UNIVERSITY OF PRETORIA
DEPARTMENT OF GEOLOGY

Groundwater GLY 265

Semester Test 2
24 August 2009

Examiner(s):	Mnr. M. A. Dippenaar	***Time:***	50 min
Moderator(s):	Prof J. L. van Rooy	***Marks:***	60

Instructions:

- Answer all questions and show all calculations.
- Number each question clearly and write legibly.
- Avoid redundant and/ or irrelevant statements and stick to the marks allocated to each question.
- Write your name on the answer book supplied as well as on the appendix of the question paper as both of these have to be handed in.
- Good luck!

Equations:

Cooper-Jacob: $$s = \frac{2.3Q}{4\pi T}\log\left(\frac{2.25Tt}{r^2 S}\right)$$

For $t_2/t_1 = 10$ $\rightarrow$ $$T = \frac{2.3Q}{4\pi\Delta s}$$

$$S = 2.25T\frac{t_0}{r^2}$$

Dupuit-Thiem: $$T = \frac{Q}{2\pi(\Delta s)}\ln\frac{r_2}{r_1}$$

For $r_2/r_1 = 10$ $\rightarrow$ $$T = \frac{2.3Q}{2\pi(\Delta s)}$$

$$s = \frac{Q}{2\pi T}\ln\frac{R}{r}$$

Radial converging flow: $$\ln\frac{x^2 - r^2}{x_0^2 - r^2} = -\frac{R_{recharge}t}{D\phi_{eff}}$$

Bernoulli equation: $$h = \frac{v^2}{2g} + z + \frac{P}{\rho g} = const.$$

$$g = 9.81\,m/s^2$$

Question 1 **[15]**

The water levels as measured in a 25 m thick homogeneous, isotropic, porous aquifer (hydraulic conductivity K = 2 x 10^{-6} m/s; porosity 25%) is given in the Appendix.

a.) Draw 2 m water table contours and indicate the direction of groundwater flow. *[6]*

→ Shown in Appendix

b.) Calculate the discharge per day for a cross-section (parallel to the potentiometric lines) of 200 m width.

$$Q = K\frac{dh}{dl}A$$

→ SOLUTION

$$= \left(2\times10^{-6} m/s\right)\left(\frac{2m}{700m}\right)\left(25m\times200m\right)$$

$$= 2.86\times10^{-5} m^3/s$$

$$= 2.47 m^3/d$$

[5]

c.) Calculate the specific discharge.

$$q = \frac{Q}{A} = K\frac{dh}{dl}$$

→ SOLUTION

$$= \frac{2.47 m^3/d}{\left(25m\times200m\right)}$$

$$= 4.8\times10^{-4} m/d$$

[2]

d.) Shortly address the influence of pumping borehole BH02 to such an extent that the water table is lowered 5 m.

→ flow direction and hydraulic gradient will change; K is constant so A or Q to change too.

[2]

Question 2 **[15]**

The following stationary heads were measured in a confined porous aquifer (30 m thickness; porosity 30%) after 3 days of continuous pumping at 10 ℓ/s. Assume steady-state conditions.

Piezometer no.	1	2	3	4
Distance r [m]	3.0	20.0	90.0	200.0
Drawdown Δs [m]	2.45	1.39	0.75	0.36

[8]

a.) Determine the transmissivity of the aquifer (graphical determination of Δh; graph paper supplied in the Appendix). *[5]*

→ Appendix for Δs; using Dupuit-Thiem *[2]*

$$T = \frac{Q}{2\pi(\Delta s)} \ln \frac{r_2}{r_1}$$

$$Q = 10\ell / s$$

$$= 0.010 m^3 / s$$

→ For $r_2 / r_1 = 10 \Rightarrow$

$$T = \frac{2.3Q}{2\pi(\Delta s)}$$

$$= \frac{2.3(0.010 m^3 / s)}{2\pi(1.13m)}$$

$$= 3.24 \times 10^{-3} m^2 / s$$

b.) Determine the extent *R* of the cone of depression (graphical solution and algebraic solution for piezometer 2).

→ **Graphical from appendix *R* = 380m**

$$R_2 = r \cdot \exp \frac{2\pi Ts}{Q}$$

→ **Algebraic solution** $= (20.0m) \exp \frac{2\pi(3.24 \times 10^{-3} m^3 / s)()1.39m)}{0.010 m^3 / s}$

$$= 335m$$

c.) Calculate the hydraulic conductivity.

→ **SOLUTION:** $K = \frac{T}{b} = \frac{3.24 \times 10^{-3} m^2 / s}{30m} = 1.08 \times 10^{-4} m / s$

Question 3 **[30]**

Distinguish between the following concepts in your own words so that the differences between them are clear.

a.) Hydraulic conductivity, intrinsic permeability and transmissivity. *[8]*

- Hydraulic conductivity *K* applies to <u>water</u> Q=KiA
- Other fluids have different properties
- Intrinsic permeability *(k)* is independent on the fluid properties, and only dependent on the medium
- Why *k* versus *K* versus *T*?
  - What fluid will flow faster through the same medium?
  - <u>Hydraulic Conductivity K</u> depends on **both** properties of the porous media as well as the properties of water (fluid). The rate at which water flows through a unit cross-sectional area under a unit hydraulic gradient.
  - <u>(Intrinsic) Permeability k</u> [m2] is the capacity of a porous media to transmit a **fluid**. It depends **solely** on the properties of the material itself.
  - <u>Transmissivity</u> = hydraulic conductivity over the thickness of a given layer
  - Hydraulic conductivity tangential to layer (*Kt*) assumed constant over the thickness b of the layer:
  - T=Kb

b.) Storativity and specific yield. *[4]*

- Storativity, *S*:
  - Product of specific storage and aquifer thickness (*b*); dimensionless
  - In confined aquifers, head may decline without change in potentiometric surface
  - Water is released from storage, but aquifer remains saturated
- Specific Yield, *Sy*:
  - In unconfined aquifers, level of saturation rises or falls with changes in the amount of water in storage
  - Water level falls → water drains from pore spaces due to **specific yield**
  - Determined over thickness of saturated zone, *h*

$$S = S_y + hS_s$$

c.) Vadose zone, phreatic zone and capillary fringe (refer to the different pressures). *[8]*

Unsaturated zone:

- Bounded from above by ground surface, and from below by water table (phreatic surface)

Phreatic surface / water table:

- Surface at every point of which the pressure in the water is atmospheric, separates saturated and unsaturated zones in unconfined aquifers

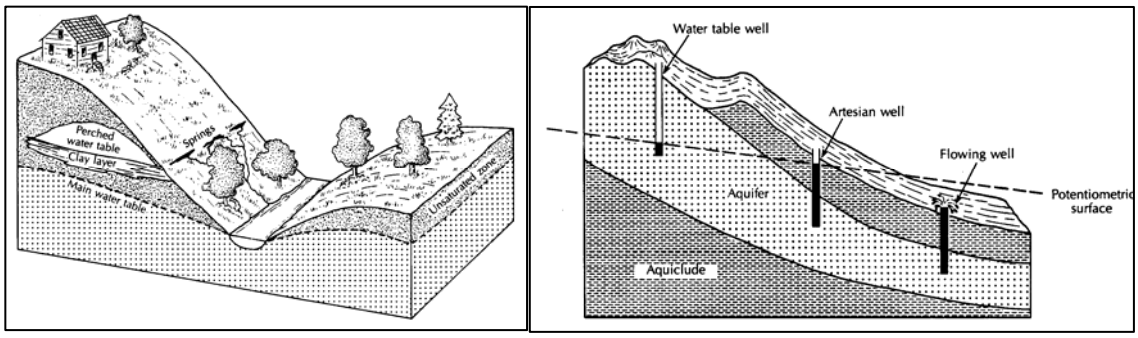
Saturated zone:

- Zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric

Capillary fringe:

- Saturated area above water table due to surface attraction forces; Pw < Pa

d.) Confined and unconfined aquifer. *[4]*



Unconfined Confined

e.) Safe yield, sustainable yield and specific capacity. *[6]*

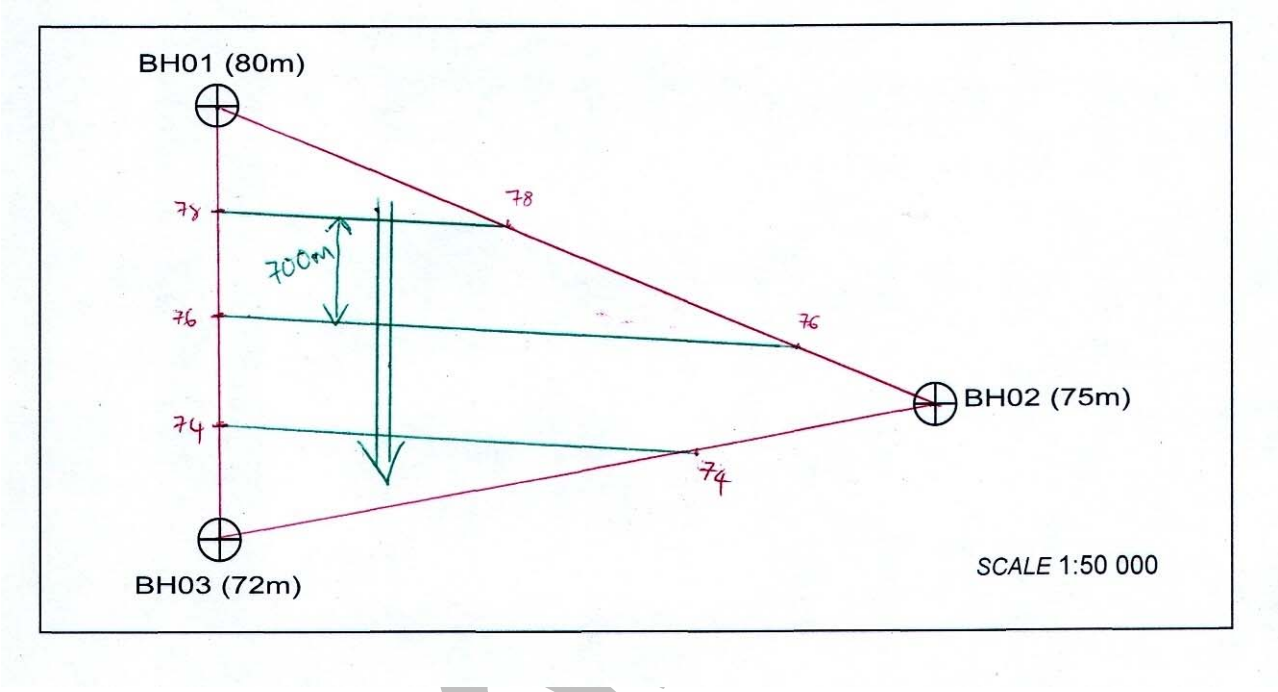
- Safe yield: Amount of water that can be withdrawn from the aquifer without producing an *undesired result* (Todd 1959); Usually limited to n**atural recharge**!
- Sustainable yield: Primarily derived from groundwater storage but ultimately from induced recharge (i.e. surface water depletion). Sustainable yield must allow for sustainability of environment and therefore should be less than safe yield. (Sophocleous 2000)

Specific capacity of a borehole: The amount of water that can be pumped out of the borehole per metre of drawdown [L/s per m]

TOTAL MARKS **[60]**

Surname:	**MEMORANDUM**	Student No:	
Remember to hand in this page with your answer book!			

Appendix for Question 1 – ANSWER



Appendix for Question 2 – ANSWER