

WATER FLOW

DARCY'S LAW $q = -K \frac{\Delta H}{\Delta L}$ OR $Q = -KA \frac{\Delta H}{\Delta L}$

Dec
2002

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 $J_c = qC$

DIFFUSION ② $J_d = -D_s \frac{\Delta C}{\Delta X}$ ③ $D_s = D_0 \theta_v \{ \}$

DISPERSION ④ $J_h = -D_h \frac{\Delta C}{\Delta X}$ ⑤ $D_h = (\alpha)(\bar{v})$

⑥ $\bar{v} = \frac{q}{\theta_v} = \frac{L}{t_b}$

⑦ $R = 1 + \frac{(BD)(K_d)}{\theta_v}$

\bar{v} = ave. velocity

q = WATER FLUX

θ_v = VOLUMETRIC WATER CONTENT

L = LENGTH

t_b = BREAKTHROUGH TIME

K_d = SORPTION COEFFICIENT

BD = BULK DENSITY

R = RETARDATION COEFFICIENT

Name _____

AGRY 465
Final Exam (150 pts)
December 13, 2002

- (4) 1. In wet aggregate analysis, the purpose in crushing aggregates and then washing them back through the sieves is:
- a) clean the sieves
 - b) determine the primary-particle size distribution
 - c) correct the MWD for humus
 - d) correct the aggregate weight for sand and stones
 - e) all of the above
- (4) 2. In the aggregate size distribution lab, if the field-moist samples had been broken to pass through a 16 mm screen rather than the usual 8 mm screen, and then wet-sieved with the usual nest of sieves of 4.76mm, 2mm, 1mm, and 0.21mm, what would the maximum possible value for MWD be?
- a) 16 mm
 - b) 10.38 mm
 - c) 6.38 mm
 - d) 4.76 mm
- (4) 3. What are “anaerobic microsites”?
- a. anaerobic soil conditions throughout the profile due to flooding
 - b. brown mottles in a predominantly gray subsoil
 - c. excess O₂ on aggregate edges caused by rapid drainage
 - d. lack of O₂ in the centers of aggregates even though pores between aggregates are well-aerated
- (4) 4. How does the composition of soil air differ from that of the atmosphere?
- (4) 5. What is the difference between evaporation and transpiration?

(8) 6. Describe 2 methods for measuring soil aeration, one method for each of the 2 basic categories of measurements listed below:

- a) volume of soil air
- b) composition of soil air

(6) 7. There are several different methods available to measure flow of soil air. One method measures permeability of the soil to flow of bulk air ("air permeability") in a manner similar to measuring hydraulic conductivity. If we want to measure diffusion of one particular gas (ie O₂) within the air, however, we have 2 other methods. One method uses a soil core, puts a vessel with the gas of interest on one end of the core, and measures its arrival in a chamber on the other end of the core. The other method measures oxygen diffusion in the soil in the field. Describe this method for measuring "oxygen diffusion rate" (ODR)--describe the physical procedure and also what the method is designed to simulate (draw a sketch to help your discussion).

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

(12) 9. 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.

Will the Stage II evaporation rate be higher or lower for the tilled soil, compared to the untilled soil? _____
Briefly explain why.

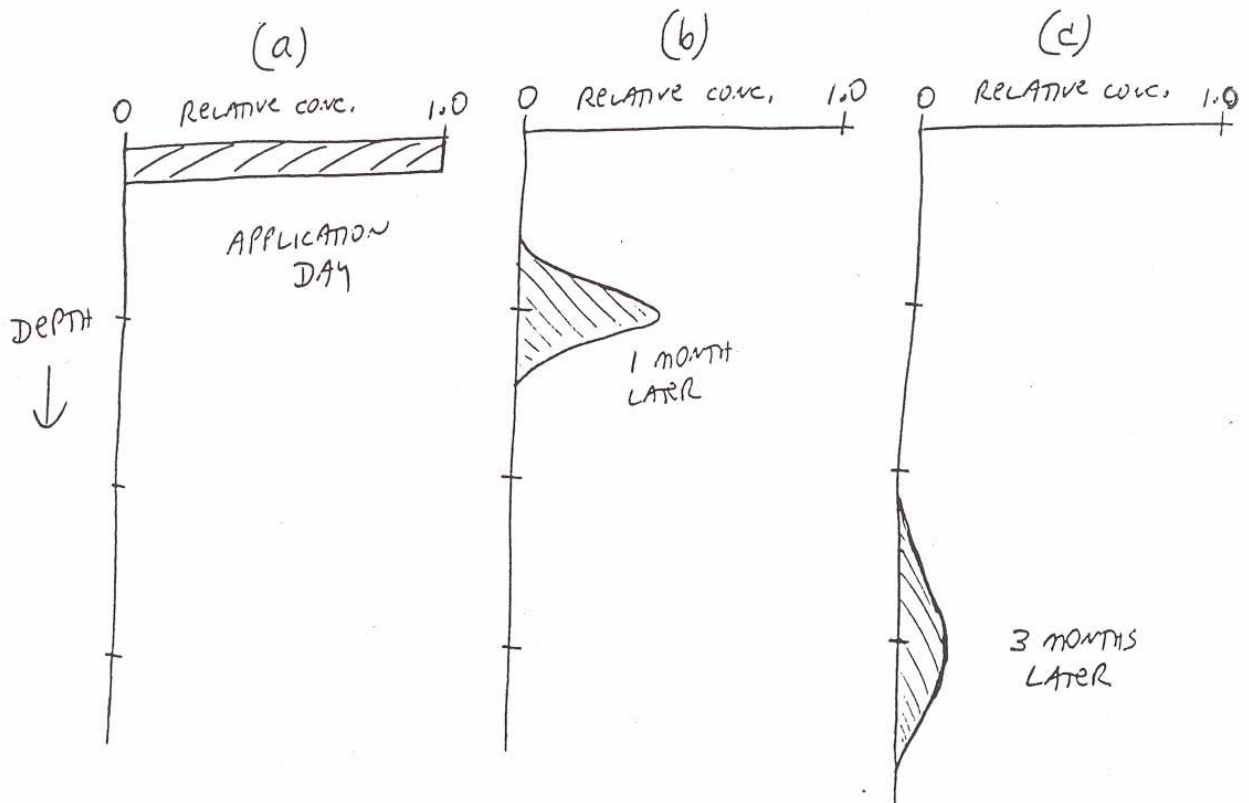
- (9) 10. Assume we have a chemical that can be both degraded and sorbed (ie a pesticide). Briefly discuss how each of the following properties of the chemical or the soil affects the time required for the chemical peak to reach groundwater (assuming piston flow) as well as the total mass (“RMF”, or residual mass fraction) of chemical that reaches groundwater, and explain why. When discussing each property, assume all other properties remain unchanged. (NOTE: For each property, you should tell me both how time changes and how mass changes (if at all), and why for both).

a) increasing the K_d or K_{oc} of the chemical

b) increasing the chemical half-life

c) increasing the soil organic matter content

- (15) 11. After a pulse or one-time application of a non-degrading and nonsorbing chemical, illustrated in (a) below, the chemical is transported downward with percolating water. Soil coring at 1 month (b) and 3 months (c) after application showed the typical decline in peak concentration and spreading out of the chemical peak. ---Discuss the 3 processes that contribute to this downward transport and spreading of the chemicals in the soil. Your answer should include a discussion of equations 1, 2, 3, 4 and 5 from the front page - what is the mechanism of each process, what do each of the symbols in each equation represent, and why are each of these terms needed to describe the process, etc. (Use the back of the page for more room to write.)



- (10) 12. The attached figure is from our tile drainage-water quality field research at the Southeast Purdue Agricultural Center. We discussed this type of figure in lecture (particularly my slide lecture), plus you had a 2-page article about our research, that included this graph.

Use this graph to help explain the concept of preferential flow. What is preferential flow? Why is preferential flow important? What are some of the characteristics of preferential flow, that are illustrated in this graph?

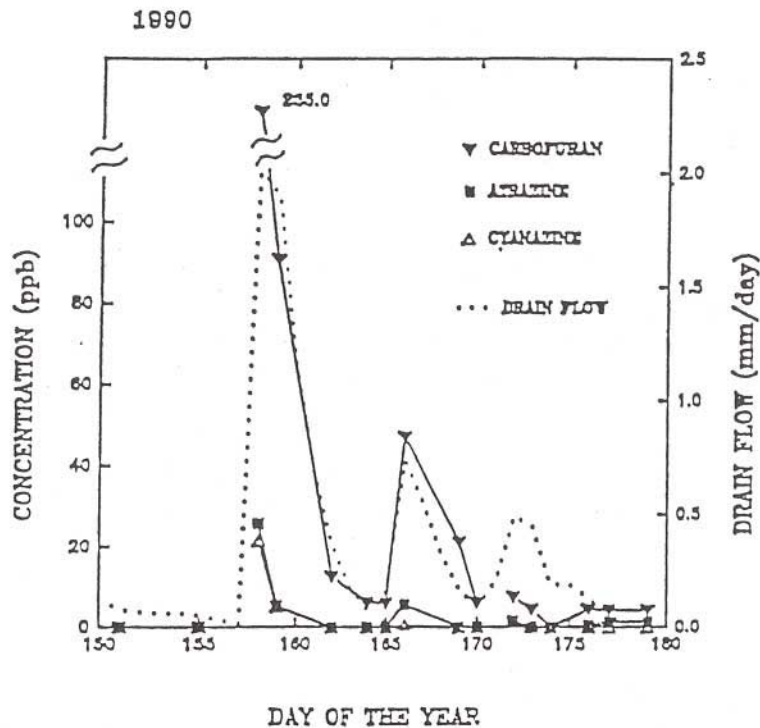
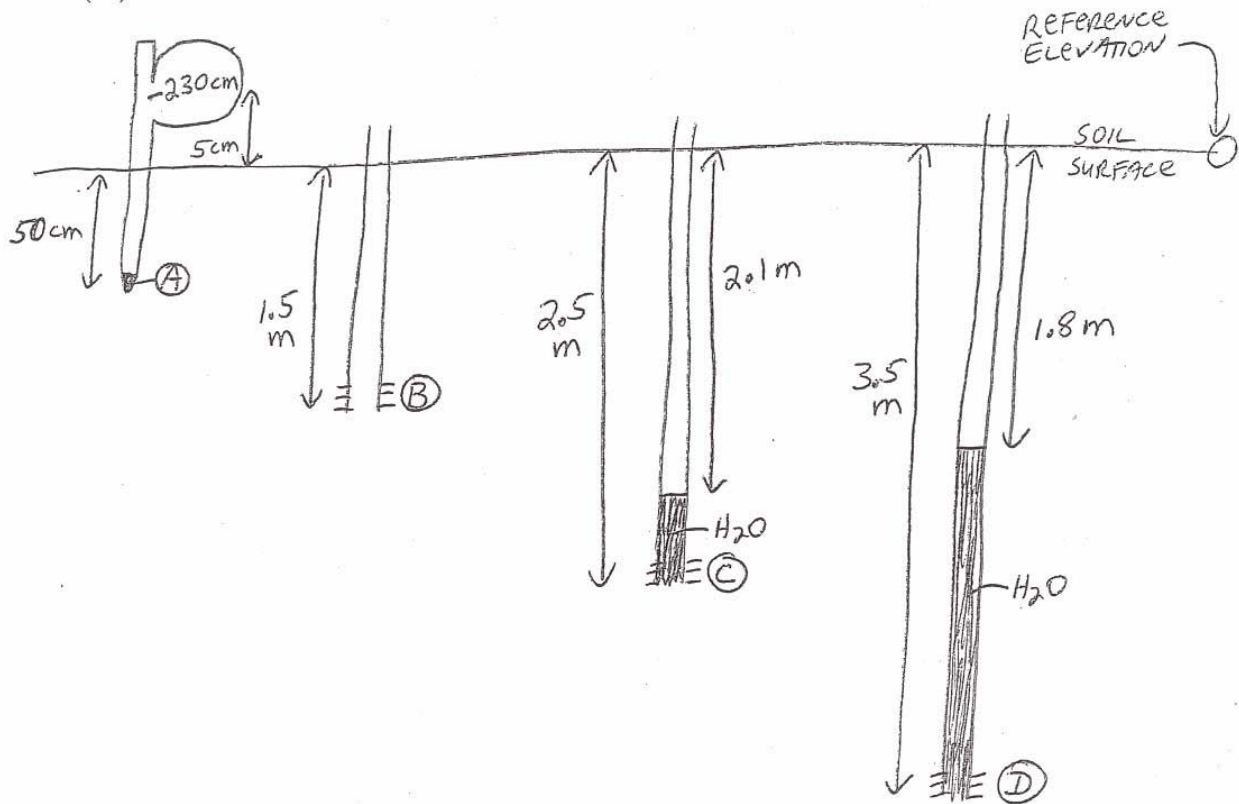


Figure 1. Tile drain outflow and pesticide concentrations from the 20 m spacing, Block 2, from day 150 to 180, 1990. (Planted on day 151).

(14) 13.

(14) 13.



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

- 1) 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).
- 2) What is the "best estimate" of the water table depth in this soil?
- 3) What would the pressure head (h_p) be at point B, if point B was in equilibrium with the water table? (use the water table estimate from part 2 above)

(15) 14. You are working to clean up a large chemical spill that occurred 20 years ago near West Lafayette. At that time a tank ruptured and large amounts of chloride ($K_d = 0 \text{ cm}^3/\text{g}$) and a non-degradable industrial chemical ($K_d = 0.27 \text{ cm}^3/\text{g}$) were spilled on the ground. Weather records show that the net infiltration over that time period has been about 300 cm of water. You take soil cores and determine soil properties as listed below (you may not actually need all of this data, but you wanted to be sure you have everything measured).

a) Calculate the current depth of the chloride peak and the industrial chemical peak, assuming only downward flow in the unsaturated zone, and no degradation.

b) If the water table depth is 25 m, calculate the expected future arrival time of each of the chemicals at the water table (assuming that the climate doesn't change).

Data collected

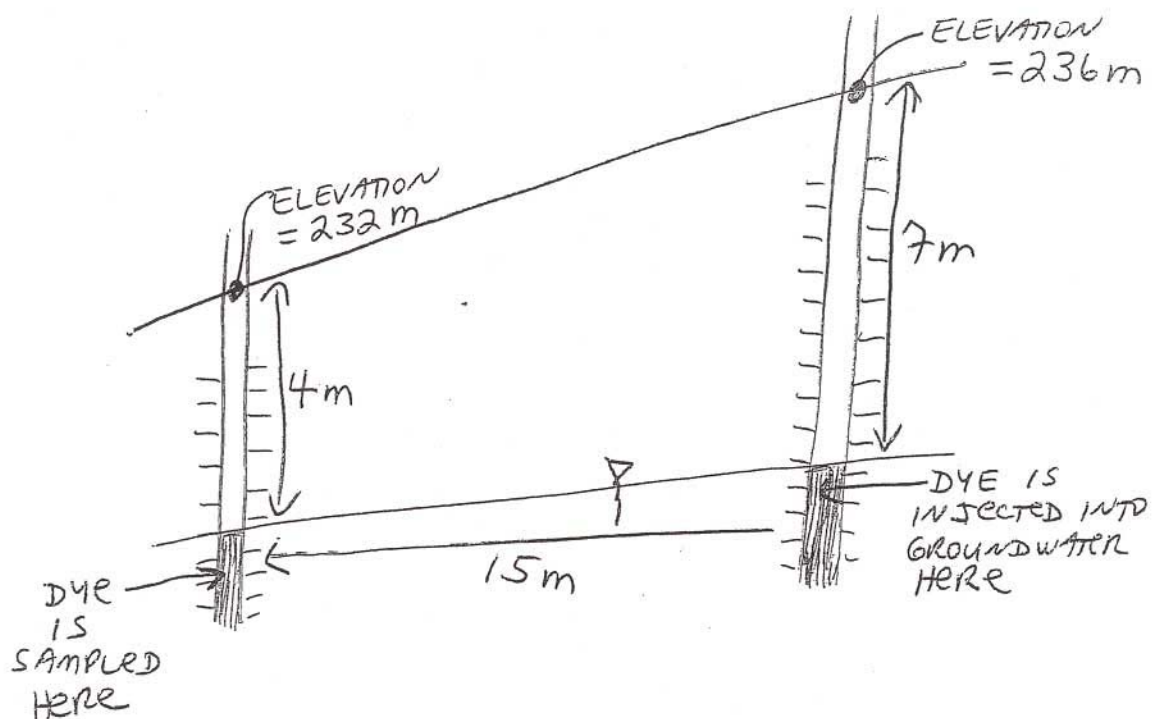
$$\theta_v = 0.32$$

$$\text{B.D.} = 1.40 \text{ g/cm}^3$$

$$\text{P.D.} = 2.65 \text{ g/cm}^3$$

$$\text{Organic C} = 1.8\%$$

$$K_{\text{sat}} = 16 \text{ cm/day}$$



(15) 15. You are trying to determine the groundwater flow characteristics near a popular State Park. You install some wells in the area, two of which are shown in the diagram. You make a number of measurements and a series of tests to determine what you need to know. Data you may or may not need are given below.

- a) Calculate the water flux between the two wells (we want **final units of cm/yr**).
- b) Calculate the horizontal chemical flux of a tracer dye, if its concentration in the groundwater surrounding the injection well is 32 mg/liter (assuming piston flow and no adsorption). (flux must have **final units of** $\frac{mg}{cm^2 yr}$)
- c) How long would it take for the non-sorbed dye to travel from the injection well to the other well? (ie what is its arrival time?) (**Final answer should be in units of yr**)

Data collected

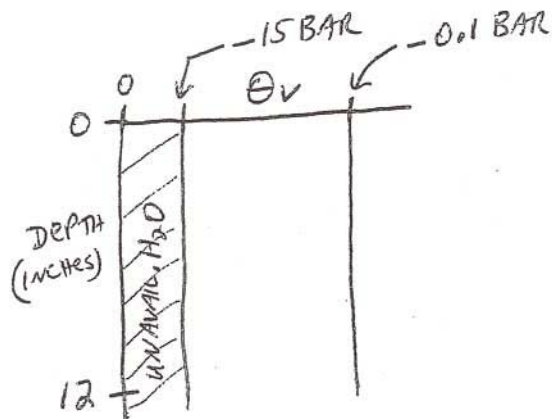
$K_{sat} = 42 \text{ cm/day}$

θ_v of saturated zone = 0.40

P.D. = 2.65 g/cm^3

dye conc = 32 mg/liter

- (10) 16. We have a 12 inch depth of uniform sandy loam in a golf green. How many inches of irrigation water do we need to bring the entire depth of sandy loam from initially dry conditions (-15 bar) up to our estimate of field capacity (-0.1 bar)?
 (NOTE--We do this calculation assuming that the irrigation water will redistribute in the soil so that it is uniformly wetted to field capacity within 24 hrs after irrigation.)



$$BD = 1.38 \text{ g/cm}^3$$

$$\theta_g - 0.1 \text{ bar} = 0.185 \text{ g/g}$$

$$\theta_g \text{ at } -15 \text{ bar} = 0.052 \text{ g/g}$$

- (10) 17. We started with a fully saturated soil profile, and then we covered it with plastic and allowed drainage to occur. After one week the measured water contents were as shown below. How much volume of water (liters) was drained from the 0 - 60 cm depth per m^2 of soil surface area? CARE WITH UNITS IS ESSENTIAL TO WORK THIS PROBLEM CORRECTLY. **Final units required : liters/ m^2**

<u>DEPTH (cm)</u>	<u>$\theta_{V(INITIAL)} \left(\frac{cm^3}{cm^3} \right)$</u>	<u>$\theta_{V(FINAL)} \left(\frac{cm^3}{cm^3} \right)$</u>
0-10	0.45	0.20
10-30	0.45	0.25
30-60	0.45	0.33

OR, ILLUSTRATING GRAPHICALLY,

