MID-TERM EXAM

Closed book, 1 sheet of notes allowed.
Answer 2 of the following 3 questions. Please state any additional assumptions you made, and show all work.

I. (50%) The Cape Fear River receives runoff from dozens of hog farms in central North Carolina. Each results in a certain dischage of nitrate-nitrogen and contributes to the loading of the river. The effective drainage area of the hog farms that impacts the Cape Fear is 200,000 ha. Assume that prior to creation of the farms, when the drainage basin was 100% pristine piedmont, the nitrate-nitrogen level in the Cape Fear was constant at 0.20 mg/L. Now the level is substantially higher as shown in the table below.

a. Determine the total nitrate-nitrogen concentration for each day using the standard log-log model
b. Using this information, estimate the effective export coefficient for the hog farms during this 10-day period in units of kg-nitrate-N/ha/yr.
c. Comment on the role of rainfall on the nitrate-nitrogen export coefficient for this watershed. Will it increase, decrease or stay the same as rainfall increases? Explain your answer.

Day	Flow (m^3/s)	Nitrate-Nitrogen Concentration (mg/L)
1	30	
2	45	0.56
3	60	
4	65	
5	100	
6	180	1.45
7	350	
8	200	
9	150	
10	100	

There are several ways of solving this depending on how you interpret the "pristine concentrations of 0.20 mg/L. You could (1) view this as a baseflow value and subtract it from the two measured concentrations before solving, or (2) just subtract it from the final loading to isolate the farm runoff.

Part a.

20 points

First approach:

				Coefficients from 2 data					
				a	b		Model		
				-1.928166	0.89793		c=10^a(Q)^b		
			10^x	0.0117987			log(c) = a + b[log(Q)]		
		Gross		Net					
		Observed	Observed	Calculated					
Day	Q(cms)	(mg/L)	(mg/L)	(mg/L)	W(g/s)				
1	30			0.25	7.50		background	0.2	mg/L
2	45	0.56	0.36	0.36	16.20				
3	60			0.47	27.97				
4	65			0.50	32.55				
5	100			0.74	73.74				
6	180	1.45	1.25	1.25	225.00				
7	350			2.27	794.87				
8	200			1.37	274.81				
9	150			1.06	159.18				
10	100			0.74	73.74				
Sum					1685.56	g/s =	145632.7	kg/d	

Second Approach:

				Coefficients from 2 data				
				a	b		Model	
				-1.386374	0.686277		c=10^a(Q)^b	
			10^x	0.0410796			log(c) = a + b[log(Q)]	
		Gross		Net				
		Observed	Observed	Calculated				
Day	Q(cms)	(mg/L)	(mg/L)	(mg/L)	W(g/s)			
1	30			0.42	12.72			
2	45	0.56	0.56	0.56	25.20			
3	60			0.68	40.93			
4	65			0.72	46.85			
5	100			0.97	96.87			
6	180	1.45	1.45	1.45	261.00			
7	350			2.29	801.00			
8	200			1.56	311.75			
9	150			1.28	191.92			
10	100			0.97	96.87			
Sum					1885.10	g/s =	162872.5	kg/d

Part b.

20 points

First Approach:

Average load =		168.56	g/s =	14,563.27	kg/d =
				5319235	kg/yr
		total area	200000	ha	
				26.6	**kg/ha/yr**

Second Approach:

background	0.2	mg/L				
Gross Average Loading =			188.51	g/s =	16,287	kg/d =
					5948917	kg/yr
Background Loading =			25.60	g/s =	2212	kg/d =
					807875	kg/yr
Net Average Loading =					14075	kg/d =
					5141043	kg/yr
			total area	200000	ha	
					25.7	**kg/ha/yr**

Part c.

10 points

Certainly based on this analysis, nitrate-nitrogen export is positively correlated with rainfall. It seems likely that nitrate is associated with particulates (soil from application of fertilizers, plant matter) which is washed into streams at higher rates during wet events. This has the unfortuante affect of changing the export coefficient based on the particular level of rainfall. Over short periods where rainfall can be quite variable, this will add a substantial amount oferror. However, over longer time periods, average rainfall becomes more uniform and export coefficients may be more accurate.

Also, it seems likely that nitrate-N washout should be seassonally-dependent. None of the simple models really take this into account.

II. (50%) Estradiol (E2) has been observed to undergo degradation to Estrone (E1) in rivers at halflives ranging from 0.2 days to 9 days (Jurgens et al., 2002)[1]. Although both are powerful estrogenic compounds capable of profoundly affecting native fish, E2 is about 10 times as potent as E1.

A. Calculate the range of first order rate constants for the biodegradation of E2 to E1.

[1] Environmental Toxicology and Chemistry, Vol 21, No.3, pp.480-488.

B. Assuming the concentration of E2 in the Assabet River just downstream of the Marlborough WWTP outfall (mile point (MP) 32) is 25 ng/L, calculate the expected high and low concentration at the confluence with the Concord River (i.e., at MP 0). Other assumptions: (1) average stream velocity of 0.12 miles/hr, (2) no other point sources downstream of the Marlborough WWTP outfall, (3) the river flow increases by a factor of 2 between MP 32 and MP 0, and (4) this increase in flow comes from runoff that is free from E2.

C. Taking the worst case scenario (high estimate from "B"), determine the relative drop in estrogenicity in the Assabet River water from MP 32 to MP 0. Consider only E2 and E1 and assume E1 does not degrade.

D. Again taking the worst case scenario, determine relative drop in estrogenicity if E2 is also removed by attachment to particles that settle at 0.1 ft/hr. Assume only half of the E2 binds to these particles and assume that the average stream depth is 5 ft.

Part A (15%)

Background					
	distance =	32	miles		
	velocity =	0.12	mi/hr =	2.88	mi/day
	travel time =	267	hrs		
		Best	**Worst**		
	t1/2	**0.2**	**9**	**days**	
	k =	**3.47**	**0.0770**	**per day**	
		0.144	**0.00321**	**per hr**	

Part B (15%)

If:	Co =	25	ng/L	at MP32
M/Mo -	1.89E-17	0.4249698		at MP0
C/Co	9.44E-18	0.2124849		at MP0
C (E2) =	**2.36E-16**	**5.31**	**ng/L**	at MP0

Part C (10%)

E1 =		7.19	ng/L	at MP0
Est/Esto		24.1%		at MP0
Est drop		**75.9%**		at MP0

Part D (10%)

depth =		5	ft		
vs =		0.1	ft/hr		
ks =		0.01	per hr =	0.24	per day
fpar =		0.5			
koverall =		0.0082	per hr =	0.197	per day
M/Mo -		0.1120208			
C/Co		0.0560104			
C (E2) =		1.40	ng/L	at MP0	
E1 =		7.19	ng/L	at MP0	
Est/Esto		8.5%			
Est drop		**91.5%**			

III. (50%) On a separate sheet of paper, answer any five (5) of the following questions.

A. Calculate the % loss of CBOD as water moves 2 kilometers downstream in a river flowing at 0.01 m/s. Assume the CBOD deoxygenation rate is 0.12 d^{-1}, and the CBOD settling rate is 0.10 d^{-1}.

velocity =	0.01	m/s		
distance =	2000	m		
travel time =	200000	s =	2.315	days
kd =	0.12	d-1		
ks =	0.1	d-1		
kr =	0.22	d-1		
c/c0 =	60.1%	remaining		
1-c/co =	**39.9%**	**lost**		

B. Describe how you would determine ultimate BOD from a wastewater sample.

1. Take WW and dilute as needed
2. Add nitrification inhibitor, and possibly bacterial seed
3. Split into several bottles (usually 300 mL BOD bottles) filling each headspace-free, measure initial DO and seal
4. Conduct multi-day tests (say 1,3,5,8 days) and store at 20C in the dark
5. Measure DO at the end of each incubation time
6. Determined k_b and L_o (i.e., the ultimate BOD) from exponential model: $BOD_t=L_o(1-e^{-kbt})$

C. What is the concentration of dioxane in a lake 1 year after Acme Chemical Company (ACC) initiates operation on its shore. The lake has an area of 100,000 m^2, an average depth of 1 m, and an outflow of 1000 m^3/day. Dioxane decays at a 1^{st} order rate of 0.5 yr^{-1}, and assume ACC discharged 11 kg/yr to the lake on the day it opened and this discharge increased linearly to 14.65 kg/yr by the end of year 1. Assume there was no dioxane in the lake before ACC started operation.

Watch units on lambda, and be sure to use both step and linear solutions

Lake Data														
	Q =	1.00E+03	m3/day		Co =	0	mg/L		tau =	0.27	yr			
	A =	1.00E+05	m2						depth =	1.00E+00	m			
	V =	1.00E+05	m3		k =	0.0013689	/day =	0.5	"/yr					
Loading Information														
		11	kg/yr	at year	0									
		14.65	kg/yr	at year	1									
Loading Functions														
	Impulse		m =	0.00E+00	kg									
	Step		W=m/T=	11	kg/yr =	11000000	mg/yr							
	Linear		Wl			bl =	3.65	kg/y/y		14.65				
	Exponential		We=	0	kg/d =	0	g/yr							
			be=	0	/yr	0								
	Sinusoidal		W=	0	kg									
			Wa=	0	kg									
			Tp=	1	yr	Omega =	6.2831853	radians/yr						
			phase shift	0	yr	Theta =	0	radians	phi(om)=	0.986803				

Solution

$$\lambda = \frac{Q}{V} + k$$

lambda = 0.011369 /d = 4.1525 /yr

Initial: $$c_g = c_o e^{-\lambda t}$$

Step: $$c_p = \frac{\overline{W}}{\lambda V}(1 - e^{-\lambda t})$$

Linear: $$C_p = \frac{\beta_\ell}{\lambda^2 V}(e^{-\lambda t} + \lambda t - 1)$$

Exponential: $$c_p = \frac{W_e}{V(\lambda + \beta_e)}(e^{\beta_e t} - e^{-\lambda t})$$

	Concentration in ug/L							
years	Initial C	Impulse	Step	Linear	Exponen	Sinusoid	Total	
0	0	0	0	0	0	0	0	
1	0	0	26.08	6.72	0	0	**32.80**	

Loading (kg/yr)				
Step	Linear	Expon	Sinusoid	Total
11000	0.00E+00	0	0	11000
11000	3.66E+00	0	0	11004

D. Describe what happens when a wastewater with ammonia is discharged into a flowing river. Be specific on the chemical changes and microbial ecology.

Some things to discuss

- Nitrification occurrs
- Requires oxygen, sensitive to low levels
- Slow reaction, producing some nitrite and ultimately nitrate, nitrosomas, nitrobacter
- good to show a nitrogen vs time/distance profile; maybe a balanced chemical reaction showing oxygen consumption
- Growth of algae due to higher N
- Possible toxicity of ammonia (unionized) near outfall
- Progression of predatory species and grazers after nitrifierss

E. Is it common to add an inhibitor to the BOD test? Why or why not?

Yes it is commont to do this. Purpose: prevent nitrifications so that oxygen loss is only due to CBOD deoxygenation and not due to oxidation of nitrogen species

F. Does SOD cause an increase, a decrease or no change in CBOD? Explain.

Usually it causes no change. SOD normally consumes oxygen from the water column, and that's it.