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BEE 6740: Week 11 Assignment
Tracers in Ecohydrology

Purpose:
In ecohydrological work, tracers can be used to track water source, movement, and “age” over time. Tracers are nonreactive, conservative substances that should not be harmful to the environment, such as chloride. By measuring the concentration and profile of the tracer at the outlet of the area of interest, certain watershed characteristics can be determined. An important question to consider is whether or not there is mixing in a watershed. This can be determined by comparing the known influent to observed effluent behavior, which can then be compared to expected characteristics of different watersheds. Figure 1 highlights the expected differences between Plug Flow Reactor (PFR), short-circuiting, and Continuously Mixed Tank Reactor (CSTR) scenarios.

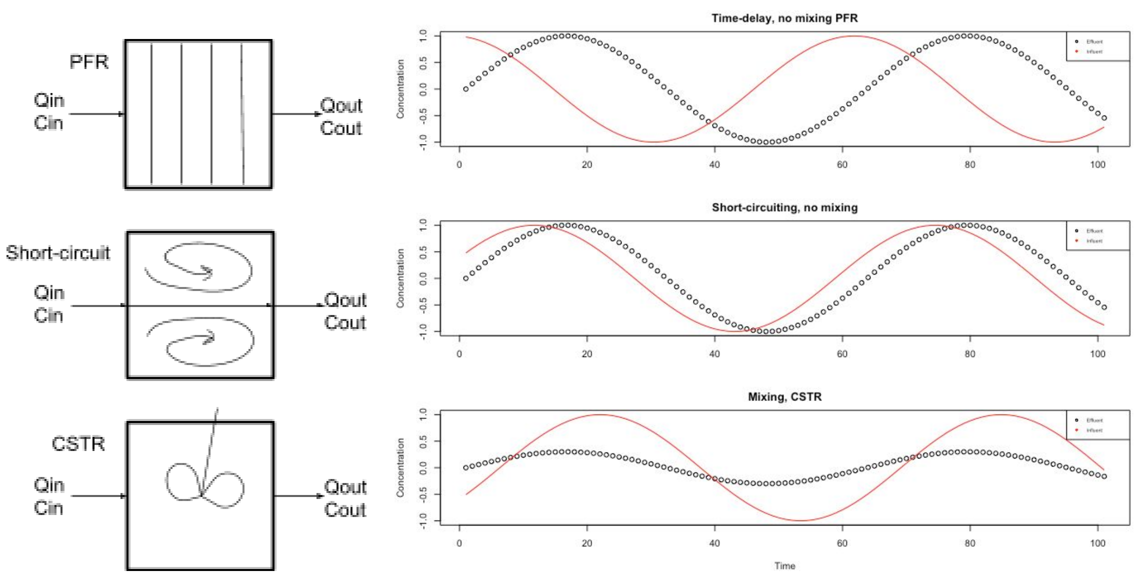

Figure 1: Watershed configuration and expected behavior of PFR, short-circuits, and CSTR systems.

Methods:
A synthetic dataset for 1950-1955 was analyzed to determine characteristics of the watershed to determine initial catchment storage and whether or not the watershed behaves like a CSTR. Mass balances were used to calculate water and tracer models. Equations and initial conditions are shown in Tables 1 and 2, where C is concentration, T is mass, and S is volume as depth and $Concentration = Mass/Volume$. It was assumed that evapotranspiration did not remove any

tracer, meaning that the tracer accumulated or became more concentrated after evapotranspiration processes.

Table 1: Water and tracer mass balances.

Catchment water balance	$\Delta S = Precipitation - Evapotranspiration - Flow$ $\Delta S = P - ET - Q$ $S_{storage}(i) = S_{storage}(i-1) + S_{precip}(i) - S_{ET}(i) - S_{Q}(i)$
Tracer concentration balance	$\Delta C_{mass} = C_{mass\ in} - C_{mass\ Q} - C_{mass\ ET}$
Tracer mixing condition	$T_{storage}(i) = T_{storage}(i-1) + (P(i) * C_{mass\ in}(i)) - [Q(i) * \frac{T_{storage}(i)}{S_{storage}(i)}]$
Tracer no-mix condition	$T_{storage}(i) = Q(i) * C_{mass\ in}(i)$

After calculating the effluent tracer concentration under mixing and no-mixing conditions, the concentrations of observed effluent concentration and simulated tracer concentration were plotted. It was clear that the initial guess of 400 mm was too large, so the calculations were rerun with the catchment storage size of 370 mm.

Table 2: Initial conditions and assumptions.

Initial catchment storage (guess)	400 mm
Initial catchment storage tracer concentration	26 mg/m
Average precipitation concentration	10 mg/m
Final catchment storage (modified)	370 mm

The mixing and no-mixing conditions are shown in Figures 2 and 3. Both representations show that the mixing assumption fits the observed data better, suggesting that the watershed could be modeled as a CSTR. Two years of chloride influent and effluent are plotting in Figure 4. Influent concentration is more variable than effluent, which agrees with the CSTR model in which mixing decreasing the amount of variability of effluent concentrations.

Figure 2: The mixing and no-mixing models for the catchment, as shown by tracer concentration.

Figure 3: The mixing and no-mixing models for the catchment, as shown by tracer mass.

Figure 4: Two years of chlorine influent and effluent data.

Chloride is a conservative tracer that is not impacted by ET. When ET increases, it would be expected that chloride concentration increases too. Figure 5 shows two years of chloride and ET data, which shows the expected trend that evapotranspiration leads to increased chloride concentration.

Figure 5: Two years of chloride concentration and ET data, showing chloride concentration increasing after high ET.

Conclusion:

The analysis of the synthetic dataset suggests that the catchment being analyzed can be modeled as a CSTR. Influent and effluent observed and simulated values are consistent with the CSTR mixing model, and accumulation of chloride show that it is a tracer that is not removed by ET. Assumptions noted in the Methods section should be considered when modeling water catchments. The CSTR model is only one of many used to understand water flow. Other modelers have emphasized the importance of dynamic modeling and the impact of model choice on outcome. The CSTR is an oversimplification of a watershed where other physical and chemical processes, like adsorption, may impact both water and tracer flow.