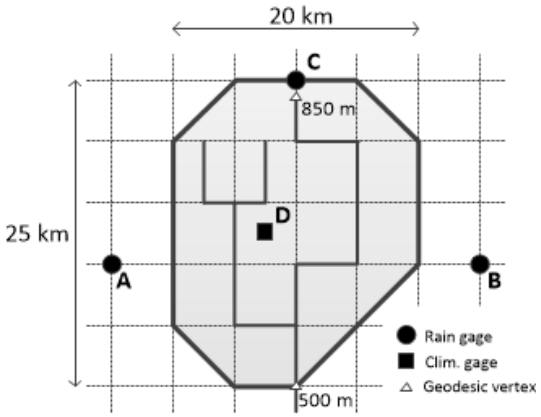
INSTITUTO SUPERIOR TÉCNICO
Master on Environmental Engineering
Joint Master Programme on Groundwater and Global Change, Impacts and Adaptation
Hydrology, Environment and Water Resources
Scholl year 2017/18 – Exam 1 – Duration: 2 hours

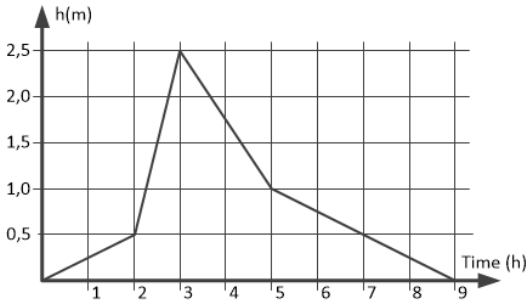
Each question is graded *2/20*

1. Consider the catchment depicted on the right with 412,5 km^2. In a given hydrological year, the annual precipitation measured at gages A, B and C is 900, 1200 mm and 800 mm, respectively. The annual real evapotranspiration at D is estimated as 500 mm. Using the Thiesen polygon method, calculate the catchment annual runoff (in mm) and annual average discharge in (m^3/s).



2. Estimate the drainage density and the average slope length of the catchment depicted on the right.

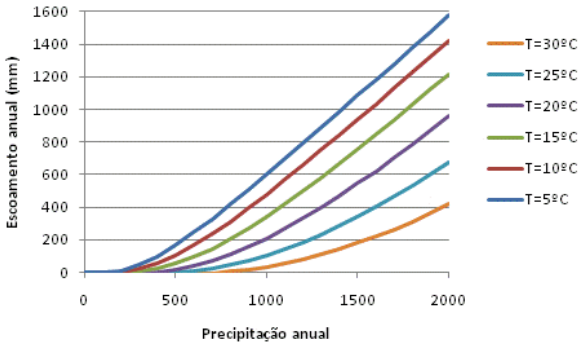
3. Consider the graph on the right of a flood hydrograph recorded at an hydrometric station with the following rating curve: $Q = 40 \cdot (h - 0{,}2)^{0{,}3}$, with Q in m^3/s and h in m. Estimate the flood volume.



4. The maximum annual flow record of a given hydrometric station has the statistics presented in the table. Assuming a log-normal distribution, estimate the flood peak flow associated with a recurrence period of 50 years.

	Q	LnQ
N	35	35
Average	685 m^3/s	6,41
Standard deviation	345 m^3/s	0,49
Skewness coefficient	1,35	-0,15

5. The graph on the right is a graphical representation of the Turc formula. Explain the shape of the curves, namely i) why the curves are different for different temperature values; ii) why the curves do leave the x-axis at precipitation values different than zero; iii) why the curves tend to a straight line for higher values of precipitation and iv) why the straight line has a 45º slope.



6. Consider the soil with the characteristics presented in the table, where a crop is cultivated. At a given season, the crop daily potential evapotranspiration equals 5 mm. What should be the time interval between irrigations and what should be the amount of water provided to the crop, if the farmer wants to maintain the soil water saturation level above 40%. Sketch the time evolution of the water content in the root zone, clearly indicating some values of the soil moisture content.

Parameter	Value
Soil depth, h (m)	0,50
Porosity, n (m/m)	0,55
Saturated soil water content, θs (m/m)	0,50
Field capacity, θfc (m/m)	0,30
Wilting point, θwp (m/m)	0,15
Hydraulic conductivity when saturated, Ks (mm/h)	5,0
Suction head, Ψf (mm)	-50

7. Consider the same soil described in the previous question, which is subject to a precipitation event with a uniform rate equal to 20 mm/h when the soil initial water content is 200 mm/m. Using the Green and Ampt model, determine the cumulative runoff after 40 min.

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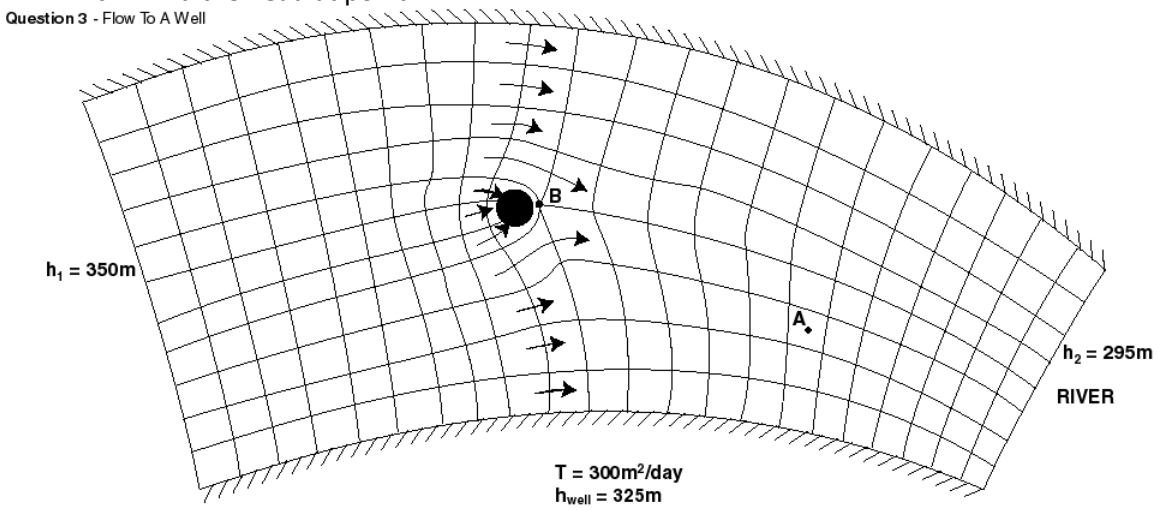
8. Consider the groundwater flownet represented in the figure. Assuming that the aquifer has a uniform thickness of 25 m
   a. Calculate the flow to the river in m^3/day;
   b. Calculate the flow rate to the well B in m^3/day;
   c. Find the head at point A.



SCALE : 1:100

9. Estimate the 100 year return period flood peak flow that may be generated in the catchment considered in question 1 and 2. The catchment area lies in an area with the following rainfall depth-frequency curve for a 100 year return period: $P = 10 \cdot D^{0,35}$, with P in mm and D in minutes. Estimate the time of concentration by the Kirpich formula and use the rational formula, assuming a coeficient of 0,6 and no correction factor.

10. A precipitation event over a watershed, with the unit hydrograph (Δt = 30 min) defined in the table, generates the flood hydrograph also defined in the table. Please determine
    a. The watershed area, in km^2;
    b. The watershed time of concentration, in hours;
    c. The net hyetograph that generated the flood event (precipitation amounts in mm).

Time (h)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
u (m^3/s/mm)	0	4	12	8	2	0		
Q (m^3/s)	0	40	200	340	240	80	10	0

Useful formulas

11.

Standard normal:

p	0.01	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	0.99
z	-2.33	-1.64	-1.28	-0.84	-0.52	-0.25	0.00	0.25	0.52	0.84	1.28	1.64	2.33

Green and Ampt:

$$f = K_s - \frac{K_s \cdot \Psi_f \cdot (\Theta_s - \Theta_i)}{F} \qquad F = K_s \cdot t + \frac{b}{K_s} ln\left(1 + \frac{K_s \cdot F}{b}\right) \qquad b = -K_s \cdot \Psi_f \cdot (\Theta_s - \Theta_i)$$

$$t_e = \frac{-\Psi_f \cdot (\Theta_s - \Theta_i)}{p \cdot \left(\frac{p}{K_s} - 1\right)}; \quad p > K_s$$

Kirpich: $t_c = 0{,}95 \cdot \frac{L^{1{,}155}}{H^{0{,}385}}$ t_c (h); L(km); H (m)