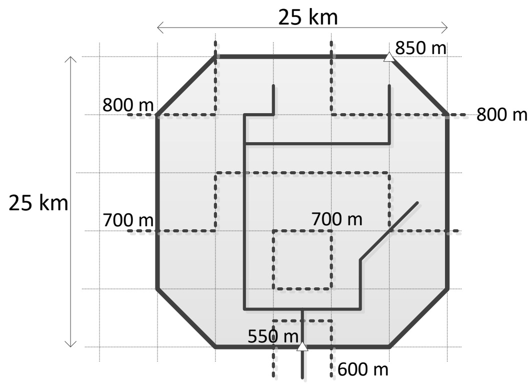
INSTITUTO SUPERIOR TÉCNICO
Master on Environmental Engineering
Joint Master Programme on Groundwater and Global Change, Impacts and Adaptation
Hydrology, Environment and Water Resources
School year 2017/18 – Exam 2 – Duration: 2 hours

Each question is graded *2/20*

1. Consider the Tagus river basin that spreads over Portugal and Spain and the data presented in the table on the right. Estimate the average annual flow under natural conditions, in m^3/s, at the river outlet in Lisbon.

	Portugal	Spain
Area (km^2)	25 600	55 700
Avg. annual precipitation (mm)	820	655
Avg. annual potential evapotransp. (mm)	600	630
Avg. annual real evapotransp. (mm)	515	415

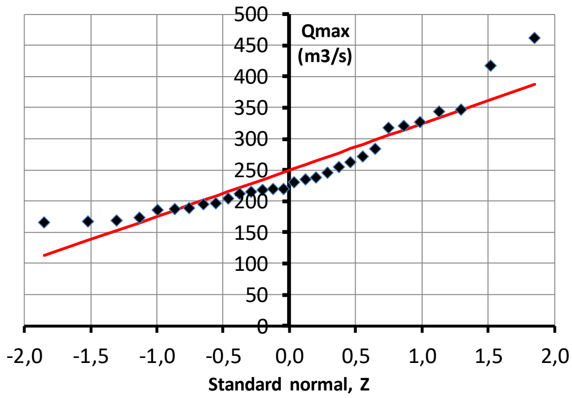
2. Consider the catchment shown on the right with 575 km^2, where the contour lines are depicted as dash lines. Draw the hipsometric curve and determine the basin average altitude and the average height, both in meters.



3. The Penman equation, used to compute evaporation from shallow lakes, is a sum of two parcels. Explain the significance of each parcel and the main variables included in their computation.

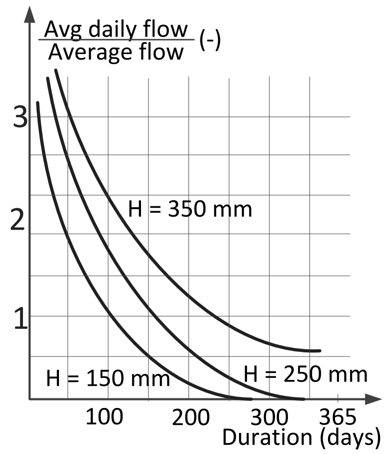
$$E = \frac{\Delta}{\Delta+\gamma}\cdot\frac{24\cdot 60\cdot[R_c\cdot(1-r)+R_L]}{L} + \frac{\gamma}{\Delta+\gamma}\cdot 0.35\cdot(e_a^*-e_a)\cdot\left(1+\frac{V}{100}\right)$$

4. The record of maximum annual flows is depicted in the graph at the right, together with a line representing the normal distribution. Assuming a Gumbel distribution, estimate the flood peak flow associated with a recurrence period of 50 years (in m^3/s)



5. Consider a watershed with 800 km^2 that generates an average annual flow volume equal to 120 hm^3. Using the flow duration curves on the right, determine the semi-permanent flow (in m^3/s) and the volume available for power production at a hydropower plant with an operating range of 1 to 2 m^3/s (in m^3). Assume that the turbinated flow contributes to the ecological flow.

6. Consider the soil with the characteristics presented in the table. When soil water content is 100 mm, the soil is subject to a precipitation event with an uniform intensity of 30 mm/h, lasting for 30 min. The runoff starts to occur after 15 min from the beginning of precipitation and adds up to 1,4 mm at the end of precipitation. Using the Green and Ampt model estimate the soil hydraulic conductivity, when saturated.



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
Suction head, Ψf (mm)	-50

7. Consider the same soil and the same event described in the previous question. Determine the soil water content, in mm and m/m, at 5 min and 15 min after the start of precipitation.

INSTITUTO SUPERIOR TÉCNICO

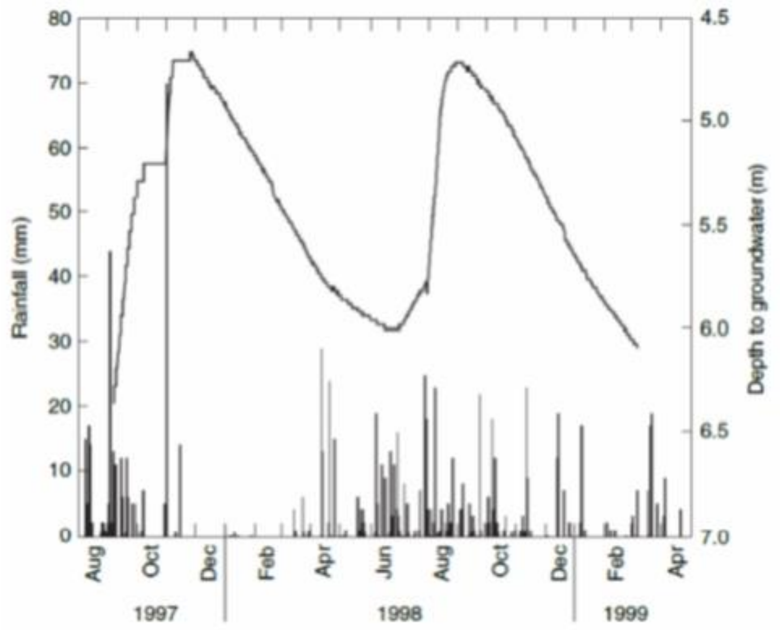
Master on Environmental Engineering

Joint Master Programme on Groundwater and Global Change, Impacts and Adaptation

Hydrology, Environment and Water Resources

School year 2017/18 – Exam 2 – Duration: 2 hours

8. The figure on the right shows precipitation data on a daily basis and a well hydrograph from a piezometer located in a fractured shale aquifer. Short-term fluctuations in response to daily rainfall events are generally absent due to attenuation of short wavelength variations by the large storage capacity of the well. The magnitude of the seasonal water-level fluctuations is consistent with a value of specific yield close to the total porosity (0.02). Estimate the recharge rate, which is consistent with the annual cycle in water level in the region.



9. Consider a basin with 120 km^2 and a time of concentration of 2.5 h, situated in a region with a set of IDF curves with the parameters shown in the table (i in mm/h; D in min). Using the rational formula with a C= 0.6 and assuming a uniformly distributed precipitation, estimate the 50-year peak flood flow, in m^3/s.

T (years)	a	b
20	300	-0.50
50	305	-0.49
100	320	-0,48

10. The table shows the records of net precipitation and flow of two flood events over the same watershed. Please determine:
    a. The watershed time of concentration, in hours;
    b. The watershed area, in km^2;
    c. The flood hydrograph resulting from a third event with a total net precipitation of 30 mm, uniformly distributed over 3 hours.

Event A	Time (h)	0-1	1-2						
	P (mm)	5	10						
	Time (h)	0	1	2	3	4	5	6	
	Q (m^3/s)	0	50	250	400	250	100	0	
Event B	Time (h)	0-1	1-2	2-3					
	P (mm)	15	20	10					
	Time (h)	0	1	2	3	4	5	6	7
	Q (m^3/s)	0	150	650	1000	850	400	100	0

Useful formulas

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:

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

Gumbel distribution: $K_G = -\frac{\sqrt{6}}{\pi}\left\{0{,}5772 + ln\left(-ln(F)\right)\right\}$