturated hydraulic conductivity (K_s): 0.25 m/d
      Rainfall event: 6 cm in 90 minutes
      The test site is situated at a gentle slope.
   b. And what if the rainfall rate was just 6 mm in 90 minutes?

3. (8 points)
   a. What is preferential flow?
   b. Which three different types of preferential flow exist?
   c. Explain how fingered flow can develop in a layered soil (fine topsoil on coarse subsoil).

4. (12 points) Below you find depicted a schematic of a tree and the different variables involved in tree transpiration and carbon assimilation. Consider this tree standing on a soil during a dry spell in summertime, when no precipitation falls during the course of one month. At the beginning of this month the soil is at field capacity. Describe what happens (in time) <u>and why</u> with the following variables of the Soil Plant-Atmosphere Continuum:



   a. Soil moisture content θ and soil matric potential ψ
   b. Soil-root resistance r_{sr}
   c. Leaf water potential ψ_l
   d. Stomal resistance r_s
   e. Transpiration
   f. Carbon-assimilation
   g. Leaf temperature T_l
   h. Vapour pressure of the atmopshere e

5. (5 points)) A small container is partially filled with water to a depth of 10 cm. If we stick a glass capillary tube into the water, water rises up in the tube.
   a. Why does this happen? Explain your answer with the aid of Young's equation and/or Young-Laplace equation (you do not need to calculate anything).
   b. How far will the water rise in the capillary? Calculate the height of air-water meniscus in the capillary with respect to the *bottom* of the container. See below for values of some quantities. The air-water-glass contact angle $\alpha = 0$.

   At equilibrium: Weight = surface tension: $\rho_w gh = 2\gamma \cos\alpha$

   c. What happens to the meniscus if we now slowly pour 10 cm more water into the container? Give the new position of the air-water meniscus in the tube (with respect to the bottom of the container).
   d. What happens if instead of additional water, we slowly pour 10 cm of benzene on top of the water? Calculate the new position of the air-water meniscus in the tube (with respecxt to the bottom in the tube). Note that benzene does not enter the tube.

Air-water interfacial tension $\gamma = 0.07$ kg/s2
Water mass density ρ_w= 1000 kg/m3
Benzene mass density = 900 kg/m3

6. (5 points) In Figure 1 below, a laboratory set up for the study of redistribution of water is shown. A sandy soil was packed into the horizontal chamber. At the left hand side, there is a water chamber. By opening a flood gate, we could allow water to enter the soil chamber. After a desired length of the soil was saturated, the flood gate was closed and the water started to redistribute. Soil moisture in the soil was measured by means of a light transmission technique. A typical soil profile along the soil sample at different times after closing the flood gate is shown in Figure 2. It is evident that even after long time, there is not much water moved from left to right. We do not expect more water redistribution. What is the explanation for the fact that water does not go from the wet part to the dry part?

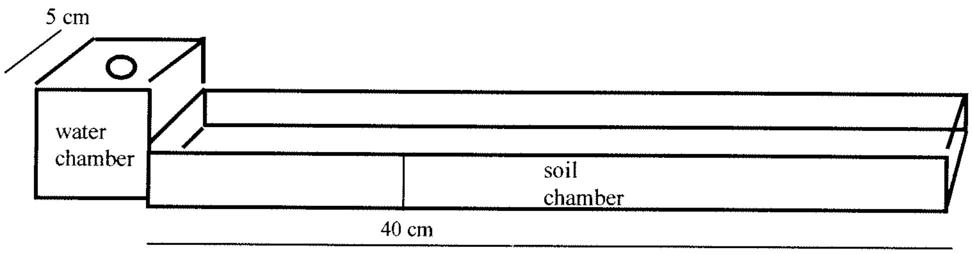


Figure 1. Set up of moisture redistribution experiment

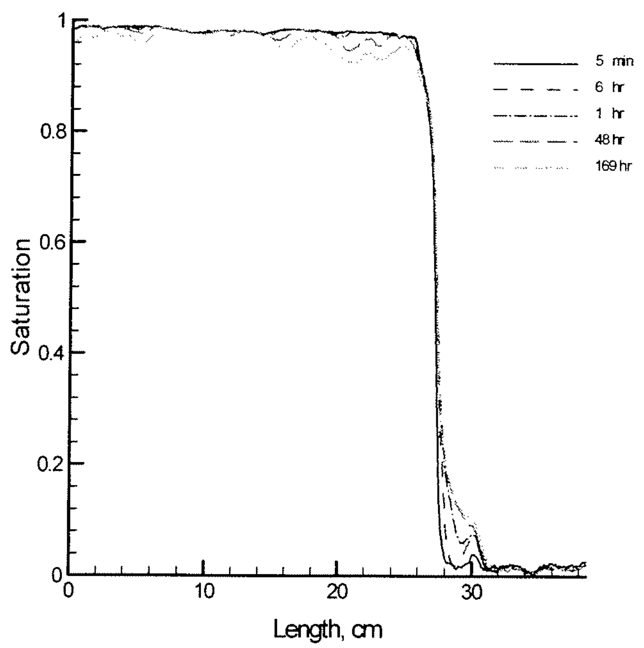


Figure 2. Saturation profile in the soil chamber