National Exams - December 2017

04-Geol-A2, Hydrogeology

Duration: 3 hours

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important. Please show your work.

6. Unless otherwise specified, use water density = 1000 kg/m^3, water viscosity = 0.001 kg/m-sec, and g = 9.81 m/s^2.

Marking Scheme:

1.	(a) 5 marks;	(b) 7 marks;	(c) 8 marks
2.	(a) 6 marks;	(b) 6 marks;	(c) 8 marks
3.	(a) 4 marks;	(b) 6 marks;	(c) 10 marks
4.	(a) 5 marks;	(b) 6 marks;	(c) 9 marks
5.	(a) 7 marks;	(b) 7 marks;	(c) 6 marks

Question 1

a) A fully confined aquifer has a specific storativity of 1.1×10^{-6} m^{-1}, a thickness of 55 m, a width of 1500 m and a length of 2400 m. What volume of water would be pumped to lower the piezometric head in the aquifer by 2 m? **(5 marks)**

b) Three wells (A, B, and C) are drilled in an aquifer. Well B is 250 m directly north of Well A. Well C is 250 m directly east of Well A. The water level in Well A is 180 m.a.s.l., in Well B it is 196 m.a.s.l. In Well C the water level is 188 m.a.s.l. Estimate the magnitude and direction of the hydraulic gradient in the aquifer. **(7 marks)**

c) A fresh water (water density = 998 kg/m^3) aquifer is separated from an underlying saline (density of 1150 kg/m^3) aquifer by a 22 m thick aquitard. A well screened at the top of the aquitard in the fresh water aquifer contains 10 m of fresh water. A well screened at the bottom of the aquitard in the saline aquifer contains 30 m of saline water. Determine the direction of water flow across the aquitard if: i) the density of the saline aquifer water was assumed to be 998 kg/m^3, and ii) if the true density of the saline aquifer water was used. **(8 marks)**

Question 2

a) A landfill has been designed with a clay aquitard separating the landfill waste from the aquifer. The clay is 2.5 m thick and has a permeability of 1.1×10^{-17} m^2. A piezometer inserted at the top of the clay liner contains 0.5 m of water. Determine the total head at the bottom of the clay aquitard that would induce a darcy velocity of 1×10^{-3} m/yr *upwards* through the clay. What would the pressure (in Pa) be at the same point? **(6 marks)**

b) If the clay aquitard in Q2 (a) was fractured with 120 micron fractures spaced 45 cm apart, determine the vertical effective hydraulic conductivity of the aquitard. **(6 marks)**

c) A water-saturated block of soil (2 m wide by 1 m high) consists of two horizontal layers that are each 0.5 m thick. When a pressure head of 10 cm of water is applied at the top of the soil block, and the bottom is maintained at atmospheric pressure, the vertical Darcy velocity through the block is 0.1 mm/min. When a pressure head of 10 cm of water is applied on one side of the block and the other side is maintained at atmospheric pressure, the Darcy velocity is 1 mm/min. Determine the hydraulic conductivities of the two layers. **(8 marks)**

Question 3

a) Sketch qualitatively, typical drawdown versus time curves in one plot using log-log scale for: (i) an ideal, homogeneous, non-leaky, isotropic confined aquifer; (ii) a leaky confined aquifer; (iii) a confined aquifer bounded by a very low permeability barrier; (iv) a confined aquifer bounded by a constant head recharge boundary. **(4 marks)**

b) A well screened through the entire depth of a fully confined aquifer is pumped at 3550 L/min. At a distance of 200 m from the pumping well, the drawdown in an observation well is 3.2 m after 4 hours and 5.2 m after 12 hours. Determine storativity and transmissivity of the aquifer. **(6 marks)**

c) Two pumping wells, A and B, are installed in an aquifer. Well A is 50 m from an observation well, and Well B is 90 m from the same observation well. Well A is pumped for 24 hours at 20 m^3/hr, and then turned off. Well B is started at the same time as Well A, but is pumped for 36 hours at a rate of 10 m^3/hr. If the aquifer is fully confined, and infinite in extent, with a thickness of 22 m, a hydraulic conductivity of 1 x 10^{-5} m/sec, and a specific storativity of 1 x 10^{-5} m^{-1}, determine the drawdown at the observation well 48 hours after pumping from the wells were started. **(10 marks)**

Question 4

a) A 24 cm diameter well pumps water from a 60 m thick confined aquifer at a rate of 16 L/sec. If the water elevation is 105 m.a.s.l. at the well, and 110 m.a.s.l. at a distance of 150 m from the pumping well determine the hydraulic conductivity of the aquifer. **(5 marks)**

b) A 25 cm diameter well pumps water from a 50 m thick unconfined aquifer at a rate of 12 L/sec. If the water elevation is 102 m.a.s.l. at the well, and 105 m.a.s.l. at a distance of 150 m from the well determine the hydraulic conductivity of the aquifer. **(6 marks)**

c) A well pumps water from a confined aquifer at a rate of 18 L/s. The aquifer has a transmissivity of $10^{-2}m^2$/sec, a storativity of 10^{-4}, and a hydraulic conductivity of 10^{-3} cm/sec. The aquitard above the aquifer has a thickness of 5.5m. Determine the drawdown at an observation well 150 m from the pumping well after 24 hours of pumping if the aquitard has a hydraulic conductivity of 10^{-6} cm/sec. If the aquitard storativity was significant, would the drawdown be larger or smaller than the value you have calculated? **(9 marks)**

Question 5

a) A unconfined aquifer is 600 m wide and the bottom of the aquifer is 55 m below the ground surface. The water level in well A in the aquifer is 44 m from the bottom of the aquifer. In a second well (B) located 160 m away from well A in the direction of groundwater flow the water level is 33 m from the aquifer bottom. The aquifer has a hydraulic conductivity of 1.2×10^{-5} m/sec and porosity of 30%. Determine the total flow through the aquifer, assuming that aquifer recharge is negligible. **(7 marks)**

b) If the vertical recharge to the aquifer in Q5 (a) is 0.20 m/year, but all other conditions are unchanged calculate the pore-water velocity at location 100 m from well A and 60 m from Well B. **(7 marks)**

c) A slug test is performed in a confined aquifer in a well that has a casing radius of 6 cm, screened section radius of 10 cm, and a screened section length of 3 m. At the beginning of the slug test the water level in the well is 0.6 m above the original level. After 5 seconds the water level in the well is 0.3 m above the original level. Determine the hydraulic conductivity of the aquifer. **(6 marks)**

Table 5.1
Values of $W(u)$ for values of u (from Wenzel, 1942)

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$\times 1$	0.219	0.049	0.013	0.0038	0.0011	0.00036	0.00012	0.000038	0.000012
$\times 10^{-1}$	1.82	1.22	0.91	0.70	0.56	0.45	0.37	0.31	0.26
$\times 10^{-2}$	4.04	3.35	2.96	2.68	2.47	2.30	2.15	2.03	1.92
$\times 10^{-3}$	6.33	5.64	5.23	4.95	4.73	4.54	4.39	4.26	4.14
$\times 10^{-4}$	8.63	7.94	7.53	7.25	7.02	6.84	6.69	6.55	6.44
$\times 10^{-5}$	10.94	10.24	9.84	9.55	9.33	9.14	8.99	8.86	8.74
$\times 10^{-6}$	13.24	12.55	12.14	11.85	11.63	11.45	11.29	11.16	11.04
$\times 10^{-7}$	15.54	14.85	14.44	14.15	13.93	13.75	13.60	13.46	13.34
$\times 10^{-8}$	17.84	17.15	16.74	16.46	16.23	16.05	15.90	15.76	15.65
$\times 10^{-9}$	20.15	19.45	19.05	18.76	18.54	18.35	18.20	18.07	17.95
$\times 10^{-10}$	22.45	21.76	21.35	21.06	20.84	20.66	20.50	20.37	20.25
$\times 10^{-11}$	24.75	24.06	23.65	23.36	23.14	22.96	22.81	22.67	22.55
$\times 10^{-12}$	27.05	26.36	25.96	25.67	25.44	25.26	25.11	24.97	24.86
$\times 10^{-13}$	29.36	28.66	28.26	27.97	27.75	27.56	27.41	27.28	27.16
$\times 10^{-14}$	31.66	30.97	30.56	30.27	30.05	29.87	29.71	29.58	29.46
$\times 10^{-15}$	33.96	33.27	32.86	32.58	32.35	32.17	32.02	31.88	31.76

Table 5.2
Values of *W(u r/B)* (after Hantush, 1956)*

u \ *r/B*	0.01	0.015	0.03	0.05	0.075	0.10	0.15	0.2	0.3	0.4
0.000001										
0.000005	9.4413									
0.00001	9.4176	8.6313								
0.00005	8.8827	8.4533	7.2450							
0.0001	8.3983	8.1414	7.2122	6.2282	5.4228					
0.0005	6.9750	6.9152	6.6219	6.0821	5.4062	4.8530				
0.001	6.3069	6.2765	6.1202	5.7965	5.3078	4.8292	4.0595	3.5054		
0.005	4.7212	4.7152	4.6829	4.6084	4.4713	4.2960	3.8821	3.4567	2.7428	2.2290
0.01	4.0356	4.0326	4.0167	3.9795	3.9091	3.8150	3.5725	3.2875	2.7104	2.2253
0.05	2.4675	2.4670	2.4642	2.4576	2.4448	2.4271	2.3776	2.3110	1.9283	1.7075
0.1	1.8227	1.8225	1.8213	1.8184	1.8128	1.8050	1.7829	1.7527	1.6704	1.5644
0.5	0.5598	0.5597	0.5596	0.5594	0.5588	0.5581	0.5561	0.5532	0.5453	0.5344
1.0	0.2194	0.2194	0.2193	0.2193	0.2191	0.2190	0.2186	0.2179	0.2161	0.2135
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011

u \ *r/B*	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5
0.000001									
0.000005									
0.00001									
0.00005									
0.0001									
0.0005									
0.001									
0.005									
0.01	1.8486	1.5550	1.3210	1.1307					
0.05	1.4927	1.2955	1.2955	1.1210	0.9700	0.8409			
0.1	1.4422	1.3115	1.1791	1.0505	0.9297	0.8190	0.4271	0.2278	
0.5	0.5206	0.5044	0.4860	0.4658	0.4440	0.4210	0.3007	0.1944	0.1174
1.0	0.2103	0.2065	0.2020	0.1970	0.1914	0.1855	0.1509	0.1139	0.0803
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0009

*Trans. Amer. Geophys. Union, 37, p. 702–714.