SOLUTIONS

CIVE 3331 | Examination #2 | Fall 2000

$\bar{x} = 80$

$SD = 17$

high = 100

low = 30

Problem 1

A standard BOD test is run using seeded dilution water. In one bottle, the waste sample is mixed with seeded dilution water giving a dilution of 1:30. Another bottle, the blank, contains just seeded dilution water. Both bottles begin the test with DO at the saturation value of 9.2 mg/L. After five days, the bottle containing waste has DO equal to 2.0 mg/L, while that containing just seeded dilution water has DO equal to 8.0 mg/L. What is the 5-day BOD of the waste?

$$P = \frac{1}{30}$$

$$BOD_w = \frac{(DO_i - DO_f) - (B_i - B_f)(1-P)}{P} \quad \text{(pg 190)}$$

$$= \frac{(9.2 - 2.0\ mg/L) - (9.2 - 8.0\ mg/L)(\frac{29}{30})}{\frac{1}{30}}$$

$$= 7.2(30)\ mg/L - (1.2)(29)\ mg/L$$

$$= 216\ mg/L - 34.8\ mg/L$$

$$= \underline{\underline{181.2\ mg/L}} \longleftarrow \text{BOD}_5 \text{ of waste}$$

Problem 2

A wastewater has a BOD_5 of 150 mg/L at 20°C. The reaction rate k at that temperature is 0.23/d.

a) What is the ultimate CBOD?
b) What is the reaction rate coefficient at 15°C?
c) What is the BOD_5 at 15°C?

$$L_o = \frac{BOD_5}{(1-e^{-kt})} \quad \text{(pg 193)}$$

$$= \frac{150 \text{ mg/L}}{(1-e^{-0.23(5)})} = \underline{\underline{219.5 \text{ mg/L}}} \longleftarrow L_o$$

$$k_T = k_{20}\theta^{(T-20)} \quad ; \quad \theta = 1.047 \quad \text{(pg 193 \& 194)}$$

$$= (0.23/d)(1.047)^{(-5)} = \underline{\underline{0.183/d}} \longleftarrow k_{15°C}$$

$$BOD_5 = L_o(1-e^{-kt}) \quad \text{(pg 194)}$$

$$= (219.5 \text{ mg/L})(1 - \exp(-0.183(5))) =$$

$$\underline{\underline{131.6 \text{ mg/L}}} \longleftarrow BOD_5 \text{ @ } 15°C$$

Problem 3

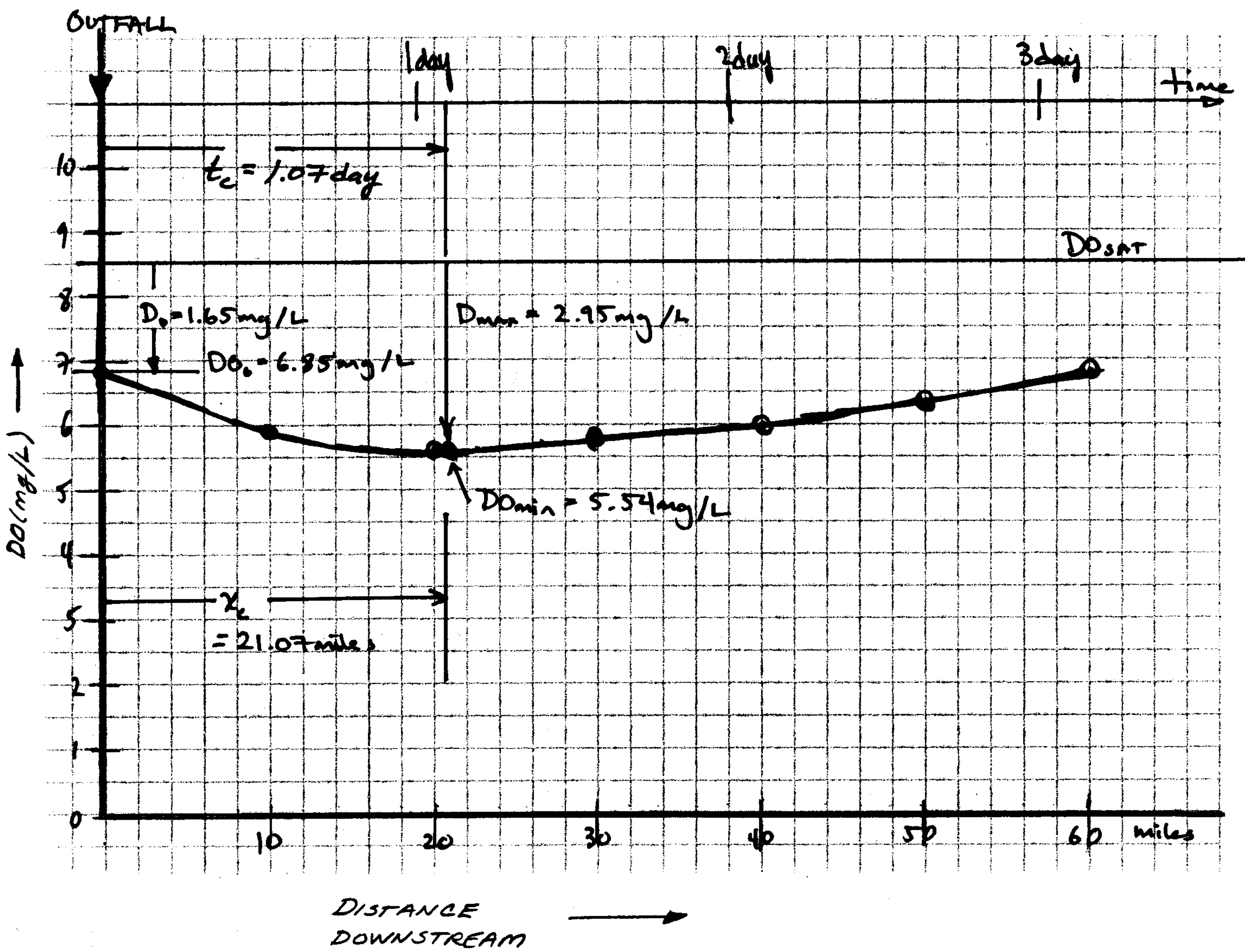
A city of 200,000 people discharges 37 ft^3/sec of sewage having a BOD_5 of 28 mg/L and a DO of 1.8 mg/L into a river with a discharge of 250 ft^3/sec and a mean section velocity of 1.2 ft/s. Upstream of the release location, the river has BOD_5 of 3.6 mg/L and DO of 7.6 mg/L. DO_{sat} for the river is 8.5 mg/L. The deoxygenation coefficient, k_d, is 0.61/day and the reaeration coefficient, k_r, is 0.76/day. Assuming complete mixing in the river at the discharge location and neglect axial dispersion.

a) Plot the DO versus distance downstream from the outfall.

From your plot, or by separate calculation find:

b) The initial oxygen deficit and ultimate BOD just downstream of the outfall.
c) The time and distance to reach the minimum DO.
d) The minimum DO.
e) The DO that could be expected 10 miles downstream.

Use the attached sheets for your calculations.



Problem 3 (continued)

Hints:

- Sketch the Problem (not really useful, but gives you something to do while panicking).
- Determine initial deficit and initial DO concentration
- Find L_o of waste and river before mixing.
- Find L_o of river after mixing.
- Use $D(x)$ formula where time is expressed as x/u to construct table of $D(x)$ and $DO(x)$. Be sure you get the time units consistent - the reaction coefficients are expressed in days^{-1} while velocity is ft/sec. Some unit conversion is necessary – choose a simple one!
- Use t_c formula, but substitute x_c/u for time and solve for x_c. Put result into $D(x)$ formula to get D_{max} and DO_{min}.
- Finally, using your tabulated values graph the curve on the grid on the previous page.

Sketch

$Q = 37\ ft^3/s$
$DO = 1.8\ mg/L$
$BOD_5 = 28\ mg/L$

$Q = 250\ ft^3/s$
$DO = 7.6\ mg/L$
$BOD_5 = 3.6\ mg/L$

$Q = 287\ ft^3/s$
$u = 1.2\ ft/s$

Initial deficit & DO

$$DO_o = \frac{37(1.8) + 250(7.6)}{(37+250)} = \underline{\underline{6.85\ mg/L}} \leftarrow \text{INITIAL DO}$$

$$D_o = DO_{SAT} - DO_o = 8.5\ mg/L - 6.85\ mg/L = \underline{\underline{1.65\ mg/L}}$$

INITIAL DEFICIT

L_o before mixing

$$L_{ow} = \frac{BOD_5}{(1-e^{-kt})} = \frac{28\ mg/L}{(1-\exp(-0.61(5)))} = 29.4\ mg/L$$

$$L_{oR} = \frac{BOD_5}{(1-e^{-kt})} = \frac{3.6\ mg/L}{(1-\exp(-0.61(5)))} = 3.78\ mg/L$$

L_o AFTER MIXING

$$L_o = \frac{Q_w L_w + Q_R L_R}{Q_w + Q_R} = \frac{37(29.4) + 250(3.78)}{37+250} = \underline{\underline{7.08\ mg/L}} \leftarrow L_o \text{ INITI}$$

Problem 3 (continued)

$$D(x) = \frac{k_d L_o}{k_r - k_d}\left(\exp\left(-k_d \frac{x}{U}\right) - \exp\left(-k_r \frac{x}{U}\right)\right) + D_o \exp\left(-k_r \frac{x}{U}\right)$$

$$U = 1.2\,ft/s \cdot \frac{86400\,s}{day} \cdot \frac{mi}{5280\,ft} = 19.64\ mi/day$$

x	$\frac{x}{U}$	(1) $\frac{k_r x}{U}$	(2) $\frac{k_d x}{U}$	(3) $\exp(-(1))$	(4) $\exp(-(2))$	$\frac{k_d L_o}{k_r - k_d}((3)-(4))$	$D_o(3)$	$D(x)$	$DO_{sat} - D(x)$ $DO(x)$
10	0.509	0.38	0.31	0.68	0.73	1.55	1.11	2.67	5.83
20	1.018	0.77	0.62	0.46	0.54	2.19	0.75	2.95	
30	1.527	1.16	0.93	0.31	0.39	2.32	0.51	2.83	
40	2.036	1.54	1.24	0.21	0.28	2.18	0.35	2.53	
50	2.545	1.93	1.55	0.14	0.21	1.93	0.24	2.17	
60	3.054	2.32	1.83	0.09	0.15	1.64	0.16	1.80	
21.07	1.07	0.81	0.65	0.44	0.52	2.22	0.73	2.95	5.5

FIND DOmin

$$t_c = \frac{x_c}{U} = \frac{1}{k_r - k_d} \ln\left(\frac{k_r}{k_d}\left(1 - \frac{D_o(k_r - k_d)}{k_d L_o}\right)\right) \quad (pg\ 203)$$

$$= \frac{1}{0.76-0.61} \ln\left(\frac{.76}{.61}\left[1 - \frac{1.647(0.76-0.61)}{0.61(7.08)}\right]\right) = 1.07\ days$$

$$x_c = U(1.07\ days) = 21.07\ miles$$

$$DO_{min} = 8.5 - 2.95 = 5.54\ mg/L$$

$$DO_{10miles} = 8.5 - 2.67 = 5.83\ mg/L$$

4) Three wells in an aquifer are monitored. The depth to water in each well is listed in Table 1. The relationship between depth to water and head is depicted in Figure 1. Determine the magnitude and direction of the hydraulic gradient. Use the attached sheet for your calculations.

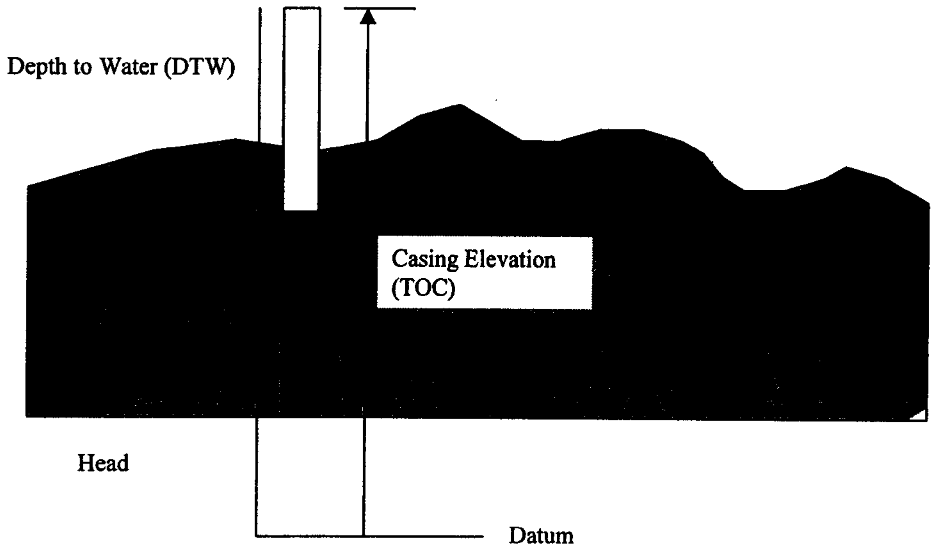


Figure 1: Schematic of Well

Table 1: Monitoring Well Data

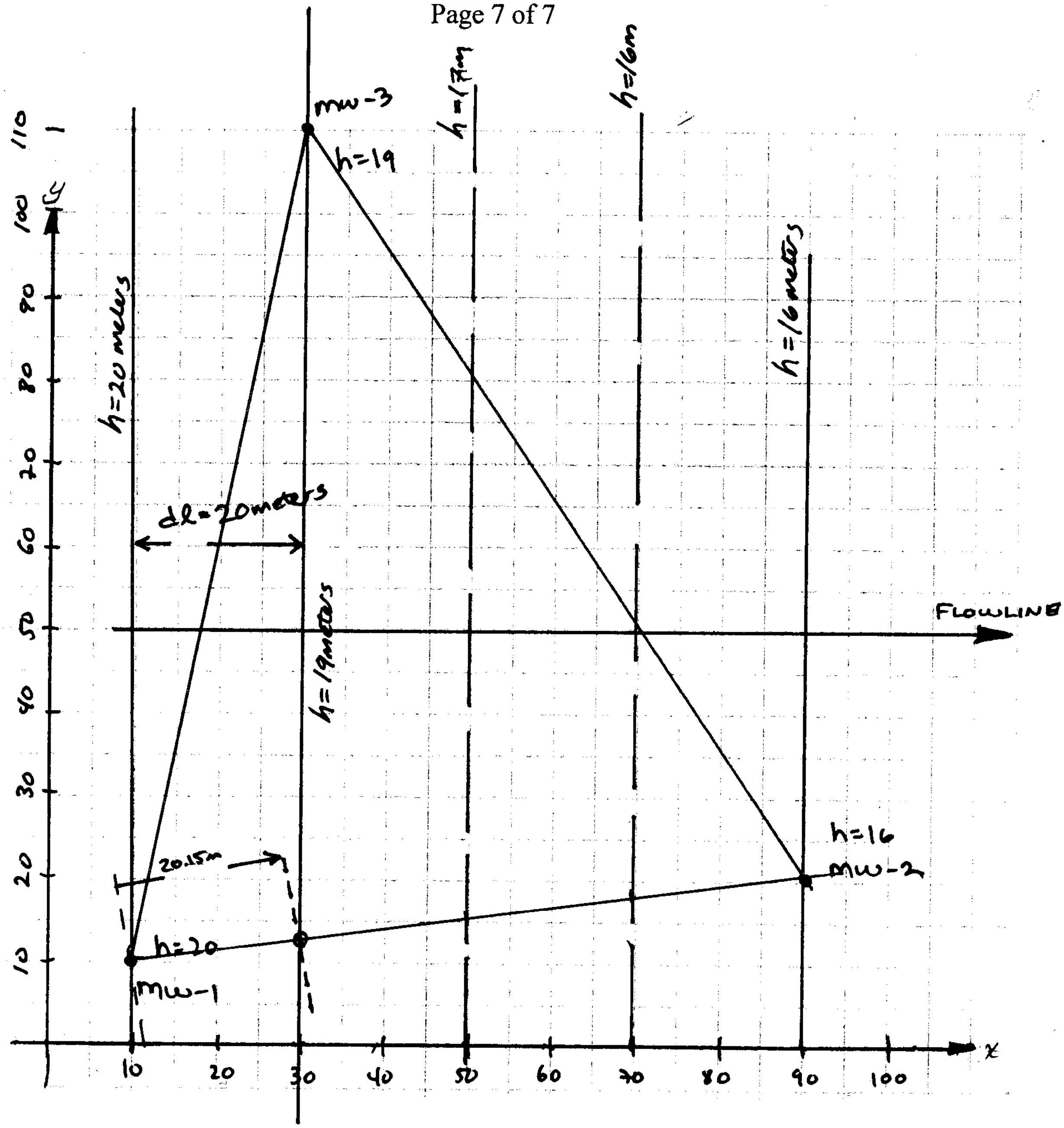
Well Designation	X-coordinate (meters)	Y-coordinate (meters)	Depth to Water (meters)	Casing elevation (meters)	Head (meters)
MW-1	10	10	83	103	20
MW-2	90	20	103	119	16
MW-3	30	110	116	135	19

103 − 83 = 20

119 − 103 = 16

135 − 116 = 19

TOC − DTW = HEAD



$d_{mw\text{-}1 \to mw\text{-}2} = \sqrt{10^2 + 80^2} = 80.6m$

$\Delta h_{1 \to 2} = 4m$

$\Delta h_{1 \to 3} = 1m$

$d_{mw\text{-}1 \to mw\text{-}3^*} = 80.6\,m \left(\frac{1m}{4m}\right) = 20.15m$

$\frac{dh}{dl} = \frac{1m}{20m} = 0.05$ $\therefore$ GRADIENT = 0.05 due EAST (AS drawn)