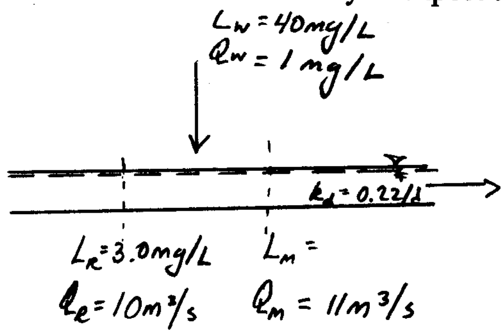
1) A wastewater treatment plant discharges 1.0 m^3/s of effluent having an ultimate BOD of 40.0 mg/L into a stream flowing at 10.0 m^3/s. Just upstream form the discharge point, the stream has an ultimate BOD of 3.0 mg/L. The de-oxygenation constant k_d is estimated at 0.22/day.

   a) Assuming complete mixing find the ultimate BOD of the mixture of waste and river downstream from the outfall.
   b) Assuming a constant cross section for the stream equal to 55 m^2, what ultimate BOD would you expect to find 10,000 m downstream?



$Q_M = Q_R + Q_W = 10 + 1 = 11 m^3/s$

a) $L_m = \frac{Q_w L_w + Q_R L_R}{Q_w + Q_R} = \frac{(1)(40)+(10)(3)}{10+1} = 6.4 mg/L$

b) 10000m downstream

$$t = \frac{x}{V} = \frac{10{,}000m}{\frac{11m^3/s}{55m^2}} \cdot \frac{1hr}{3600s} \cdot \frac{1day}{24hr} = 0.578\ day$$

$$L_t = L_m e^{-kt} = (6.4mg/L)(e^{-0.22(0.578)}) = 5.6mg/L$$

2) For a solution containing 200mg/L of glycine [$CH_2(NH_2)COOH$] whose oxidiation can be represented as

$$2\,CH_2(NH_2)COOH + 3\,O_2 \Rightarrow 4CO_2 + 2H_2O + 2NH_3$$

$$NH_3 + 2O_2 \Rightarrow NO_3^- + H^+ + H_2O$$

a) Find the theoretical carbonaceous oxygen demand (CBOD).
b) Find the ultimate nitrogeneous oxygen demand (NBOD)
c) Find the total theoretical (carbonaceous and nitrogeneous) oxygen demand (BOD).

$$MW = \underset{(C)}{(2)(12)} + \underset{(H)}{(5)(1)} + \underset{(N)}{(1)(14)} + \underset{O}{(2)(16)} = 75\,g/mol$$

a) $$CBOD = \frac{3\,mol\ O_2}{2\,mol\ glycine} \cdot \frac{32g\ O_2/mol}{75g\ glycine/mol} \cdot \frac{200mg\ glycine}{1L} \doteq 128\,mg/L$$

b) NBOD $$NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$$

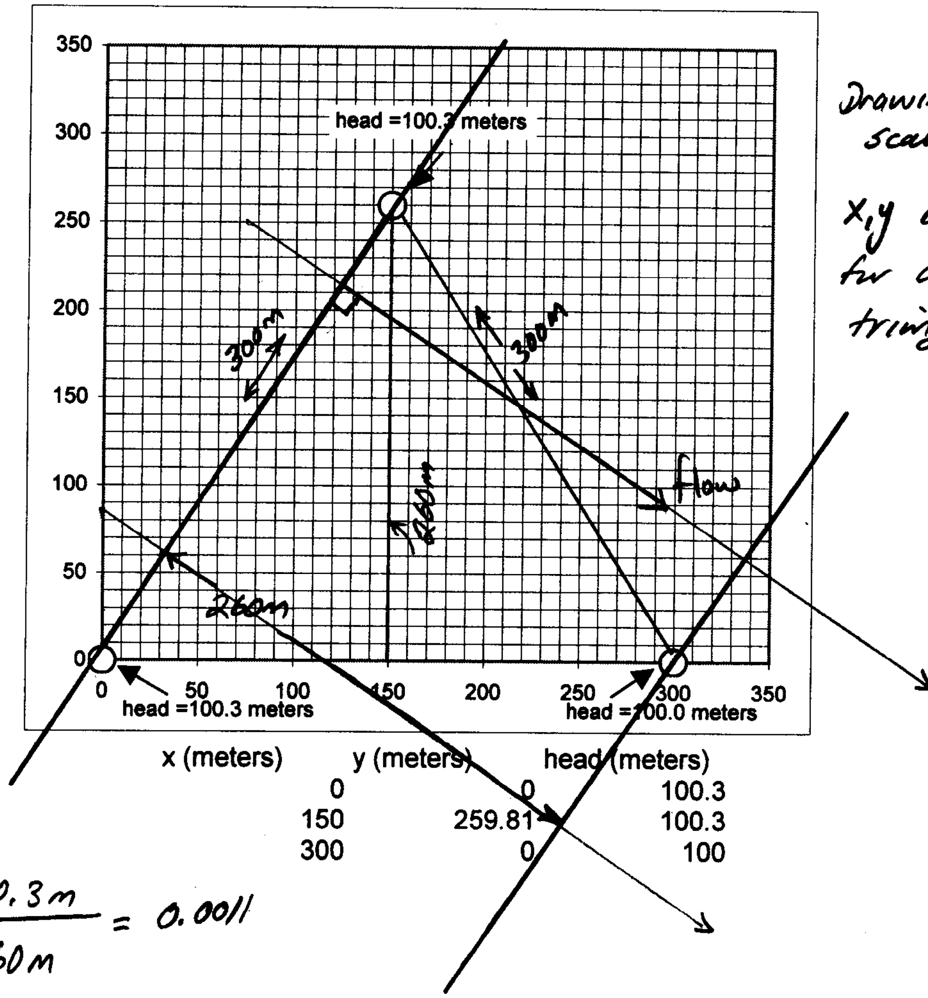
$$NBOD = \frac{2\,mol\ O_2}{1\,mol\ NH_3} \cdot \frac{2\,mol\ NH_3}{2\,mol\ glycine} \cdot \frac{32g\ O_2}{75g/mol\ glucine} \times \frac{200mg\ glycine}{1L} = 171\,mg/L$$

c) $ThBOD = CBOD + NBOD$

$$= 128\,mg/L + 171\,mg/L = 299\,mg/L$$

3) Consider three monitoring wells located as shown. The head in each well is noted next to the well (it is also listed in the table at the bottom of the picture. The aquifer has a porosity of 0.35 and a hydraulic conductivity of 900m/d.

a) Determine the magnitude and direction of the hydraulic gradient in this aquifer.
b) Determine the average linear velocity of the groundwater
c) If the front edge of a straight plume arrives simultaneously at wells 1 and 2, how long will it take the plume to arrive at well 3 if the retardation factor is 2?



Drawing not to scale, but x,y coordinates are for an equilateral triangle

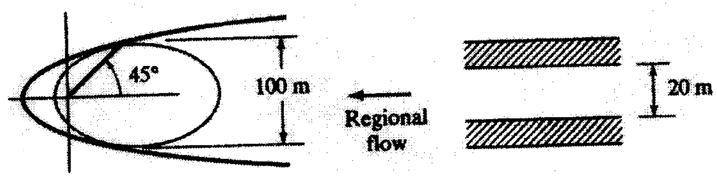
x (meters)	y (meters)	head (meters)
0	0	100.3
150	259.81	100.3
300	0	100

a) $\therefore \frac{\Delta h}{\Delta l} = \frac{0.3m}{260m} = 0.0011$

b) $v = \frac{K}{n}\frac{\Delta h}{\Delta l} = \frac{900m/d}{0.35}(0.0011) = 2.83m/d$

c) $x = vt = \frac{260}{2.83} = 91.8$ days ; $R = 2 \therefore$ $2(91.8) = \underline{183.7 \text{ days}}$

4) A single well is to be used to remove a symmetrical oblong plume of contaminated groundwater in an aquifer 20.0 m thick, porosity 0.35, hydraulic conductivity 1.0 x 10^{-4} m/sec, and hydraulic gradient 0.0020. With the plume and well oriented as shown, the angle from the well to the edge of the plume at the widest part of the plume is 45°. The plume is 100 meters wide at this point. What pumping rate is required to achieve these conditions?



$$y = \frac{Q}{2Bv}\left[1-\frac{\phi}{\pi}\right] = \frac{Q}{2Bv}\left[1-\frac{\pi/4}{\pi}\right] = \frac{3Q}{8Bv} = 50m$$

$$v = K\frac{\Delta h}{\Delta l} = 1 \cdot 10^{-4} * 0.0020 = 2 \cdot 10^{-7}$$

$$B = 20m$$

Solve for Q

$$Q = \frac{8Bvy}{3} = \frac{(8)(20)(1 \cdot 10^{-4} \cdot 0.0020)(50)}{3} = 0.00053\ m^3/sec$$

5) A sample of water has the following analysis:

Cations	mg/L	mg/L as $CaCO_3$	Anions	mg/L	mg/L as $CaCO_3$
Ca^{2+}	40.0	99.6	HCO_3^-	110.0	90.2
Mg^{2+}	10.0	41.1	SO_4^{2-}	67.2	69.88
Na^+	??.? 11.95mg/L	*25.93	Cl^-	11.0	15.51
K^+	7.0	8.96			

a) Express each concentration on an equivalent carbonate basis (eg. mg/L as $CaCO_3$)
b) Assuming no other constituents are missing, use an anion-cation balance to estimate the concentration of Na+.
c) What is the total hardness (TH)?
d) What is the carbonate hardness (CH)?
e) What is the noncarbonate hardness (NCH)?
f) Draw an ion concentration bar chart.

Σ Cations = 99.6 + 41.1 + ?? + 8.96 = 149.66 mg/L as $CaCO_3$

Σ Anions = 90.2 + 69.88 + 15.51 = 175.59 mg/L as $CaCO_3$

$Na^+ = 25.93$*

$$Na^+ = \frac{25.93}{2.17} = 11.95 \text{ mg/L}$$

$$\begin{array}{r} 140.7 \\ 90.2 \\ \hline 50.5 \end{array}$$

$TH = Ca^{2+} + Mg^{2+} = 99.6 + 41.1 = 140.7$ mg/L as $CaCO_3$

$CH = HCO_3^- = 90.2 = 90.2$ mg/L as $CaCO_3$

$NCH = TH - CH = 50.5$ mg/L as $CaCO_3$