1.020 Ecology II: Engineering for Sustainability
Spring 2008

Lectures 08_1 & 08_2 Outline: Introduction, Mass Balance, Everglades

Introduction: See course information sheet

Motivation/Objective:
Develop a model to compute time-varying phosphorous concentrations in a stormwater detention pond. Examine effect of pond size.

Approach:
1. Define system, control volume (CV), system properties, identify unknown (dissolved pond phosphorous concentration C_t at time t)
2. Write mass balance equation (incremental, over a specified time interval)
3. Relate boundary and gain/loss terms in mass balance equation to unknown C_t.
4. Specify all inputs, solve mass balance equation for unknown (MATLAB)
5. Use model to evaluate how different pond characteristics affect phosphorous concentration.

Concepts and Definitions:
Definitions: system, surroundings, control volume
Distinguish isolated, closed, open systems
Thermodynamic systems are described by bulk system properties, processes
Distinguish mass inflows/outflows across CV boundary from internal gains/losses.
Mass Conservation:

Incremental form: $\Delta M_{cv} = \Delta M_{in} - \Delta M_{out} + \Delta M_{gain} - \Delta M_{loss}$ over $[t, t+1]$

Instantaneous (or rate) form: $\frac{dM_{cv}}{dt} = \dot{m}_{in} - \dot{m}_{out} + \dot{m}_{gain} - \dot{m}_{loss}$

Steady-state: $\Delta M_{cv} = \frac{dM_{cv}}{dt} = 0$

Distinguish conservative vs non-conservative system properties.
Relationship between mass and concentration: $M_{cv} = V_{cv} C_{cv}$

For Everglades example (open system):

$$\Delta M_{cv} = VC_{t+1} - VC_t, \quad \Delta M_{in} = q_{in} C_{in,t} \Delta t, \quad \Delta M_{out} = qC_t \Delta t, \quad \Delta M_{loss} = \alpha C \Delta t, \quad \Delta M_{gain} = 0$$

q = flow rate ($m^3\ hr^{-1}$) (inflow = outflow), C_{in} = phopsohorous concentration in inflow

Final Mass Balance Equation (expressed in terms of the unknown concentration C_t):

$$C_{t+1} = C_{in,t} \frac{\Delta t}{\tau} + [1 - \frac{\Delta t}{\tau} - \alpha \Delta t] C_t \;,\; \tau = \frac{V}{q}$$ = residence time , Δt = interval (hrs) between t and $t+1$

Model Results
Note impact of pond volume and plant uptake rate on magnitude and variability of pond phosphorous concentrations.