CEE 577 24 March 2010

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%) Hubbard Creek receives runoff from more than a dozen wheat farms in a small area of central Nebraska. Each results in a certain dischage of organic nitrogen and contributes to the loading of Hubbard Creek. The effective drainage area of the wheat farms that impacts Hubbard Creek is 20,000 ha (mistakenly printed as 20 ha, so the solution below uses that number instead). Assume that prior to creation of the farms, when the drainage basin was 100% pristine prairie, the organic nitrogen level in Hubbard Creek was constant at 0.25 mg/L. Now the level is substantially higher as shown in the table below.

a. Determine the total organic nitrogen concentration for each day using the standard log-log model
b. Using this information, estimate the effective export coefficient for the wheat farms during this 10-day period in units of kg-organic N/ha/yr.
c. Comment on the relationship between the organic nitrogen export coefficient for this watershed and the amount of rainfall in a given year.

Day	Flow (m^3/s)	Organic Nitrogen Concentration (mg/L)
1	1.7	
2	1.8	1.9
3	2.9	
4	4.4	
5	7.6	
6	12.1	4.25
7	11.1	
8	8.3	
9	5.4	
10	3.3	

There are several ways of solving this depending on how you interpret the "pristine concentrations of 0.25 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		
				0.0988493	0.464737		c=10^a(Q)^b		
			10^x	1.2555942			log(c) = a + b[log(Q)]		
		Gross		Net					
Day	Q(cms)	Observed (mg/L)	Observed (mg/L)	Calculated (mg/L)	W(g/s)				
1	1.7			1.61	2.73		background	0.25	mg/L
2	1.8	1.9	1.65	1.65	2.97				
3	2.9			2.06	5.97				
4	4.4			2.50	11.00				
5	7.6			3.22	24.49				
6	12.1	4.25	4	4.00	48.40				
7	11.1			3.84	42.66				
8	8.3			3.36	27.86				
9	5.4			2.75	14.85				
10	3.3			2.19	7.22				
Sum					188.15	g/s =	16255.86	kg/d	

Second Approach:

				Coefficients from 2 data				
				a	b		Model	
				0.1708975	0.422513		c=10^a(Q)^b	
							log(c) = a + b[log(Q)]	
Day	Q(cms)	Observed (mg/L)	Calculated (mg/L)	W(g/s)				
1	1.7		1.85	3.15				
2	1.8	1.9	1.90	3.42				
3	2.9		2.32	6.74				
4	4.4		2.77	12.20				
5	7.6		3.49	26.54				
6	12.1	4.25	4.25	51.43				
7	11.1		4.10	45.49				
8	8.3		3.62	30.08				
9	5.4		3.02	16.32				
10	3.3		2.45	8.10				
Sum	58.60			203.46	g/s =	17579.01	kg/d	

Part b.

20 points

First Approach:

Average load =		18.81	g/s =		1,625.59	kg/d =
					593745.3	kg/yr
		total area	20	ha		
					29687	**kg/ha/yr**

Second Approach:

ackground	0.25	mg/L				
Gross Average Loading =			20.35	g/s =	1,758	kg/d =
					642073	kg/yr
Background Loading =			1.47	g/s =	127	kg/d =
					46232	kg/yr
Net Average Loading =					1631	kg/d =
					595841	kg/yr
			total area	20	ha	
					29792	**kg/ha/yr**

Part c.

10 points

Certainly based on this analysis, organic nitrogen export is positively correlated with rainfall. It seems likely that organic nitrogen 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 organic-N washout should be seassonally-dependent. None of the simple models really take this into account.

II. (50%) Pleasantville is a rapidly growing community in an exclusive area of California. Starting on January 1, 1988, half of the population of Pleasantville began taking 20 mg/day of the newly released drug, fluoxetine (trade name: Prozac). Studies have shown that 80% of ingested fluoxetine is excreted. Furthermore the removal efficiency of the Pleasantville wastewater treatment plant (serving the entire population of Pleasantville) for fluoxetine is only 60% prior to discharge into nearby Tranquil Lake. This lake as a total volume of 9×10^6 m^3 and an outflow of 8000 m^3/d. Fluoxetine decays in the lake at a rate of 0.10 yr^{-1} due to direct photolysis. No other losses are known.

Pleasantville, CA

Year	Population on Jan 1
1988	300,000
1993	350,000
1998	400,000
2003	450,000
2008	500,000

A. Calculate the expected fluoxetine concentration at the beginning of the year 2008.
B. If a new WWTP capable of completely removing fluoxetine is placed on line at the beginning of 2008, when will the lake fluoxetine level finally drop below 2.0 µg/L?

Part A.

30 points

Note that this includes both a step load and a linear load:

Lake Model					t zero =	1/1/1988			
Lake Data									
Q =	8.00E+03	m3/day	Co =	0	mg/L		tau =	3.08	yr
A =	3.00E+06	m2					depth =	3.00E+00	m
V =	9.00E+06	m3	k =	0.0002738	/day =	0.1	"/yr		

Loading Information							
300000	people	10	mg/d/cap	80%	excreted	40%	discharged
10000	people/yr						

Loading Functions									
Impulse	m =	0.00E+00	kg						
Step	W=m/T=	350.64	kg/yr =	350640000	mg/yr				
Linear	Wl			bl =		11.688	kg/y/y		
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	0.25	yr	Theta =	1.5707963	radians	phi(om)=	1.50331116	

Solution

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

lambda =	0.001163	/d	=	0.4246667	/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							Loading (kg/yr)		
Date	years	Initial C	Impulse	Step	Linear	Exponen	Sinusoid	Total	Step	Linear	Expon
1/1/1988	0	0	0	0	0	0	0	0	350640	0.00E+00	0
1/1/1998	10	0	0	90.43	23.49	0	0	114	350640	1.17E+02	0
1/1/2008	20	0	0	91.72	53.96	0	0	**146**	350640	2.34E+02	0

Part B.

20 points

Note that this is a simple decay without any loading. The lambda is the same as above.

Years	Target Conc					
30.098	2				Dates	
		years	days		starting	ending
		30	35.81		1/1/1988	**2/5/2018**

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

A. Calculate the % loss of CBOD as the water moves 1 km downstream in a river flowing at 0.01 m/s. Assume the CBOD deoxygenation rate is 0.15 d^{-1}, and the CBOD settling rate is 0.11 d^{-1}.
B. Explain how you determined ultimate BOD from a wastewater sample.
C. Describe how the algal metabolism parameters, P and R, can be determined experimentally in a lake
D. Explain the relationship between the critical concentration and wastewater loading in a river with only a single point load
E. Is it common to add an inhibitor to the BOD test? Why or why not?
F. Describe the relationship between drainage basin area and flow
G. Does SOD cause an increase, a decrease or no change in CBOD? Explain.

Most of the answers shown below are not complete; instead they make reference to sources of the correct information.

Part A.

10 points

Simple stream BOD model

	0.01	m/s			
	1000	m			
	travel time =	100000	s =	1.157407	days
	kd =	0.15	d-1		
	ks =	0.11	d-1		
	kr =	0.26	d-1		
	c/c0 =	74.0%	remaining		
	1-c/co =	**26.0%**	**lost**		

Part B.

10 points

Measure BOD at various incubation times (oxygen consumption in a BOD bottle). Fit the BOD vs time data to the exponential BOD bottle model and determine the asymptotic value (Lo or BOD ultimate). See notes from class or website for more detail.

Part C.

10 points

Use the light and dark bottle method. See notes/web for description.

Part D.

10 points

It's a simple linear relationship between loading and the critical deficit. As loading decreases, so does the critical deficit. The critical concentration is therefore also linearly related.

Part E.

10 points

An inhibitor is used to stop nitrification. The BOD test is intended to measure carbonaceous BOD only.

Part F.

10 points

Based on the simple rational formula, flow and basin area are linearly related. In reality, the relationship is more complicated due to infiltraiton, evapotranspiration, etc. The makes the relationship more and more non-linear as basin size increases.

Part G.

10 points

The sediment oxygen demand should have no effect on dissolved carbonaceous BOD in the water column.