Problem Set 4
Fate and Transport 2016

1. A mixing experiment is conduct in a stratified lake, similar to the experiment discussed in class for the lake in British Columbia. Rhodamine WT dye tracer is release as an instantaneous, point discharge near the center of the lake. The tracer drifts downward in a line and stops at the thermocline at a depth of 10 m. Mass of dye added is 0.4 kg. A steady wind blows across the lake at an average of 8.0 mph. Orient the x-axis with the direction of the wind. Assume uniform and isotropic turbulent dispersion such that $D_x = D_y$ = Constant. (To simplify the problem over a relatively short time scale, assume the D_{xy} does *not* increase much as the plume grows.)

    a. If D_{xy} =0.05 m/s, calculate the value of C_{max} for the plume at 10 min, 30 min and 60 min. Also show the x displacement of the plume at each of these times.

    b. If a pollutant of interest (not the dye tracer) actually does decay with k = 0.46 h^{-1}, what would be the new C_{max} values at the three times. You can put answers to a) and b) in a single spreadsheet.

    c. If we included a "4/3rd rule" type of model for D, what effect would it have (qualitatively) on your results?

2. The Squeamish River is in a rural part of Washington State. The largest employer in that region is a cadmium plating plant that belongs to Cadmax, Inc. Cadmax supplies cadmium-plated parts to the electronics industry as well as to Boeing for use in aircraft. Cadmax has a 15 year old permit to discharge waste water with an average total Cd conc. of 3,100 mg/L (coming out of the pipe). WA Dept. of Ecology needs to establish a new Total Maximum Daily Load (TMDL) for Cd in the Squeamish, and set discharge limits on the Cadmax plant that will bring total Cd impacts back within current guidelines. Cadmax has hired your consulting firm to do some studies of Cd chemistry in the estuary so the lawyers can best shape their case. Cadmax is notoriously cheap, however, and has given you only a very small contract for services.

    The Cd enters the river from a pipe near midstream at a flow rate of 120 L/s and then mixes with river water, forming a mixing zone plume approximately 0.5 km long. The river channel in this (non-estuarine) region has a nearly constant mean width of 22 m and an average depth of 1.9 m. The cross-sectional mean velocity of the river has been measured at 0.12 m/s. At some point downstream of the "uniform Cd zone", the river enters the estuary and begins mixing with seawater which, in the ocean away from the estuary, contains only negligible Cd (<10^{-9} M). Salinity data allow you to infer the composition of the water mixture throughout the estuary. Cadmax wants to see some preliminary assessments from available data before they will pay the expense of field sampling. Fortunately for your budget, calculations are cheap.

a. Your ultimate goal is to deploy automated water samplers at four locations in a transect down the mainstem of the estuary at mean salinities of S = 0, 10, 20 and 30. The autosampler will collect hourly samples throughout a 24-h cycle of tides and aggregate them to create a single, tidal-cycle-averaged sample for each site. If Cd behaves conservatively in the system (*no* removal), what is the predicted total concentration of Cd at each of the proposed sampling locations?

b. Prepare an estuary mixing curve showing Cd as a function of salinity in the estuary.

Assumptions

- Use the flow and input data given in the text above.
- Assume the ocean salinity is S = 35.