Updated: 6 November 2017

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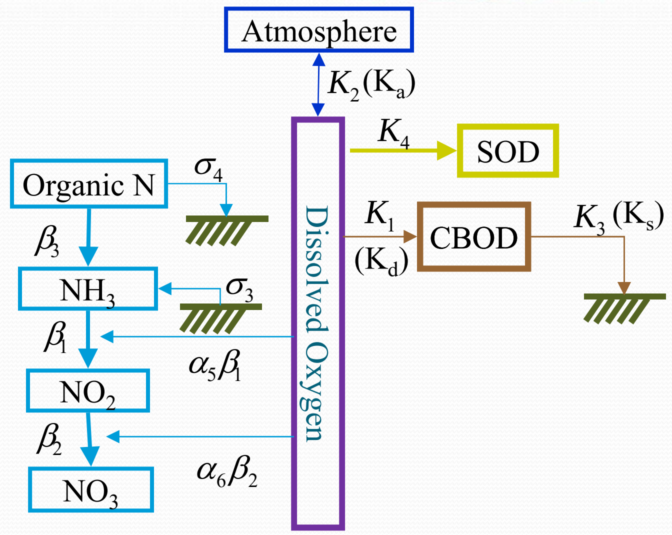
CEE 577: Surface Water Quality Modeling

Lecture #20

Streeter-Phelps: Photosynthesis/Respiration

(Chapra, L24)

General Model Kinetics



Modeling procedures

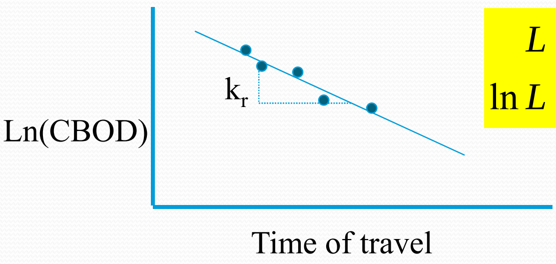
- Verify model calculations
  - using a simplified example, check computer vs. analytical
- Identify inputs (loads, rate coefficients, transport)
  - reaction coefficients - general
    - all rate constants must be uniform in space and time unless variations are linked to system characteristics
    - rates and formulations should fall within the range reported in the literature (e.g., `Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling`, `Bowie et al., US EPA, Athens Environmental Research Laboratory, EPA/600/3-85/040, June 1985., see: http://www.epa.gov/ORD/WebPubs/surfaceH2O/surface.html) or course website`

Identifying inputs (cont.)

- k_d, k_r
  - simplified method:
  - in-stream assessment

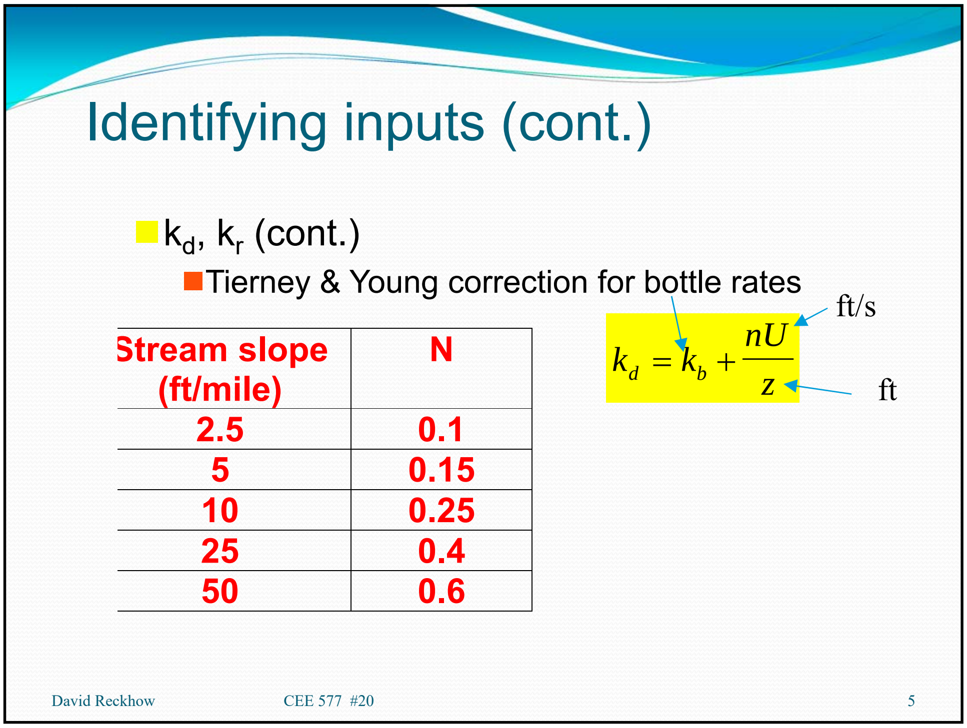
$$k_d = 0.3\left(\frac{H}{8}\right)^{-0.434} \text{ d}^{-1}\text{; for H < 8 ft}$$

$$k_d = 0.3 \text{ d}^{-1} \quad \text{for H > 8 ft}$$



$$L = L_o e^{-k_r t}$$

$$\ln L = \ln L_o - k_r t$$



Identifying inputs (cont.)

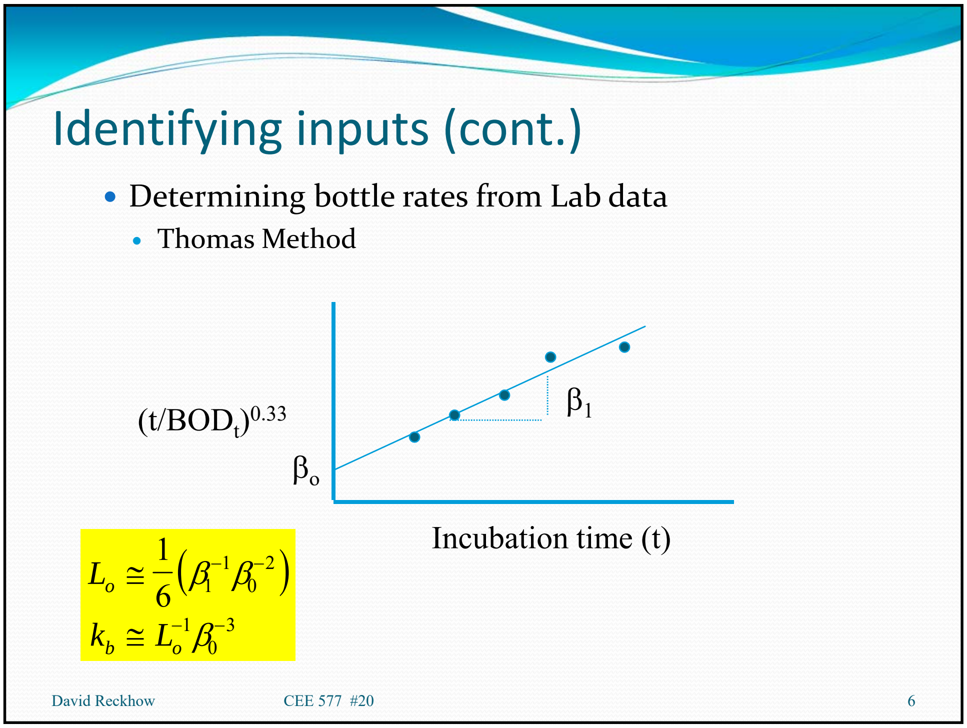
- k_d, k_r (cont.)
  - Tierney & Young correction for bottle rates

Stream slope (ft/mile)	N
2.5	0.1
5	0.15
10	0.25
25	0.4
50	0.6

$$k_d = k_b + \frac{nU}{z}$$

ft/s

ft



Identifying inputs (cont.)

- Determining bottle rates from Lab data
  - Thomas Method

$$L_o \cong \frac{1}{6}\left(\beta_1^{-1}\beta_0^{-2}\right)$$

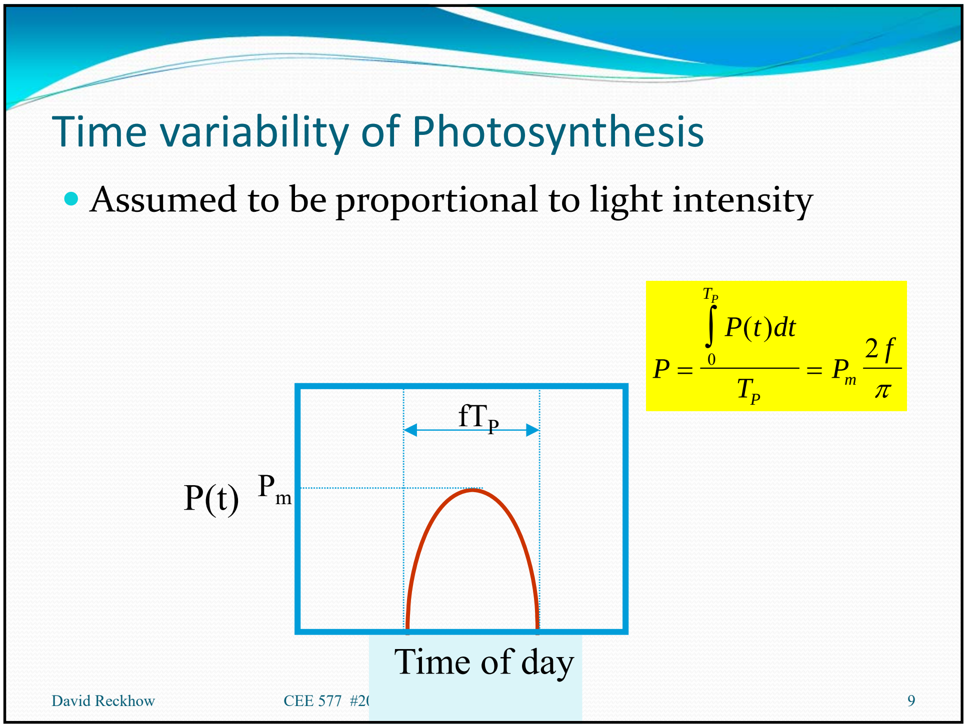
$$k_b \cong L_o^{-1}\beta_0^{-3}$$

Identifying inputs (cont.)

- Photosynthesis/Respiration (Chapra L24)
  - chemistry $6CO_2 + 6H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$
  - two important issues
    - long term effect: net of P & R
    - short term effect: extent of DO drop during night
- Three common methods
  - Light and Dark bottle method
    - expose aquatic biota to natural light conditions, with "control" in the dark
  - Estimation from Observed Chlorophyll levels
  - Measurement of Diurnal DO Range

Additional notes on WLA (cont.)

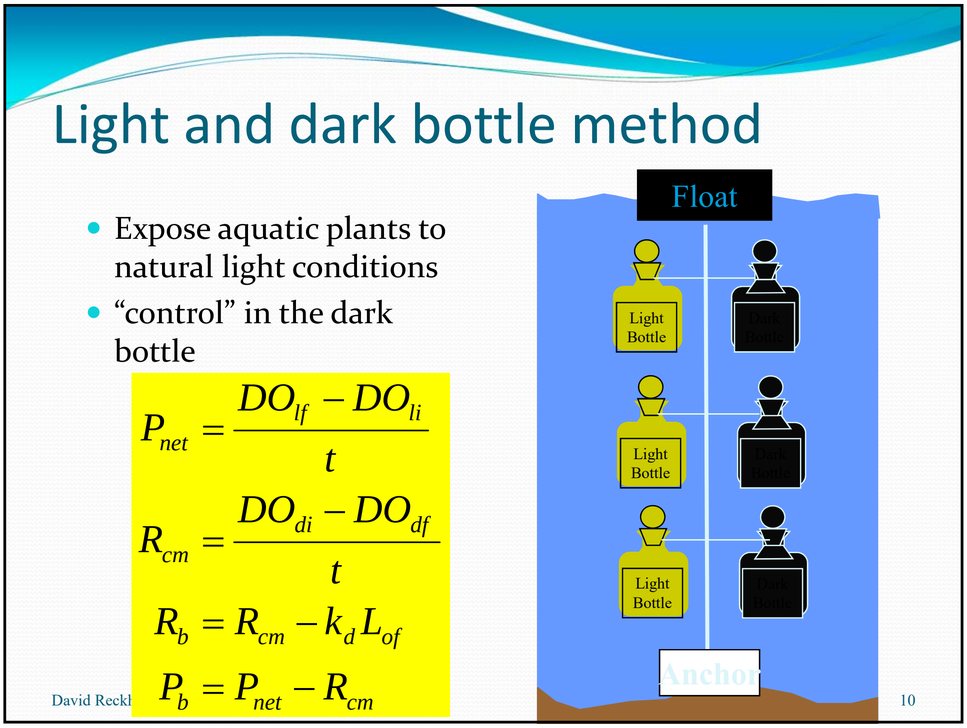
- Algal modeling
  - Level I
    - measure P-R: diurnal swings in D.O.
  - Level II
    - measure chlorophyll a, light, light extinction, nutrients "in-situ"
    - calculate P-R
  - Level III
    - assess nutrient loadings, light extinction
    - model nutrient conc., chlorophyll a, P-R



Time variability of Photosynthesis

- Assumed to be proportional to light intensity

$$P = \frac{\int_0^{T_P} P(t)dt}{T_P} = P_m \frac{2f}{\pi}$$



Light and dark bottle method

- Expose aquatic plants to natural light conditions
- "control" in the dark bottle

$$P_{net} = \frac{DO_{lf} - DO_{li}}{t}$$

$$R_{cm} = \frac{DO_{di} - DO_{df}}{t}$$

$$R_b = R_{cm} - k_d L_{of}$$

$$P_b = P_{net} - R_{cm}$$

Estimation from observed chlorophyll levels

- Under conditions where algal metabolism is not limited

Light attenuation factor

$$P = \overbrace{r_{oa} G_{\max} 1.066^{T-20} a}^{P_s} \phi_l \approx 0.25a$$

Oxygen generated per unit biomass produced (0.1-0.3 mg-O_2/µg-chla)

Maximum plant growth rate for optimal conditions (1.5-3.0 d^{-1})

Concentration of plant biomass (µg-chla/L)

P-R method

- Respiration is from rates and stoichiometry
  - Need chlorophyll level

$$R = r_{oa} k_{ra} 1.08^{T-20} a$$
$$\approx 0.025a$$

Plant respiration rate (0.05-0.25 d^{-1})

- To next lecture