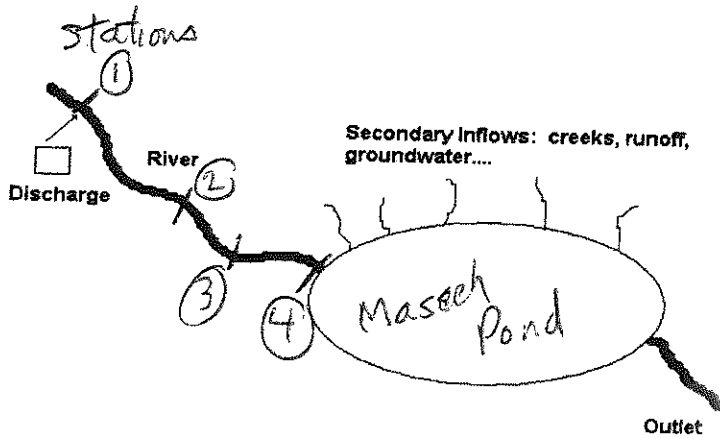


Problem Set 3. (2016)
Fate & Transport of Toxics in the Environment
CE/ESR 479/579

A pharmaceutical factory is seeking a permit to discharge wastes in a continuous flow into the Fishkill River. This river enters a shallow lake about 15 km away. The goal of this assignment is to determine the average concentration of a toxic but highly degradable waste chemical, methyl dichloroacetate, in the lake. (By the way, although this problem is hypothetical, there really is a Fishkill River in upstate New York (Near Schuylerville on the Hudson River).



Hydrologic Data for the Fishkill River:

In August of 2016, a group of students made measurements of the mean depth and mean width of the river at four locations during the dry season (low flow) conditions. In addition, they measured the mean velocity for the three reaches defined within these four stations. The 4th station is at the point the river enters Maseeh Pond.

Station Number	Distance downstream from discharge (km)	Reach	Mean Velocity of River (m/s)	Mean depth of reach (m)	Mean width of reach (m)	River Elevation (m above MSL) at each station
1	0					115.9
2	9.0	1-2	0.72	1.10	7.5	101.0
3	11.5	2-3	0.88	0.90	8.5	98.3
4	16.4	3-4	0.93	1.30	9.5	90.8

Maseeh Pond Data: Surface area = 5.0 hectares. Mean depth = 2.0 m. The outflow from the pond is 18.5 m³/s.

Chemical Data: Methyl dichloroacetate (MDA) degrades primarily by base hydrolysis (more on that subject later in class) and for the pH and temperature of the Fishkill the expected half-life is 3.0 h.

QUESTIONS:

- a) Calculate the mixing zone length (L_m) for the first reach. State whether the mixing zone is confined to the first reach or if it also extends into the second reach.
- b) Assume a continuous and steady input of MDA at a mass rate of 5.0 kg/min. The discharge pipe is located at Station 1 in the center of the river, both vertically and laterally. Calculate the maximum MDA concentration at several points *within* the mixing zone. Proceed as follows:
 - a. Assume 3D mixing but with the “boundary Layer approximation” discussed in class which, in this case drops out the x-direction dispersion, and only transverse and vertical mixing are important in the mixing zone. (This is because the “curvature” of the C - function is significant only in y and z directions and is basically linear (hence unimportant) in the x-direction).
 - b. For this situation the simplified approximate solution (steady state) is of the form:

$$C = \frac{q}{4\pi(D_t D_v)^{1/2} x} \left[\exp - \left(\frac{y^2 U}{4x D_t} + \frac{z^2 U}{4x D_t} + \frac{kx}{U} \right) \right]$$

Where q is mass flow in mass per second, D_t is transverse dispersion, D_v is vertical dispersion (assume this is $0.5 * D_t$) and U is the mean velocity. Note that this solution gets even simpler if you solve only for the *centerline* concentration. Note which variables are then equal to zero and cause several terms drop out of the equation. Show your simplified solution equation in your write-up. Be careful with input units and such; verify that all units work out to the desired values for concentration.

- c. Let's not worry about adding images sources at this point since we will stay well inside the mixing zone . Thus, calculate $C_{max}(x)$ at three points, $x = 0.2L_m$, $x = 0.5L_m$ and $x = 0.8L_m$. Show this these data in a simple plot of C vs. x.
- d. How important is decay as an attenuation process compared to dispersion? In other words is one much more significant than the other in decreasing C, or are they similar in the effect on C?
- c) Are the study reaches gaining or losing discharge? If a reach is gaining, then assume the inputs contain no MDA and are a dilution factor. If the reach is losing, there is mass loss equal to the reach-average concentration times the volumetric outflow of water.
- d) Recognize that, once we are past the mixing zone, the river system is 1D and at steady state. This leads to a very simple model. Hint: You don't need the ADE. Use this assumption to find the steady-state concentrations of MDA at Stations 2, 3 and 4.
- e) If Maseeh Pond is completely mixed, what is the expected average MDA concentration in the pond?