National Exams May 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 = 998 kg/m^3 and water viscosity = 0.001 kg/m-sec at 20 °C, and g = 9.81 m/s^2.

Marking Scheme:

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

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Question 1

a) A falling-head permeameter has a falling-head tube diameter of 1.8 cm, a sample tube diameter of 12.0 cm, and flow length of 15 cm. The initial head is 6.0 cm and it falls to 0.50 cm over a period of 550 minutes. If the test is conducted at 15 °C for the entire duration of the test, determine the hydraulic conductivity and intrinsic permeability of the soil. Comment on the type of the soil tested. **(7 marks)**

b) A confined aquifer has a specific storage of 5.33×10^{-3} m^{-1} and porosity of 0.3. What is the compressibility of the aquifer skeleton? The compressibility of water is 4.6×10^{-10} m^2/N. **(4 marks)**

c) If the aquifer in Q1(b) is 30 m thick, how much water would it yield if the piezometric surface declines 2.5 m over a circular area with a radius of 220 m? **(4 marks)**

d) An 11.8 cm^3 moist soil sample weight is reduced from 23.1 g to 21.1 g after drying. Determine the soil porosity, bulk density, void ratio, and moisture content of the original soil. The soil mineral (solid) density is 2.65 g/cm^3. **(5 marks)**

Question 2

a) A fully confined aquifer contains three soil layers. The top layer is 3.5 m thick, and has a hydraulic conductivity of 1.1×10^{-3} cm/sec. The middle layer is 2.5 m thick, and has a hydraulic conductivity of 4.2×10^{-6} cm/sec. The bottom layer is 2.8 m thick and has a hydraulic conductivity of 1.3×10^{-4} cm/sec. Determine aquifer effective horizontal and vertical hydraulic conductivities. **(4 marks)**

b) If the pressure is 104 kPa across the entire top of the aquifer in Q2(a), and 184 kPa across the entire bottom of the aquifer, determine the magnitude and direction of the Darcy velocity in each layer and pressure at the bottom of the top layer. **(7 marks)**

c) A fresh water aquifer is separated from an underlying saline (density of 1160 kg/m^3) aquifer by an 11 m thick aquitard. A well screened at the top of the aquitard in the fresh water aquifer contains 11.5 m of fresh water. A well screened at the bottom of the aquitard in the saline aquifer contains 21 m of saline water. Determine the direction of water flow across the aquitard. **(5 marks)**

d) A slug test is performed in a confined aquifer in a well that has a casing radius of 5 cm, screened section radius of 10 cm, and a screened section length of 3.2 m. At the beginning of the slug test the water level in the well is 0.52 m above the original level. After 3 seconds the water level in the well is 0.186 m above the original level. The thickness of the aquifer is 15 m. Determine the transmissivity of the aquifer. **(4 marks)**

Question 3

a) A confined aquifer is 5.0 m thick and has a hydraulic conductivity of 7×10^{-3} cm/sec and an effective porosity of 0.25. The piezometric level drops 0.2 m between two observation wells that are located at 240 m apart. Determine the discharge of groundwater through a 10 m wide strip of the aquifer, and average linear velocity of groundwater. **(6 marks)**

b) Hydraulic conductivity of an unconfined aquifer in the figure below is 14.3 m/day. The value of h_1 is 17.7 m and value of h_2 is 13.2 m. The length (L) of this aquifer is 525 m. The average rate of recharge is 0.007 m/day.
(i) Determine the average discharge per unit width at x = 480 m.
(ii) Is there a water-table divide? If so, where is it located?
(iii) What is the maximum height of the water table?
(10 marks)

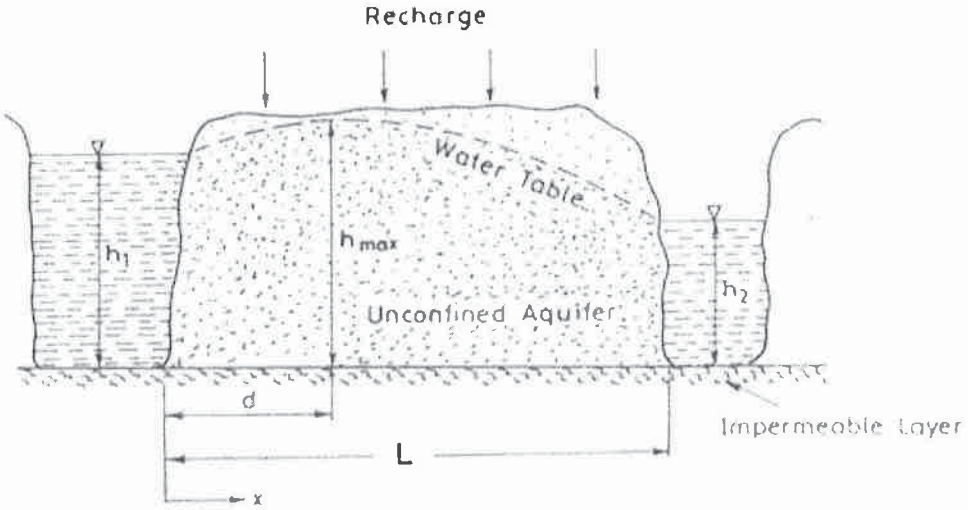

Figure 1: Unconfined aquifer

c) Sate the assumptions used to develop the analytical solutions for the flow problem shown in the above figure. **(4 marks)**

Question 4

a) A fully confined aquifer is bounded by a constant head boundary that is 190 m directly west of a pumping well. Determine the drawdown at a point 100 m directly north of the pumping well after the well pumps for 12 hours at a rate of 6 L/sec. The aquifer is 22 m thick and has a hydraulic conductivity of 10^{-2} cm/sec and a specific storativity of 1.0×10^{-4} m^{-1}. **(7 marks)**

b) If the boundary in Q4(a) is an impermeable boundary instead of a constant head boundary and the pump stops after 12 hours, determine the drawdown after 18 hours from the start of the pump. All other conditions are the same. **(9 marks)**

c) A 32 cm diameter well pumps water from a 48 m thick unconfined aquifer at a rate of 9.8 L/sec. If the water elevation is 102 m.a.s.l. at the well, and 106 m.a.s.l. at a distance of 145 m from the well, determine the hydraulic conductivity of the aquifer. **(4 marks)**

Question 5

a) A confined 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 6.2 m. A well installed in the aquifer, screened for the entire depth of the aquifer, pumps water at a rate of 60 m^3/hour. Determine the drawdown at an observation well 90 m from the pumping well after 24 hours of pumping if the aquitard above is impermeable. **(8 marks)**

b) If the aquitard in Q5(a) has a hydraulic conductivity of 10^{-6} cm/sec, determine the drawdown at an observation well 80 m from the pumping well after 24 hours of pumping. **(8 marks)**

c) Sketch qualitatively typical drawdown versus time curves on one plot in 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, and (iv) a confined aquifer bounded by a constant head recharge boundary. **(4 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.