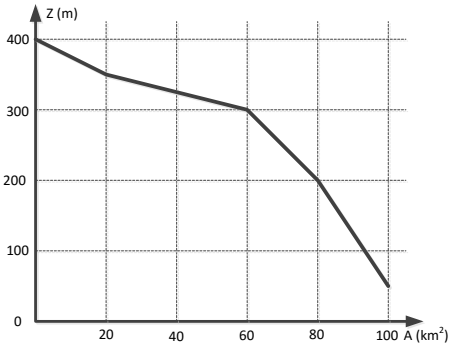
**INSTITUTO SUPERIOR TÉCNICO**
**Hydrology, Environment and Water Resources**
**School year 2015/16 – 1st exam – Duration: 2 hours**

*(Each question is graded 2/20)*

1. The area of the Tejo river watershed is 80.600 km$^2$, distributed by 55.800 km$^2$ in Spain and 24.800 km$^2$ in Portugal. In the Spanish part of the watershed the mean annual precipitation is 655 mm and the mean annual real evapotranspiration is 460 mm. Compute the mean annual flow that flows to Portugal in natural (pristine) conditions, in mm and in hm$^3$.

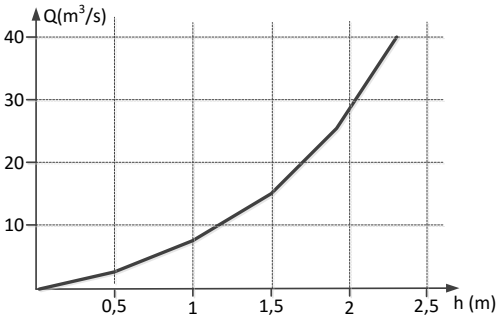
2. The figure on the right shows the hypsometric curve of a given watershed. Determine the average and median altitude and the average and median height of the watershed.




3. In a given day, when solar radiation at the top of the atmosphere is 35 MJ/m$^2$/day, solar radiation on earth surface is 20 MJ/m$^2$/day, the reflected radiation by the earth surface is 5 MJ/m$^2$/day and the net balance of energy transfers between the atmosphere and the earth's surface is -1 MJ/m$^2$/day (long wave radiation), Determine the albedo of the earth surface.

4. Using the Turc formula estimate the potential evapotranspiration for a region and month, where the average solar radiation at the top of the atmosphere was 900 cal/cm$^2$/day, the incident solar radiation at the soil surface was 550 cal/cm$^2$/day and the average monthly temperature was 15º C.

5. The figure on the right shows the rating curve of a hydrometric curve where the following stage measurements were obtained in a given day. Estimate the average discharge, in m$^3$/s, that flowed through the station from 0:00 to 24:00.




| Date | 1/1/2016 0:00 | 1/1/2016 06:00 | 1/1/2016 12:00 | 1/1/2016 18:00 | 1/1/2016 24:00 |
|---|---|---|---|---|---|
| h(m) | 0,50 | 1,50 | 1,25 | 1,00 | 0,50 |

6. From the 30-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 determine the mean and median flows of the hydrometric station. Estimate the average number of days per year that a hydropower plant can operate in this location if its operating range is between 2 to 4 m$^3$/s and if an ecological flow of 1 m$^3$/s is to be maintained.

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

7. The record of annual maxima discharges from a hydrometric station located upstream of a small town has the following statistics. Knowing that flooding occurs whenever the flow rate exceeds 90 m$^3$/s, please estimate the flooding return period, assuming two probability distributions: the Gumbel distribution and the log-Normal distribution.

| | N | Average (m3/s) | Coef. Var. (m3/s) | Skewness |
|---|---|---|---|---|
| Q | 30 | 83,9 | 1,28 | 4,2 |
| lnQ | 30 | 3,9 | 0,26 | 0,0 |

8. An agriculture plot with an area of 0,3 ha has a soil with a wilting point of 0,08. When saturated, the soil has a permeability of 0,4 mm/min and a volumetric moisture content of 0,15. Following a long and intense drought, the soil received an uniform distributed precipitation during 20 min. Superficial flow started to occur 10 min after the beginning of the precipitation during the precipitation event. Knowing that the suction head at the wetting front is -40 mm, compute the total precipitation of the event and total runoff, both in mm.

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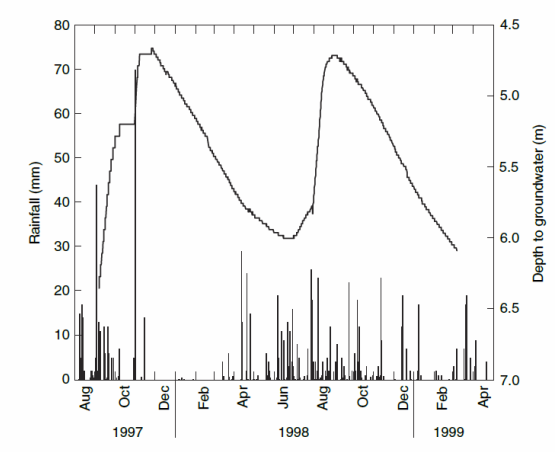
9. The figure on the right shows precipitation data on a daily basis and a well hydrograph from a piezometer located in a fractured shale aquifer. Short-term fluctuations in response to daily rainfall events are generally absent due to attenuation of short wavelength variations by the large storage capacity 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.




10. Consider a basin situated in a region for which the following rainfall depth-duration-frequency curve for a return period of 50 years $P = 45 \cdot D^{0,6}$, with P in mm and D hours. Knowing that the flood hydrograph shown in table was registered at the outlet of the watershed following precipitation event with a uniform net precipitation of 15 mm, lasting for 30 min, estimate the peak flood flow for a uniform rainstorm with a return period of 50 years shown in the table, assuming that 25% of the precipitation infiltrates.

| T (min) | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|
| Q (m3/s) | 0 | 15 | 55 | 75 | 70 | 35 | 15 | 5 | 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 |

Gumbel probability factor:

$$K_G = -\frac{\sqrt{6}}{\pi}\{0{,}5772 + \ln[-\ln(F(x))]\}$$

Turc formula to estimate potencial evapotraspiration (T in ºC, Ra and Rc in cal/cm2/day, ETP in mm):

$$ETP = 0{,}40\,\frac{T}{T+15}\,(R_c + 50)$$

$$R_c = \left(\alpha + \beta\frac{n}{N}\right) R_A$$

Green & Ampt:

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