ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2016 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-GE-A2 Hydrogeology

1) **(10 points)** During a laboratory test, an empty container is filled with 936 cm^3 of dry sand. The combined mass of the sand and container is 2718 grams. Water is then added until the sand becomes fully saturated. The total mass of the container, water and sand is then equal to 3030 grams.
   a) Calculate the porosity of the sand.
   b) Knowing that the bulk density of the saturated sand is 2222.5 kg/m^3, calculate the density of the sand.

2) **(20 points)** Figure 1 shows piezometers A and B in a surficial aquifer whose vertical thickness is 30 m and hydraulic conductivity is 5 x 10-5 m/s. Groundwater flow in the aquifer is horizontal and the two piezometers are oriented in the flow direction and separated by a horizontal distance of 250 m. The measuring location for piezometer A is 4 m above the base of the aquifer. Groundwater pressure at that location, measured with a pressure gauge, is 205.8 kPa. The measuring location for piezometer B is 2 m above the base of the aquifer and the measured water level in the piezometer is 2 m below ground surface.
   a) For each piezometer, determine the pressure head, elevation head and hydraulic head.
   b) Determine the specific discharge (q) in the aquifer and indicate if groundwater flows from A to B or from B to A.
   c) Assume now that piezometer B contains saltwater, instead of freshwater. If the saltwater density is 1035 kg/m^3, compute the hydraulic head in piezometer B.

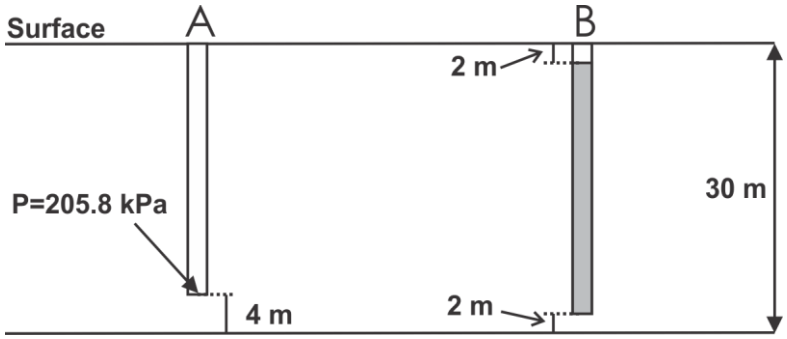

Figure 1. Vertical cross-section of an aquifer containing piezometers A et B.

3) **(15 points)** Figure 2 shows the hydrograph of a river for two consecutive years, from January 1st of the first year to December 31st of the second year. The measured flowrate (discharge) in the

river is shown by the solid line and baseflow, determined from the visual separation of the hydrograph, is shown by the dotted line. The river drains a watershed whose area is 2500 km^2.

a) Calculate the recession constant for the river.
b) Calculate the potential volume of groundwater that would have fed the river if the recession at the end of the second winter, which ends between days 420 and 440, had been complete. For calculation purposes, assume that the recession is complete when the flowrate decreases to 10 % of the initial flow rate measured at the start of the recession.
c) A surficial aquifer is present everywhere in the watershed and its specific yield is equal to 0.25. Assume that the hypothetical recession computed in b) would lead to a drop in the water table elevation. If drainage is the main process causing the water table drop, by what amount (height) would the water table drop for the recession in b).

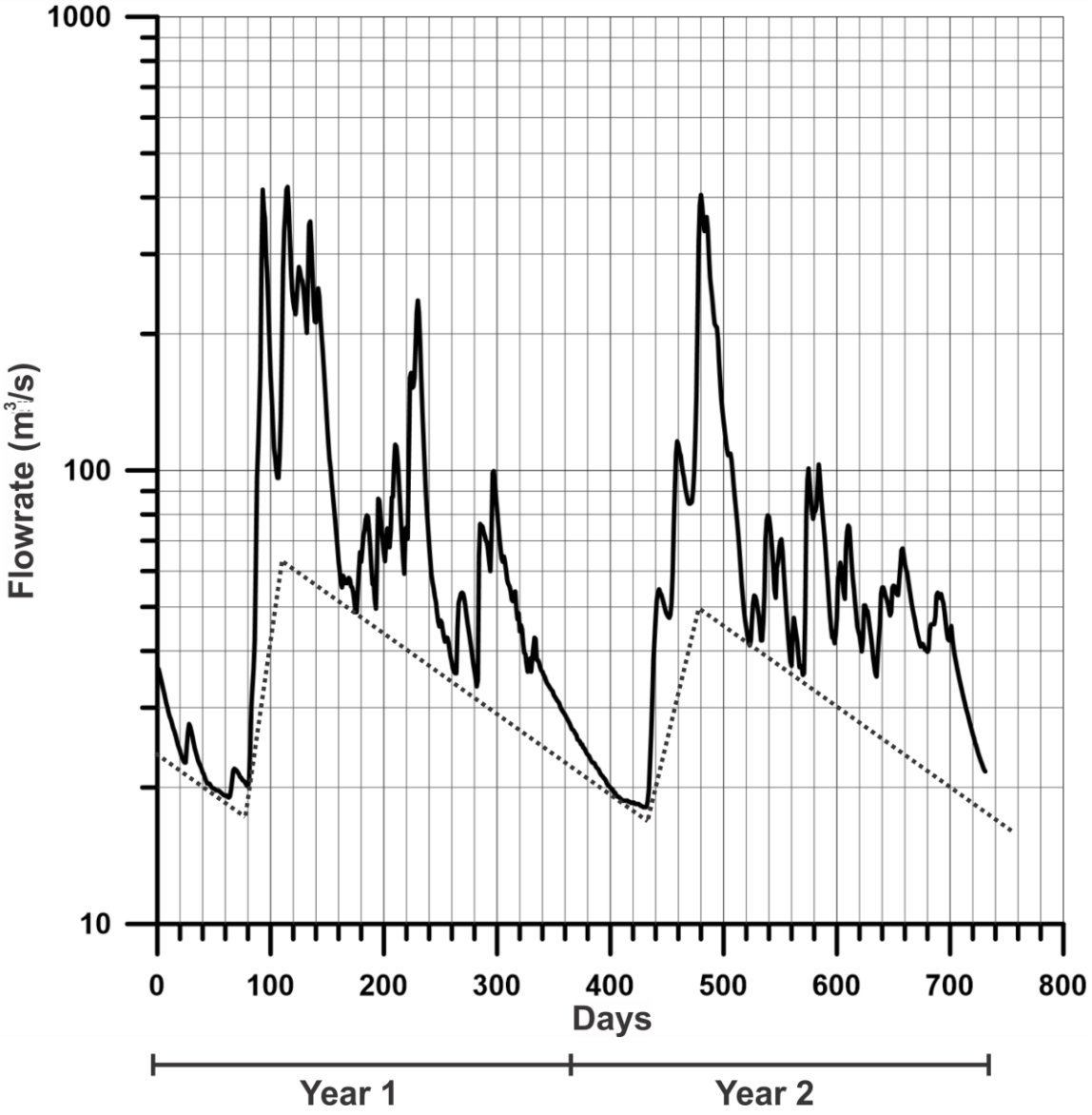

Figure 2. River hydrograph for a 2-year period.

4) **(15 points)** The following table shows measurements made in a nest of 3 piezometer (A, B, C) installed at different depths in a single borehole. For each piezometer A, B and C, calculate
   a) The elevation head (in metres)
   b) The pressure head (in metres)
   c) The hydraulic head (in metres)
   d) The fluid pressure (in Pascals)
   e) The vertical hydraulic gradient between A and B and between B and C.

Table 1. Measurements in 3 piezometers.

Measurement	Piezometer		
	A	**B**	**C**
Elevation of the top of the piezometer (m)	200	200	200
Depth from the top to the measurement point (m)	60	20	10
Water level depth, from the top of the piezometer (m)	44	12	6

5) **(20 points)** A city is planning the construction of a municipal pumping well. The well will be located in a confined aquifer with a thickness of 10 m and whose transmissivity is 275 m^2/day and storativity is 2.5×10^{-4}. The planned pumping rate is 3.5 m^3/min. The pumping well will be at a distance of 500 m from homes where individual domestic wells are used for water supply.
   a) Determine the drawdown that will be produced in the residential wells by pumping the municipal well for 120 days. Assume transient flow conditions during pumping.
   b) Assume now that the aquifer does not behave like a confined aquifer but rather like a leaky confined aquifer. Water is then transmitted through an overlying confining layer whose thickness is 10 m and hydraulic conductivity is 0.01 m/day. Determine the drawdown at the residential wells after 120 days of pumping.

6) **(20 points)** Figure 3 illustrates the drawdown measured in an observation well during a pumping test in a confined aquifer. The measured drawdown is also shown in Table 2. The observation well is located 130 m from the pumping well and the pumping rate was 250 m^3/day. Calculate the aquifer transmissivity (T) and the storativity (S).

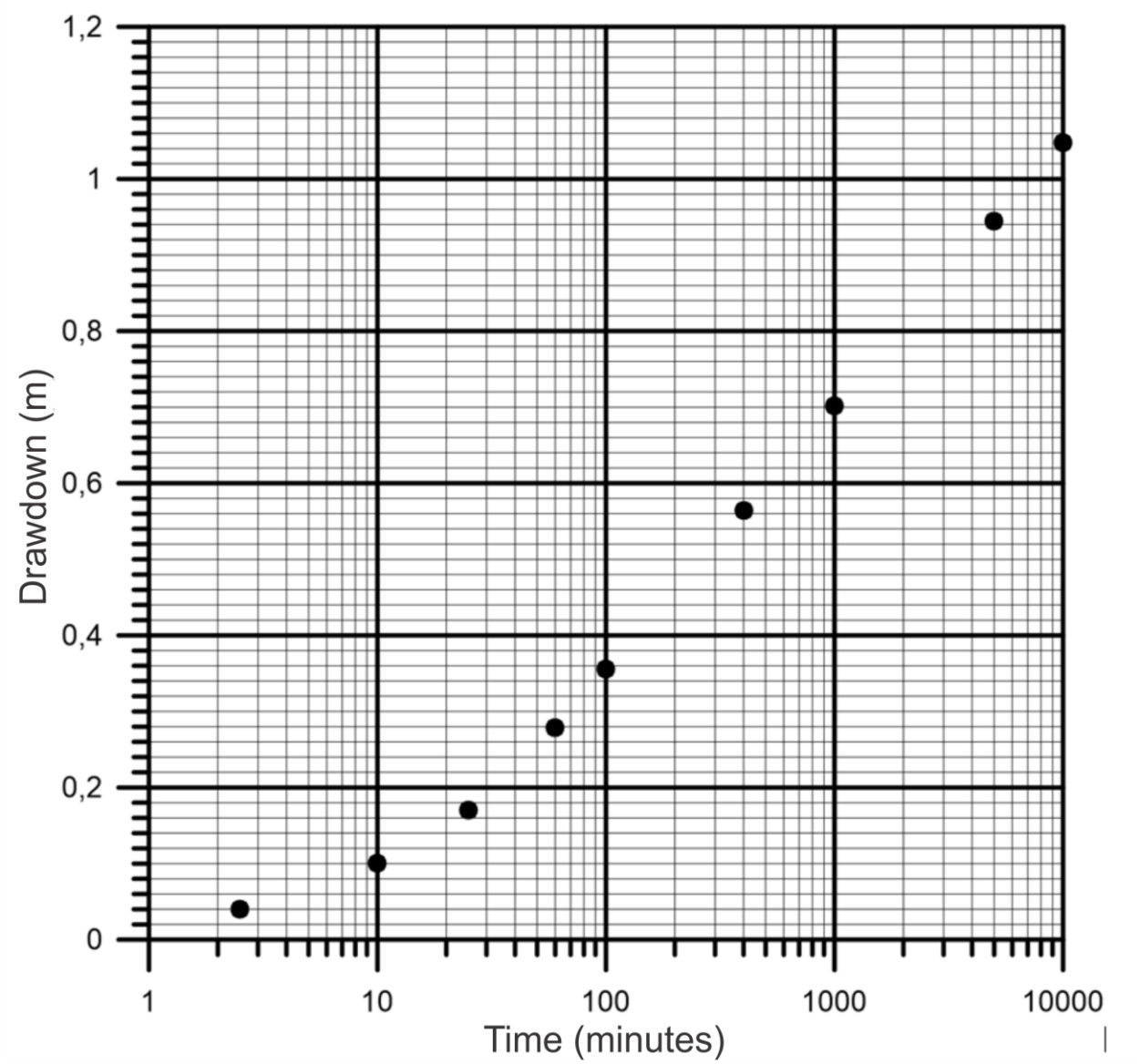

Figure 3. Drawdown measured in an observation well.

Table 2. Drawdown measured in an observation well.

t (min)	2.5	10	25	60	100	400	1000	5000	10000
s (m)	0.04	0.1	0.17	0.279	0.356	0.564	0.702	0.944	1.048