# INTRODUCTION TO TOPOGRAPHIC MAPS

*c:\wou\geomorph\f2000\introlab.wpd*

**All of the following questions refer to the Monmouth, OR Quadrangle.**

1) What is the fractional scale, contour interval, and magnetic declination of this map?
a) Scale: b) Contour Interval: c) Declination:

2) What quadrangle maps are located immediately adjacent to the Monmouth Quad.?
a) North: b) South: c) East: d) West:

3) What is the quadrangle size series of this map (in long. and lat.)?

4) What is the date of publication of this map?

5) What does the tick with 4956000m N. mean? (lower right of map)

6) What is the name of the major fluvial system flowing through this area. Of What larger drainage basin(s) does this river form a part of?

7) What is the approximate elevation of the Natural Sciences Building based on the map representation?

8) Given the fractional scale determine the following

5 inches on the map= ____________ Feet on ground = __________ Miles on ground.
10 inches on the map= ___________ Meters on ground = _________ Kilometers on ground.

9) A. What is the road distance in miles along Rt. 99 between Helmick State Park and Monmouth city limits?

B. What is the distance in kilometers?

10) A. Determine the average stream gradients (in Ft/Mi) for the following drainages:

A. Willamette River: Gradient: Length:
B. Luckiamute River: Gradient: Length:

11) A. What is the highest point of elevation represented on this map?

B. What is the lowest point of elevation represented on this map?

C. What is the maximum relief.

12) A. What is the longitude and latitude location of the road intersection at Buena Vista

B. What is the longitude and latitude location of Davidson Hill?

C. What is the straight line distance in miles between these two points?

D. What is the azimuth bearing FROM Davidson Hill TOWARDS Buena Vista?

E. What is the quadrant bearing FROM Buena Vista TOWARDS Davidson Hill?

13) A. What is the nature of the topographic slope in the vicinity of the town of Monmouth?

C. What is the local relief between WOU and the Willamette adjacent to Independence?

D. Is the outline of the topography east of Independence relatively arcuate or irregular in outline?

E. What processes might have formed the pattern in D above?

14) Examine the cultural activity immediately north of Monmouth and Independence.

A. Write a brief assessment of the potential for environmental degradation to the surface and groundwater of this area. List three types of water quality degradation (i.e. contamination) problems that may exist in this area.

18. Determine the elevations of the following locations:
A. Wigrich
B. Oak Hill (SC)
C. Dicker Reservoir (NE)
D. Davidson Bridge (SC)

19. Draw a topographic profile along a line connecting Oak Hill (SC) to Vitae Springs. Use a horizontal scale of 1 in = 4000 Ft, and a vertical scale of 1 in = 333.33 ft (see attached profile paper).

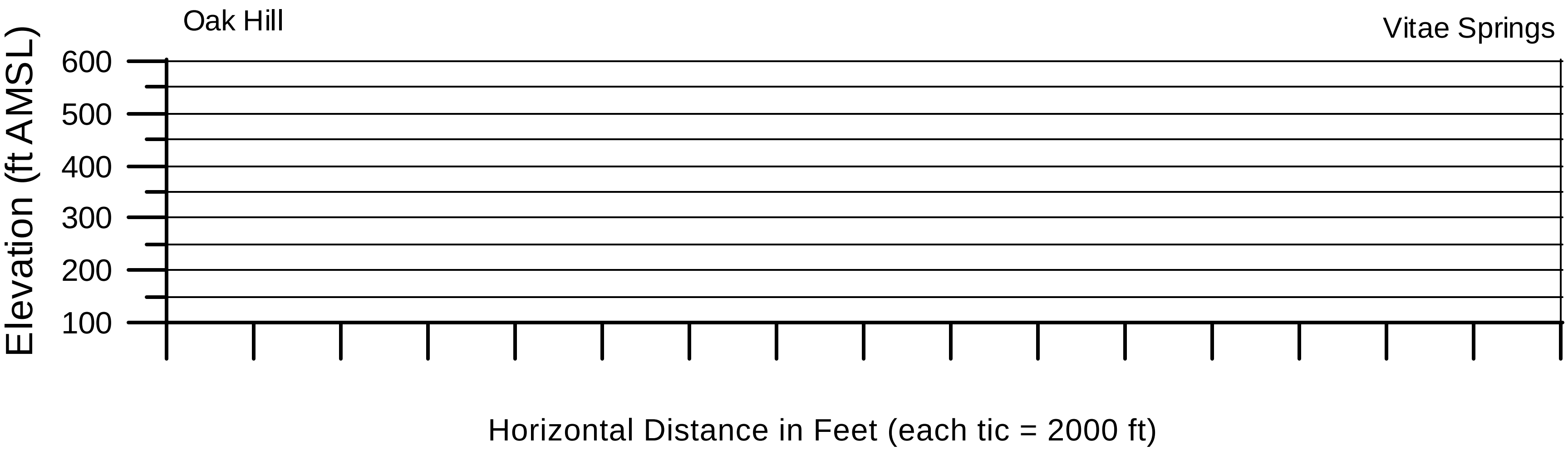
A. Determine the minimum slope grade represented on the profile in percent.

B. Determine the maximum slope grade represented on the profile in percent.

C. Where are the areas most likely associated with flooding?

D. The vertical exaggeration of a profile is calculated by: VE = H scale / V scale;
Calculate the vertical exaggeration represented on the attached profile.

# Topographic Profile from Oak Hill to Vitae Springs, Monmouth, OR Quad.




Horizontal Scale: 1 in = 4000 ft
Vertical Scale: 1 in = 333.33 ft

V.E. = H/V =

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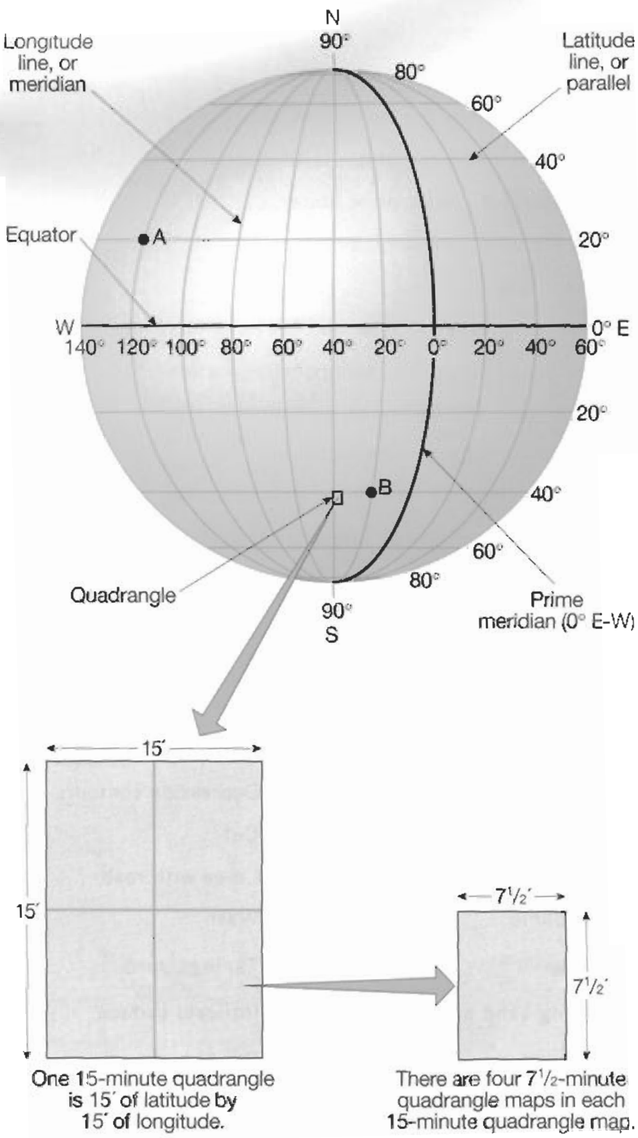



**FIGURE 9.1** Latitude and longitude geographic grid and coordinate system. Earth's spherical surface is divided into lines of latitude (*parallels*) that go around the world parallel to the Equator, and lines of longitude (*meridians*) that go around the world from pole to pole. There are 360 degrees (360°) around the entire Earth, so the distance from the Equator to a pole (one-fourth of the way around Earth) is 90° of latitude. The Equator is assigned a value of zero degrees (0°) latitude, the North Pole is 90 degrees North latitude (90° N), and the South Pole is 90 degrees south latitude (90° S). The *prime meridian* is zero degrees of longitude and runs from pole to pole through Greenwich, England. Locations in Earth's Eastern Hemisphere are located in degrees east of the prime meridian, and points in the Western Hemisphere are in located in degrees west of the prime meridian. Therefore, any point on Earth (or a map) can be located by its latitude-longitude coordinates. The latitude coordinate of the point is its position in degrees north or south of the Equator. The longitude coordinate of the point is its position in degrees east or west of the Prime Meridian. For example, point **A** is located at coordinates of: 20° North latitude, 120° West longitude.

For greater detail, each degree of latitude and longitude can also be subdivided into 60 minutes (60′), and each minute can be divided into 60 seconds (60″). Note that a 15-minute (15′) quadrangle map represents an area of Earth's surface that is 15 minutes of longitude wide (E-W) and 15 minutes of latitude long (N-S). A 7.5-minute quadrangle map is one-fourth of a 15-minute quadrangle map.

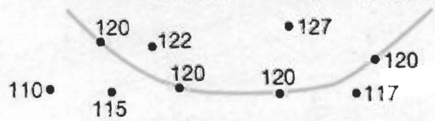
used to discover changes on the landscape, and the changes are overprinted on the maps in a standout color like purple, red, or gray.

## Contour Lines

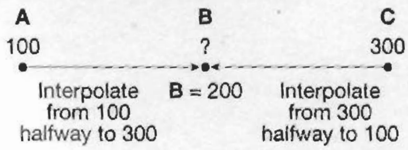
Examine the image of one of the Galapagos Islands in Figure 9.4, a perspective view of the landscape that has been false colored to show relief. It was made by transmitting imaging radar from an airplane (flying at a constant altitude). Timed pulses of the radar measured the distance between the airplane (flying at a constant elevation) and the ground. Overlapping pulses of the radar produced the three-dimensional perspective similar to the way that overlapping lines of sight from your eyes enable you to see in stereo. Notice that the island has a distinct coastline, which has the same elevation all of the way around the island (zero feet above sea level). Similarly, all points at the very top of the green (including yellow-green) regions form a line at about 300 ft above sea level. These lines of equal elevation (i.e., the coastline and 300-ft line) are called **contour lines**. Unfortunately, the 1200-ft contour line (located at the boundary between yellow and pink) is not visible behind Darwin and Wolf Volcanoes in this perspective view. The only way that you could see all of the 0-ft, 300-ft, and 1200-ft contour lines at the same time would be if you viewed

## RULES FOR CONTOUR LINES

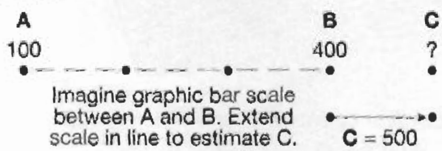
1. Every point on a contour line is of the exact same elevation; that is, contour lines connect points of equal elevation. The contour lines are constructed by surveying the elevation of points, then connecting points of equal elevation.




2. Interpolation is used to estimate the elevation of a point B located in line between points A and C of known elevation. To estimate the elevation of point B:




3. Extrapolation is used to estimate the elevations of a point C located in line beyond points A and B of known elevation. To estimate the elevation of point C, use the distance between A and B as a ruler or graphic bar scale to estimate in line to elevation C.

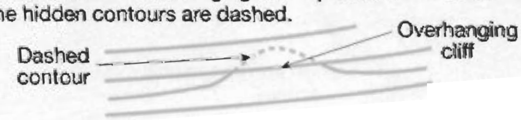



4. Contour lines always separate points of higher elevation (uphill) from points of lower elevation (downhill). You must determine which direction on the map is higher and which is lower, relative to the contour line in question, by checking adjacent elevations.

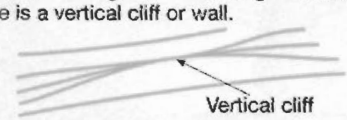
5. Contour lines always close to form an irregular circle. But sometimes part of a contour line extends beyond the mapped area so that you cannot see the entire circle formed.

6. 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.

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




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

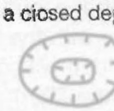



9. Evenly spaced contour lines of different elevation represent a uniform slope.

10. The closer the contour lines are to each other the steeper the slope. In other words, the steeper the slope the closer the contour lines.

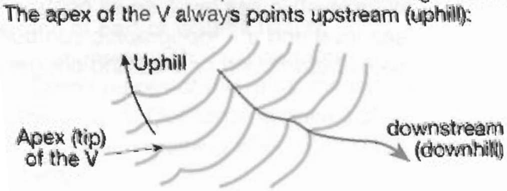

11. A concentric series of closed contours represents a hill:

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



See Figure 9.8

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




14. Contour lines that occur on opposite sides of a valley or ridge always occur in pairs. See Figure 9.9.

**FIGURE 9.6** Rules for constructing and interpreting contour lines on topographic maps.

each having an area of 1 square mile (640 acres). These squares are called **sections.**

Sections are numbered from 1 to 36, beginning in the upper right corner (Figure 9.11B). Sometimes these are shown on topographic quadrangle maps (Figure 9.3, red grid). Any point can be located precisely within a section by dividing the section into quarters (labeled NW, NE, SW, SE). Each of these quarters can itself be subdivided into quarters and labeled (Figure 9.11C).

## GPS—Global Positioning System

The **Global Positioning System (GPS)** is a constellation of 28 navigational communication satellites in 12-hour orbits approximately 12,000 miles above Earth (about 24 of these are operational at any given time). The GPS constellation is maintained by the United States (NOAA and NASA) for operations of the U.S. Department of Defense, but it is free for anyone to use. Since GPS receivers can be purchased for as little as $100, they are widely used by airplane navigators, automated vehicle navigation systems, ship captains, hikers, and scientists to map locations on Earth. More expensive and accurate receivers with millimeter accuracy are used for space-based geodesy measurements that reveal plate motions over time (Laboratory 2).

Each GPS satellite communicates simultaneously with fixed ground-based Earth stations and other GPS satellites, so it knows exactly where it is located relative to the center of Earth and Universal Time Coordinated (UTC, also called Greenwich Mean Time). Each GPS satellite also transmits its own radio signal on a different channel, which can be detected by a fixed or handheld GPS receiver. If you turn on a handheld GPS receiver in an unobstructed outdoor location, then the receiver immediately *acquires* (picks up) the radio channel of the strongest signal it can detect from a GPS satellite. It downloads the navigational information from that satellite channel, followed by a second, third, and so on. A receiver must acquire and process radio transmissions from at least four GPS satellites to triangulate a determination of its exact position and elevation (Figure 2.2)— this is known as a *fix*.

Most newer models of GPS receivers are *12 channel parallel receivers*, which means they can receive and process radio signals from as many as twelve satellites at the same time (the maximum possible number for any point on Earth). Older models cycle through the channels one at a time, or have fewer parallel channels, so they take longer to process data and usually give less accurate results. An unobstructed view is also best (GPS receivers cannot operate indoors). If the path from satellite to receiver is obstructed by trees, canyon walls, or buildings, then the receiver has difficulty acquiring that radio signal. It is also possible that more or fewer satellites will be nearly overhead at one time than another, because they are in constant motion within the constellation. Therefore, if you cannot obtain a fix at one time (because four satellite channels cannot be acquired), you may be able to obtain a fix in another half hour or so. Acquiring more than four satellite channels will provide more navigational data and more accurate results. Most handheld, 12-channel parallel receivers have an accuracy of about 10–15 meters.

When using a GPS receiver for the first time in a new region, it generally takes about one to three minutes for it to triangulate a fix. This information is stored in the receiver, so readings taken over the next few hours at nearby locations normally take only seconds. Consult the operational manual for your receiver so you know the time it normally takes for a *cold* fix (first time) or *warm* fix (within a few hours of the last fix).

GPS navigation does not rely on a latitude-longitude or the public land survey system. It relies on an Earth-centered geographic grid and coordinate system called the *World Geodetic System 1984* or *WGS 84*. *WGS 84* is a **datum** (survey or navigational framework) based on the Universal Transverse Mercator (UTM) grid described below.

## UTM—Universal Transverse Mercator System

The U.S. National Imagery and Mapping Agency (NIMA) developed a global military navigation grid and coordinate system in 1947 called the **Universal Transverse Mercator System (UTM)**. Unlike the latitude-longitude grid that is spherical and measured in degrees, minutes, seconds, and nautical miles (1 nautical mile = 1 minute of latitude), the UTM grid is rectangular and measured in decimal-based metric units (meters).

The UTM grid (top of Figure 9.12) is based on sixty north–south **zones**, which are strips of longitude having a width of 6°. The zones are consecutively numbered from Zone 01 (between 180° and 174° west longitude) at the left margin of the grid, to Zone 60 (between 174° and 180° east longitude) at the east margin of the grid. The location of a point within a zone is defined by its **easting** coordinate—its distance within the zone measured in meters from west to east, and a **northing** coordinate—its distance from the Equator measured in meters. In the Northern Hemisphere, northings are given in meters north of the Equator. To avoid negative numbers for northings in

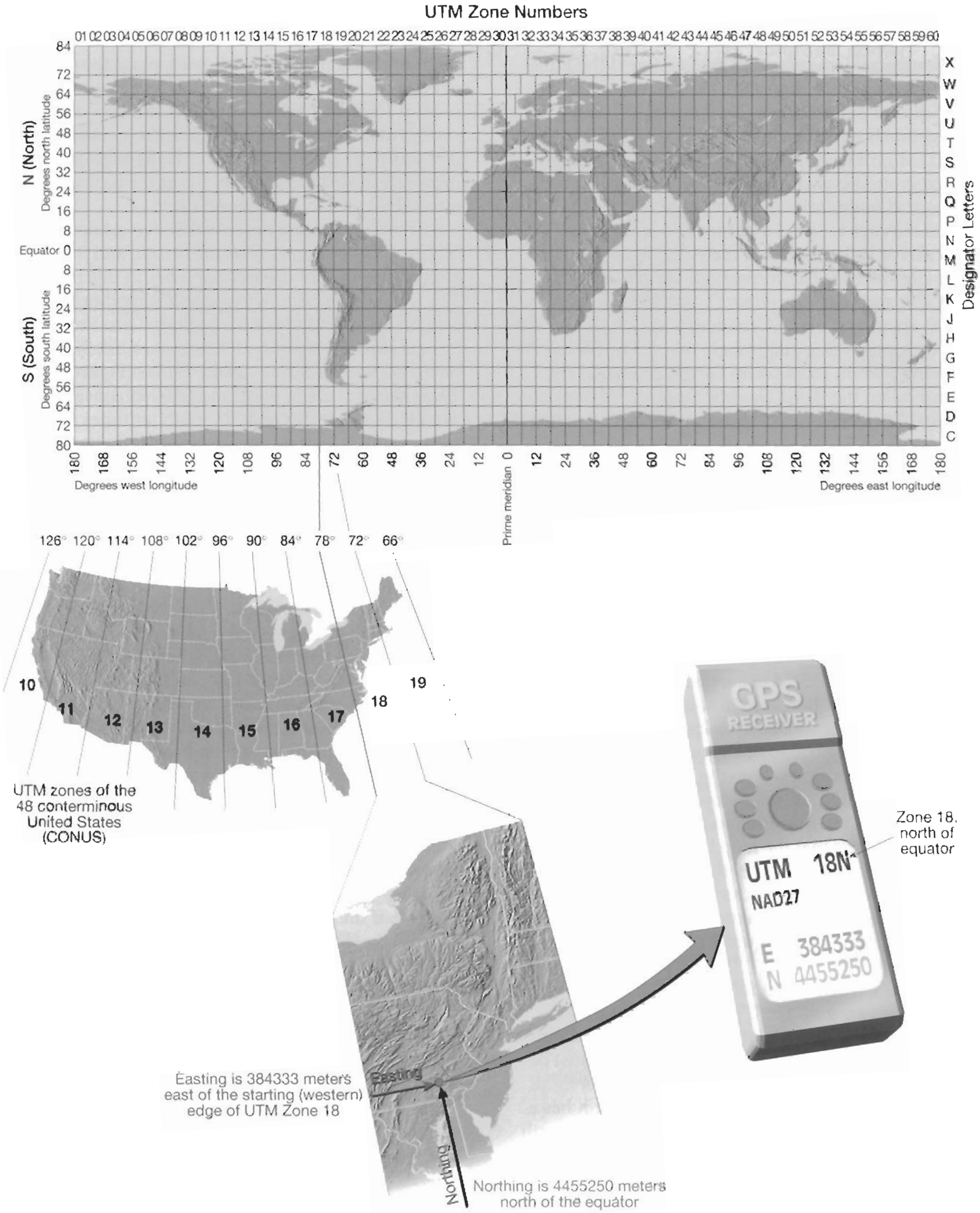



**FIGURE 9.12** UTM and GPS. A handheld Global Positioning System (GPS) receiver operated at point **X** indicates its location according to the Universal Transverse Mercator (UTM) grid and coordinate system, *North American Datum 1927* (*NAD27*). Refer to text for explanation.

the Southern Hemisphere, NIMA assigned the Equator a reference northing of 10,000,000 meters.

Since satellites did not exist until 1957, and GPS navigational satellites did not exist until decades later, the UTM grid was applied for many years using regional ground-based surveys to determine locations of the grid boundaries. Each of these regional or continental surveys is called a **datum** and is identified on the basis of its location and the year it was surveyed. Examples include *North American Datum 1927 (NAD27)* and *North American Datum 1983 (NAD83)*, which appear on many Canadian and U.S. Geological Survey topographic quadrangle maps. The Global Positioning System relies on an Earth-centered UTM datum called the *World Geodetic System 1984* or *WGS 84*, but GPS receivers can be set up to display regional datums like *NAD27*. When using GPS with a topographic map, be sure to set the GPS receiver to display the UTM datum of that map.

Study the illustration of a GPS receiver in Figure 9.12. Notice that the receiver is displaying UTM coordinates (based on *NAD27*) for a point **X** in Zone 18 (north of the Equator). Point **X** has an easting coordinate of E384333, which means that it is located 384333 meters east of the starting (west) edge of Zone 18. Point **X** also has a northing coordinate of N4455250, which means that it is located 4455250 meters north of the Equator. Therefore, Point **X** is located in southeast Pennsylvania. To plot Point **X** on a 1:24,000 scale, $7\frac{1}{2}$ minute topographic quadrangle map, see Figure 9.13.

Point **X** is located within the Lititz, PA $7\frac{1}{2}$ Minute Series (USGS, 1:24,000 scale) topographic quadrangle map (Figure 9.13). Information printed on the map margin indicates that the map has blue ticks spaced 1000 m apart along its edges that conform to *NAD27*, Zone 18. Notice how the ticks for northings (blue) and eastings (green) are represented on the northwest corner of the Lititz map—Figure 9.13B. One northing label is written out in full ($^{44}56^{000m}$ N) and one easting label is written out in full ($^{3}84^{000m}$ E), but the other values are given in UTM shorthand for thousands of meters (i.e., do not end in $^{000m}$). Since Point **X** has an easting of E384333 within Zone 18, it must be located 333 m east of the tick mark labeled $^{3}84^{000m}$ E along the top margin of the map. Since Point **X** has a northing of N4455250, it must be located 250 m north of the tick mark labeled as $^{44}55$ in UTM shorthand. Distances east and north can be measured using a ruler and the map's graphic bar scale as a reference (333 m = 0.333 km, 250 m = 0.250 km). However, you can also use the graphic bar scale to construct a UTM grid like the one in Figure 9.13C. If you construct such a grid and print it onto a transparency, then you can use it as a UTM *grid overlay*. To plot a point or determine its coordinates, place the grid overlay on top of the square kilometer in which the point is located. Then use the grid as a two-dimensional ruler for the northing and easting. Grid overlays for many different scales of UTM grids are provided in GeoTools Sheets 1–3 at the back of the manual for you to cut out and use.

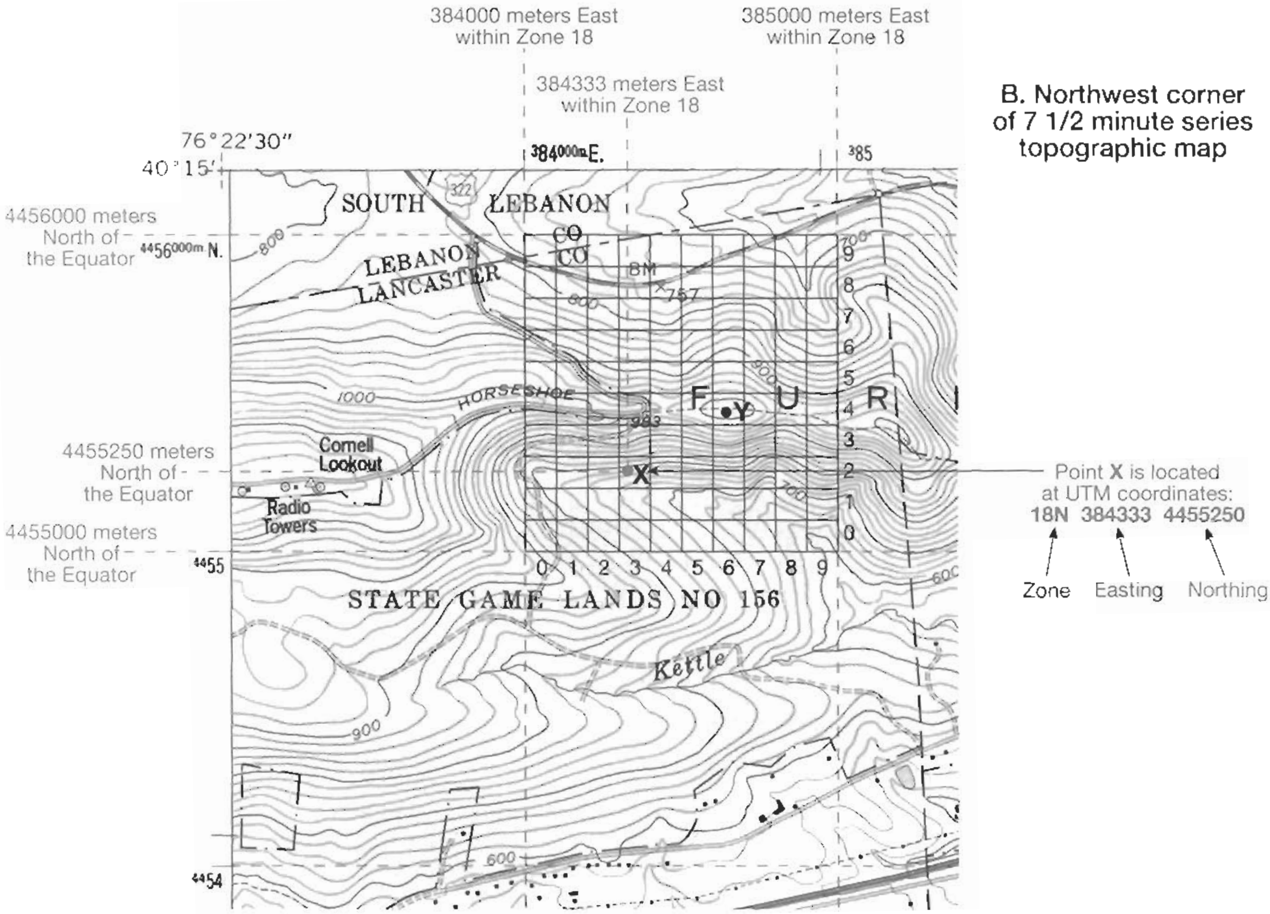
The UTM system described above is known as the *civilian UTM grid and coordinate system*, and it is the system you should use in your work in this manual. The U.S. Department of Defense has modified this civilian UTM grid to form a Military Grid Reference System (MGRS) that divides the zones into horizontal sections identified by *designator letters* (Figure 9.12). These sections are 8° wide and lettered consecutively from **C** (between 80° and 72° south latitude) through **X** (between 72° and 84° north latitude). Letters I and O are not used.

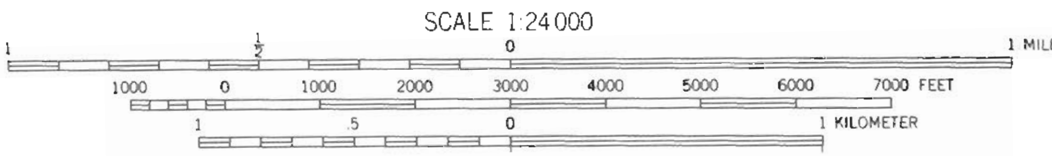
## Compass Bearings

A **bearing** is the *compass direction* along a line from one point to another. If expressed in degrees east or west of true north or south, it is called a *quadrant bearing*. Or it may be expressed in degrees between 0 and 360, called an *azimuth bearing*, where north is 0° (or 360°), east is 90°, south is 180°, and west is 270°. Linear geologic features (faults, fractures, dikes), lines of sight and travel, and linear property boundaries are all defined on the basis of their bearings.

Remember that a compass points to Earth's *magnetic north* (MN) pole rather than the *grid north* (GN) pole that was used to construct the UTM and latitude-longitude grids of a map. Therefore, a diagram at the margin of every topographic map shows the *declination* (degrees of difference) between MN and GN. If the MN arrow is to the right of GN, then subtract the degrees of declination from your compass reading. If the MN arrow is to the left of GN, then add the degrees of declination to your compass reading. These adjustments will mean that your compass readings are synchronized with the map. However, the magnetic pole migrates very slowly, so the declination is exact only for the year listed on the map.

To determine a compass bearing on a map, draw a straight line from the starting point to the destination point and also through any one of the map's borders. Align a protractor (left drawing, Figure 9.14) or the N–S or E–W directional axis of a compass (right drawing, Figure 9.14) with the map's border, and read the bearing in degrees toward the direction of the destination. Imagine that you are buying a property for your dream home. The boundary of the property is marked by four metal rods driven into the ground,




A. Map margin

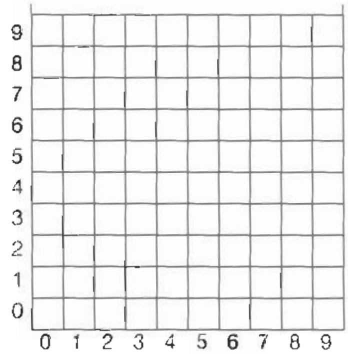
Produced by the United States Geological Survey
in cooperation with Commonwealth of Pennsylvania agencies

Compiled by photogrammetric methods from imagery dated 1951
Field checked 1956. Revised from imagery dated 1992 and
other sources. Field checked 1995. Map edited 1996

North American Datum of 1927 (NAD 27). Projection and
10 000-foot ticks: Pennsylvania coordinate system, south zone
(Lambert conformal conic)
Blue 1000-meter Universal Transverse Mercator ticks, zone 18

North American Datum of 1983 (NAD 83) is shown by dashed
corner ticks. The values of the shift between NAD 27 and NAD 83
for 7.5-minute intersections are obtainable from National Geodetic
Survey NADCON software

There may be private inholdings within the boundaries of
the National or State reservations shown on this map



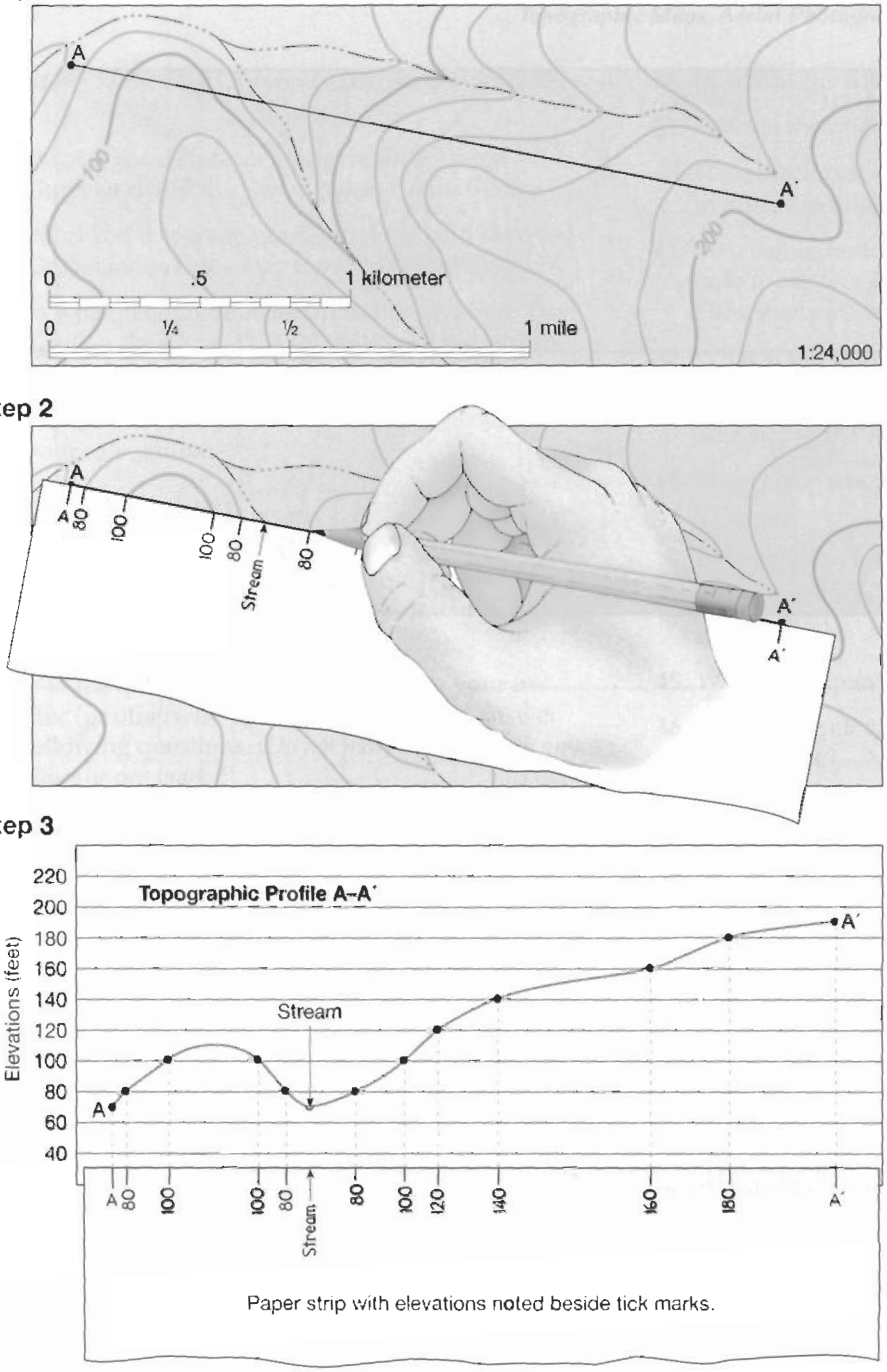

C.

**FIGURE 9.13** UTM and topographic maps—refer to text for discussion. Point **X** (from Figure 9.12) is located within the Lititz, PA $7\frac{1}{2}$ Minute Series (USGS, 1:24,000 scale) topographic quadrangle map. **A.** Map margin indicates that the map includes UTM grid data based on *North American Datum 1927* (*NAD27*, Zone 18) and represented by blue ticks spaced 1000 meters (1 km) apart along the map edges. **B.** Connect the blue 1000 m ticks to form a grid square, each representing 1 square kilometer. Northings (blue) are read along the N-S map edge, and eastings (green) are located along the E-W map edge. **C.** You can construct a 1 km grid (1:24,000 scale) from the map's bar scale, then make a transparency of it to form a grid overlay (see GeoTools Sheet 1, 3 at back of manual). Place the grid overlay atop the 1-kilometer square on the map that includes point **X**, and determine the *NAD27* coordinates of **X** as shown (red).

Step 1

Step 2

Step 3




## Step 4 Vertical Exaggeration

On most topographic profiles, the vertical scale is exaggerated (stretched) to make landscape features more obvious. One must calculate how much the vertical scale (V) has been exaggerated in comparison to the horizontal scale (H).

The horizontal scale is the map's scale. This map has an H ratio scale of 1:24,000, which means that 1 inch on the map equals 24,000 inches of real elevation. It is the same as a H fractional scale of 1 / 24,000.

On the vertical scale of this topographic profile, one inch equals 120 feet or 1,440 inches (120 feet x 12 inches/foot). Since one inch on the vertical scale equals 1,440 inches of real elevation, the topographic profile has a V ratio scale of 1:1,440 and a V fractional scale of 1/1,440.

The vertical exaggeration of this topographic profile is calculated by either method below:

**Method 1**: Divide the horizontal ratio scale by the vertical ratio scale.

$$\frac{\text{H ratio scale}}{\text{V ratio scale}} = \frac{1{:}24{,}000}{1{:}1{,}440} = \frac{24{,}000}{1{,}440} = 16.7\times$$

**Method 2**: Divide the vertical fractional scale by the horizontal fractional scale.

$$\frac{\text{V fractional scale}}{\text{H fractional scale}} = \frac{1/1{,}440}{1/24{,}000} = \frac{24{,}000}{1{,}440} = 16.7\times$$

**FIGURE 9.21** Topographic profile construction and vertical exaggeration. Shown are a topographic map (Step 1), topographic profile constructed along line **A–A′** (Steps 2 and 3), and calculation of vertical exaggeration (Step 4). **Step 1**—Select two points (**A, A′**), and the line between them (line **A–A′**), along which you want to construct a topographic profile. **Step 2**—To construct the profile, the edge of a strip of paper was placed along line **A–A′** on the topographic map. A tick mark was then placed on the edge of the paper at each point where a contour line and stream intersected the edge of the paper. The elevation represented by each contour line was noted on its corresponding tick mark. **Step 3**—The edge of the strip of paper (with tick marks and elevations) was placed along the bottom line of a piece of lined paper, and the lined paper was graduated for elevations (along its right margin). A black dot was placed on the profile above each tick mark at the elevation noted on the tick mark. The black dots were then connected with a smooth line to complete the topographic profile. **Step 4**—*Vertical exaggeration* of the profile was calculated using either of two methods. Thus, the vertical dimension of this profile is exaggerated (stretched) to 16.7 times greater than it actually appears in nature compared to the horizontal/map dimension.