CIVE 6361 Groundwater Hydrology   Fall 1996   Final Examination

Student Name: Solution

1) A saturated aquifer sample core of diameter 2.54 cm and length 6 cm and weighs 63 grams. After drying, the sample weighs 53 grams. The core sample was placed into a permeameter and exposed to a unit hydraulic gradient (hydraulic gradient across the sample equals one). The measured flowrate under this condition was 25.4 milliters/second.

The water level in three wells in the same aquifer was measured in meters above mean sea level. The levels are: Well MW-1; 83.1 meters; Well MW-2; 84.6 meters; Well MW-3; 83.9 meters. MW-2 is located 1000 meters north of Well MW-1, and Well MW-3 is located 700 meters northeast of MW-1.

a) From the core sample information estimate the porosity of the aquifer.

$$V_s = \frac{\pi d^2}{4} \cdot L = \frac{\pi (2.54)^2}{4} \cdot 6.0\ cm = 30.36\ cm^3$$

$$V_w = V_v = \frac{M_w}{\rho_w} = \frac{10 g}{1 g/cm^3} = 10\ cm^3$$

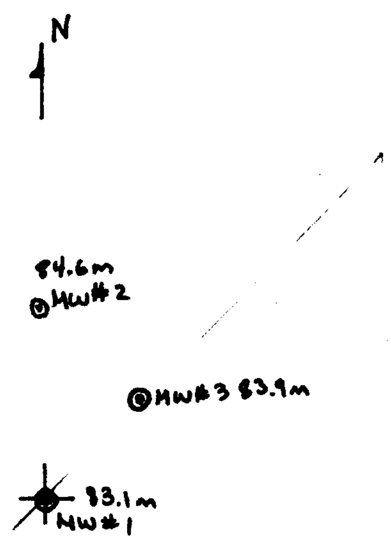
$$n = \frac{V_v}{V_s} = \frac{10}{30.36} = 0.33$$

b) From the permeameter information given, estimate the hydraulic conductivity of the aquifer. Express your **answer in meters per day.**

$$Q = KA\frac{dh}{dL} \qquad \frac{dh}{dL} = 1.0 \qquad \therefore Q/A = K = \frac{25.4\ cm^3/sec}{\frac{\pi (2.54\ cm)^2}{4}} = 5.01\ cm/sec$$

$$5.01\ cm/sec \cdot \frac{1 m}{100 cm} = 0.05\ m/sec = 4320\ m/day$$

c) Sketch the relative positions of the three wells below. Assume that MW-1 is the origin of the local coordinate system, and north is to the top of the page.



d) Determine the magnitude and direction of the hydraulic gradient in the aquifer monitored by the three wells.

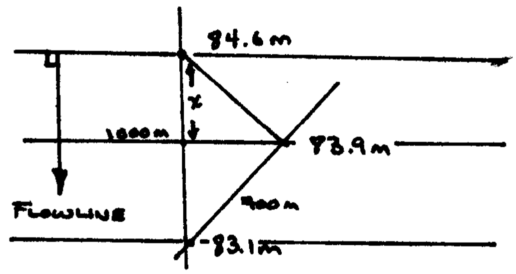
$84.6 - 83.9 = 0.7$

$84.6 - 83.1 = 1.5$

$\frac{x}{0.7} = \frac{1000}{1.5}$

SOLVE FOR x

$x = 466.\ m$



$\Delta h = 0.7m$

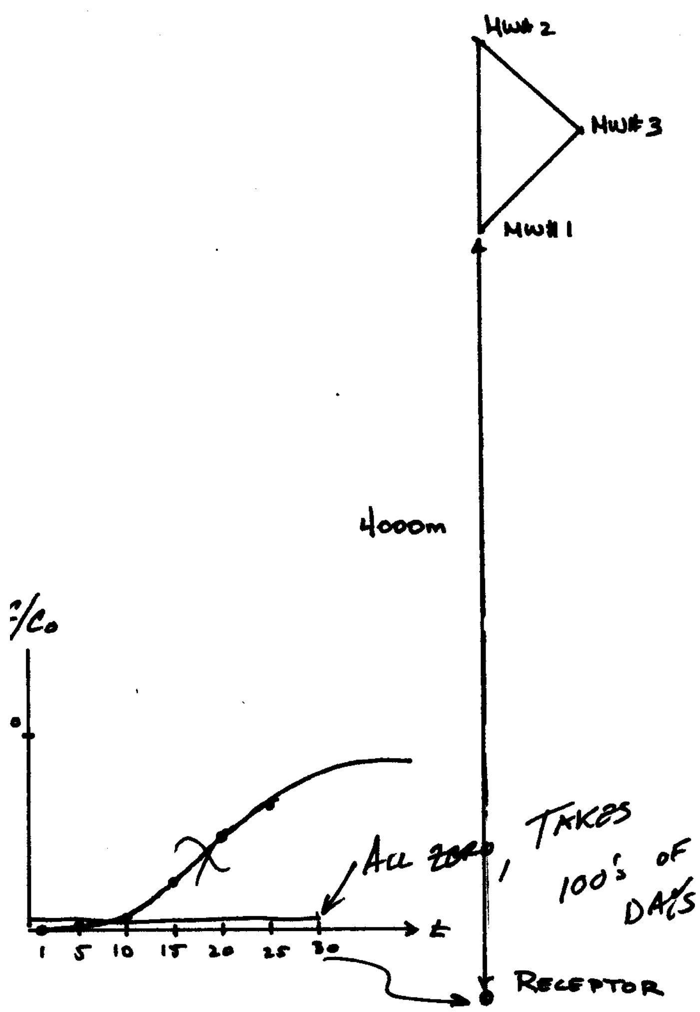
$\Delta \ell = 466.m$

$\therefore \frac{\Delta h}{\Delta L} = \frac{0.7}{466} = 0.0015$

GRADIENT = 0.0015 ↓ (DUE SOUTH)

(ASSUME $C_o = 1.0$)

e) Calculate the concentration of a conservative contaminant at a receptor 4000 meters away from MW#1 on a flowline that passes through MW#1 using the infinite source model, assuming MW#1 is the source location. Use one-tenth of the path length as the aquifer dispersivity (dispersion coefficient is the product of dispersivity and average linear velocity). Calculate the receptor concentration at 1,5,10,15,20, and 25 days after release. Sketch the concentration history at the receptor.



$D = \alpha V$ → $D = 400(196.3) = 78520 m^2/$

$\alpha = (0.1)(4000) = 400m$

$V = \frac{K}{n}\frac{\Delta h}{\Delta L} = \frac{0.5 m/sec}{0.33} \cdot 0.0015$

$= 0.00227\ m/sec$

$=$ ~~196.3~~ 19.6 m / day

$$C_L = \frac{C_o}{2}\left[\mathrm{erfc}\left(\frac{L-vt}{2\sqrt{Dt}}\right) + \exp\left(\frac{vL}{D}\right)\mathrm{erfc}\left(\frac{L+vt}{2\sqrt{Dt}}\right)\right]$$

t	(1) $\frac{L-vt}{2\sqrt{Dt}}$	(2) $\frac{vL}{D}$	(3) $\frac{L+vt}{2\sqrt{Dt}}$	erfc(1)	exp(2)	erfc(3)
1	~~6.7~~67	9.98	~~2.3~~ 3.48	0	21692.4	0
5	~~2.46~~24	"	3.92	.000689	"	0
10	~~1.45~~11	"	3.36	0.119	"	0
15	~~0.45~~4	"	3.19	0.479	"	0
20	0.032	"	3.16	0.94	"	0
25	-0.32	"	3.17	1.32	"	0
					"	

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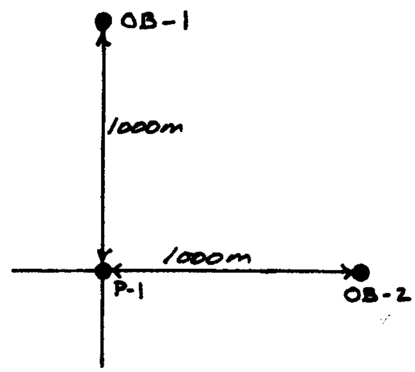
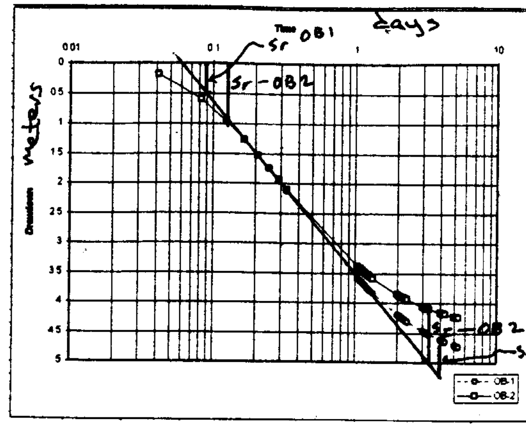
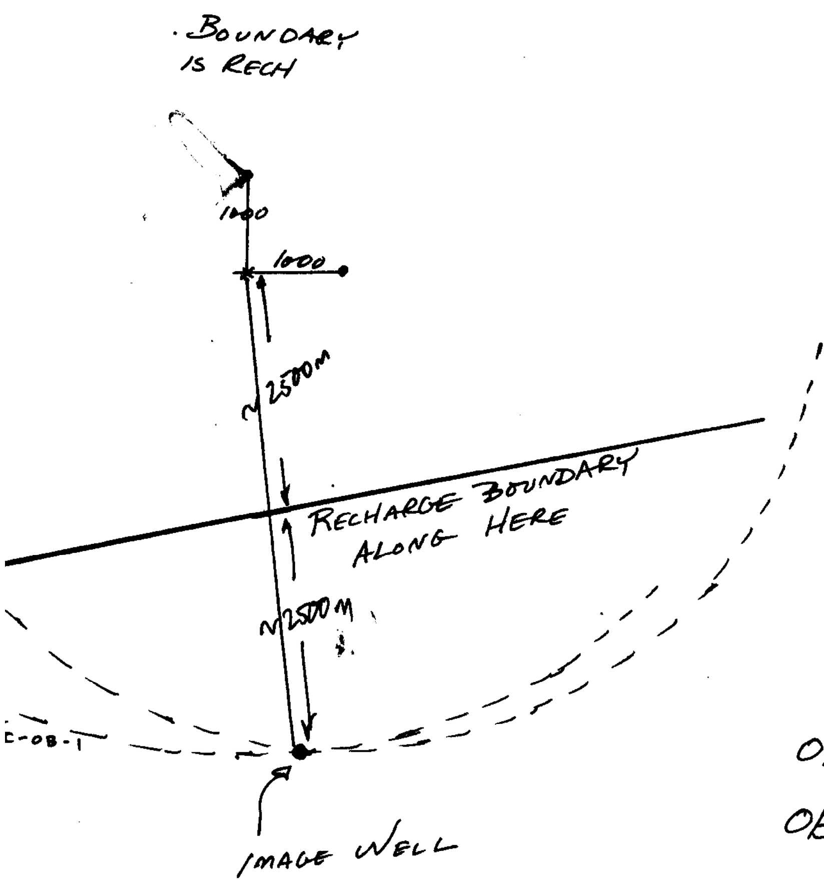
2) A pumping test is performed in a homogeneous, confined aquifer. The presence of any hydrologic boundaries was not obvious from surface geology, but time drawdown data from two observation wells suggests the presence of a recharge boundary somewhere near the three wells. Determine the location and orientation of the recharge boundary from the time-drawdown data. (Use Jacob's approximation for your analysis).



P-1; Q = 86400 m³/day





- Boundary is Recharge Boundary. Note departure from straight line
- At late time, DDN from real well = DDN from image well

$$\therefore W\left(\frac{r_r^2 S}{4T t_r}\right) = W\left(\frac{r_I^2 S}{4T t_I}\right)$$

$$\Rightarrow r_I^2 = r_r^2 \frac{t_I}{t_R}$$

Where t_I & t_r are departure times shown above.

OB-1; $t_I = 4$ days, $r_r = 1000$m, $t_r = 0.09$

OB-2; $t_I = 3.2$ days, $r_r = 1000$ m, $t_r = 0.12$

$$\therefore r_{I_{OB1}} = r_r \sqrt{\frac{t_I}{t_r}} = 1000\sqrt{\frac{4}{0.09}} = \sout{2108m}\ 6666\,m$$

$$r_{I_{OB2}} = r_r \sqrt{\frac{t_I}{t_r}} = 1000\sqrt{\frac{3.2}{0.12}} = 5164\,m$$

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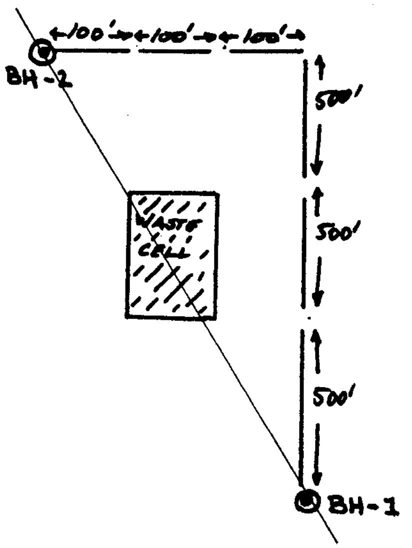
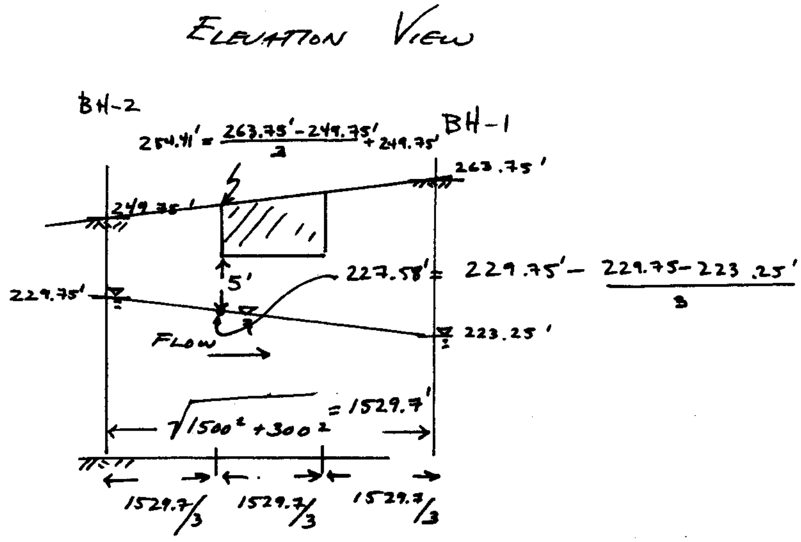
3) (Typical Question from P.E. Exam) Two borings are completed in the water table aquifer depicted below. The ground elevation at borehole BH-1 is 263.75 ft. The ground elevation at borehole BH-2 is 249.75 ft. The water table elevation at borehole BH-1 is 223.25 ft. The water table elevation at borehole BH-2 is 229.75 ft. The soil types in the area are silty-clay with a hydraulic conductivity of 3.0 E-5 ft/sec and a porosity of 0.4. A 300 x 500 foot waste cell is located between the two boreholes as shown. The bottom of the cell must be 5 feet above the water table.





a) What is the hydraulic gradient, direction of groundwater flow, and average linear velocity of the groundwater (from the information given)?

$$\frac{\Delta h}{\Delta L} = \frac{229.75' - 223.25'}{1529.7'} = 0.00425,$$ Flow From BH-2 to BH-1

$$V = \frac{q}{n} = \frac{K}{n}\frac{\Delta h}{\Delta L} = \frac{3\cdot 10^{-5}\ ft/sec}{0.40} \cdot 0.00425 = 3.18\cdot 10^{-7}\ ft/sec$$

b) What is the minimum elevation of the bottom of the waste cell?

Calculate wt height under leading edge of cell, see elev. View above.

wt + 5' = min elevation

∴ Min elev = 227.58' + 5' = 232.58'

c) If the waste cell fails, estimate the average travel time before contaminanted water will reach the downstream bore hole.

$$t = \frac{x}{v} = \frac{\frac{1529.7\ ft}{3}}{3.18\cdot 10^{-7}\ ft/sec} = 50.8\ yrs$$

$1.6\cdot 10^{9}$ sec

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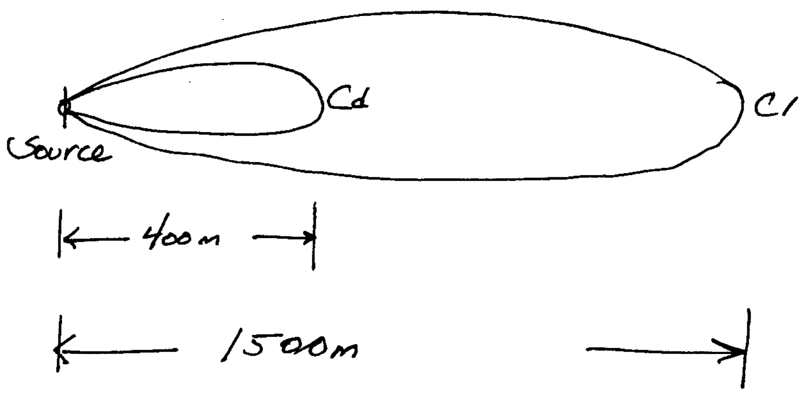
4) In a plan view of a contaminant plume you notice that chloride has moved approximately 1500 meters, while cadmium has moved only 400 meters. Assuming both species were released at the same time, determine the distribution coefficient for cadmium if the porosity is 30% and the solids density is 2.22 grams/cubic centimeter.



FORMULA IN BOOK

$$R = 1 + \frac{\rho_s}{n} K_d$$

$$V_{cl} = \frac{x_{cl}}{t} \qquad V_{cd} = \frac{x_{cd}}{t}$$

$$R = \frac{V_{cl}}{V_{cd}} = \frac{x_{cl}}{t} \cdot \frac{t}{x_{cd}} = \frac{1500m}{400m} = 3.75$$

$$\therefore K_d = [R-1]\frac{n}{\rho_s} = [3.75-1]\frac{0.30}{2.22} = 0.37 \frac{mL}{g}$$

FORMULA FROM NOTES

$$n\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} - q\frac{\partial c}{\partial x} - (1-n)\rho_s K_d \frac{\partial c}{\partial t}$$

$$[n + (1-n)\rho_s K_d]\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} - q\frac{\partial c}{\partial x}$$

$$n\underbrace{\left[1 + \frac{1-n}{n}\rho_s K_d\right]}_{R}\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} - q\frac{\partial c}{\partial x}$$

$$R = \frac{V_{cl}}{V_{cd}} = \frac{x_{cl}}{t} \cdot \frac{t}{x_{cd}} = \frac{1500}{400} = 3.75$$

$$[3.75-1]\frac{n}{(1-n)\rho_s} = K_d$$

$$[2.75]\frac{0.3}{0.7(2.22)} = K_d$$

$$= 0.53 \frac{mL}{g}$$