

WATER FLOW

AGRY 560

DARCY'S LAW $J_w = -K_{SAT} \frac{dH}{dz}$ OR $Q = -K_{SAT} A \frac{dH}{dz}$

BUCKINGHAM-DARCY LAW $J_w = -k(\psi_m) \frac{dH}{dz}$

POISEUILLE'S LAW $Q = -\frac{\pi R^4 \rho g \Delta H}{8 \eta L}$

ASSUME $\eta = 1 \times 10^{-2} \frac{g}{cm \cdot sec}$

$$\rho = 1 g/cm^3$$

$$g = 9.8 m/sec^2$$

CHEMICAL TRANSPORT

CONVECTION ① $J_{lc} = J_w C$

DIFFUSION ② $J_{ld} = -D_{ls} \frac{dc}{dx}$ ③ $D_{ls} = D_w \theta_v \xi_l$

DISPERSION ④ $J_{lh} = -D_{lh} \frac{dc}{dx}$ ⑤ $D_{lh} = \lambda \bar{v}$

⑥ $D_e = D_{ls} + D_{lh}$

⑦ $\bar{v} = \frac{J_w}{\theta_v} = \frac{L}{t_b}$

\bar{v} = AVE. VELOCITY

J_w = WATER FLUX

t_b = BREAKTHROUGH TIME

⑧ $R = 1 + \frac{\rho_b K_d}{\theta_v}$

K_d = SORPTION COEF.

ρ_b = BULK DENSITY

R = RETARDATION COEF.

GAS DIFFUSION IN SOIL

$$J_g = -D_g^s \frac{\Delta C}{\Delta X}$$

$$D_g^s = D_g^a \xi_g$$

PENMAN FORM $\xi_g = (0.66)(f_a)$

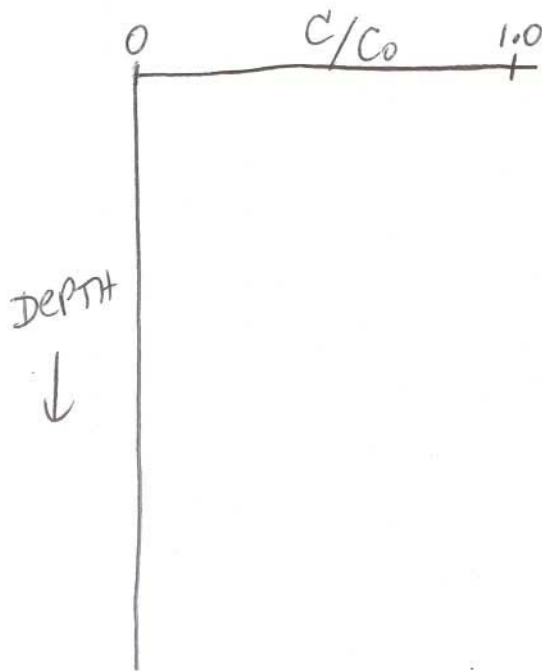
Name _____

AGRY 560 Final Exam
December 14, 2004 (150 points)

- (9) 1. In the lectures about tile drainage and water quality, we discussed that the presence of tile drainage generally decreases the losses of certain substances and increases the loss of others (loss being defined here as the loss of materials from the agricultural field and into the surface water ditches and streams). Give an example of a) a substance (chemical or material) that usually has greater total losses once tile drains are installed, and b) a substance that usually has less total loss once tile drains are installed. Assume that the land is already in agricultural production and that it is a naturally poorly-drained soil (ie it is wet and needs some type of drainage for adequate crop production).
- c) Explain why (a) has increased and (b) has decreased (ie what are the processes that are changed in fields with tile drainage vs. those without).
- (9) 2. Describe 3 different types of methods for studying chemical transport in soils. Discuss advantages and limitations of each method, and state what each method actually measures (chemical concentration or mass or flux).

(9). 3. What is “preferential flow?” Discuss and explain the concept. Why is it important?

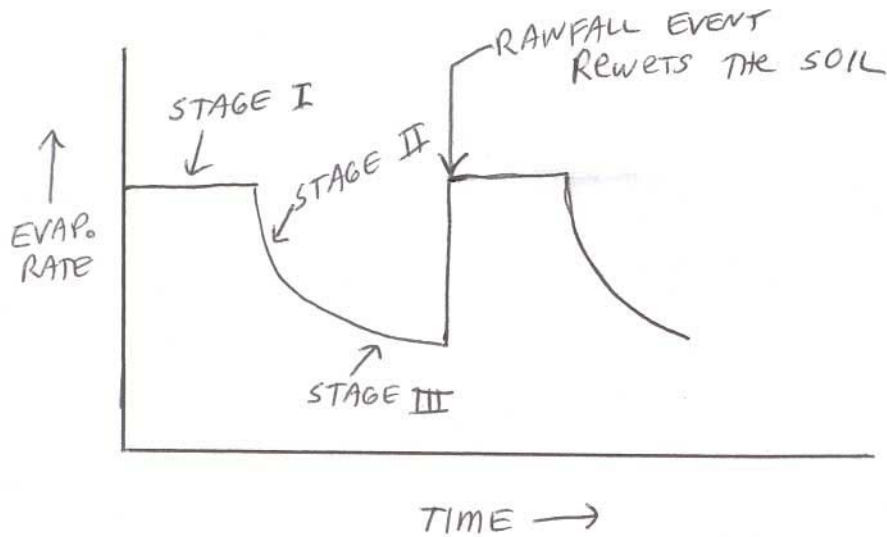
(9) 4. On the graph below, sketch the curve for relative concentration (C/C_0) vs. soil depth, for two chemicals: Chemical A moves by convection, dispersion and diffusion only, and Chemical B also shows preferential flow. Note that there are several possible scenarios for exactly how the preferential flow curve might look--give one of them and clearly explain what the curve shows, and why you drew it the way you did.



- (12) 5. In the recent past, one of the approaches to describing chemical transport through soils has been to use various “2-region models.” We discussed the “classic version” of 2-region models in class, namely, the mobile-immobile water model. We also briefly discussed the transfer function model approach of Jury.

Describe the mobile-immobile water model for chemical transport. Draw a picture to help you in your discussion. Also draw a graph of chemical concentration vs. time for the mobile-immobile water model as compared with the standard convection-dispersion (CDE) model. Include in your discussion such topics as a) what is the reason this model was developed, what conditions does it try to describe, etc., b) what are the assumptions of the model (there are 3 major ones), c) why does the outflow vs. time graph look the way you drew it, d) anything else you deem important.

- (6) 6. What is a semi-variogram, and how it is constructed? Describe in general terms (not equations) how the values are calculated and plotted, and what the overall objective is when doing this type of calculation.
- (4) 7. What are “anaerobic microsites”?
- a. brown mottles in a predominantly gray subsoil
 - b. excess O₂ on aggregate edges caused by rapid drainage
 - c. lack of O₂ in the centers of aggregates even though pores between aggregates are well-aerated
 - d. anaerobic soil conditions throughout the profile due to flooding
- (4) 8. What is the minimum volume of large pores that is considered necessary so that aeration problems will not exist in a soil?
- a. 5%
 - b. 10%
 - c. 15%
 - d. 20%
- (4) 9. Which of these gases are normally in higher concentration in soil air than in the atmosphere? (check all that are correct)
- a. ___ N₂
 - b. ___ O₂
 - c. ___ H₂O vapor
 - d. ___ CO₂
- (4) 10. Why is the diffusion coefficient for a gas in the air, D , different from the diffusion coefficient for gas in soil, D_s ?



(12) 11. Different techniques can be used to change evaporation rates, depending on whether you want to control Stage I or Stage II evaporation (or both).

- a) If a straw mulch is placed on top of bare soil, will the Stage I evaporation rate be higher or lower for the mulched soil compared to the bare soil?

_____ Briefly explain why.

- b) If a soil is tilled and remains very loose in the top 4 inches, will the Stage I evaporation rate be higher or lower for the tilled soil compared to the untilled soil? _____

Briefly explain why.

- c) Will the Stage II evaporation rate be higher or lower for the tilled soil, compared to the untilled soil? _____

Briefly explain why.

(6) 12. What are the 3 conditions necessary in order for continued evaporation to occur?

(6) 13. At a field site in Indiana, a bromide tracer was applied to the soil surface and its outflow in a tile drain was measured. The main peak of bromide arrived at the drain at 1 year after application. What was the average effective volumetric water content of the soil during the year? Data you may or may not need are given below.

arrival time at drain = 1 year

drain depth = 75 cm

net drainage = 15 cm/yr

$K_{SAT} = 5$ cm/day

organic carbon = 2.3%

- (15) 14. You are working for a landscaping company that just built a "desert garden" for one of its clients. In their effort to simulate an arid, sodic soil, they mistakenly added too much salt to the sandy loam soil. They also miscalculated and sprayed too much herbicide on the soil.

You decide to remedy the problem by leaching the area with water, under saturated conditions, to flush out the salts and the pesticide into the subsurface drainage system. Calculate the amount of water you will need a) to flush the salts (Cl^-) out of the soil, and b) to flush the pesticide out of the soil. Final answers must be **in units of cm**. Other data you may or may not need are given below.

Data collected

soil depth = 45 cm

B.D. = 1.50 g/cm^3

P.D. = 2.65 g/cm^3

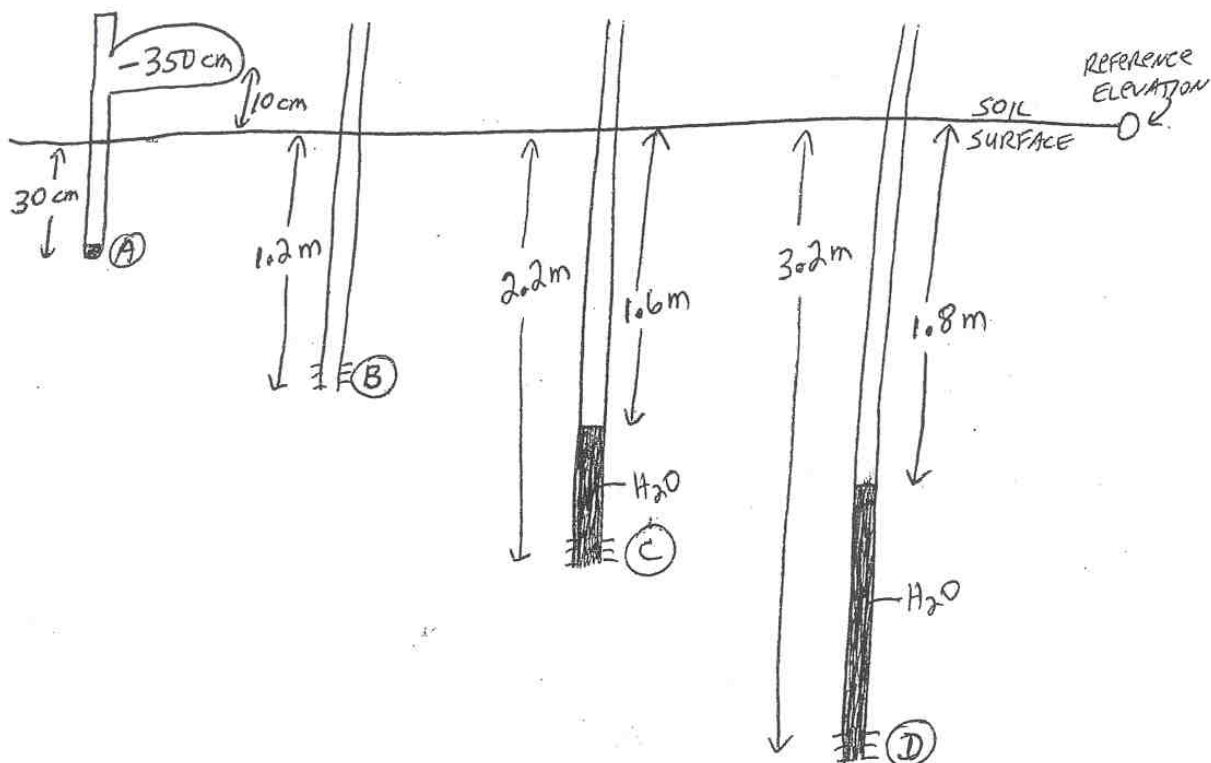
organic C = 0.9%

$K_{\text{sat}} = 3 \text{ cm/hr}$

pesticide $K_d = 0.35 \text{ cm}^3/\text{g}$

soil stays saturated during
leaching

(15) 15.



One tensiometer and three piezometers are installed in the soil as shown.

a) Calculate pressure head, elevation head, and total hydraulic head for the soil at points A, B, C, and D. (Note that at one of those points you do not have enough information to calculate pressure head and total hydraulic head).

b) What is the "best estimate" of the water table depth in this soil?

c) Calculate the water flux (units of cm/day) between the 2.2 m and 3.2 m depths, and tell me whether the water is moving upward or downward. Assume $K_{SAT} = 15$ cm/day.

(10) 16. A chemical plume was detected in shallow groundwater, and it is moving in the direction of a shallow well. Data you may or may not need are given below.

a) When will the plume arrive at the well, assuming piston flow?

b) Calculate the horizontal chemical flux (final units must be $\frac{\text{mg}}{\text{cm}^2 \text{day}}$)

Data

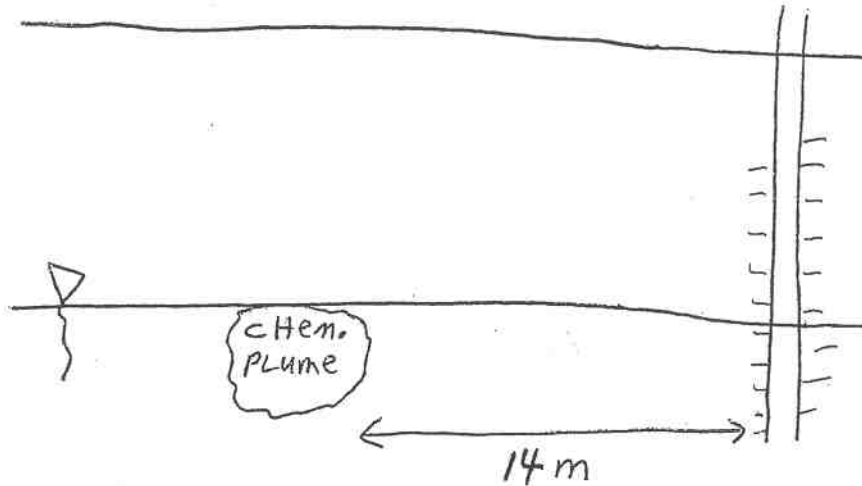
Chemical conc. in plume = 25 mg/liter

θ_v of saturated zone = 0.40

BD of saturated zone = 1.60 g/cm^3

PD of saturated zone = 2.65 g/cm^3

horizontal groundwater flux = 4 cm/day



(16) 17. The Animal Science Farm, north of the Agronomy Farm, has a predominance of wet, prairie-derived soils, including the Drummer silty clay loam. These are not soils that typically need irrigation, however the farm has liquid swine effluent to dispose of, and it uses this effluent as irrigation water and a nutrient source for the crops.

a) Using information contained on the xerox sheet from the Tippecanoe County Soil Survey, estimate the available water (in inches) stored in the rooting zone of the soil profile at the beginning of the growing season. Calculate using the low end of the estimated available water for each horizon.

Soil type: Drummer (Du)

Rootzone depth: 0-50 inches

b) If the typical corn crop requires 25 inches of water to yield well in our climate, how much rainfall must we receive during the growing season, for the crop to not suffer from water stress?

c) The farm has 1.4 million gallons per day (1.4×10^6 gal/day) of liquid swine effluent to dispose of on fields of this same soil type. If we decide that we do not want to put on more than 3 inches of irrigation water each week, how many acres would be needed to properly dispose of all the effluent produced each week (ie, a total of 9.8×10^6 gallons). (Note: you can do part c even if you don't have parts a or b correct)

1 gallon = 0.1337 ft^3

1 Acre = $43,560 \text{ ft}^2$

1 foot = 12 inches

TABLE 18.--PHYSICAL AND CHEMICAL PROPERTIES OF THE SOILS--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permeability	Available water capacity	Soil reaction	Shrink-swell potential	Erosion factors		Wind erodi- bility group	Organic matter
								K	T		
	In	Pct	g/cc	In/hr	In/in	pH					Pct
DpD2: Desker-----	0-9	7-15	1.40-1.70	2.0-6.0	0.12-0.15	5.6-6.5	Low-----	0.20	4	3	2-4
	9-14	12-18	1.50-1.70	2.0-6.0	0.09-0.12	5.6-7.3	Low-----	0.17			
	14-30	4-10	1.60-1.80	6.0-20	0.06-0.09	6.6-8.4	Low-----	0.15			
	30-60	1-5	1.70-1.80	>20	0.02-0.04	7.9-8.4	Low-----	0.10			
Rodman-----	0-8	5-20	1.30-1.60	2.0-6.0	0.09-0.12	6.6-7.8	Low-----	0.15	3	8	2-4
	8-12	5-25	1.40-1.60	2.0-6.0	0.09-0.12	6.6-7.8	Low-----	0.20			
	12-60	0-10	1.60-1.80	>20	0.02-0.04	7.4-8.4	Low-----	0.10			
Du: Drummer-----	0-17	28-35	1.20-1.60	0.6-2.0	0.21-0.23	5.6-7.3	Moderate----	0.28	5	7	3-6
	17-54	20-35	1.40-1.60	0.6-2.0	0.21-0.24	5.6-7.8	Moderate----	0.28			
	54-70	20-33	1.40-1.70	0.6-2.0	0.17-0.20	6.1-7.8	Moderate----	0.28			
	70-80	15-30	1.50-1.70	0.6-2.0	0.11-0.19	7.4-8.4	Low-----	0.28			
Drummer, stratified sandy substratum-----	0-11	28-35	1.20-1.60	0.6-2.0	0.21-0.23	6.1-7.3	Moderate----	0.28	5	7	3-6
	11-44	28-35	1.40-1.60	0.6-2.0	0.20-0.22	6.1-7.3	Moderate----	0.28			
	44-58	15-27	1.50-1.70	0.6-2.0	0.17-0.20	6.6-7.8	Low-----	0.28			
	58-70	5-15	1.50-1.70	0.6-2.0	0.05-0.14	7.4-8.4	Low-----	0.20			
Dy-----	0-49	18-27	1.20-1.60	0.6-2.0	0.18-0.24	6.6-8.4	Low-----	0.28	5	6	3-5
Du Page	49-60	10-20	1.50-1.70	0.6-2.0	0.17-0.19	7.9-8.4	Low-----	0.28			
EkA-----	0-10	7-15	1.40-1.70	2.0-6.0	0.18-0.20	5.1-7.3	Low-----	0.20	4	3	2-4
Elston	10-25	5-18	1.50-1.70	2.0-6.0	0.10-0.14	5.1-6.5	Low-----	0.24			
	25-49	3-12	1.60-1.80	6.0-20	0.08-0.10	5.1-7.3	Low-----	0.17			
	49-60	1-5	1.60-1.80	>20	0.02-0.04	7.4-8.4	Low-----	0.10			
EmA-----	0-14	10-18	1.30-1.60	2.0-6.0	0.20-0.22	5.1-7.3	Low-----	0.28	4	5	2-4
Elston	14-19	10-18	1.40-1.60	2.0-6.0	0.17-0.19	5.1-6.5	Low-----	0.32			
	19-38	5-18	1.50-1.70	2.0-6.0	0.10-0.14	5.1-6.5	Low-----	0.24			
	38-58	3-12	1.60-1.80	6.0-20	0.08-0.10	5.1-7.3	Low-----	0.17			
	58-70	1-5	1.60-1.80	>20	0.02-0.04	7.4-8.4	Low-----	0.10			
FcB: Fincastle-----	0-8	15-27	1.30-1.60	0.6-2.0	0.22-0.24	5.1-7.3	Low-----	0.37	5	5	1-3
	8-32	23-35	1.40-1.60	0.6-2.0	0.18-0.20	4.5-6.5	Moderate----	0.37			
	32-42	18-32	1.50-1.70	0.2-0.6	0.15-0.19	5.1-7.8	Moderate----	0.37			
	42-60	12-18	1.70-2.00	0.06-0.2	0.05-0.19	7.4-8.4	Low-----	0.37			
Crosby-----	0-9	15-27	1.30-1.60	0.6-2.0	0.20-0.24	5.1-7.3	Low-----	0.43	3	5	1-3
	9-38	20-35	1.50-1.70	0.06-0.2	0.15-0.20	5.1-7.3	Moderate----	0.43			
	38-60	15-27	1.70-2.00	0.06-0.2	0.05-0.17	7.4-8.4	Low-----	0.43			
Hd-----	0-11	22-27	1.20-1.60	0.6-2.0	0.21-0.24	7.4-8.4	Low-----	0.28	5	4L	3-6
Harpster	11-30	25-35	1.40-1.60	0.6-2.0	0.18-0.22	7.4-8.4	Moderate----	0.28			
	30-60	15-30	1.40-1.60	0.6-2.0	0.17-0.22	7.4-8.4	Low-----	0.28			
HfB2, HfC2-----	0-9	18-25	1.30-1.60	0.6-2.0	0.22-0.24	5.6-7.3	Low-----	0.37	4	6	1-3
High Gap Variant	9-28	28-35	1.50-1.70	0.6-2.0	0.15-0.19	4.5-6.0	Moderate----	0.37			
	28-36	30-45	1.50-1.70	0.2-0.6	0.07-0.11	4.5-6.0	Moderate----	0.37			
	36	---	---	---	---	---	---	---			
HnB-----	0-10	3-12	1.40-1.70	6.0-20	0.04-0.06	5.6-7.8	Low-----	0.17	4	2	1-2
Hononegah	10-34	6-15	1.60-1.80	6.0-20	0.03-0.05	5.6-7.8	Low-----	0.15			
	34-60	2-7	1.60-1.80	>20	0.02-0.03	7.9-8.4	Low-----	0.15			