## EXERCISE 5

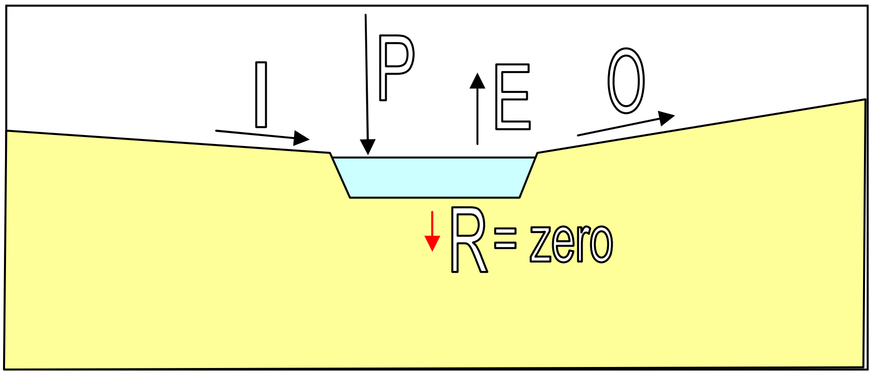
The following data were measured at a water reservoir (5 $km^2$ water surface area, impermeable layer/ no leakage at the bottom):

| | |
|---|---|
| Precipitation rate | 4 mm/24 hrs |
| Change in water level of reservoir due to evaporation | - 1.9 mm |
| Inflow (tributary river) into the reservoir | 100 L/sec |
| Outflow from the reservoir | 40 L/sec |

a. Schematically depict the water budget.
b. Formulate the water balance for the lake.
c. Calculate the evaporation losses [mm] during 24 hrs.
d. Calculate the total volume of evaporated water.

**ANSWER:**

a)




b) Influx – Outflux = dV/dt = $V_P + V_{in\text{-}Out} - V_{ET} - V_{\Delta wl}$

c) Volume of precipitation (**Note: 1 mm = 1 L/m² = 10³ m³/km²**)

$V_P$ = 4 mm * 5 $km^2$ = 4 * $10^3$ $m^3/km^2$ * 5 $km^2$ = 20000 $m^3$

Inflow – outflow = 100 L/s – 40 L/s = 60 L/s = 60 L/s * $10^{-3}$ $m^3$/L = 0.06 $m^3$/s

In 24 hrs: $V_{in\text{-}out}$ = 0.06 $m^3$/s * 24 hrs (60*60 s/hrs) = 5184 $m^3$

d) Volume of water evaporated :

$\Delta$wl = -1.9 mm * 5 $km^2$ = -1.9 $10^3$ $m^3/km^2$ * 5 $km^2$ = -9500 $m^3$

$V_{ET} = V_P + V_{in\text{-}Out} - V_{\Delta wl}$

$V_{ET}$ = 20000 $m^3$ + 5184 $m^3$ – (-9500) $m^3$ = 34684 $m^3$

ET = $V_{ET}$/ Area = 34684 $m^3$ / 5 $km^2$ = 34684 $m^3$ / (5 $km^2$* $10^6$ $m^2/km^2$)

ET = 6.937*$10^{-3}$ m = 6.937 mm

## EXERCISE 6

The De Hoop Dam is presently being constructed in the Steelpoort River between Roossenekal and Steelpoort. The catchment covers an area of 2 865 $km^2$ with mean annual precipitation of 706 mm and mean annual runoff of 116 million $m^3$. Assuming recharge at 3.0% of MAP, answer the following questions:

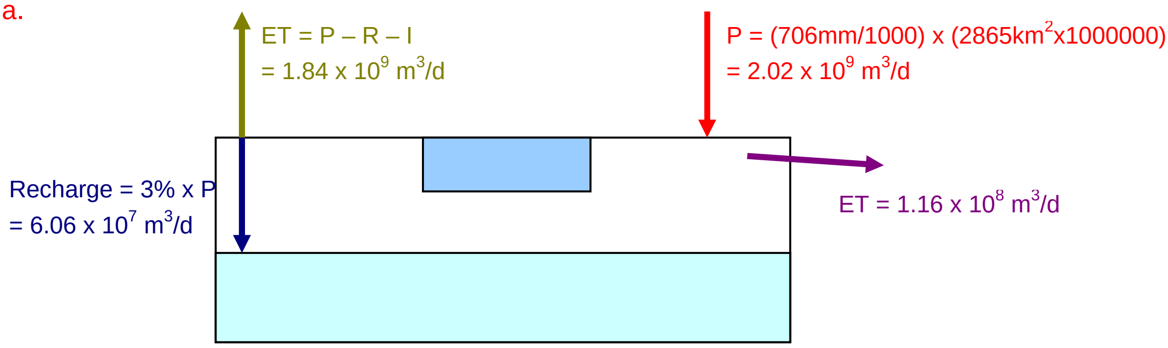
a. Schematically depict the water budget and balance the inflows and outflows (calculate and show all volumes in $m^3/a$).

b. Calculate the actual annual evaporation in millimetres.

c. 80 million $m^3$ of water from the dam is to be used to supply water to the proximate properties. What – in your opinion – will be the influence of this on the water balance?

**ANSWER:**

a.




Precipitation = Evapotranspiration + Runoff + Recharge

b. ET = ((1.84 x $10^9$ $m^3/a$) x $10^{-3}$) / 2865 $km^2$ = 643 mm

c. Removing water from dam → probably removal from surface runoff; i.e.
116 000 000 – 80 000 000 = 36 000 000 $m^3/a$.

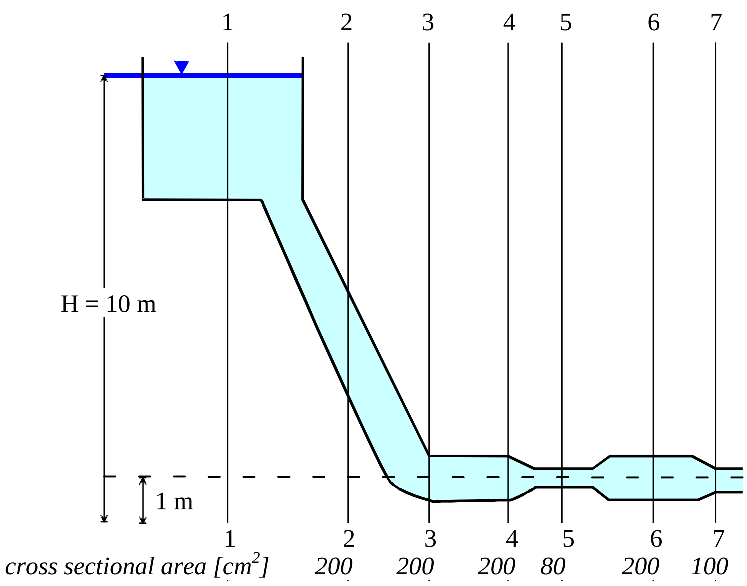
## EXERCISE 6

Water is flowing from a water tower into piping of different cross sectional areas, before it leaves the system at point 7.

Cross sectional areas of pipes:

$F_2 = F_3 = F_4 = F_6 = 200\ cm^2$ $\quad$ $F_5 = 80\ cm^2$ $\quad$ $F_7 = 100\ cm^2$

What is the hydraulic head, the flow velocity, the pressure head and the elevation head at each point of the pipe network? (Hint: Use the Bernoulli and the continuity equation)




**ANSWER:**

$$H = \frac{v^2}{2g} + z + \frac{p}{\rho g}$$

Ideal, frictionless fluid → no energy lost!

$\Rightarrow H_1 = H_2 = .... = H_7 = const = 10$ m (initial head at point 1 = total head)

**<u>Position 7</u>**: Water leaves pipeline → pressure head drops to zero: $\frac{p}{\rho g} = 0$,

elevation head = 1 m:

$$H_7 = \frac{v_7^2}{2g} + z_7 + 0$$

$$v_7 = \sqrt{2g(H_{7(=1)} - z_7)}$$

$v_7 = \underline{13{,}28\ m/s} \Rightarrow Q = v_7\ F_7 = 0{,}1328\ m^3/s$

Continuity equation:

$\Rightarrow Q = v_1\ F_1 = v_2\ F_2 = v_3\ F_3 = v_{......}\ F_{......} = v_7\ F_7$

$\Rightarrow v_2\ F_2 = v_7\ F_7$

$\Rightarrow v_2 = v_7\ F_7\ /F_2 = \underline{6.65\ m/s}$

Because: $F_2 = F_3 = F_4 = F_6 \Rightarrow v_2 = v_3 = v_4 = v_6 = 6.65$ m/s

$v_5 = v_7F_7/F_5 = \underline{16.60\ m/s}$

c) pressure head = total head – velocity head – elevation head

$$h = H - \frac{v^2}{2g} - z$$

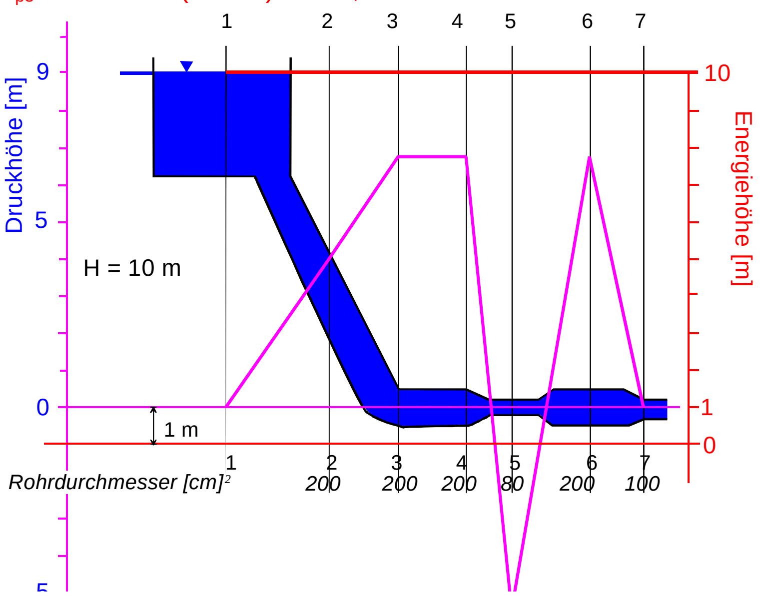
$h_{p1} = 10 - 0 - 10 = 0$

$h_{p7} = 0$

$h_{p2} = 10 – 6.65^2/(2*9.81) - 5 = 2.75$ m

$h_{p3}, h_{p4}, h_{p6} = 10 - 6.65^2/(2*9.81) - 1 = 6.75$ m

$h_{p5} = 10 - 16.6^2/(2*9.81) - 1 = -5{,}04$ m




| **EXERCISE 7** |
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The following parameters were measured in a constant head permeameter test:

$\Delta h = - 5$ cm $\Delta l = 10$ cm

Cross sectional area A = 100 cm2 Duration of experiment t = 1 h

Volume of percolated water after 1 h: V = 3,6 l

a) What is the hydraulic conductivity of the sample?

b) What is the darcy velocity and the linear velocity, if the sample (porosity 0.2) is representative for an aquifer (hydraulic gradient dh/dL= - 0.0025)?

**ANSWER:**

$Q = k_f \, I \, A \Rightarrow k_f = Q/(I*A)$

$Q = 3.6 \text{ l in } 1 \text{ h} = = \frac{3.6 \bullet 10^{-3} \text{ m}^3}{60 \bullet 60 \text{ s}} = \underline{1 * 10^{-6} \text{ m}^3/\text{s}}$

$A = 100 \text{ cm}^2 = 0{,}01 \text{ m}^2$

$I = \frac{Dh}{Dl} = \frac{5 \text{ cm}}{10 \text{ cm}} = 0{,}5$

$k_f = \frac{1 \bullet 10^{-6} \text{ m}^3/\text{s}}{0.5 \bullet 0.01 \text{ m}^2} = 2 * 10^{-4} \text{ m/s} \rightarrow$ sand

Darcy velocity

$v_f = \frac{Q}{F} \Rightarrow v_f = k_f * I \Rightarrow v_f = 2 * 10^{-4} \text{ m/s} * 0.0025 = 5.0 * 10^{-7} \text{ m/s}$

Linear velocity:

$v_n = v_a = \frac{v_f}{n_e} = 2.5 * 10^{-6} \text{ m/s}$