OLLSCOIL NA hÉIREANN, GAILLIMH GX 2445
NATIONAL UNIVERSITY OF IRELAND, GALWAY

(International Postgraduate Hydrology Courses)

Postgraduate Higher Diploma in Hydrology
Spring Examinations 2000

PHYSICAL PROCESSES

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Time allowed is ***three*** hours. Attempt any ***five*** questions.

1. *Indicate*, on your answer sheet, legibly and unambiguously, the *symbols* (e. g. (i)-(a), (ii)-(c), etc.) corresponding to the appropriate answers to each of the following *multiple-choice questions* (with *only one* answer to each question):

(i) The *volumetric moisture content* of a soil:
  (a) varies between zero and unity,
  (b) cannot be larger than unity,
  (c) is always numerically larger than the gravimetric moisture content.

(ii) Consider two properly functioning standard field *tensiometers*, the sensors (i.e., the porous cups) of which are placed at two adjacent but different points (A and B) in the soil profile. If the actual readings of the tensiometers (with the minus sign omitted) are 10 cbar at A and 15 cbar at B, we may conclude that:
  (a) the soil water flows from A to B,
  (b) the soil water flows from B to A,
  (c) the direction of the soil water flow may be either from A to B or from B to A, depending on the difference in elevation between A and B.

(iii) For a given soil, at a given initial moisture content, the *ponding* of the soil surface during a constant-intensity rain event:
  (a) will occur earlier if the rainfall intensity is lower,
  (b) will occur earlier if the rainfall intensity is higher,
  (c) will never occur if the rainfall intensity is higher than the saturated hydraulic conductivity of the soil.

(iv) The *Philip two-term infiltration equation*:
- (a) is applicable only when the influence of gravity is negligible, e. g., for the horizontal absorption,
- (b) can be used for all times, while the Philip infinite power series solution is applicable only for short times,
- (c) is applicable only for short times.

(v) If the soil water storage equals the *field capacity* of the soil, then:
- (a) no more water can be accommodated in the soil profile, not even temporarily,
- (b) no drainage of the soil profile due to gravity takes place,
- (c) a slow drainage of the soil profile takes place.

(vi) During a typical dry sunny day in a desert environment, the *air temperature*:
- (a) *increases* vertically upwards,
- (b) *decreases* vertically upwards,
- (c) is virtually independent of the elevation above the ground.

(vii) The *canopy resistance* is virtually zero if:
- (a) the plant leaves are wetted by a previous rain or irrigation,
- (b) the stomates in the plant leaves are completely closed,
- (c) the relative humidity of air is 100 %.

2. *Make three sketches* of equilibrium vertical profiles of:

a) the gravitational head h_g,
b) the pressure head h_p,
c) the hydraulic head h,
d) the pneumatic head h_a,
e) the matric head ϕ

for a soil profile, 3 m thick, in which the groundwater table lies 2 m below the soil surface, *taking* the coordinate system and the datum as follows:

Sketch 1: The z-axis is positive upwards, the origin is on the groundwater table and the soil surface is taken as the datum.

Sketch 2: The z-axis is positive downwards, the origin is at the soil surface and the groundwater table is taken as the datum.

Sketch 3: The z-axis is positive upwards and both the origin and the datum lie at the soil surface.

Assume that the pore air pressure is atmospheric everywhere above the groundwater table.

3. *Using* the Green-Ampt theory, *estimate*:

a) the cumulative infiltration i (mm),

b) the infiltration rate v_0 (mm/min),

c) the velocity v_L (mm/min) of the wetting front movement,

d) the time t (min) elapsed since the start of the infiltration,

for the vertical downward infiltration from a shallow pond of negligible depth into a deep homogeneous soil, at the instant when the wetting front has just reached the depth L = 8.56 cm below the soil surface. The Green-Ampt parameters pertaining to this case are H_s = 55.2 cm, K_{ga} = 0.295 m/day and $\Delta\theta$ (= $\theta_1 - \theta_0$) = 28.5 %.
Then, *estimating* Philip's sorptivity S from the Green-Ampt parameters and *taking* Philip's parameter A as being equal to the given value of K_{ga}, *use* the Philip two-term equation for *estimating* the cumulative infiltration i and the infiltration rate v_0 for that time t, of part d) above, which you have obtained from the Green-Ampt theory.
Finally, *round* your final results to *four* significat digits and *compare* the results obtained from the Green-Ampt theory with those obtained from the Philip two-term equation.

4. *Assume* that the transpiration rate of a dense grass canopy is equal to the potential transpiration rate, which is estimated as being 5.6 mm.day^{-1}, as long as the average soil moisture content in the root zone is higher then the critical point which, for the given type of weather, is θ_{cr} = 12.5 % (in terms of the volumetric moisture content). *Recognising* that the transpiration rate will start to decline as soon as the moisture content falls below the critical point, *estimate* how long it will take for the actual transpiration rate during a rainless period to fall below the potential level, provided that the average intial volumetric moisture content in the root zone is 18.8 %, the root zone thickness is 45 cm and transpiration is the only relevant mechanism of water withdrawal from the root zone. *Round* your final result *down* to *entire days.*

5. *Estimate* the evapotranspiration rate for a well-watered grass canopy, *using* the Penman equation, for the following weather scenario:

Net radiation:	R_n = 138 W.m^{-2}
Soil heat flux (positive downwards):	G = 7.6 W. m^{-2}
Air temperature:	T = 16.1 °C
Relative humidity:	RH = 61 %
Wind speed at 2 m:	u = 2.86 m.s^{-1}

Assume the following values of the physical parameters:

Psychrometric constant:	γ = 65.7 Pa.K^{-1}
Water density:	ρ_w = 1000 kg.m^{-3}
Latent heat of vaporisation:	λ = 2 460 000 J.kg^{-1}

Decide yourself which of the available forms of the Penman wind function is the most appropriate. *Use* the following conversion factors if necessary: 1 mile = 1609 m, 1 mbar = 100 Pa. *Use* the semi-empirical exponential formula for calculating the saturated vapour pressure and its derivative with respect to time. *Round* your final result to *three* significant digits.

6. *Examine* the attached graphs, taken from Marshall, T. J., and Holmes, J. W.,1979: Soil physics. Cambridge Univ. Press, p. 125. Then, *explain* which quantities are plotted on the axes, which processes are taking place in the soil, whether or not the soil is homogeneous and whether or not a perched groundwater table may occur anywhere in the profile.

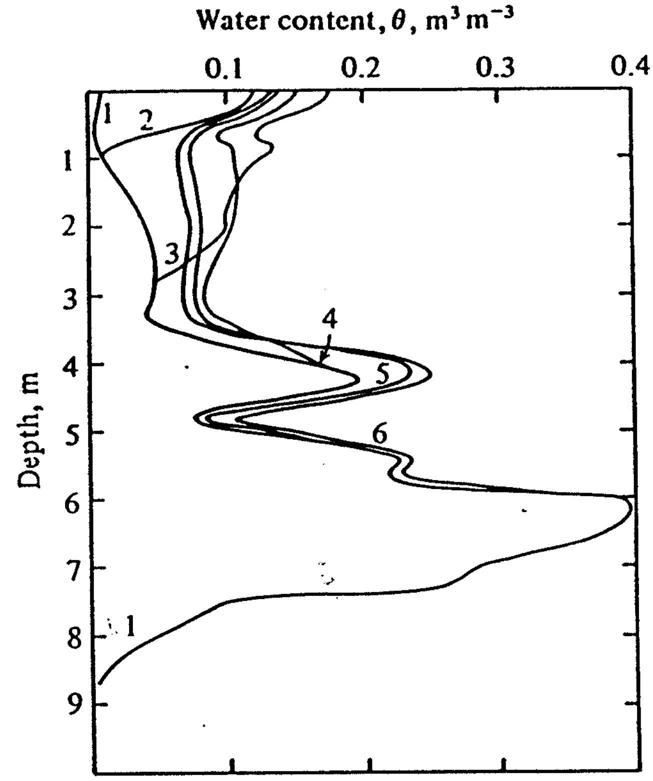

Fig. 5.8. Water content profiles measured in a deep sand profile (overlying two layers of clay,accumulation of 4.2 m and 6.3 m) during rain-fed infiltration in the sequence 1 to 6 (Holmes and Colville, unpublished).

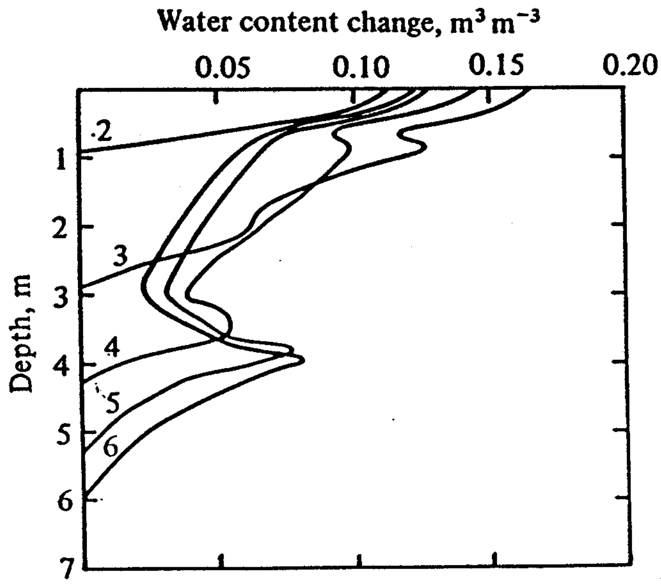

Fig. 5.9. The data of Fig. 5.8 replotted to show water content increment independent of absolute magnitude of the water content, for the purpose of comparison of field data with infiltration theory and prediction.

7. *Examine* the attached graph, taken from Kutilek, M., and Nielsen D. R., 1994: Soil hydrology. Catena Verlag, Cremlingen-Destedt, p. 211. Then, *explain* which quantities are plotted on the axes, which conclusions can be drawn from the data plotted and what their practical consequences may be.

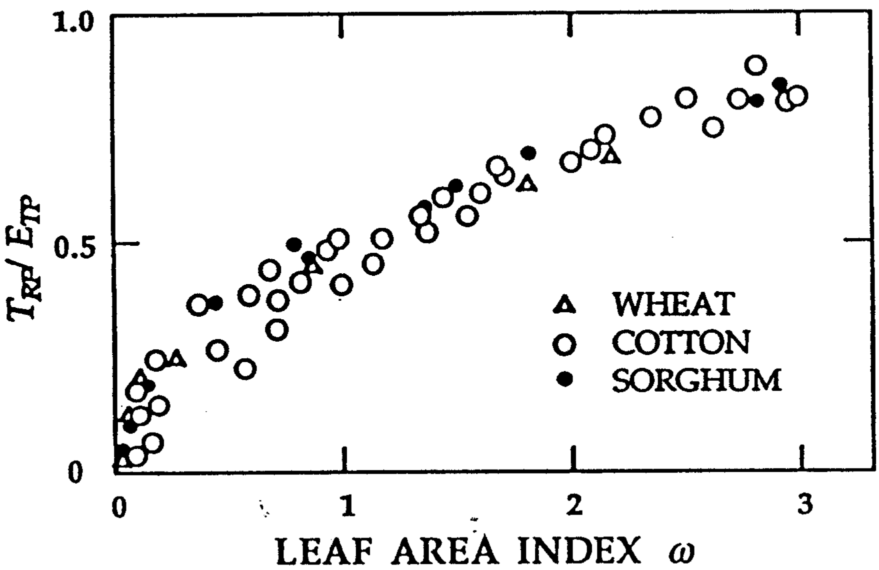

Figure 6.50. The dependence of T_{RP}/E_{TP} upon leaf area index of various plants. Data collected from the literature by (Novák, 1981). T_{RP} is potential transpiration and E_{TP} potential evapotranspiration.