

Name \_\_\_\_\_

**CE4505 Surface Water Quality Engineering  
Fall 2009  
Midterm 1b**

A list of equations is given on the final page of the exam.

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1. The National Oceanic and Atmospheric Administration (NOAA) estimates that 20,000 tons of trash end up in the Anacostia River in Maryland every year. This is largely nonpoint-source pollution. Environmental groups are petitioning the Maryland Dept. of the Environment to list the river and its tributaries as “impaired”. Such a classification would then require the state to develop a plan for clean-up of the river under what law? (4 pts)

Clean Water Act

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2. Agricultural activities in California’s Central Valley continue to withdraw increasing amounts of water from the upper San Francisco Bay and the Sacramento-San Joaquin Delta for irrigation. This water loss has driven the delta smelt close to extinction. Conservation groups are petitioning the Fish and Wildlife Service to list the species as endangered. Protecting the smelt would benefit 22 million people who use the waterway for drinking water as well as fishermen and local communities whose livelihood is based on the delta. What law would provide the basis for protecting the delta smelt? (4 pts)

Endangered Species Act

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3. In 2002 the Army Corps of Engineers and the Fish and Wildlife Service issued permits to 10 mining companies to allow them to mine for limestone in the eastern Everglades. The mine pits would have drained water from the everglades, contaminated drinking water supplies, and undermined the huge Everglades Restoration project. As a result of a lawsuit, a federal district court blocked the permits because the agencies violated federal law by ignoring threats posed by the mines to the environment. What federal law requires that environmental threats by federally financed projects be enumerated and alternative actions evaluated? (4 pts)

NEPA – National Environmental Policy Act

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4. We often use conservative substances to verify the accuracy of a hydrologic budget. A) If the small pond described in the table below is at steady state and if there are no other sources or sinks for chloride other than those listed, is the hydrologic budget correct? (Assume that the reported chloride concentrations are correct.) Show your work or your reasoning. (4 pts)

Budget component	Flow (m <sup>3</sup> /yr)	Chloride conc. (g/m <sup>3</sup> )
Precipitation	1000	0.1
Streamflow	10,000	5.0
Lake outflow	10,200	4.0

**SOLUTION:**

Mass balance: Change in mass/time = Inputs – Outputs – Reaction

@ steady state: Inputs = Outputs (Reactions are zero for conservative substances)

PCA + Q<sub>in</sub>C<sub>in</sub> = Q<sub>out</sub>C<sub>out</sub>

Precipitation + Streamflow = Outflow

$$Q_{pptn} C_{pptn} + Q_{stream} C_{stream} = Q_{out} C_{out}$$

$$\left(1000 \frac{m^3}{yr}\right) 0.1 \frac{g}{m^3} + \left(10000 \frac{m^3}{yr}\right) \left(5.0 \frac{g}{m^3}\right) = \left(10200 \frac{m^3}{yr}\right) \left(4.0 \frac{g}{m^3}\right)$$

$$100 \frac{g}{yr} + 50000 \frac{g}{yr} = 40800 \frac{g}{yr}$$

$$50100 \frac{g}{yr} \neq 40800 \frac{g}{yr}$$

The hydrologic budget cannot be correct because inputs do not equal outputs.

B) What are three potential errors in the hydrologic budget that could explain the discrepancy in the chloride budget? (6 pts)

- Underestimation of outflow
- Failure to include groundwater outflows
- Overestimation of streamflow

5. The eigenvalue for a substance in a lake is determined to be 4 yr<sup>-1</sup>. The hydraulic retention time of the lake is 4 years, the mean depth of the lake is 8 m, the surface area is 40,000 m<sup>2</sup>, and the settling rate for the substance from the lake is 24 m/yr. There is also a first-order decomposition reaction for this substance; what is the rate constant for this decomposition reaction? (8 pts)

$$\lambda = \sum k_i = k_{flushing} + k_{settling} + k_{decomposition}$$

$$k_{decomposition} = \lambda - k_{flushing} - k_{settling}$$

**SOLUTION:**

$$k_{decomposition} = 4 yr^{-1} - \frac{1}{4 yr} - \frac{24 m}{yr} \cdot \frac{1}{8 m}$$

$$k_{decomposition} = 0.75 yr^{-1}$$

6. List three symptoms of eutrophication. (2 pts each)

1. Bad taste, bad odors
2. High chlorophyll, high turbidity, algal scums, algal mats
3. Low dissolved oxygen, decline in cold-water fish, increase in rough fish

True/False – 2 pts each

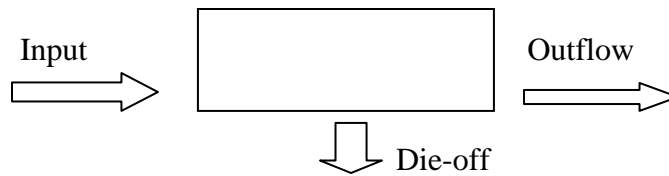
7. Periphyton are bacteria that infect plants. (True or **False**) (circle one)
8. Mixotrophic organisms are benthic macroinvertebrates that cause mixing of lake sediments. (True or **False**) (circle one)
9. Paleolimnology refers to the prediction of future conditions in lakes. (True or **False**)
10. Varves are the pupae for midge larvae in sediments. (True or **False**) (circle one)
11. Healthy lake sediments may contain up to several thousand benthic macroinvertebrates per square meter. (**True** or False) (circle one)
12. Long food webs are more prevalent under oligotrophic conditions. (**True** or False)

Multiple choice (2 pts each) – Circle all correct answers

13. The movement of fine sediment from the lake edge to the deep areas of the lake is called:
  - a. Centering
  - b. Resuspension
  - c. **Focusing**
  - d. Sedimentation
  - e. None of the above
14. A lake that is permanently stratified might be called:
  - a. **Amictic**
  - b. **Meromictic**
  - c. Polymictic
  - d. Monomictic
  - e. None of the above
15. Typical rates of sediment accumulation in a lake are:
  - f. 10-300 meters per year
  - g. 1-30 meters per year
  - h. 100-3000 cm per year
  - i. 10-300 cm per year
  - j. **0.1-3 cm per year**
  - k. 0.001-0.03 cm per year

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16. One contaminant in urban run-off is coliform bacteria derived from pets and wild animals. Sewer overflows, either combined (CSO) or sanitary (SSO), can greatly exacerbate the problem. Typical concentrations in runoff are  $3 \times 10^6$  (bacteria)  $L^{-1}$  ( $0.3 \times 10^6$  per 100 mL) compared to water quality criteria of 1300-3000  $L^{-1}$ . Storm water treatment is now required for all municipalities with populations above 25,000 as well as for some smaller communities. Where land is sufficient, detention ponds are a common method of storm water treatment. The only processes that affect bacterial abundance in detention ponds are inputs, bacterial die-off (a first-order process), and outflow.
- a. Draw a schematic of a detention showing all of the processes that would affect coliform bacteria in the pond. (8 pts)



- b. Write the mass balance equation for coliform bacteria in a detention pond. You may assume that the volume of the pond will remain constant. (8 pts)

$$V \frac{dC}{dt} = Q_{in} C_{in} - QC - k_{die-off} CV$$

- d. The allowable bacterial concentration in the stream is 300 per 100 mL in any single sample; the dilution factor for the pond water mixing with the stream is 12.8. What is the maximum concentration that should exist in the pond in order to meet the stream water quality criterion? (4 pts)

**SOLUTION:** The concentration in the pond must be below:

$$\frac{300}{100mL} \cdot \frac{10^3 mL}{L} \cdot 12.8 = 38,400 L^{-1}$$

- e. The pond receives drainage from 1  $km^2$  of a residential area; the annual water inflow is  $5.0 \times 10^5$  cubic meters. Assume a constant concentration of  $3 \times 10^6 L^{-1}$  in the runoff. The rate constant for die-off is  $0.84 d^{-1}$ . What volume of pond would be required to maintain coliform bacteria concentrations below the limit you calculated in part d? (10 pts)

$$C = \frac{W}{Q + kV}$$

**SOLUTION:** At Steady state  $V = \frac{W - CQ}{Ck} = \frac{5 \times 10^5 \frac{m^3}{yr} \cdot 3 \times 10^3 \frac{bac}{m^3} - 38.4 \frac{bac}{m^3} \cdot 5 \times 10^5 \frac{m^3}{yr}}{38.4 \frac{bac}{m^3} \cdot \frac{0.84}{d} \cdot \frac{365d}{yr}}$

$$V = 125,775 m^3$$

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f. What would be the hydraulic residence time of your pond? (4 pts)

**SOLUTION:**  $\tau = \frac{V}{Q} = \frac{125775m^3}{5 \times 10^5 \frac{m^3}{yr}} = 0.25 yr$

g. What would be the coliform residence time in the pond? (5 pts)

**SOLUTION:**  $\tau = \frac{V}{Q + kV} = \frac{125775m^3}{5 \times 10^5 \frac{m^3}{yr} + 0.84 \frac{1}{d} \cdot 365 \frac{d}{yr} \cdot 125775m^3} = 0.003 yr = 1.2d$

h. What would be the transfer coefficient for coliform bacteria in this pond? (4 pts)

**SOLUTION:**  $\beta = \frac{C}{C_{in}} = \frac{38.4}{3 \times 10^3} = 0.0128$

i. List four considerations that would influence the choice of surface area and pond depth. (4 pts)

- ANSWER:**
1. Cost of land
  2. Depth to water table
  3. Topography
  4. Variability in flow

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## EQUATIONS

$$a = Q + kV + vA = W/C$$

$$\beta = \frac{C}{C_{in}} = \frac{Q}{a} = \frac{Q}{Q + kV + vA}$$

$$rate = V_m \frac{C}{C + K_m}$$

$$\tau = \frac{total \cdot mass \cdot in \cdot system}{total \cdot flux \cdot through \cdot system} = \frac{1}{\lambda} = \frac{V}{a}$$

$$\lambda = \frac{Q}{V} + k + \frac{v_s}{H} = \frac{a}{V}$$

$$\frac{k_1}{k_2} = \Theta^{T_2 - T_1}$$

$$Q_{10} = \theta^{10} = \frac{k_{T+10}}{k_T}$$

$$f_{part.} = \frac{K_D \cdot C_{SS}}{1 + K_D \cdot C_{SS}}$$

$$rate = k(C - C^*)$$

$$C_0 - C = kt$$

$$k = A \exp\left(\frac{-E_A}{RT}\right)$$