Solutions to Practice Problems No. 1

2. \( Q_r = 10 \text{ m}^3/\text{s} \)  
\( Q_w = 20 \text{ L}/\text{s} \)  
\( C_w = 200 \text{ mg/L} \)  
\( A_{xs} = 15 \text{ m}^2 \) [but note that this is not needed until the next problem]  

At steady state, change in storage = 0, so  

\[ m'_{r,\text{mix}} = m'_{r,\text{pure}} + m'_{w} \]
\[ (QC)_{r,\text{mix}} = (QC)_{r,\text{pure}} + (QC)_{w} \]

\[ (10 + 0.02 \text{ m}^3/\text{s}) C_{r,\text{mix}} = (10 \text{ m}^3/\text{s})(0 \text{ mg/L}) + (20 \text{ mg/L})(200 \text{ L}/\text{s}) \]
\[ C_{r,\text{mix}} = \frac{[ (0) + (4000 \text{ mg/s})] }{10.02 \text{ m}^3/\text{s}} = 400 \text{ mg/m}^3 = 0.4 \text{ mg/L} = 400 \text{ ug/L} \]

This is 8x higher than the drinking water std.

3. Without decay the stream at steady state has a uniform concentration of 400 ug/L everywhere. With decay, the conc drops over time, hence over space downstream. First order decay occurs over time, so need to know how much time elapses from discharge to the target point 12 km downstream.

\[ t_{12\text{km}} = \frac{L}{v} = \frac{L}{(Q/A)} = \frac{LA}{Q} = \frac{(12,000 \text{ m})(15 \text{ m}^2)}{10 \text{ m}^3/\text{s}} = 18,000 \text{ s} = 5 \text{ h} \]

\( C_o = 400 \text{ ug} \) (the conc without decay)

\[ C_{12\text{km}} = C_o e^{-kt} = 400 \text{ mg/L} \left[ \exp(-0.14 \text{ h}^{-1})(5 \text{ h}) \right] = 400(0.5) = 200 \text{ ug/L} \]

So the conc is only half as much, although still well above the standard.

4. \( A_s = 100 \text{ hA} = 10^6 \text{ m}^2 \)  
\( d = 6 \text{ m} \)  
\( V = 6 \times 10^6 \text{ m}^3 \)

\[ Q_1 + Q_2 = Q_3 + Q_{\text{evap}} +/- Q_{gw} \]

\[ Q_{\text{evap}} = v_{\text{evap}}A_s = (2 \text{ mm/d})(10-3 \text{ m/mm})(10^6 \text{ m}^2) \div [(86,400 \text{ s/d})] = 0.23 \text{ m}^3/\text{s} \]

\[ (1.2 + 2.0) \text{ m}^3/\text{s} = (3.0 + 0.23) \text{ m}^3/\text{s} - Q_{gw} \]

\[ Q_{gw} = (3.23 - 3.20) \text{ m}^3/\text{s} = 0.03 \text{ m}^3/\text{s} = 30 \text{ L}/\text{s} \]  So a small inflow of groundwater.  
Face velocity is \( Q_{gw} / A_{sed} = Q_{gw}/A_s \)  if we make the reasonable assumption that sediment area is very close to the surface area of a shallow lake.
\[ v = \frac{0.03 \text{ m}^3/\text{s}}{10^6 \text{ m}^2} = 3 \times 10^{-8} \text{ m/s} = 0.00001 \text{ mm/s} = 0.9 \text{ mm/d} \]

So the velocity of the water is minuscule, even by groundwater standards.

\[ T_{\text{res}} = \frac{V}{Q_{\text{in}}} = \frac{6 \times 10^6 \text{ m}^3}{(3.23 \text{ m}^3/\text{s})(86,400 \text{ s/d})} = 21 \text{ d} \text{ or 3 weeks} \]

5. Work backward to get mass flow:

\[ m'_{\text{r,mix}} = m'_{\text{r,pure}} + m'_{\text{w}} \]

\[ m'_{\text{w}} = (QC)_{\text{r,mix}} - (QC)_{\text{r,pure}} = (QC)_{\text{r,mix}} = \frac{(1200 \text{ L/s})(100 \text{ ug/L})}{10 \text{ kg/d}} = 120,000 \text{ ug/s} = 120 \text{ mg/s} \]

(I asked it in mg/d but obviously better in kg/d)

\[ (QC)_{\text{r,mix}} = (QC)_{\text{r,pure}} + (QC)_{\text{w}} \]

\[ m'_{\text{lake, out}} = m'_{\text{in}} \]

\[ Q_3 C_{\text{lake}} = 120 \text{ mg/s} \]

\[ C_{\text{lake}} = \frac{(120 \text{ mg/s})}{Q_3} = \frac{(120 \text{ mg/s})}{(3000 \text{ L/s})} = 0.04 \text{ mg/L} = 40 \text{ ug/L} \]

So its only 40% of the river concentration due to dilution by Stream 2