G473/573 Environmental Geology

Introductory Exercise to Quantitative Analysis
(Thinking with Numbers)

A Note About Working with Math Problems

1.10 WORKING THE PROBLEMS

Most of the chapters have end-of-chapter problems for students to work. The answers to most of the odd-numbered problems are given. These problems are designed so that students can work them using calculators, graph paper, and tables found in the appendices. Many solved example problems will be found throughout the book. By working the problems, students will gain a much deeper understanding of the material.

In working the problems, students should pay attention to the number of *significant digits* that are used. Significant digits arise when using measured values. Although we can count objects exactly, a measurement is always an approximation. The last digit in the measurement shows the degree of approximation. For example, a measurement of 17.63 cm is only an estimate. All we know for sure is that the object measured is actually somewhere between 17.625 and 17.635 cm long. The measurement 17.63 cm has four significant digits. If someone else measures the same object and says that it is 18 cm long, the actual length is between 17.5 and 18.5 cm, and the measurement has been made to two significant digits.

When two or more numbers are multiplied (or divided), their product (or quotient) should have the same number of significant digits as the multiplier (or divisor) with the least number. For example, if we measure the sides of a rectangle as 17.63 cm and 14.2356 cm, the area of the rectangle is 251.0 cm^2, not 250.97363 cm^2. We use the number of significant digits of the least precise measurement, in this case four. We report the number as 251.0, not 251, to show the number of significant digits.

When measurements are added (or subtracted), the sum (or difference) should not have any significant digits to the right of the last significant digit of any of the addends (or subtrahends). For example, if we add 17 + 2.35 + 1.346 + 0.072, the sum is 21, not 20.768. Since 17 has only two significant digits, the sum can only have two significant digits. Notice that we have rounded the number that is obtained from the calculator to the appropriate number of significant digits. However, if the measurements were 17.0, 2.35, 1.346, and 0.072, the sum would be 20.8, not 21, because 17.0 has three significant digits. Be aware that the numbers 17, 17.0, 17.00, and 17.000 differ in the number of significant digits. When zeros occur to the left of the decimal, it is harder to determine the number of significant digits. For example, 100.0 has four significant digits, but does 100 have one, two, or three significant digits? Unless an uncertainty range is specified, this question is unanswered. For example, 100 ± 1 has three significant digits and 100 ± 10 has two significant digits. For purposes of working problems in the text, for a number such as 100 (or 2500 or 10,000) assume that it is exact and determine the number of significant digits from other numbers in the problem.

In solving the problems in the text we frequently employ the concept of *dimensional analysis*. In dimensional analysis the units of measurement are used as a guide in the calculations to obtain the desired units for the answer.

A simple example of dimensional analysis is in calculating the number of inches in a measured distance of 1.7 mi. We know that there are exactly 12 in. in 1 ft and exactly 5280 ft in 1 mi. The problem can be set up as follows:

$$1.7 \text{ mi} \times \frac{5280 \text{ ft}}{1 \text{ mi}} \times \frac{12 \text{ in.}}{1 \text{ ft}} = 107{,}712 \text{ in.}$$

Some of the units cancel each other, since they appear in both the numerator and the denominator. In this example miles and feet cancel, leaving inches as the unit.

The answer of 107,712 in. then must be adjusted to the proper number of significant digits.

EXAMPLE PROBLEM How many significant digits are in 107,712 in.?

The mileage measurement of 1.7 has only two significant digits, so we round the answer to 110,000 in., a number with two significant digits.

In working the problems, you will also need to use *conversion factors*. These are shortcuts to dimensional analysis when converting units from one system of measurement to another. Conversion factors for length, area, volume, and time are found in the appendices; those of flow are inside the front cover.

EXAMPLE PROBLEM Use a conversion factor to find the number of inches in 1.7 miles.

In Appendix 7 we see that 1 mi is equal to 63,360 in.

$$1.7 \text{ mi} \times \frac{63{,}360 \text{ in.}}{1 \text{ mi}} = 107{,}710 \text{ in.}$$

$$\approx 110{,}000 \quad \text{(rounded to the correct number of significant digits)}$$

The units with which you will work in this book have all been derived from three basic factors, mass *(M)*, time *(T)*, and length *(L)*. Areas are in units of length times length (L^2) and volumes are in units of length cubed (L^3). For example, velocity is length divided by time (L/T) and is expressed in such units as feet per day. Concentration is mass of solute per unit volume of solution (M/L^3) and is expressed in units such as milligrams per liter. Density is the mass of an object per unit volume (M/L^3) and is expressed in units such as kilograms per cubic meter. As a check on dimensional analysis using units, it is often helpful to conduct dimensional analysis using *M*, *L*, and *T*.

Conversion Tables / Basic Math Functions

TABLE 4.1 English and SI Units

$1 N = 1 Kg \cdot m/sec^2$

Parameter	English Unit	SI Unit	Conversion Factor	Dimensional Formula
Force	pound (lb)	newton (N)	1 lb = 4.448 N	ML/T^2
Mass	slug	kilogram (kg)	1 slug = 14.594 kg	M
Length	foot (ft)	meter (m)	1 ft = 0.3048 m	L
Time	second (s)	second	1 s = 1 s	T
Density	$slug/ft^3$	kg/m^3	1 $slug/ft^3$ = 515.4 kg/m^3	M/L^3
Specific weight	lb/ft^3	N/m^3	1 lb/ft^3 = 157.1 N/m^3	M/L^2T^2
Pressure	lb/ft^2	N/m^2	1 lb/ft^2 = 47.88 N/m^2	M/LT^2
Dynamic viscosity	$lb\text{-}s/ft^2$	$N \cdot s/m^2$	1 $lb\text{-}s/ft^2$ = 47.88 $N \cdot s/m^2$	M/LT
Bulk modulus	lb/ft^2	N/m^2	1 lb/ft^2 = 47.88 N/m^2	M/LT^2

g = ACCELERATION DUE TO GRAVITY = $9.8\ m/sec^2$

Equations for areas and volumes

Circumference of circle = 3.1416 × dia = 6.2832 × radius
Area of circle = 0.7854 × $(dia)^2$ = 3.1416 × $(radius)^2$
Area of sphere = 3.1416 × $(dia)^2$
Volume of sphere = 0.5236 × $(dia)^3$
Area of triangle = 0.5 × base × height
Area of trapezoid = 0.5 × sum of the two parallel sides × height
Area of square, rectangle, or parallelogram = base × height
Volume of pyramid = area of base × 1/3 height
Volume of cone = 0.2618 × (dia of base)^2 × height
Volume of cylinder = 0.7854 × height × $(dia)^2$

Pressure

Unit	Equivalent[1,2] pounds per square inch	pounds per square feet	atmospheres	kilograms per square centimeter	kilograms per square meter	inches of water (68°F)[3]	feet of water (68°F)[3]	inches of mercury (32°F)[4]	millimeters of mercury (32°F)[4]	bars	kilo Pascals
pounds per square inch	1	144	6.805×10^{-2}	7.031×10^{-2}	703.1	27.73	2.311	2.036	51.72	6.895×10^{-2}	6.895
pounds per square feet	6.945×10^{-3}	1	4.73×10^{-4}	4.88×10^{-4}	4.882	0.1926	1.605×10^{-2}	1.414×10^{-2}	0.3591	4.79×10^{-4}	4.79×10^{-2}
atmospheres	14.7	2,116	1	1.033	1.033×10^{4}	407.5	33.96	29.92	760	1.013	101.3
kilograms per square centimeter	14.22	2,048	0.9678	1	1×10^{4}	394.4	32.87	28.96	735.6	0.9807	98.07
kilograms per square meter	1.422×10^{-3}	0.2048	9.678×10^{-5}	0.001	1	3.944×10^{-2}	3.287×10^{-3}	2.896×10^{-3}	7.356×10^{-2}	9.807×10^{-5}	9.807×10^{-3}
inches of water (68°F)[3]	3.609×10^{-2}	5.197	2.454×10^{-3}	2.53×10^{-3}	25.38	1	8.333×10^{-2}	7.343×10^{-2}	1.865	2.49×10^{-3}	0.249
feet of water (68°F)[3]	0.4328	62.32	2.945×10^{-2}	3.043×10^{-2}	304.3	12	1	0.8812	22.38	2.984×10^{-2}	2.984
inches of mercury (32°F)[4]	0.4912	70.73	3.342×10^{-2}	3.453×10^{-2}	345.3	13.62	1.135	1	25.4	3.386×10^{-2}	3.386
millimeters of mercury (32°)[4]	1.934×10^{-2}	2.785	1.316×10^{-3}	1.36×10^{-3}	13.6	0.5362	4.468×10^{-2}	3.937×10^{-2}	1	1.333×10^{-3}	0.1333
bars	14.5	2,089	0.9869	1.02	1.02×10^{4}	402.2	33.51	29.53	750.1	1	100
kilo Pascals	0.145	20.89	9.869×10^{-3}	1.02×10^{-2}	102	4.022	0.3351	0.2953	7.501	0.01	1

APPENDIX 7
Table for length conversion

Unit	mm	cm	m	km	in	ft	yd	mi
1 millimeter	1	0.1	0.001	10^{-6}	0.0397	0.00328	0.00109	6.21×10^{-7}
1 centimeter	10	1	0.01	0.0001	0.3937	0.0328	0.0109	6.21×10^{-6}
1 meter	1000	100	1	0.001	39.37	3.281	1.094	6.21×10^{-4}
1 kilometer	10^6	10^5	1000	1	39,370	3281	1093.6	0.621
1 inch	25.4	2.54	0.0254	2.54×10^{-5}	1	0.0833	0.0278	1.58×10^{-5}
1 foot	304.8	30.48	0.3048	3.05×10^{-4}	12	1	0.333	1.89×10^{-4}
1 yard	914.4	91.44	0.9144	9.14×10^{-4}	36	3	1	5.68×10^{-4}
1 mile	1.61×10^6	1.01×10^5	1.61×10^3	1.6093	63,360	5280	1760	1

APPENDIX 8
Table for area conversion

Unit	cm^2	m^2	km^2	ha	in^2	ft^2	yd^2	mi^2	ac
1 sq. centimeter	1	0.0001	10^{-10}	10^{-8}	0.155	1.08×10^{-3}	1.2×10^{-4}	3.86×10^{-11}	2.47×10^{-8}
1 sq. meter	10^4	1	10^{-6}	10^{-4}	1550	10.76	1.196	3.86×10^{-7}	2.47×10^{-4}
1 sq. kilometer	10^{10}	10^6	1	100	1.55×10^9	1.076×10^7	1.196×10^6	0.3861	247.1
1 hectare	10^8	10^4	0.01	1	1.55×10^7	1.076×10^5	1.196×10^4	3.861×10^{-3}	2.471
1 sq. inch	6.452	6.45×10^{-4}	6.45×10^{10}	6.45×10^{-8}	1	6.94×10^{-3}	7.7×10^{-4}	2.49×10^{-10}	1.574×10^{-7}
1 sq. foot	929	0.0929	9.29×10^{-8}	9.29×10^{-6}	144	1	0.111	3.587×10^{-8}	2.3×10^{-5}
1 sq. yard	8361	0.8361	8.36×10^{-7}	8.36×10^{-5}	1296	9	1	3.23×10^{-7}	2.07×10^{-4}
1 sq. mile	2.59×10^{10}	2.59×10^6	2.59	259	4.01×10^9	2.79×10^7	3.098×10^6	1	640
1 acre	4.04×10^7	4047	4.047×10^{-3}	0.4047	6.27×10^6	43,560	4840	1.562×10^{-3}	1

APPENDIX 9
Table for volume conversion

Unit	mL	liters	m^3	in^3	ft^3	gal	ac-ft	million gal
1 milliliter	1	0.001	10^{-6}	0.06102	3.53×10^{-5}	2.64×10^4	8.1×10^{-10}	2.64×10^{-10}
1 liter	10^3	1	0.001	61.02	0.0353	0.264	8.1×10^{-7}	2.64×10^{-7}
1 cu. meter	10^6	1000	1	61,023	35.31	264.17	8.1×10^{-4}	2.64×10^{-4}
1 cu. inch	16.39	1.64×10^{-2}	1.64×10^{-5}	1	5.79×10^{-4}	4.33×10^{-3}	1.218×10^{-8}	4.329×10^{-9}
1 cu. foot	28,317	28.317	0.02832	1728	1	7.48	2.296×10^{-5}	7.48×10^6
1 U.S. gallon	3785.4	3.785	3.78×10^{-3}	231	0.134	1	3.069×10^{-6}	10^6
1 acre-foot	1.233×10^9	1.233×10^6	1233.5	75.27×10^6	43,560	3.26×10^5	1	0.3260
1 million gallons	3.785×10^9	3.785×10^6	3785	2.31×10^8	1.338×10^5	10^6	3.0684	1

APPENDIX 10
Table for time conversion

Unit	sec	min	hours	days	years
1 second	1	1.67×10^{-2}	2.77×10^{-4}	1.157×10^{-5}	3.17×10^{-8}
1 minute	60	1	1.67×10^{-2}	6.94×10^{-4}	1.90×10^{-6}
1 hour	360	60	1	4.17×10^{-2}	1.14×10^{-4}
1 day	8.64×10^4	1440	24	1	2.74×10^{-3}
1 year	3.15×10^7	5.256×10^5	8760	365	1

Appendix 9.A. Continued

Velocity

Unit	Equivalent[1,2]				
	feet per day	kilometers per hour	feet per second	miles per hour	meters per second
feet per day	1	1.27×10^{-5}	1.157×10^{-5}	7.891×10^{-6}	3.528×10^{-6}
kilometers per hour	7.874×10^{4}	1	0.9113	0.6214	0.2778
feet per second	8.64×10^{4}	1.097	1	0.6818	0.3048
miles per hour	1.267×10^{5}	1.609	1.467	1	0.447
meters per second	2.835×10^{5}	3.6	3.281	2.237	1

Mass

Unit	Equivalent[1,2]							
	ounce	pound	kilogram	metric slug	slug	short ton	metric ton	long ton
ounce	1	6.25×10^{-2}	2.835×10^{-2}	2.891×10^{-3}	1.943×10^{-3}	3.125×10^{-5}	2.835×10^{-5}	2.79×10^{-5}
pound	16	1	0.4536	4.625×10^{-2}	3.108×10^{-2}	5×10^{-4}	4.536×10^{-4}	4.464×10^{-4}
kilogram	35.28	2.205	1	0.102	6.852×10^{-2}	1.102×10^{-3}	0.001	9.842×10^{-4}
metric slug	345.9	21.62	9.807	1	0.6721	92.51	9.807×10^{-3}	9.651×10^{-3}
slug	514.7	32.17	14.59	1.49	1	62.17	1.459×10^{-2}	1.436×10^{-2}
short ton	3.2×10^{4}	2,000	907.2	92.51	62.16	1	0.907	0.8929
metric ton	3.528×10^{4}	2,205	1,000	102	68.52	1.103	1	0.9842
long ton	3.584×10^{4}	2,240	1,016	103.7	69.63	1.12	1.016	1

Force

Unit	Equivalent[1,2]			
	dyne	newton	$\text{pound}_{\text{force}}$	$\text{kilogram}_{\text{force}}$
dynes	1	1×10^{-5}	2.248×10^{-6}	1.02×10^{-6}
newtons	1×10^{5}	1	0.2248	0.102
$\text{pound}_{\text{force}}$	4.448×10^{5}	4.448	1	0.4536
$\text{kilogram}_{\text{force}}$	9.807×10^{5}	9.807	2.205	1

Density

Unit	Equivalent[1,2]				
	pounds per cubic inch	pounds per cubic feet	pounds per gallon	grams per cubic centimeter	grams per liter
pounds per cubic inch	1	1,728	231	27.68	2.768×10^{4}
pounds per cubic feet	5.787×10^{-4}	1	0.1337	1.6×10^{-2}	16.02
pounds per gallon	4.33×10^{-3}	7.481	1	0.1198	119.8
grams per cubic centimeter	3.61×10^{-2}	62.43	8.345	1	1,000
grams per liter	3.61×10^{-5}	6.24×10^{-2}	8.35×10^{-3}	0.001	1

APPENDIX 9.A.
Conversion Tables

Length

Unit	Equivalent[1,2]					
	millimeters	inches	feet	meters	kilometers	miles
millimeters	1	3.937×10^{-2}	3.281×10^{-3}	1×10^{-3}	1×10^{-6}	6.214×10^{-7}
inches	25.4	1	8.33×10^{-2}	2.54×10^{-2}	2.54×10^{-5}	1.578×10^{-5}
feet	304.8	12	1	0.3048	3.048×10^{-4}	1.894×10^{-4}
meters	1,000	39.37	3.281	1	1×10^{-3}	6.214×10^{-4}
kilometers	1×10^{6}	3.937×10^{4}	3,281	1,000	1	0.6214
miles	1.609×10^{6}	6.336×10^{4}	5,280	1,609	1.609	1

Area

Unit	Equivalent[1,2]						
	square inches	square feet	square meters	acres	hectares	square kilometers	square miles
square inches	1	6.944×10^{-3}	6.452×10^{-4}	1.594×10^{-8}	6.452×10^{-8}	6.452×10^{-10}	2.491×10^{-10}
square feet	144	1	9.29×10^{-2}	2.296×10^{-5}	9.29×10^{-9}	9.29×10^{-8}	3.587×10^{-8}
square meters	1,550	10.76	1	2.471×10^{-4}	1×10^{-4}	1×10^{-6}	3.861×10^{-7}
acres	6.273×10^{6}	4.356×10^{4}	4,047	1	0.4047	4.047×10^{-3}	1.563×10^{-3}
hectares	1.55×10^{7}	1.076×10^{5}	1×10^{4}	2.471	1	0.01	3.861×10^{-3}
square kilometers	1.55×10^{9}	1.076×10^{7}	1×10^{6}	247.1	100	1	0.3861
square miles	4.014×10^{9}	2.788×10^{7}	2.59×10^{6}	640	259	2.59	1

Volume

Unit	Equivalent[1,2]						
	cubic inches	liters	gallons	cubic feet	cubic yards	cubic meters	acre-ft
cubic inches	1	1.639×10^{-2}	4.329×10^{-3}	5.787×10^{-4}	2.143×10^{-5}	1.639×10^{-5}	1.329×10^{-8}
liters	61.02	1	0.2642	3.531×10^{-2}	1.308×10^{-3}	0.001	8.106×10^{-7}
gallons	231.0	3.785	1	0.1337	4.951×10^{-3}	3.785×10^{-3}	3.068×10^{-6}
cubic feet	1,728	28.32	7.481	1	3.704×10^{-2}	2.832×10^{-3}	2.296×10^{-5}
cubic yards	4.666×10^{4}	764.6	202.0	27	1	0.7646	6.198×10^{-4}
cubic meters	6.102×10^{4}	1,000	264.2	35.31	1.308	1	8.106×10^{-4}
acre-ft	7.527×10^{7}	1.233×10^{6}	3.259×10^{5}	4.356×10^{4}	1,613	1,233	1

Discharge (flow rate, volume/time)

Unit	Equivalent[1,2]				
	gallons per minute	liters per second	acre-feet per day	cubic feet per second	cubic meters per day
gallons per minute	1	6.309×10^{-2}	4.419×10^{-3}	2.228×10^{-3}	5.45
liters per second	15.85	1	7.005×10^{-2}	3.531×10^{-2}	86.4
acre-feet per day	226.3	14.28	1	0.5042	1,234
cubic feet per second	448.8	28.32	1.983	1	2,447
cubic meters per day	1.369×10^{9}	8.64×10^{7}	6.051×10^{6}	3.051×10^{6}	1

A Review of Drawing Contour Lines

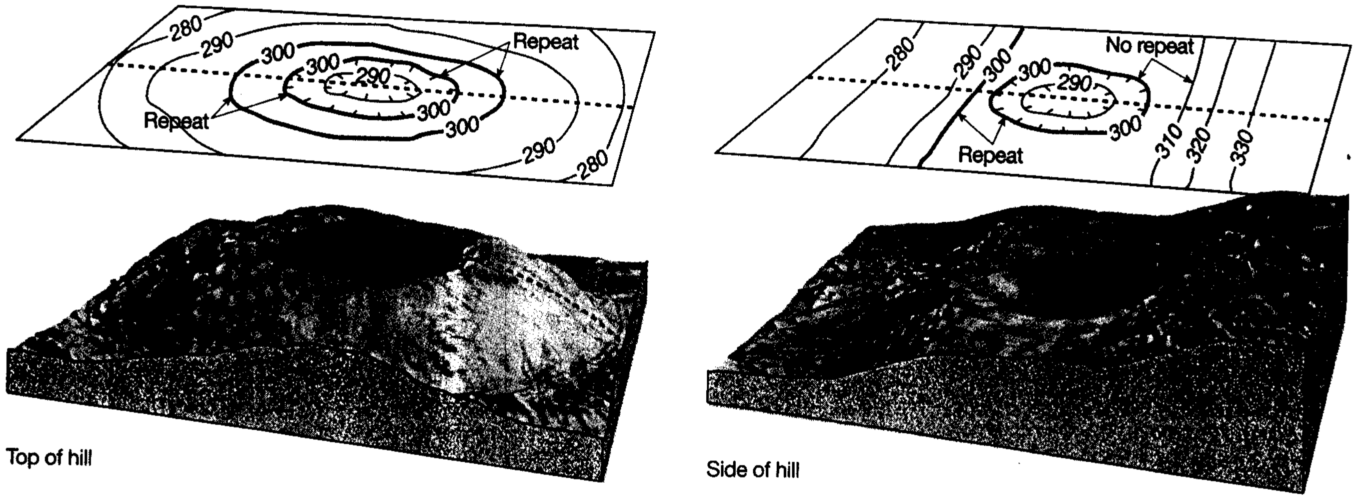


FIGURE 8.10 Contour lines repeat on opposite sides of a depression (left illustration), except when the depression occurs on a slope (right illustration).

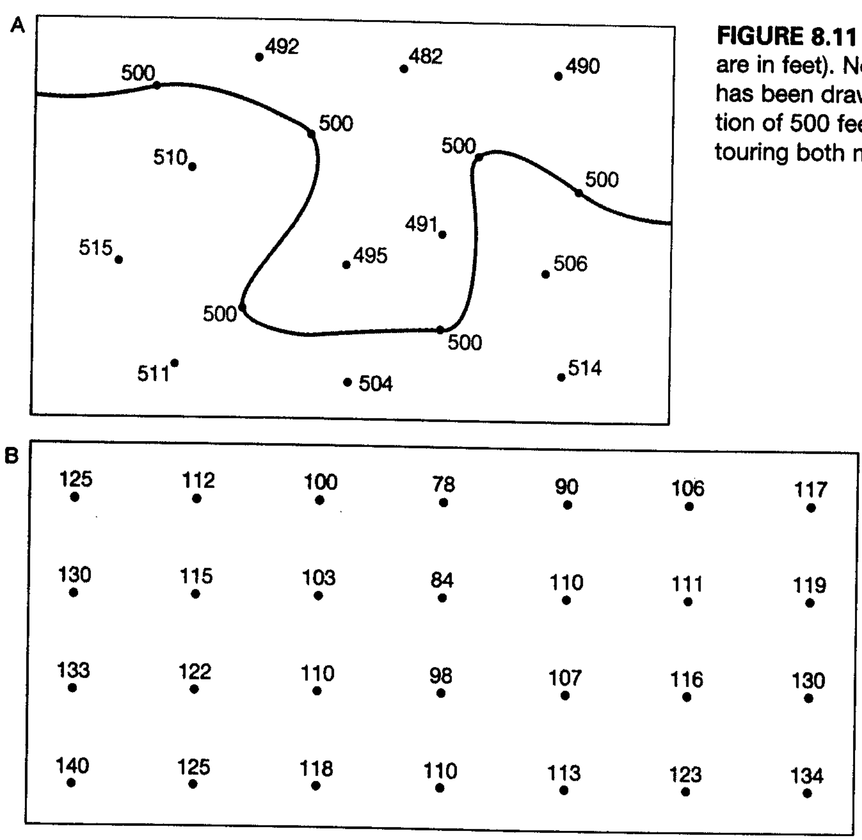


FIGURE 8.11 Topographic map construction (elevations are in feet). Notice in map **A** that a 500-foot contour line has been drawn through all the points that have an elevation of 500 feet above mean sea level. Can you finish contouring both maps using a contour interval of 10 feet?

RULES FOR CONTOUR LINES

1. Every point on a contour line is of the exact same elevation; that is, contour lines connect points of equal elevation.

2. Contour lines always separate points of higher elevation (uphill) from points of lower elevation (downhill). You must determine which direction on the map is higher and which is lower, relative to the contour line in question, by checking adjacent elevations.

3. Contour lines always close to form an irregular circle. But sometimes part of a contour line extends beyond the mapped area so that you cannot see the entire circle formed.

4. The elevation between any two adjacent contour lines of different elevation on a topographic map is the *contour interval*. Often every fifth contour line is heavier so that you can count by five-times the contour interval. These heavier contour lines are known as *index contours*, because they generally have elevations printed on them.

5. Contour lines never cross one another except for one rare case: where an overhanging cliff is present. In such a case, the hidden contours are dashed.

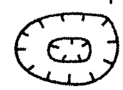
6. Contour lines can merge to form a single contour line only where there is a vertical cliff.

7. Evenly spaced contour lines of different elevation represent a uniform slope.

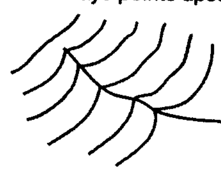
8. The closer the contour lines are to one another the steeper the slope. In other words, the steeper the slope the closer the contour lines.

9. A concentric series of closed contours represents a hill:

10. *Depression contours* have hachure marks on the downhill side and represent a closed depression:



11. Contour lines form a V pattern when crossing streams. The apex of the V always points upstream (uphill):



12. Contour lines that occur on opposite sides of a valley always occur in pairs.

13. Topographic maps published by the U.S. Geological Survey are contoured in feet or meters referenced to sea level.

FIGURE 8.8 Rules for contour lines on topographic maps.

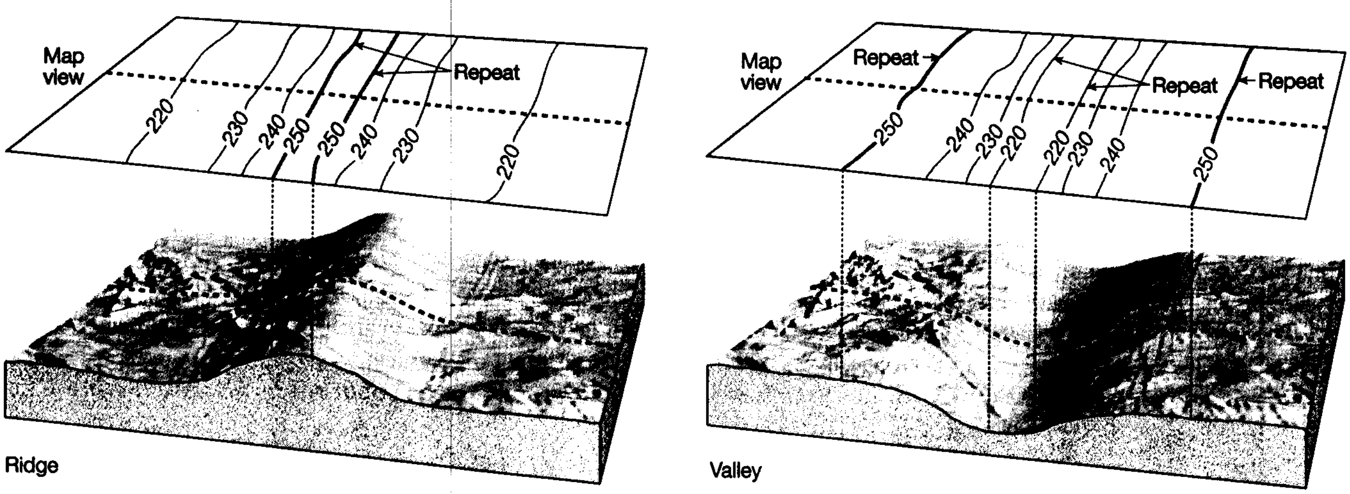


FIGURE 8.9 Contour lines repeat (occur in pairs) on opposite sides of ridges and valleys. For example, in the ridge illustration, if you walked the dashed line from right to left, you would cross the 230-foot contour line, go over the top of the ridge, and cross the 230-foot contour again as you walk down the other side.

Introductory Problem Set

PROBLEMS

Answers to odd-numbered problems will appear at the end of the book.

1. A farmer has a reservoir with vertical sides and a surface area of 2.5 ac. Following the rainy season, the reservoir is filled to a depth of 3.0 m. During the dry season the reservoir loses 2.5 in. of water per week (wk) to evaporation. If the average irrigation demand during the dry season is 0.23 ac-ft per day, for how many weeks can the farmer irrigate from the reservoir?
2. How long must a pump with a capacity of 12 gal/min pump to fill a tank with a capacity of 37 m^3?
3. A circular water transmission pipe has a diameter of 1.0 ft and is 8.3 mi long. How much water does it take to fill the pipe?
4. If the water is flowing into the pipe of Problem 3 at a velocity of 1.3 feet per second (ft/s), what is the rate at which the pipe is transmitting water?
5. A small urban watershed has an area of 16.34 mi^2. A summer storm drops an average of 1.50 in. of rain over the entire watershed. If 50% of the rainfall runs off the watershed into surface-water bodies, what is the volume of runoff:
   A. In cubic inches?
   B. In cubic feet?
   C. In cubic meters?

1.1. The annual evaporation from a lake, with a surface area of 1600 hectares, is 3 meters. Determine the average daily evaporation rate in hectare-centimeters per day during the year.

1.2. Rainfall takes place at an average intensity of 1 cm/h over a 250-hectare area for 3 days. Determine the average rate of rainfall in cubic meters per second (m^3/s). Determine the 3-day volume of rainfall in hectare-cm and hectare-meters. Also determine the 3-day volume of rainfall in centimeters of equivalent depth over the 250-hectare area.

1.3. Water is to be supplied from a reservoir fed by a stream with a discharge of 2 m^3/s to meet domestic requirements of an area with a population of 150,000. The average daily consumption is 300 liters per person. The lowest discharge of the stream is 0.25 m^3/s for a period of 15 days. Determine the reservoir size in km^3 and the rate of outflow when the reservoir is full.

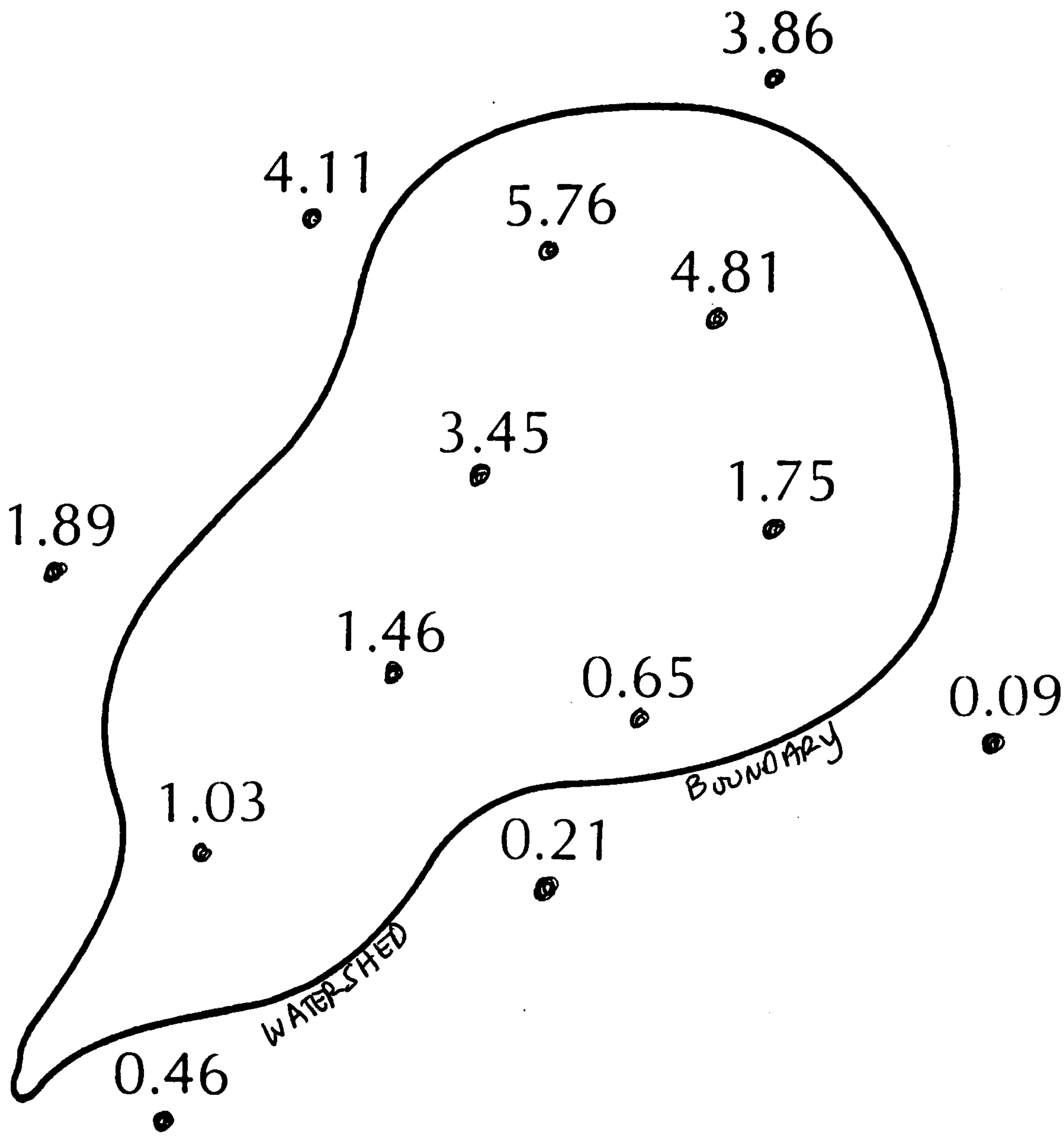
1.4. Compute the time required to fill the reservoir in Exercise 1.3 when the demand of the population is being simultaneously fed by the stream and the reservoir is empty after a drought period. The stream discharge is 1.75 m^3/s.

1.5. An area is being irrigated by a stream with a drainage area of 300 km^2. The drainage area contribution is 0.1 $m^3/s/km^2$. Determine the discharge of the channel and the area irrigated if 0.37 m^3/s are required per 1000 hectares.

1.6. The average monthly precipitation in a watershed of 4500 km^2 is 46 cm. If the cumulative losses are 20% of precipitation, determine the area of Exercise 1.5 that can be irrigated with the remaining water. Also calculate the channel discharge.

1.7. Estimate the storage capacity of a reservoir for Exercise 1.6 when the average precipitation is 28 cm for a period of 20 days. The area calculated above is to be continuously supplied with its full demand.

1.8. Water is to be supplied to an area for both domestic and agricultural purposes. The population is 200,000 and the area to be irrigated is 3600 hectares. Water is to be pumped from the river. If the average daily consumption is 320 liters per person and the agricultural demand 0.33 $m^3/s/1000$ hectares, find the number of pumps required when 30% of the pumps are required to be standby. Also calculate the minimum discharge in the river to meet the above demand. The individual pump capacity is 0.1 m^3/s.



The map above shows an outline of a drainage basin or watershed. The data points represent locations of rain gage stations. The numbers show the total 24-hour rainfall amounts (inches) for each station. Draw an isohyetal contour map (contour map with lines connecting points of equal rainfall) using a contour interval of 0.5 inches (i.e. draw contour lines for the following isohyets: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5). Remember to follow the rules of contour and to interpolate the lines between data points as necessary.

Calculate the following data parameters for the watershed:

Maximum 24-hour Rainfall Recorded ____________

Minimum 24-hour Rainfall Recorded ____________

Average 24-hour Rainfall Recorded ____________

Standard Deviation of 24-hour Rainfall Rec'd ____________

Median of 24-hour Rainfall Recorded ____________

Total Number of Gage Stations ____________