1.061 / 1.61 Transport Processes in the Environment
Fall 2008

1.061/1.61: Homework # 7 [10 pt total]

Problem 1 [5 pts]: A slug of tracer is released into a smooth irrigation canal at X = 0m. The canal is 1 m deep by 1 m wide with a mean velocity 1 m/s. The isotropic diffusivity is $D = 0.01\ m^2s^{-1}$. At X = 500 m the tracer distribution is Gaussian with standard deviation $\sigma_1 = 32$ m. Between 500 m and 1000 m the banks of the canal are vegetated with reeds that retard the flow, but do not stop it completely. Assume that the water depth, h, and flow rate, Q, are unchanged in this reach. Beyond X = 1000 m the canal returns to a smooth, unvegetated state.

(a) Estimate the coefficient of shear dispersion, K_{X1}, in the first reach x = 0 to 500m.
(b) On the same graph draw the lateral profile of velocity, u(y), in both the first reach (X = 0 to 500m) and the second reach (X = 500 to 1000m).
(c) At X = 1000m the concentration distribution is Gaussian with standard deviation, σ_2. Will σ_2 > = < $(2\ K_{X1}\ L/U)^{1/2}$, where L = 1000m and U = 1 m/s? Explain. What can you interpret from the fact that C(X = 1000m , t) is Gaussian? Can you infer the magnitude of laterl diffusion, D_Y?
(d) Estimate the clouds length at X = 10 km. State and justify your assumptions.

Problem 2 [5 pts]: A chemical plant is under construction and you have been hired to write the Environmental Impact Statement. A pipe will inject a waste stream containing chemical XX into a stream of depth h = 1m and width b = 2m. Assume a rectangular cross-section. The injection rate for XX is $10\ gs^{-1}$. The injection point (x=0, y=0, z=0) is at mid-depth and mid-width. The mean current speed u = 15 cm/s. The isotropic diffusivity is $D = 20cm^2s^{-1}$.

a) Write an expression in variable form for the near-field concentration, *i.e.* before the plume has reached uniformity in either y or z, under steady state conditions. Account for the following boundary conditions. The chemical is so volatile that any molecule that touches the free surface is instantly volatilized, such that the concentration at the water surface is zero, C(x, y, z = h)=0. The chemical does not adsorb, settle, react, or pass through the channel bed or walls.
b) At x = 10m plot the vertical profile at mid-width (y = 0) and the lateral profile at mid-depth (z = 0). Confirm that the boundary conditions are met.