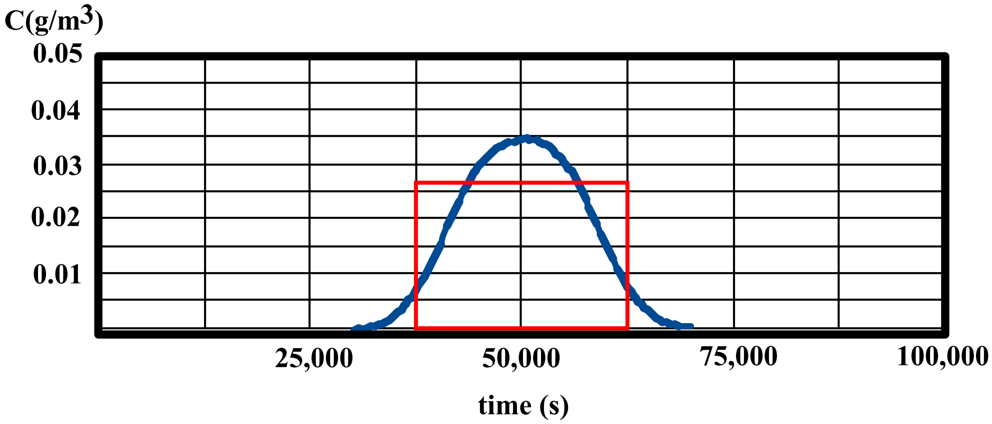
Answer 2.3

a) Calculate the nominal residence time of the pond.
$T_R = Ah/Q = (1m)(5000m^2)/(0.1m^3s^{-1}) = 50{,}000s = 0.58$ d.

b) What is the lowest exit concentration that could be achieved in this pond?
The lowest exit concentration would be achieved if the circulation in the pond were plug-flow. If plug-flow existed, the steady exit concentration would be,

$$C_e = C_O\exp(-kT_R) = (2 \text{ mg/L}) \exp(-(1d^{-1} \times 0.58d)) = 1.1 \text{ mg/L}$$

c) Use the tracer study results to estimate thetotal dye mass that leaves the pond. Explain your result.
The mass leaving the pond is $M = \int QCdt$. Since the flow rate is constant, $M = Q\int Cdt$. We can estimate the integral by the area under the curve in the plot below. The red square shown below has an approximately equal area to the blue curve, so we estimate, $M \approx (0.1m^3s^{-1})(0.026 \text{ gm}^{-3})(25{,}000s)=65$ g.



The estimated mass that leaves the pond is less than the injected mass. This result suggests that there is a sink for the dye within the pond. The sink could be due to 1) absorption to organic material, or 2) photodegradation. One might guess that some mass has been captured in dead-zones, with subsequent release after the observation of exit concentration has ended. However, the detention time (T_{det}) is equal to T_R, suggesting that no dead-zones are present. Because of the symmetry of C(t), T_{det} corresponds to the time of peak arrival (50,000s). Finally, instrument error may have caused underestimation of the dye concentration.

d) Based on the concentration time series shown below, is the system short circuiting?
The peak concentration is observed at T_R. This suggests that short-circuiting is not occurring.