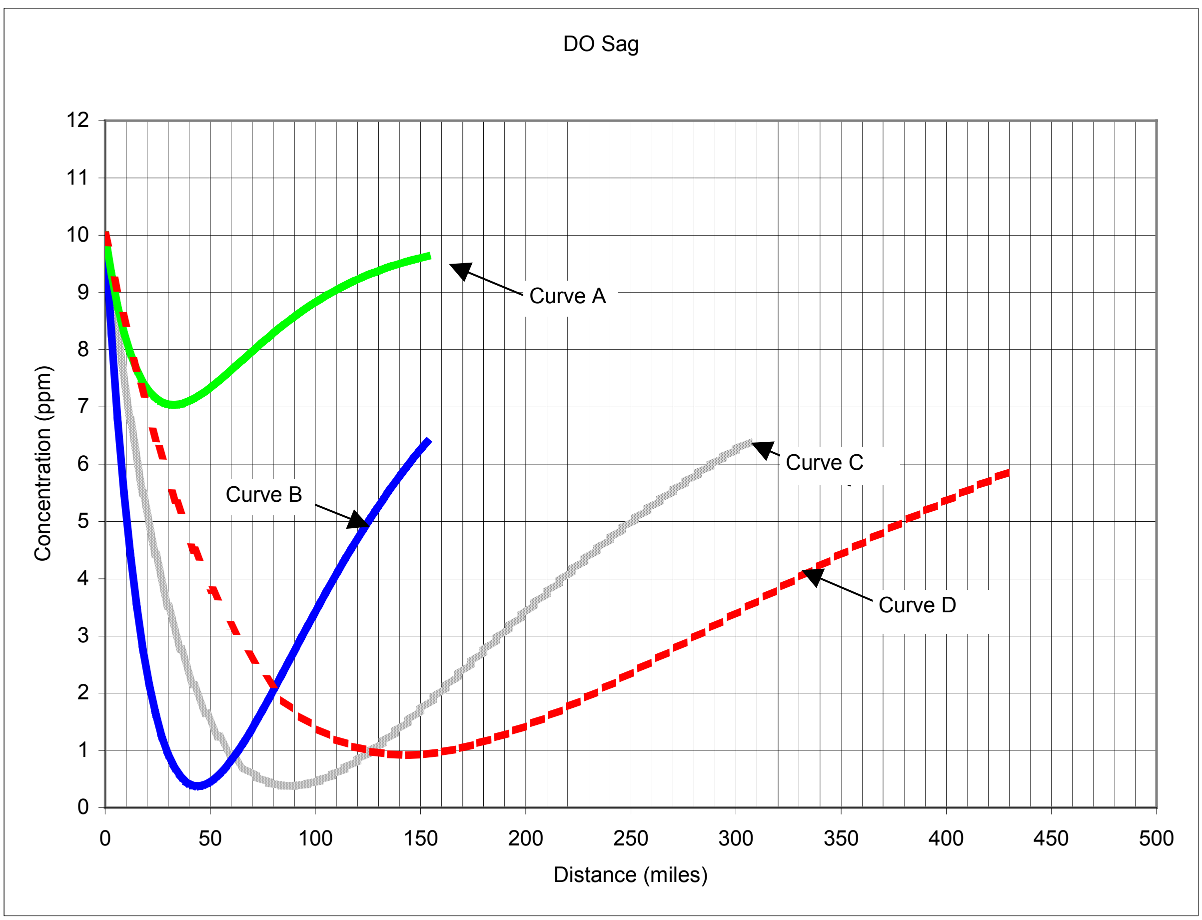
FEX-001

The ultimate BOD of a river just below a sewage outfall is 50 mg/L and the DO is at the saturation value of 10.0 mg/L. The deoxygenation coefficient k_d is 0.30/day and the reaeration coefficient k_r is 0.90/day. The river is flowing at the speed of 48.0 miles per day. The only source of BOD is the single outfall.

This information was used to produce the following dissolved oxygen sag curves, one of which is correct for this case. Select the correct and determine:

a) Select the correct dissolved oxygen profile for the situation described
b) Determine the critical distance downstream at which DO is a minimum. (Show calculations)
c) Determine the minimum DO (Show calculations)
d) If a wastewater treatment plant is to be built, what fraction of the BOD would have to be removed from the sewage to assure a minimum of 5.0 mg/L everywhere downstream?



FEX-002

Suppose some pond water contains 10.0 mg/L of some algae, which can be represented by the chemical formula $C_6H_{15}O_6N$. Use the following reactions:

$$C_6H_{15}O_6N + 6O_2 \Rightarrow 6CO_2 + 6H_2O + NH_3$$

$$NH_3 + 2O_2 \Rightarrow NO_3^- + H^+ + H_2O$$

e) Find the theoretical carbonaceous oxygen demand.
f) Find the total theoretical (carbonaceous and nitrogeneous) oxygen demand.

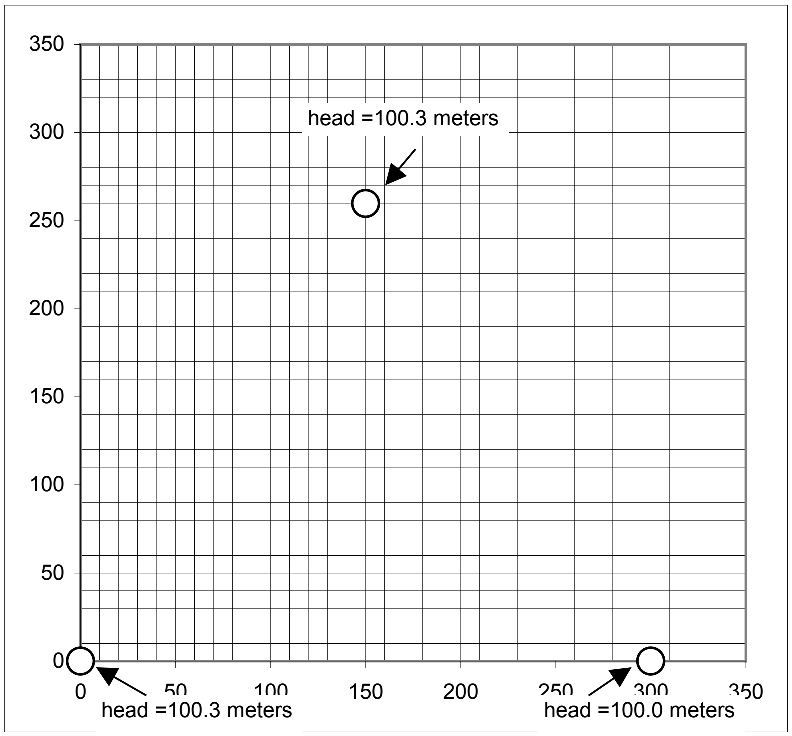
FEX-003

A mixture consisting of 30 mL of waste and 270 mL of seeded dilution water has an initial DO of 8.55 mg/L; after five days, it has final DO of 2.40 mg/L. Another bottle containing just the seeded dilution water has an initial DO of 8.75 mg/L and a final DO of 8.53 mg/L. Find the five day BOD of the waste.

FEX-004

Consider three monitoring wells located as shown. The head in each well is noted next to the well (it is also listed in the table at the bottom of the picture. The aquifer has a porosity of 0.23 and a hydraulic conductivity of 1000m/d.

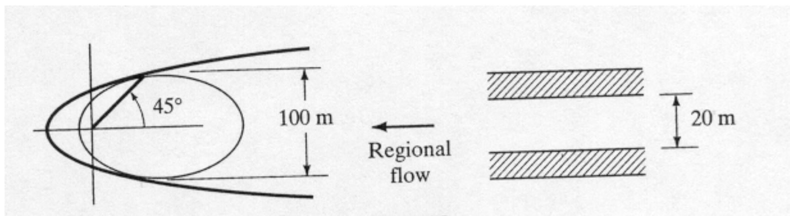
a) Determine the magnitude and direction of the hydraulic gradient in this aquifer.
b) Determine the average linear velocity of the groundwater
c) If the front edge of a straight plume arrives simultaneously at wells 1 and 2, how long will it take the plume to arrive at well 3 if the retardation factor is 2?



x (meters)	y (meters)	head (meters)
0	0	100.3
150	259.81	100.3
300	0	100

FEX-005

A single well is to be used to remove a symmetrical oblong plume of contaminated groundwater in an aquifer 20.0 m thick, porosity 0.30, hydraulic conductivity 1.0 x 10^{-4} m/sec, and hydraulic gradient 0.0015. With the plume and well oriented as shown, the angle from the well to the edge of the plume at the widest part of the plume is 45^{o}. The plume is 100 meters wide at this point. What pumping rate is required to achieve these conditions?



FEX-006

A confined aquifer 30.0 m thick has been pumped from a fully penetrating well at a steady rate of 5000 m^3/day for a long time. Drawdown at an observation well 15 m away from the pumped well is 3.0m and drawdown at a second observation well 150m away is 0.30 m.

a. Find the hydraulic conductivity of the aquifer.
b. Find the travel time for groundwater to travel from the observation well 15 meters away to the pumped well with diameter 0.40 m. The porosity is 0.30.

Sketch the aquifer system!
The equation for travel time is:

$$t = \pi \frac{Bn}{Q}(R^2 - r_w^2) \quad \text{(see p. 262; problem 5.47)}$$

FEX-007

The process of nutrient enrichment of a water body, with attendant increases in organic matter is called eutrophication. Eutrophication can be modeled using a generic "algae" to represent the organic matter that increases in a water body. One representation of the chemical structure of algae is $C_{388}H_{567}O_{277}N_{23}S_{1}P_{1}$.

a. Determine the mass in milligrams of each element in one gram of algae.
b. Suppose there are 0.10 mg of N, 0.05 mg of S, and 0.04 mg of P entering the water body per liter per day. Furthermore assume there are 30 mg of C, 10 mg O_2 per liter per day entering the water (assume there is always enough H). What mass of algae per liter per day could be expected to grow in this system?
c. Which component is the limiting nutrient?
d. If the nitrogen source is reduced 50% how much algae will grow?
e. If the phosphorous source is cut by 50% how much algae will grow?
f. If the sulfur source is cut by 50% how much algae will grow?

FEX-008

For each of the cases below, assuming all other things unchanged, describe the effect of the following parameter variations on the magnitude of the maximum oxygen deficit in a river. Answers should state whether the deficit will increase, decrease, or stay the same, and should provide a brief explanation for the response. The last case has an example of the level of detail expected in your answer.

Parameter	Magnitude of Deficit
Increased initial deficit	
Increased ultimate CBOD @ x = 0	
Increased deoxygenation rate	
Increased reaeration rate	
Increased ThOD @ x = 0	The effect of an increased ThOD at x = 0 depends on the degradability of the material. If the material is chemically and/or biologically degradable, it will increase the ultimate BOD and thus the maximum deficit. However if the material is not degradable no change in deficit will occur.

Problem FEX-009

A sample of water has the following concentration of ions:

Cations	mg/L	Anions	mg/L
Ca^{2+}	40.0	HCO_3^-	110.0
Mg^{2+}	10.0	SO_4^{2-}	67.2
Na^+	?	Cl^-	11.0
K^+	7.0		

a) Assuming all constituients are present, use an anion-cation balance to estimate the concentration of Na^+.
b) What is the total hardness (TH)?
c) What is the carbonate hardness (CH)?
d) What is the noncarbonate hardness (NCH)?
e) Draw an ion concentration diagram.

(Hint: Express concentrations in mg/L as $CaCO_3$)

Problem FEX-010

A three-reactor wastewater treatment system in Figure1 has an inflow rate of 1.0 MGD and an incoming BOD of 100.0 mg/L. The decay rate constant of the BOD is 0.30/day. The volume of all reservoirs is 4 million gallons. 0.5 MGD from the third reservoir is recycled into the first reservoir.

a) Write a mass balance equation for each reservoir (the system is steady state)
b) Determine the BOD in each reservoir of the reactor system. (Hint: 3 equations, 3 unknowns, solve simultaneously)
c) Repeat your calculations for a recycle rate of 0 MGD (no recycle).

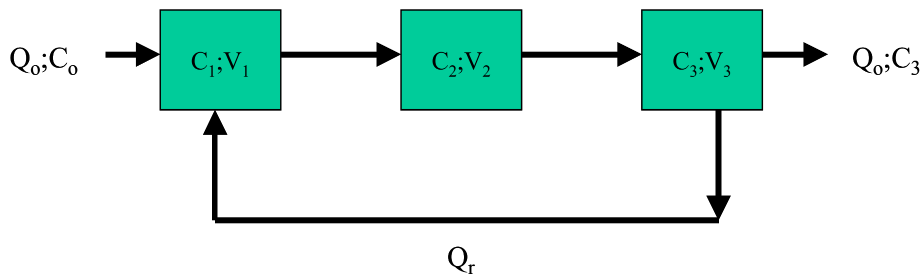


Figure 1. Schematic of Three-Reservoir Reactor.

Problem FEX-011

Consider a box model for an air shed over a city 1×10^5 m on a side and a mixing depth of 1200 m. Winds with $SO_2 = 0$ kg/m^3 blow on the west side of the box at 4 m/s. SO_2 is generated within the box (assume complete mixing) at a rate of 20 kg/s. Assume SO_2 is conservative.

a. Sketch the box model.
b. Write the mass balance equation for SO_2 in the airshed.
c. Estimate the steady state SO_2 concentration in the air shed.
d. Assume the air shed is initially free of SO_2, estimate the SO_2 concentration after 5 days of emissions (Non-steady solution).
e. Assume that emissions stop after five days and stay zero for two days. What will the air shed SO_2 concentration be at the end of this 7 day period? (Non-steady solution).

Problem FEX-012

Suppose the following temperature profile is collected.

Altitude (m)	Temp (^oC)
0	20
100	18
200	16
300	15
400	16
500	17
600	18

a. What would the mixing depth be?
b. How high would you expect a plume to rise if it is emitted at 21^oC from a 80-m stack if it rises at the dry adiabatic lapse rate?
c. Would you expect the plume to be looping, coning, fanning, or fumigating?

Problem FEX-013

The world's population 10,000 years ago was about 5 million.

a. What exponential rate of growth would have been required for the population to reach 1 billion in 1853?
b. Had the rate continued what would the population be in the year 2003?
c. The current global population is about 6 billion. Is the population predicted in part b larger or smaller that the current population?
d. What growth rate change occurred from 1853 to the present to explain the current population?
e. What significant changes in the "world" from 1853 onward do you think can explain the rate change?

Problem FEX-014

Assume a factory releases a continuous flow of wastewater into a stream that results in an in-stream carcinogen concentration of 0.1 mg/L at the outfall. Assume this carcinogen has an oral slope factor (potency) of 0.30 $(mg/kg/d)^{-1}$ and it biodegrades in the stream with a reaction rate coefficient K of 0.10/day. Assume the stream is uniform in cross section, flows at a rate of 1 mile per hour, and has no other sources or sinks for this carcinogen. At a distance of 100 miles downstream, a town uses this water for drinking water. Estimate the individual residential lifetime cancer risk caused by drinking this water.

FEX-015

Assume the current year is 2000AD. The world's population 10,000 years ago was about 5 million. What exponential rate of growth would have been required for the population to reach 1 billion in 1850? Had the rate continued what would the population be in the year 2000?

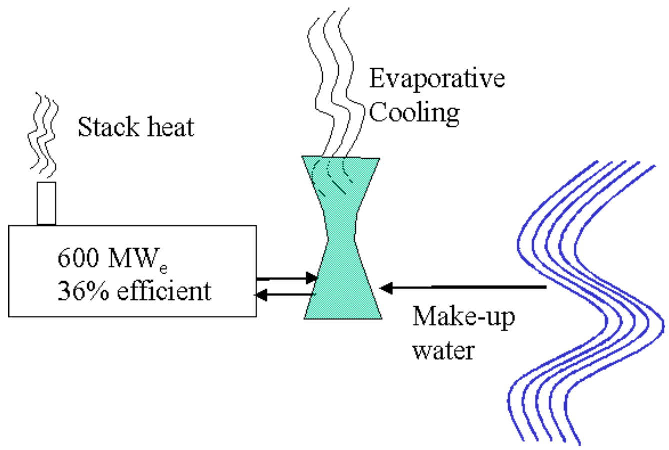
FEX-016

A pristine stream with flow rate 55 m^3/s feeds a reservoir with volume 10^7 m^3. A industrial wastewater plant discharges 5.5 m^3/s of water with a COD of 100 mg/L. The reaction rate coefficient for COD in the reservoir is 0.25/day.

a) Sketch a schematic of the reservoir; label mass inputs and outputs.
b) Write a mass balance equation for the reservoir (the system is NOT steady state).
c) Find the equilibrium (steady state) concentration of COD in the reservoir.
d) If the discharge concentration is suddenly reduced by ½, find the new equilibrium concentration.
e) Determine the time it will take for the new equilibrium to be reached in the reservoir.

FEX-017

A 600 MW_e (electric output) power plant has an efficiency of 36 percent with 15 percent waste heat being released into the atmosphere as stack heat and the other 85% taken away by cooling water. Instead of drawing water from a river, heating it, and returning the heated water to the river, the plant uses an evaporative cooling tower to release heat to the atmosphere as water is evaporated. At what rate must 15°C makeup water be provided from the river to offset the water evaporated in the cooling tower?



FEX-018

A 200-MW power plant has a 100-m stack with a radius of 2.5 m, flue gas exit velocity 13.5 m/s, and gas exit temperature 145 ^{0}C. The ambient temperature is 15 ^{0}C, wind speed at the stack is 5m/s, and the atmosphere is stable, Class E, with a lapse rate of 5 ^{0}C/km. If the stack emits 300g/s of SO_2, estimate the ground level concentration at a distance of 16 km directly down wind.

(Hints: You will need to calculate plume rise using Eqns. 7.48, 7.49, and 7.50 on page 419 of text. Example 7.14 is representative of required calculations. Once you have plume rise, then can enter effective stack height into equation 7.46 and determine downwind concentration. Example 7.12 illustrates required calculations.)

For the conditions above, determine the peak downwind location and concentration. Please show your work on the chart below and report the peak downwind concentration.

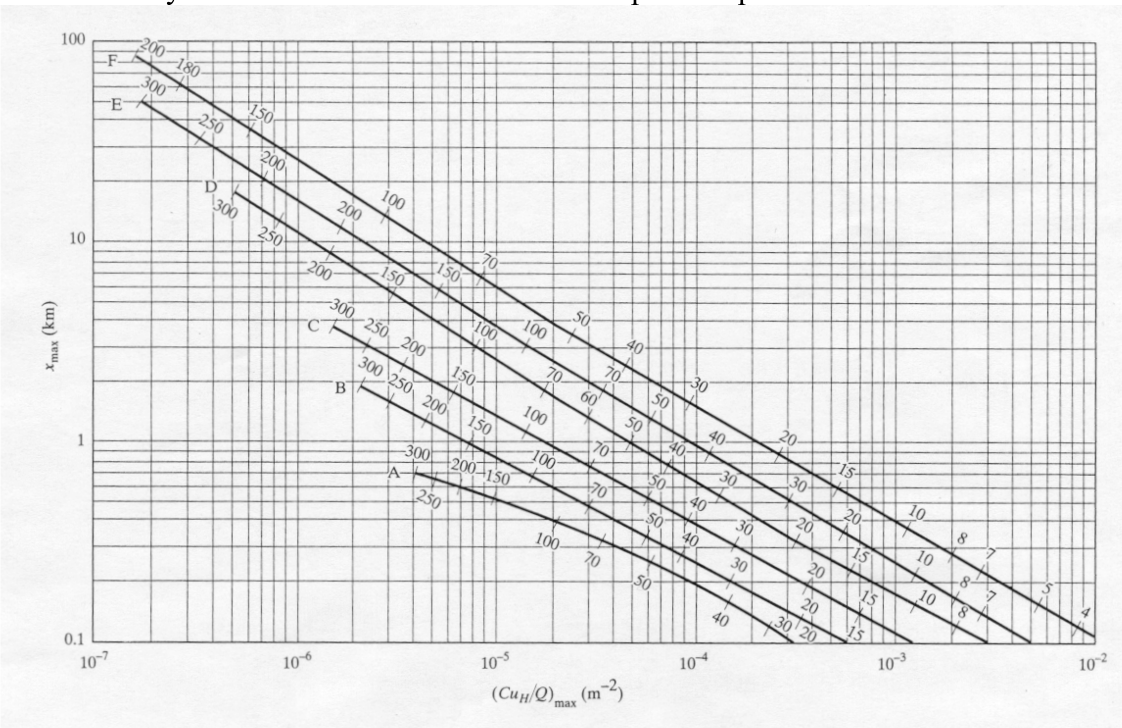
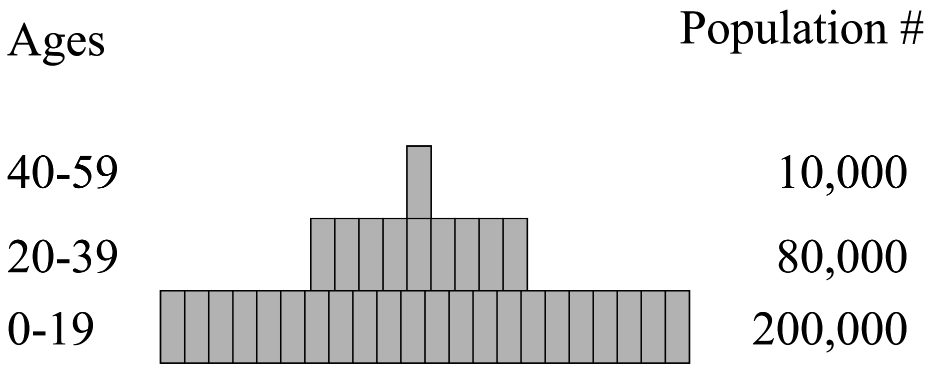


FIGURE 7.50 To determine the downwind concentration peak, enter the graph at the appropriate stability classification and effective stack height (numbers on the graph in meters) and then move across to find the distance to the peak, and down to find a parameter from which the peak concentration can be found (Turner, 1970).

FEX-020

Consider the following simplified age structure: All births are on the 20th birthday and all deaths are on the 60th birthday. Total population starts at 290,000 (½ male; ½ female) and is growing at a constant rate of 3.5 %/year. Draw the age structure in 20 years. If the total fertility rate is a single constant value during those 20 years, what is it?



FEX-021

Assume the current year is 2000AD. The world's population 10,000 years ago was about 5 million. What exponential rate of growth would have been required for the population to reach 1 billion in 1850? Had the rate continued what would the population be in the year 2000?

FEX–023

Disinfection with chlorine is well modeled as a first–order reaction. The first-order decay rate under a given concentration of chlorine is measured as 0.35/hr. The flow rate is 12000L per hour and the desired inactivation of pathogens is from 10 x 10^6 /100mL to less than 1/100 mL. Determine

a) The reactor volume required assuming a completely mixed reactor.
b) The reactor volume required assuming a plug flow reactor.

FEX-024

A lake with a volume of 5 x10^6 cibuc meters has a freshwater flow of 20 cms. A waste is discharged into the lake at a rate of 50 g/s with a first order decay rate of 0.2/d. What is the steady-state concentration in the lake assuming complete mixing?

FEX-025

A sedimentation basin has an overflow of 3 ft/hr. The influent wastewater has a particle distribution of:

% - sample	Settling velocity (m/hr)
20	0.30-0.61
30	0.61 to 0.91
50	0.91 to 1.22

FEX-026

A waste with a flow of 2.8 L/s is discharged to a small stream with a flow of 141 L/s. The waste has a 5-d BOD of 200 mg/L (K=0.2/d). What is the BOD after 1-day of travel in the stream?