ENV 4417: WATER QUALITY & TREATMENT

Fall 2015	University of South Florida
Problem set #5	Civil & Environmental Eng.
Due Thursday, Oct. 29	Prof. J. A. Cunningham

1. (10 pts) Municipal wastewater contains a relatively high concentration of BOD_5. The BOD_5 comes from both dissolved constituents and from suspended solids. A rule of thumb is that the BOD_5 concentration (in mg/L) exerted by suspended solids is equal to 60% of the suspended solids concentration (in mg/L). Consider a wastewater treatment plant that has the following properties:
   - The influent wastewater has a BOD_5 concentration of 200 mg/L and a suspended solids concentration of 240 mg/L, and
   - The primary sedimentation basins (primary clarifiers) remove 50% of the suspended solids.

   For this wastewater treatment plant, estimate/calculate the following:
   (a) the fraction of the BOD_5 associated with suspended solids in the influent water;
   (b) the concentration of BOD_5 (mg/L) exiting the primary clarifiers; and
   (c) the fraction of the BOD_5 associated with suspended solids in the water exiting the primary clarifiers.

2. (60 pts) *Based on a problem from Water and Wastewater Engineering: Design, Principles, and Practice, by Mackenzie L Davis*
   The flow rate entering a wastewater plant is time-varying. The influent concentration of BOD_5 is also time-varying. Consider a wastewater treatment plant that knows its influent flow rate and BOD_5 concentration are approximately the following.

time	flow rate (m^3/s)	BOD_5 (mg/L)	time	flow rate (m^3/s)	BOD_5 (mg/L)
12:00 AM	0.0875	110	12:00 PM	0.135	160
1:00 AM	0.0700	81	1:00 PM	0.129	150
2:00 AM	0.0525	53	2:00 PM	0.123	140
3:00 AM	0.0414	35	3:00 PM	0.111	135
4:00 AM	0.0334	32	4:00 PM	0.103	130
5:00 AM	0.0318	42	5:00 PM	0.104	120
6:00 AM	0.0382	66	6:00 PM	0.105	125
7:00 AM	0.0653	92	7:00 PM	0.116	150
8:00 AM	0.113	125	8:00 PM	0.127	200
9:00 AM	0.131	140	9:00 PM	0.128	215
10:00 AM	0.135	150	10:00 PM	0.121	170
11:00 AM	0.137	155	11:00 PM	0.110	130

problem 2 continues →

2. continued

(a) Plot the flow rate (m^3/s) versus time.

(b) Estimate/calculate the average flow rate, in units of m^3/s. Draw a dashed horizontal line on your graph corresponding to the average flow rate. Assume that the *effluent* flow rate from the tank is always equal to the average flow rate. Given this assumption, at what time of day is the water level in the tank at its lowest? At what time of day is the water level in the tank at its highest?

(c) Specify the volume of the equalization basin that you would design for this plant. Over-design the volume by 25% to account for days when unusually high flows occur. For brownie points, determine the volume two different ways, and compare the values.

(d) Estimate/calculate the average concentration of BOD_5 entering the plant. Perform the calculation as

$$BOD_5^{avg} = \frac{\sum Q(t)\, BOD_5(t)}{\sum Q(t)}$$

(e) Imagine that at midnight, the tank is 90% full, i.e., it contains a water volume equal to 90% of what you specified in part (c). The concentration of BOD_5 in the water in the tank is equal to the value that you found in part (d). Then, water flows in to the tank at the flow rate and concentration given in the table. Also, water flows out of the tank at the average flow rate (which you found in part (b)). Assume that the tank is well mixed, so that the concentration exiting the tank is equal to the concentration in the tank. For this scenario, calculate the concentration of BOD_5 in the tank as a function of time (i.e., at midnight, 1 AM, 2 AM, etc., up to 11 PM). Hint: From a material balance, we can derive

$$V(t)\frac{dC(t)}{dt} = Q_{in}(t)\left[C_{in}(t) - C_{out}(t)\right]$$

Then the trick is how to solve that differential equation numerically; use a Crank-Nicolson approach. Don't forget to track how the volume in the tank is changing with time, along with how the BOD_5 concentration is changing with time.

(f) Make a new graph that shows the BOD_5 concentration entering the tank and the BOD_5 concentration exiting the tank, both graphed versus time. Plot both curves (influent conc. and effluent conc.) on the same graph.

(g) Briefly discuss the effect that equalization has on the concentration of BOD_5 that goes to the rest of the treatment plant. Do you think this effect is desirable? Why or why not?

3. (30 pts) Answer problems 12.7, 12.14, and 12.23 in your text book (10 pts each).