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Instructor's Manual
to accompany

BASIC ENVIRONMENTAL TECHNOLOGY

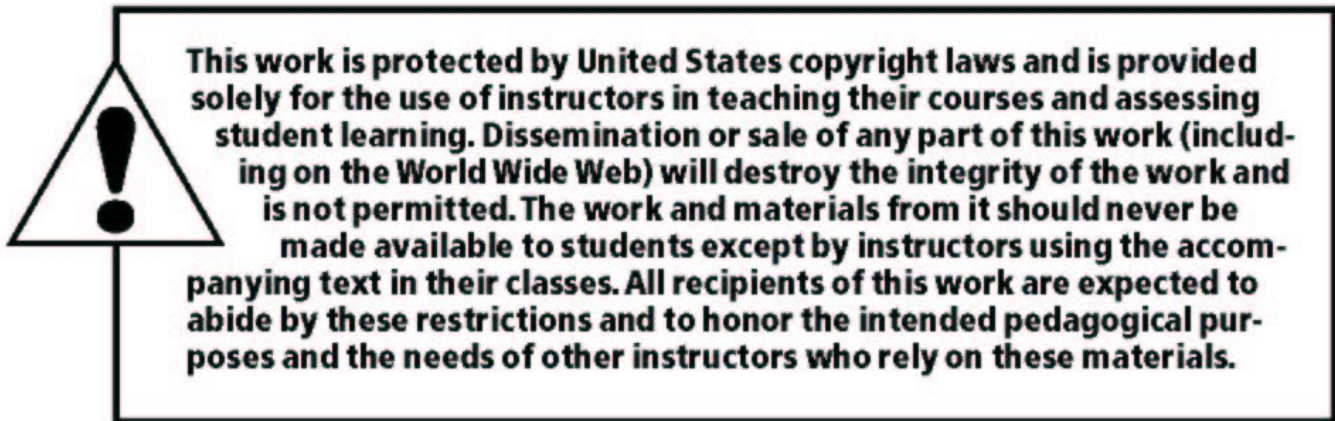
Water Supply, Waste Management, and Pollution Control

Fifth Edition

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This manual provides instructors with (a) text page references and Internet URLs where answers to the end-of-chapter *Review Questions* can be found, (b) worked out solutions to each of the *Practice Problems*, and (c) supplemental problems and 100 multiple choice questions (and answers) that can be incorporated in tests or a final examination.

Generally, answers to end-of-chapter Practice Problems are rounded-off to reflect the precision of the data and/or the accuracy of the assumed factors in the problems. These answers are also listed in Appendix F of the text for students to use in checking their work. (The author has made every attempt to keep errors to a minimum. He can be notified of any mistakes that may be found in the text or in this manual at: nathanson1@comcast.net).

CHAPTER 1 BASIC CONCEPTS

Review Question Page References

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(3) 6	(17) 17	(31) http://www.epa.gov/epahome/laws.htm
(4) 7	(18) 18	(32) http://www.usgs.gov/nawqa/
(5) 7	(19) 17-19	(33) http://www.envirosources.com
(6) 8-9	(20) 18, 19	
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(There are no Practice Problems for Chapter 1)

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(23) www.usbr.gov/wrrl	(24) www.envirosources.com		

Solutions to Practice Problems

- $P = 0.43 \times h$ (Equation 2-2b)
 $P = 0.43 \times 50 \text{ ft} = 22 \text{ psi}$ at the bottom of the reservoir
 $P = 0.43 \times (50 - 30) = 0.43 \times 20 \text{ ft} = 8.6 \text{ psi}$ above the bottom
- $h = 0.1 \times P = 0.1 \times 50 = 5 \text{ m}$ (Equation 2-3a)
- Depth of water above the valve: $h = (78 \text{ m} - 50 \text{ m}) + 2 \text{ m} = 30 \text{ m}$
 $P = 9.8 \times h = 9.8 \times 30 = 294 \text{ kPa} \approx 290 \text{ kPa}$ (Equation 2-2a)
- $h = 2.3 \times P = 2.3 \times 50 = 115 \text{ ft}$, in the water main
 $h = 115 - 40 = 75 \text{ ft}$
 $P = 0.43 \times 75 = 32 \text{ psi}$, 40 ft above the main (Equation 2-2b)
- Gage pressure $P = 30 + 9.8 \times 1 = 39.8 \text{ kPa} \approx 40 \text{ kPa}$
 Pressure head (in tube) $= 0.1 \times 40 \text{ kPa} = 4 \text{ m}$
- $Q = A \times V$ (Eq. 2-4), therefore $V = Q/A$
 $A = \pi D^2/4 = \pi (0.3)^2/4 = 0.0707 \text{ m}^2$
 $100 \text{ L/s} \times 1 \text{ m}^3/1000\text{L} = 0.1 \text{ m}^3/\text{s}$
 $V = 0.1 \text{ m}^3/\text{s} / 0.0707\text{m}^2 = 1.4 \text{ m/s}$
- $Q = (500 \text{ gal/min}) \times (1 \text{ min}/60 \text{ sec}) \times (1 \text{ ft}^3/7.5 \text{ gal}) = 1.11 \text{ cfs}$
 $A = Q/V$ (from Eq. 2-4)
 $A = 1.11 \text{ ft}^3/\text{sec} / 1.4 \text{ ft/sec} = 0.794 \text{ ft}^2$
 $A = \pi D^2/4$, therefore $D = \sqrt{4A/\pi} = \sqrt{(4)(0.794)/\pi} = 1 \text{ ft} = 12 \text{ in.}$

8. $Q = A_1 \times V_1 = A_2 \times V_2$ (Eq. 2-5)

Since $A = \pi D^2/4$, we can write

$$D_1^2 \times V_1 = D_2^2 \times V_2 \text{ and } V_2 = V_1 \times (D_1^2/D_2^2)$$

In the constriction, $V_2 = (2 \text{ m/s}) \times (4) = 8 \text{ m/s}$

9. Area of pipe A = $\pi(0.3)^2/4 = 0.0707 \text{ m}^2$

Area of pipe B = $\pi(0.1)^2/4 = 0.00785 \text{ m}^2$

Area of pipe C = $\pi(0.2)^2/4 = 0.03142 \text{ m}^2$

$$Q_A = Q_B + Q_C = 0.00785 \text{ m}^2 \times 2 \text{ m/s} + 0.03142 \text{ m}^2 \times 1 \text{ m/s}$$

$$= 0.04712 \text{ m}^3/\text{s} \text{ (from continuity of flow: } Q_{\text{IN}} = Q_{\text{OUT}})$$

$$V_A = Q_A/A_A = 0.04712/0.0707 \approx 0.67 \text{ m/s (from Eq. 2-4)}$$

10. $p_1/w + V_1^2/2g = p_2/w + V_2^2/2g$ (Eq. 2-8)

$$A_1 = \pi(1.33)^2/4 = 1.4 \text{ ft}^2 \quad A_2 = \pi(0.67)^2/4 = 0.349 \text{ ft}^2$$

$$V_1 = 6/1.4 = 4.29 \text{ ft/sec} \quad V_2 = 6/0.349 = 17.2 \text{ ft/sec}$$

$$w = 62.4 \text{ lb/ft}^3 \text{ and } g = 32.2 \text{ ft/sec}^2$$

From Eq. 2-8, and multiplying $\text{psi} \times 144 \text{ in}^2/\text{ft}^2$ to get lb/ft^2

$$50(144)/62.4 + 4.29^2/2(32.2) = p_2(144)/62.4 + 17.2^2/2(32.2)$$

$$115.38 + 0.28578 = 2.3076p_2 + 4.5937$$

$$p_2 = 111.07/2.307 \approx 48 \text{ psi}$$

11. $p_1/w + v_1^2/2g = p_2/w + v_2^2/2g$ (Eq. 2-8)

$$A_1 = \pi(0.300)^2/4 = 0.0707 \text{ m}^2 \quad A_2 = \pi(0.100)^2/4 = 0.00785 \text{ m}^2$$

$$Q = 50 \text{ L/s} \times 1 \text{ m}^3/1000 \text{ L} = 0.05 \text{ m}^3/\text{s}$$

$$V_1 = 0.05/0.0707 = 0.70721 \text{ m/sec} \quad V_2 = 0.05/0.00785 = 6.369 \text{ m/sec}$$

$$w = 9.81 \text{ kN/m}^3 \text{ and } g = 9.81 \text{ m/s}^2; \text{ From Eq. 2-8,}$$

$$700/2(9.81) + 0.70721^2/2(9.81) = p_2/2(9.81) + 6.369^2/2(9.81)$$

$$35.67789 + 0.02549 = 0.05097p_2 + 2.06775 \text{ and } p_2 = 660 \text{ kPa}$$

12. From Figure 2.15, with $Q = 200 \text{ L/s}$ and $D = 600 \text{ mm}$, read $S = 0.0013$.
 Therefore $h_L = S \times L = 0.0013 \times 1000 \text{ m} = 1.3 \text{ m}$
 Pressure drop $p = 9.8 \times 1.3 = 12.7 \approx 13 \text{ kPa per km}$
13. $h_L = 2.3 \times 20 = 46 \text{ ft}$ and $S = 46/5280 = 0.0087$ (where $1 \text{ mi} = 5280 \text{ ft}$)
 From Figure 2.15, with $Q = 1000 \text{ gpm}$ and $S = 0.0087$, read $D = 10.3 \text{ in.}$
 Use a 12 in. standard diameter pipe
14. $S = 10/1000 = 0.01$
 From the nomograph (Figure 2.15) read $Q \approx 100 \text{ L/s} = 0.1 \text{ m}^3/\text{s}$
 Check with Eq. 2-9: $Q = 0.28 \times 100 \times 0.3^{2.63} \times 0.01^{0.54} \approx 0.1 \text{ m}^3/\text{s}$ OK
15. Use (Eq. 2-10): $Q = C \times A_2 \times \{(2g(p_1 - p_2)/w)/(1 - (A_2/A_1)^2)\}^{1/2}$
 where $A_1 = \pi(6)^2/4 = 28.27 \text{ in}^2$ and $A_2 = \pi(3)^2/4 = 7.07 \text{ in}^2$
 $g = 32.2 \text{ ft/s}^2 = 386.4 \text{ in/s}^2$
 $w = 62.4 \text{ lb/ft}^3 \times 1 \text{ ft}^3/12^3 \text{ in}^3 = 0.0361 \text{ lb/in}^3$
 $Q = 0.98 \times 7.07 \times \{(2(386.4)(10)/0.0361)/(1 - (7.07/28.27)^2)\}^{1/2}$
 $Q = 0.98 \times 7.07 \times \sqrt{228,354} = 3311 \text{ in}^3/\text{s} = 1.9 \text{ cfs} \approx 2 \text{ cfs}$
16. Use (Eq. 2-10): $Q = C \times A_2 \times \{(2g(p_1 - p_2)/w)/(1 - (A_2/A_1)^2)\}^{1/2}$
 $A_1 = \pi(0.15)^2/4 = 0.01767 \text{ m}^2$ and $A_2 = \pi(0.075)^2/4 = 0.00442 \text{ m}^2$
 $g = 9.81 \text{ m/s}^2$ $w = 9.81 \text{ kN/m}^3$
 $1 - (A_2/A_1)^2 = 1 - (0.00442/0.01767)^2 = 0.93743$
 $Q = 0.98 \times 0.00442 \times \{(2(9.81)(100)/9.81)/0.93743\}^{1/2} = 0.063 \text{ m}^3/\text{s}$
 (or, $Q = 0.063 \text{ m}^3/\text{s} \times 1000 \text{ L/m}^3 = 63 \text{ L/s}$)
17. Use Manning's nomograph (Figure 2.21): With $D = 800 \text{ mm} = 80 \text{ cm}$, and
 $S = 0.2\% = 0.002$, read $Q = 0.56 \text{ m}^3/\text{s} = 560 \text{ L/s}$ and $V = 1.17 \text{ m/s}$
18. $S = 1.5/1000 = 0.015$; from Fig. 2.21, $Q \approx 1800 \text{ gpm}$ and $V \approx 2.3 \text{ ft/s}$
19. $Q = 200 \text{ L/s} = 0.2 \text{ m}^3/\text{s}$; from Fig. 2.21, $D \approx 42 \text{ cm}$; use 450 mm pipe

20. $Q = 7 \text{ mgd} = 7,000,000 \text{ gal/day} \times 1 \text{ day}/1440 \text{ min} \approx 4900 \text{ gpm}$
 From Fig. 2.21, with 36 in and 4900 gpm: $S = 0.00027$, $V = 1.54 \text{ ft/s}$
 Since 1.54 ft/s is less than the minimum self-cleansing velocity of 2 ft/s, it is necessary to increase the slope of the 36 in pipe.
 From Fig. 2.21, with 36 in and 2 ft/s: $S = 0.00047 = 0.047\% \approx 0.05\%$

21. For full-flow conditions, with $D = 300 \text{ mm}$ and $S = 0.02$, read from
 Fig. 2.21: $Q = 0.135 \text{ m}^3/\text{s} = 135 \text{ L/s}$ and $V = 2 \text{ m/s}$ "
 $q/Q = 50/135 = 0.37$ From Fig. 2.22, $d/D = 0.42$ and $v/V = 0.92$
 Depth at partial flow $d = 0.42 \times 300 = 126 \text{ mm} \approx 130 \text{ mm}$
 Velocity at partial flow $v = 0.92 \times 2 \approx 1.8 \text{ m/s}$

22. For full-flow conditions, from Fig. 2.21 read $Q = 1800 \text{ gpm}$. From Fig. 2.22, the maximum value of $q/Q = 1.08$ when $d/D = 0.93$. Therefore, the highest discharge capacity for the 18 in pipe, $q_{\max} = 1800 \times 1.08 \approx 1900 \text{ gpm}$, would occur at a depth of $d = 18 \times 0.93 \approx 17 \text{ in}$.

23. For full-flow conditions, from Fig. 2.21 read $Q = 0.55 \text{ m}^3/\text{s} = 550 \text{ L/s}$. From Fig. 2.22, the maximum value of $v/V = 1.15$ when $d/D = 0.82$. Therefore, the highest flow velocity for the 900 mm pipe, $v_{\max} = 0.9 \times 1.15 \approx 1 \text{ m/s}$, would occur at a depth of $d = 900 \times 0.82 \approx 740 \text{ mm}$
 When the flow occurs at that depth, $q/Q = 1.05$ and the discharge $q = 580 \text{ L/s}$

24. $S = 0.5/100 = 0.005$
 For full-flow conditions, $Q = 0.44 \text{ m}^3/\text{s} = 440 \text{ L/s}$ and $V = 1.6 \text{ m/s}$
 Since $d/D = 200/600 = 0.33$, from Fig. 2.22 $q/Q = 0.23$ and $v/V = 0.8$
 Therefore, $q = 440 \times 0.23 \approx 100 \text{ L/s}$ and $v = 1.6 \times 0.8 \approx 1.3 \text{ m/s}$

25. $Q = A \times V = 2 \times 0.75 \times 25/75 = 0.5 \text{ m}^3/\text{s} = 500 \text{ L/s}$

26. From Eq. 2-12, $Q = 2.5 \times (4/12)^{2.5} = 0.16 \text{ cfs}$

27. $150 \text{ mm} \times 1 \text{ in}/25.4 \text{ mm} \times 1 \text{ ft}/12 \text{ in} = 0.492 \text{ ft}$

From Eq. 2-12, $Q = 2.5 \times (0.492)^{2.5} = 0.425 \text{ cfs} \times 28.32 \text{ L/ft}^3 \approx 12 \text{ L/s}$

28. From Eq. 2-13, $Q = 3.4 \times (20/12) \times (10/12)^{1.5} = 4.3 \text{ cfs} \approx 120 \text{ L/s}$

CHAPTER 3 HYDROLOGY

Review Question Page References

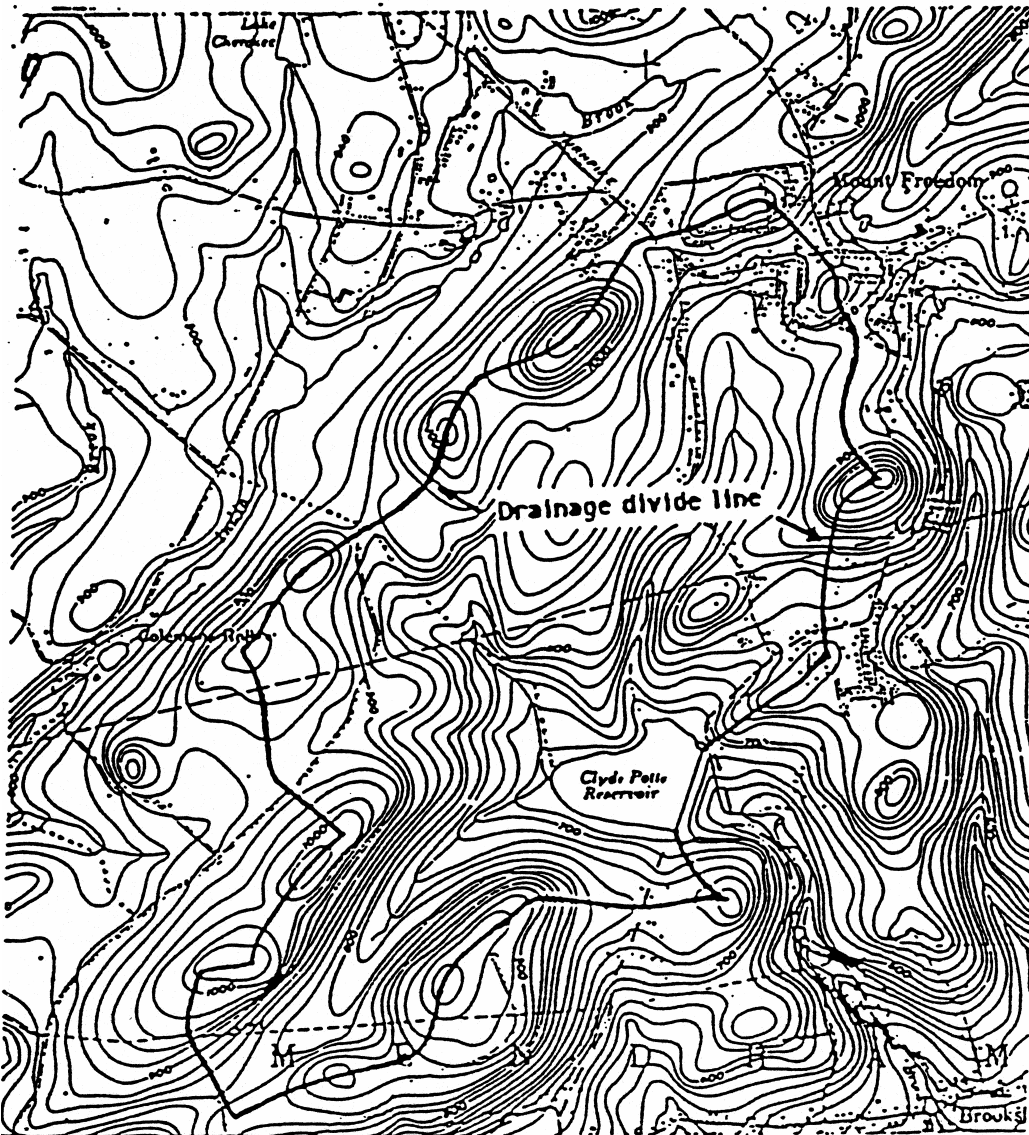
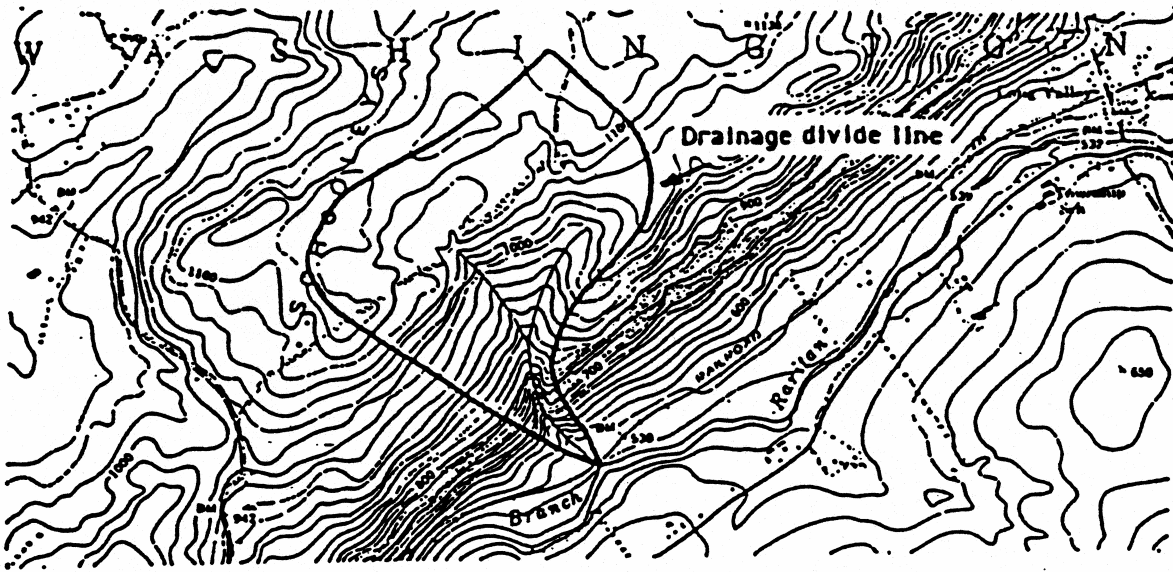
(1) 57	(7) 61	(13) 64	(19) 71	(25) 79
(2) 58	(8) 61	(14) 66	(20) 71	(26) 79
(3) 58	(9) 62	(15) 67	(21) 72	(27) 79
(4) 58	(10) 63	(16) 70	(22) 74	(28) 79
(5) 60	(11) 63	(17) 70	(23) 75	(29) 80
(6) 60	(12) 63	(18) 71	(24) 79	(30) 81
(31) http://hydrolab.arsL/sda.gov	(32) www.epa.gov/surf			
(33) www.envirosources.com				

Solutions to Practice Problems

- Intensity = 500 mm/ 10 h = 50 mm/h
Volume = depth x area = 0.5 m x 750 000 m³ = 375 000 m³ = 375 ML
- Intensity = 1 in./0.5 h = 2 in./h
Volume = depth x area = 1 in. x 1 ft/12 in. x 96 ac = 8 ac-ft
Volume = 8 ac-ft x 43,560 ft²/ac ≈ 350,000 ft³
- (a) 100 mm/h (4 in./h); (b) 45 mm/h (1.7 in./h); (c) 50 mm/h (2 in./h)
- 75 mm/0.5 h = 150 mm/h; line up 30 min and 150 mm/h in Fig. 3.5. The intersection falls on the 100-yr storm curve. The probability of a greater storm occurring within the next year is $P = 1/100 = 0.01 = 1\%$
- From Eq. 3-3, $i = 3000/(90 + 20) = 27$ mm/h
- $P = 1/N = 1/20 = 0.05 = 5\%$

7.	Low Flow	Rank	Probability	Low Flow	Rank	Probability	
	57	1	0.059	45	9	0.529	Multiply vertical axis values on Figure 3.16 by 10, and plot Low Flow versus Probability. Read MA7CD10 flow to be approximately 35m ³ /s (where the recurrence value = 10 yrs.)
	53	2	0.117	44	10	0.588	
	50	3	0.176	42	11	0.647	
	50	4	0.235	41	12	0.706	
	50	5	0.294	40	13	0.765	
	48	6	0.353	39	14	0.824	
	47	7	0.412	36	15	0.882	
	45	8	0.471	33	16	0.941	

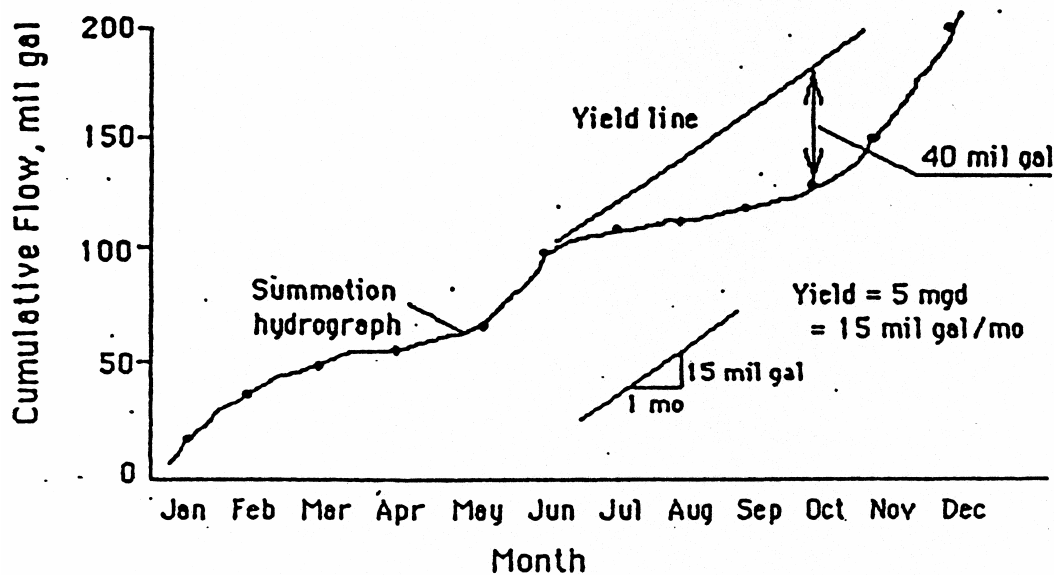
8. (a) & (b)



9.

Cumulative Flows, mil gal							
Month	Flow	Month	Flow	Month	Flow	Month	Flow
Jan	20	Apr	52	Jul	108	Oct	119
Feb	40	May	62	Aug	111	Nov	149
Mar	50	Jun	100	Sep	113	Dec	199

The required reservoir volume is approximately 40 million gallons.



10. $V = K \times S$ (Darcy's Law, Equation 3-4)
 $V = 0.05 \text{ mm/s} \times 0.5/100 = 0.05 \times 0.005 = 0.00025 \text{ mm/s}$
 $V = 0.00025 \text{ mm/s} \times 3600 \text{ s/h} \times 24 \text{ h/d} = 0.9 \text{ mm/h} \approx 22 \text{ mm/d}$
11. $K = VIS$ (From Eq. 3-4)
 $V = 0.05 \text{ m/h} \times 1000 \text{ mm/m} \times 1\text{h}/3600 \text{ s} = 0.0139 \text{ mm/s}$
 $K = 0.0139/0.035 \approx 0.4 \text{ mm/s}$ (For sand, $K = 0.01$ to 10 mm/s)
12. $\text{Yield} = 2 \text{ m}^3/\text{h}/\text{m} \times 15 \text{ m} = 30 \text{ m}^3/\text{h}$
 $10\% \text{ of } 30 = 3$; new yield $\approx 33 \text{ m}^3/\text{h}$

CHAPTER 4 WATER QUALITY

Review Question Page References

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(3) 93	(13) 98	(23) 105	(33) 110
(4) 94	(14) -	(24) 106	(34) 112
(5) -	(15) 102	(25) 106	(35) 112
(6) 94	(16) 101	(26) 106	(36) 112
(7) 94	(17) 102	(27) 107	(37) 113
(8) 95	(18) 102	(28) 107	(38) 114
(9) 96	(19) 103	(29) 108	(39) 115
(10) 98	(20) 103	(30) 108	(40) 117
(41) www.wqa.org	(42) www.epa.gov/nerlcwww	(43) www.envirosources.com	

Solutions to Practice Problems

1. $275 \text{ ppm} = 275 \text{ mg/L}$ (since $1 \text{ ppm} = 1 \text{ mg/L}$)
 $275 \text{ mg/L} \times 1 \text{ gpg}/17.1 \text{ mg/L} = 16.1 \text{ gpg}$
2. $4 \times 17.1 = 68 \text{ mg/L}$ of hardness as CaCO_3
This level is not objectionable; it is considered to be soft water and not cause scaling problems or interfere noticeably with lathering.
3. Since $1 \text{ mg/L} = 8.34 \text{ lb/mil gal}$, we can write
 $50 \text{ mg/L} \times (8.34 \text{ lb/mil gal})/(1 \text{ mg/L}) \times 3 \text{ mil gal/day} = 1250 \text{ lb/d}$
4. $30 \text{ ac-ft} \times 43,560 \text{ ft}^3/\text{ac-ft} \times 7.48 \text{ gal/ft}^3 = 9,775,000 \text{ gal}$
 $50 \text{ lb}/9.775 \text{ mil gal} \times (1 \text{ mg/L})/(8.34 \text{ lb/mil gal}) = 0.6 \text{ mg/L}$
5. 1 L of water has a mass of 1 kg
 $2 \text{ ppm} = 2 \text{ mg/L} = 2 \text{ kg/ML}$ (multiply mg/L by $10^6/10^6$)
 $2 \text{ kg/ML} \times 5 \text{ ML} = 10 \text{ kg}$ of chlorine
6. $\text{lb/d} = \text{concentration in ppm} \times \text{flow rate in mgd} \times 8.34$
 $\text{lb/d} = 0.5 \text{ ppm} \times 25 \text{ mil gal/d} \times (8.34 \text{ lb/mil gal})/(1 \text{ ppm}) \sim 100 \text{ lb/d}$
7. $0.005 \text{ mg}/0.200 \text{ L} = 0.025 \text{ mg/L} = 25 \mu\text{g/L} = 25 \text{ ppb}$

8. $BOD_5 = 14 - 6 = 8 \text{ mg/L}$; there apparently is some organic material in the stream, but it is not possible to determine if the organics are from decaying leaves and animal wastes or from sewage, from this one test alone.

9. We could say that the BOD_5 of the stream is at least 14 mg/L , but it could also be higher than that. Since this exceeds 10 mg/L , it is likely that the stream is polluted with sewage.

10. $BOD_t = BOD_L \times (1 - 10^{-kt})$ (Equation 4-2)

Since $t = 5 \text{ d}$ and $k = 0.15/\text{d}$, $k \times t = 0.75$

$$BOD_L = 270 / (1 - 10^{-0.75}) = 304 \approx 300 \text{ mg/L}$$

11. $BOD_5 = (DO_0 - DO_5) \times 300/V$ (Equation 4-3)

$$BOD_5 = (9.2 - 4.7) \times 300/5 = 270 \text{ mg/L}$$

$$BOD_L = 270 / (1 - 10^{-0.14 \times 5}) = 337 \approx 340 \text{ mg/L}$$

12; $BOD_5 = 280 \times (1 - 10^{-0.1 \times 5}) = 190 \text{ mg/L}$ (Eq. 4-2)

$$190 = (9.0 - DO_5) \times 300/5 \quad (\text{Eq. 4-3})$$

$$DO_5 = 9.0 - (190/60) = 9.9 - 3.2 = 5.8 \text{ mg/L}$$

13. $TDS = (A - B) \times 1000/C$ (Equation 4-4)

$$TDS = (38\,845 \text{ mg} - 38\,820 \text{ mg}) \times 1000/50 \text{ ml} = 500 \text{ mg/L}$$

14. $TSS = (A - B) \times 1000/C$ (Equation 4-4)

$$TSS = (580 - 545) \times 1000/100 = 350 \text{ mg/L}$$

$$(560 - 545) / (580 - 545) \times 100 = 43\% \text{ volatile solids}$$

15. $\text{coliforms}/100 \text{ mL} = 22 \times 100/10 = 220 \text{ per } 100 \text{ mL}$

16. From Table 4.4, the MPN of this sample = 120 per 100 ml

CHAPTER 5 WATER POLLUTION

Review Questions Page References

(1) 123	(8) 128	(14) 133	(21) 138	(28) www.epa.gov/owow/iakes/lakes.htm/
(2) 124	(9) 129	(15) 134	(22) 140	(29) www.epa.gov/owow/estuaries/about1.html
(3) 124	(10) 130	(16) 135	(23) 140	(30) www.epa.gov/owowwtr1
(4) 125	(11) 130	(17) 135	(24) 141	(31) www.envirosources.com
(5) 126	(12) 132	(18) 136	(25) 142	
(6) 126	(13) 132	(19) 138	(26) 143	
(7) 127		(20) 138	(27) www.epa.gov/iwi	

Solutions to Practice Problems

1. $c_d = (c_s Q_s + c_w Q_w) / (Q_s + Q_w)$ (Equation 5-1)

$$\text{TDS} = (100 \times 6 + 500 \times 1.5) / (6 + 1.5) = 177 \approx 180 \text{ mg/L}$$

2. $c_d = (c_s Q_s + c_w Q_w) / (Q_s + Q_w)$ (Equation 5-1)

$$10 = (3 \times Q_s + 100 \times 1.5) / (Q_s + 1.5)$$

$$10Q_s + 15 = 3Q_s + 150 \quad Q_s = 135/7 = 19.3 \approx 20 \text{ ML/d}$$

3. $D_i = 11 - 8 = 3 \text{ mg/L}$; with Equation 5-2, find critical time as follows:

$$t_c = \{1 / (0.4 - 0.1)\} \times \log\{(0.4/0.1) \times (1 - 3 \times (0.4 - 0.1) / (0.1 \times 25))\} =$$

$$(1/0.3) \times \log\{4 \times (1 - 0.36)\} = (1/0.3) \times \log 2.56 = 1.36 \text{ days}$$

Using Equation 5-3, solve for the critical oxygen deficit:

$$D_c = (0.1 \times 25 / 0.4 - 0.1) \times \{10^{-0.1 \times 1.36} - 10^{-0.4 \times 1.36}\} + 3 \times 10^{-0.4 \times 1.36}$$

$$= 8.33 \times 0.455 + 3 \times 0.286 = 4.6 \text{ mg/L}; \text{DO}_{\min} = 11 - 4.6 = 6.4 \text{ mg/L}$$

4. $\text{BOD}_5 = (6 \times 16 + 28 \times 4) / (16 + 4) = 10.4 \text{ mg/L}$ (Equation 5-1)

From Equation 4-2, $10.4 = \text{BOD}_L \times (1 - 10^{-0.1 \times 5})$;

Solve for the ultimate BOD: $\text{BOD}_L = 10.4 / 0.68337 = 15.2 \text{ mg/L}$

Compute the initial DO level and the DO deficit below the mixing zone:

$$\text{DO} = (7 \times 16 + 2 \times 4) / (16 + 4) = 6.0 \text{ mg/L}; \text{DO}_i = 10.0 - 6.0 = 4.0 \text{ mg/L}$$

Compute the critical time, using Equation 5-2:

$$t_c = 1 / (0.3 - 0.1) \times \log\{(0.3/0.1) \times (1 - 4.0 \times (0.3 - 0.1) / (0.1 \times 15.2))\} = 0.7631 \text{ d}$$

4. (continued)

Compute the critical oxygen deficit, using Equation 5-3:

$$D_c = (0.1 \times 15.2 / (0.3 - 0.1)) \times \{10^{-0.1 \times 0.7631} - 10^{-0.3 \times 0.7631}\} \\ + 4 \times 10^{-0.3 \times 0.7631} = 7.6 \times 0.279 + 4 \times 0.590 = 4.5 \text{ mg/L}$$

$$\text{Minimum DO} = 10.0 - 4.5 = 5.5 \text{ mg/L}$$

Distance downstream where the minimum DO occurs:

$$\text{Distance} = \text{velocity} \times \text{time} = 0.1 \text{ m/s} \times 0.7631 \text{ d} \times 24 \text{ h/d} \times 3600 \text{ s/h} \\ = 6593 \text{ m} \approx 6.6 \text{ km}$$

$$5. \text{ DO} = (3 \times 6 + 10 \times 30) / (6 + 30) = 318 / 36 = 8.8 \text{ mg/L}$$

$$6. \text{ BOD}_5 = (2 \times 30 + 10 \times 5) / (2 + 10) = 110 / 12 = 9.17 \text{ mg/L} \quad \text{Eq. 5-1}$$

$$\text{From Equation 4-2, } 9.17 = \text{BOD}_L \times (1 - 10^{-0.1 \times 5});$$

$$\text{Solve for the ultimate BOD: } \text{BOD}_L = 9.17 / 0.68337 = 13.4 \text{ mg/L}$$

Compute the initial DO level and the DO deficit below the mixing zone:

$$\text{DO} = (3 \times 2 + 9 \times 10) / (2 + 10) = 8.0 \text{ mg/L}; \text{ DO}_i = 12.0 - 8.0 = 4.0 \text{ mg/L}$$

Compute the critical time, using Equation 5-2:

$$t_c = 1 / (0.3 - 0.1) \times \log\{(0.3 / 0.1) \times (1 - 4.0 \times (0.3 - 0.1) / (0.1 \times 13.4))\} = 0.412 \text{ d} \\ 9.89 \text{ h} \approx 10 \text{ h}$$

Compute the critical oxygen deficit, using Equation 5-3:

$$D_c = (0.1 \times 13.4 / (0.3 - 0.1)) \times \{10^{-0.1 \times 0.412} - 10^{-0.3 \times 0.412}\} \\ + 4 \times 10^{-0.3 \times 0.412} = 1.053 + 3.01 = 4.1 \text{ mg/L}$$

$$\text{Minimum DO} = 12.0 - 4.1 = 7.9 \text{ mg/L}$$

Distance downstream where the minimum DO occurs:

$$\text{Distance} = \text{velocity} \times \text{time} = 20 \text{ ft/min} \times 9.89 \text{ h} \times 1/60 \text{ h/min} \times 3600 \text{ s/h} \\ = 11,868 \text{ ft} \approx 2.2 \text{ miles}$$

CHAPTER 6 DRINKING WATER PURIFICATION

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(2) 150	(10) 158	(18) 164	(26) 170	(34) www.idadesa.org/pdf/ABCs1.pdf
(3) *	(11) 160	(19) 166	(27) 171	(35) www.awwa.org/mstream.htm
(4) 151	(12) 160	(20) 167	(28) 175	(36) www.epa.gov/ogwdw/pwsinv.html
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* Community systems are public systems that serve year-round residents while noncommunity systems serve travelers or intermittent users (e.g., camping sites and motels).

Solutions to Practice Problems

1. Tank volume $V = \pi(50)^2/4 \times 9 \times 7.48 \text{ gal/ft}^3 = 132,183 \text{ gal}$
Eq. 6-1: detention time $T_D = V/Q = 132,183 \text{ gal}/15,000 \text{ gal/d} \approx 8.8 \text{ d}$
(This is an unrealistic time for practical purposes. Typical detention times are about 2 h.)
2. From Eq. 6-1, $V = T_D \times Q = 3 \text{ h} \times (1 \text{ d}/24 \text{ h}) \times 10 \text{ ML/d} = 1.25 \text{ ML}$
 $V = 1.25 \text{ ML} = (1.25 \times 10^6 \text{ L}) \times (1 \text{ m}^3/1000 \text{ L}) = 1250 \text{ m}^3$
 $\text{SWD} = 1250 \text{ m}^3/(10 \times 25) \text{ m}^2 = 5 \text{ m}$
3. $V_O = 500 \text{ gal/d ft}^2 \times 1 \text{ ft}^3/7.48 \text{ gal} = 66.8 \text{ ft/d}$
 $66.8 \text{ ft/d} \times 1 \text{ d}/24 \text{ h} \times 1 \text{ h}/60 \text{ min} \times 12 \text{ in./ft} \approx 0.5 \text{ in./min}$
4. Eq. 6-1: $V = T_D \times Q = 3 \text{ h} \times 2 \text{ mil gal/d} \times 1 \text{ d}/24 \text{ h} = 0.25 \text{ mil gal}$
 $V = 250,000 \text{ gal} \times 1 \text{ ft}^3/7.48 \text{ gal} = 33,400 \text{ ft}^3$
From Eq. 6-2: $A_S = Q/V = 2,000,000/800 = 2500 \text{ ft}^2$
Since $A = \pi D^2/4$, we get diameter $D = \sqrt{4A/\pi}$ and
 $D = \sqrt{4 \times 2500/\pi} = 56.4 \text{ ft}$; $\text{SWD} = 33,400/2500 = 13.4 \text{ ft}$