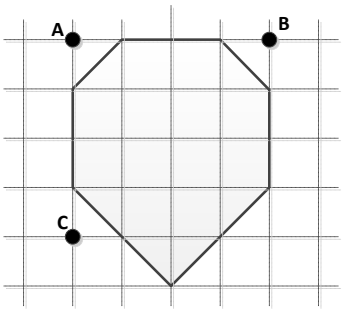
INSTITUTO SUPERIOR TÉCNICO
MESTRADO INTEGRADO EM ENGENHARIA DO AMBIENTE
Hidrologia, Ambiente e Recursos Hídricos
School year 2013/14 – Exam 1 – Total duration: 2 horas

(Each question is graded 2/20)

1. The Tagus river basin has 80,600 km2, distributed between Portugal (24 800 km^2) and Spain (55 800 km^2). The average annual precipitation in Portugal and Spain is, respectively, 875 mm and 655 mm; the mean annual evapotranspiration in Portugal and Spain is, respectively, 520 mm and 420 mm; Assuming the average annual flow of the Tagus River at the border and at mouth, in Lisbon is, respectively, 12'400 hm^3/year and 20'700 hm^3/year, estimate the net volume of water consumed annually (i.e., deducted from returns to the river basin) in Portugal and in Spain, in hm^3/year.



2. Consider a basin with 150 km^2 and the location of three rain gauges shown in the figure where the following values of annual rainfall were recorded: P_A = 800 mm, P_B = 900 mm and P_C = 700mm. Use the Thiessen method to estimate the annual precipitation over the watershed.

3. Global warming resulting from climate change can reduce areas covered by snow and ice and decrease the albedo of the earth's surface. Indicate, justifying, to what extent this effect may affect potential evapotranspiration.

4. The table below shows the measurements of the water level in an hydrometric station where the following rating curve is currently in use: $Q = 30 \cdot (h - 0{,}3)^{0{,}7}$. Calculate the average daily flow, in m^3/s, between Day 1 - 9:00 and day 2 - 9:00.

Time	Day 1, 9:00	Day 1, 12:00	Day 1, 15:00	Day 1, 18:00	Day 2, 9:00
Hydrometric level (m)	1,00	2,00	1,50	1,20	1,00

5. From the 20 year record of a hydrometric station it is possible to calculate the following percentage values of discharge values above certain levels. Sketch the average duration curve of the average daily flow and estimate the average number of days per year that a hydropower plant can operate if its operating range is between 2 to 4 m^3/s, as well as the average annual volume, in hm^3, that goes through the turbines.

Q* (m3/s)	60	20	8	4	2	1
Percentage of values above Q*	5%	20%	40%	60%	80%	100%

6. The record of annual maxima discharge from a hydrometric station located upstream of a small town has the following statistics and reveals that the distribution of values can be represented by a log-normal distribution. Knowing that flooding occurs whenever the flow rate exceeds 150 m^3/s, please estimate the flooding return period.

	N	Average (m3/s)	Std. deviation (m3/s)	Skewness	Coef.Variation
Q	30	83,9	107,4	4,2	1,28
lnQ	30	3,9	1,0	0,0	0,26

7. Consider a soil with the characteristics shown in the table, where a crop is grown which in a given month presents a cultural evapotranspiration equal to 120 mm. At this month, when the degree of saturation of the soil is 25%, a rainfall occurs during a few hours leading to an infiltration equal to 40 mm. Under these conditions, what is the moisture content at the end of the rainstorm (in mm) and what is the deadline for the next rotation irrigation, assuming it does not rain?

Parameter	Value
Soil depth, h (m)	0,6
Porosity, n	0,500
Saturated soil water content, θs	0,463
Field capacity, θcc	0,255
Wilting point, θe	0,117
Hydraulic conductivity, Ks (mm/h)	3,5
Suction head at the wetting front, Ψf (mm)	-8,89

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8. Consider the soil described in the previous problem and assume that the 40 mm of infiltration occurred at soil capacity. Use the Green-Ampt model to estimate the time, in hours, required for this infiltration to occur.

9. Following are average monthly precipitation values (in mm) observed from 2005 till 2007 in Querença-Silves carbonate aquifer in Algarve. Calculate yearly recharge rates (in % of average precipitation) using Kessler method.

Year/ Month	1	2	3	4	5	6	7	8	9	10	11	12
2005	2,5	15,2	31,8	5,5	16,7	0,0	3,7	0,9	0,6	133,1	172,3	83,9
2006	72,3	61,8	107,5	48,9	0,1	32,3	4,0	30,7	25,1	175,7	173,7	37,2
2007	27,3	69,0	22,3	62,2	30,7	14,7	0,0	2,4	61,1	46,4	67,9	113,1

10. Consider a basin with a 10-min unit hydrograph shown in the table, situated in a region for which the following rainfall depth-duration-frequency curve for a return period of 50 years $P = 25 \cdot D^{0,6}$, with P in mm and D hours. Assuming that 35% of the precipitation infiltrates, estimate the peak flood flow for an uniform rainstorm with a return period of 50 years.

T (min)	0	10	20	30	40	50	60	70
U (m3/s/mm)	0	10	40	80	75	30	15	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 e Ampt model:

$$f = K_s - \frac{K_s \Psi_f (\theta_s - \theta_i)}{F} \qquad F = K_s t + \frac{b}{K_s} \ln\left(1 + \frac{K_s \cdot F}{b}\right) \qquad b = -K_s \Psi_f (\theta_s - \theta_i) \qquad t_e = \frac{(-\Psi_f)(\theta_s - \theta_i)}{p\left(\frac{p}{K_s} - 1\right)}, p > K_s$$

Kessler method:

$$\mu = \frac{P_{Set-Dez} - \bar{P}_{Set-Dez}}{\bar{P}_{Set-Dez}}$$

Relation of corrective precipitation rate, μ, and constant corrective value, k

Corrective precipitation rate, μ (%)	**Constant value, k**
0 – 5	0
6 – 15	1
16 – 25	2
26 – 35	3
36 – 45	4
46 – 55	5
56 – 60	7
61 – 65	10
66 - 70	13
> 70	15

Infiltration (recharge) rate (%) *vs* corrected determinative precipitation rate (%)