PART 4 GEOSPATIAL APPLICATIONS

13 Digital Landscaping

Topographic Maps, US Topos, Contours, Digital Terrain Modeling, Digital Elevation Models (DEMs), Lidar, 3DEP, and Applications of Terrain Data

There's one big element in geospatial technology that we haven't yet dealt with: the terrain and surface of Earth. All of the maps, imagery, and coordinates discussed have dealt with two-dimensional (2D) images of either the surface or the developed or natural features on the land. We haven't yet described how the actual landscape can be modeled with geospatial technology. This chapter delves into how terrain features can be described, modeled, and analyzed using several of the geospatial tools (such as GIS and remote sensing) that we're already familiar with. Whether you are modeling topographic features for construction or recreational opportunities, or you're just interested in seeing what the view from above looks like, the landforms on Earth's surface are a principal subject for geospatial analysis (see **Figure 13.1** for an example of visualizing Mount Everest with Google Earth).

First, when we're examining landforms on Earth's surface, we will have to assign an elevation to each location. In terms of coordinates, each *x*/*y* pair will now have a ***z*-value** that will indicate that location's elevation. These elevations have to be measured relative to something—when a point has an elevation of 900 feet, this indicates that it is 900 feet above something. The "something" represents a baseline, or **vertical datum**, that is the zero point for elevation measurements. Some maps of landforms indicate that the vertical datum is taken as mean sea level (represented by the National Vertical Datum of 1929). When this vertical datum is used and an elevation value on a map indicates 1000 feet, that number can be read as 1000 feet above mean sea level. Much geospatial data in North America utilizes the North American Vertical Datum of 1988 (**NAVD88**) as the origin point for elevations. The U.S. National Geodetic Survey has announced

***z*-value** the elevation assigned to an *x*/*y* coordinate

vertical datum a baseline used as a starting point in measuring elevation values (which are either above or below this value)

NAVD88 the North American Vertical Datum of 1988, the vertical datum used for much geospatial data in North America

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FIGURE 13.1
Mount Everest modeled as a digital terrain landscape and shown in Google Earth.

that it is currently developing a new vertical datum to take the place of NAVD88, but it will not be ready until 2022. Coastal terrain models may also use mean high water as their vertical datum.

How Can Terrain Be Represented on Topographic Maps?

topographic map a map created by the USGS to show landscape and terrain as well as the location of features on the land

A common (and widely available) method of representing terrain features is the **topographic map**. As its name implies, a topographic map is a printed paper map designed to show the topography of the land and the features on it. A U.S. topographic mapping program that ran from 1945 to 1992 produced topographic maps that were published by the USGS (United States Geological Survey) at a variety of map scales. A common topographic map was a 1:24000 quadrangle, also referred to as a 7.5 minute topographic map, insofar as it displays an area covering 7.5 minutes of latitude by 7.5 minutes of longitude. Topographic maps were also available in smaller map scales, such as 1:100000 and 1:2000000.

DRG Digital Raster Graphic; a scanned version of a USGS topographic map

GeoTIFF a graphical file format that can also carry spatial referencing

Topographic maps are available in a digital format as a **DRG** (Digital Raster Graphic). DRGs are scanned versions of topographic maps that have been georeferenced (see Chapter 3) so that they'll match up with other geospatial data sources when used in GIS. Usually, DRGs are available in **GeoTIFF** file format (see Chapter 7 for more information about TIFFs), which allows for high-resolution images while also providing spatial reference.

However, DRGs are just scanned images. To use the specific features on a topographic map (such as the streets or rivers) as separate

GIS datasets, those features would have to be digitized (see Chapter 5) into their own geospatial layers. This is what a Digital Line Graph (**DLG**) is—the digitized features from a topographic map. DLGs are vector datasets representing transportation features (such as streets, highways, and railroads), hydrography features (such as rivers or streams), or boundaries (such as state, county, city, or national forest borders (see **Figure 13.2** for an example of several DLGs and their corresponding DRG).

Topographic maps (and thus, DRGs) model the landscape through the use of **contour lines**—imaginary lines drawn on the map that join points of equal elevation (see **Figure 13.3**). These contour lines are available in DLG format as a hypsography layer. A particular elevation on the surface is represented by a contour line drawn on the map. However, because elevation is really a continuously variable phenomenon, it's often difficult to represent every change in elevation (such as from 8 feet of elevation to 10 feet of elevation) without overloading the map to the point of uselessness with contour lines. Thus, contour lines are drawn a certain elevation distance apart (say, a new contour line for every 50 feet of elevation).

DLG Digital Line Graph; the features (such as roads, rivers, or boundaries) digitized from USGS maps

contour line an imaginary line drawn on a map to connect points of common elevation

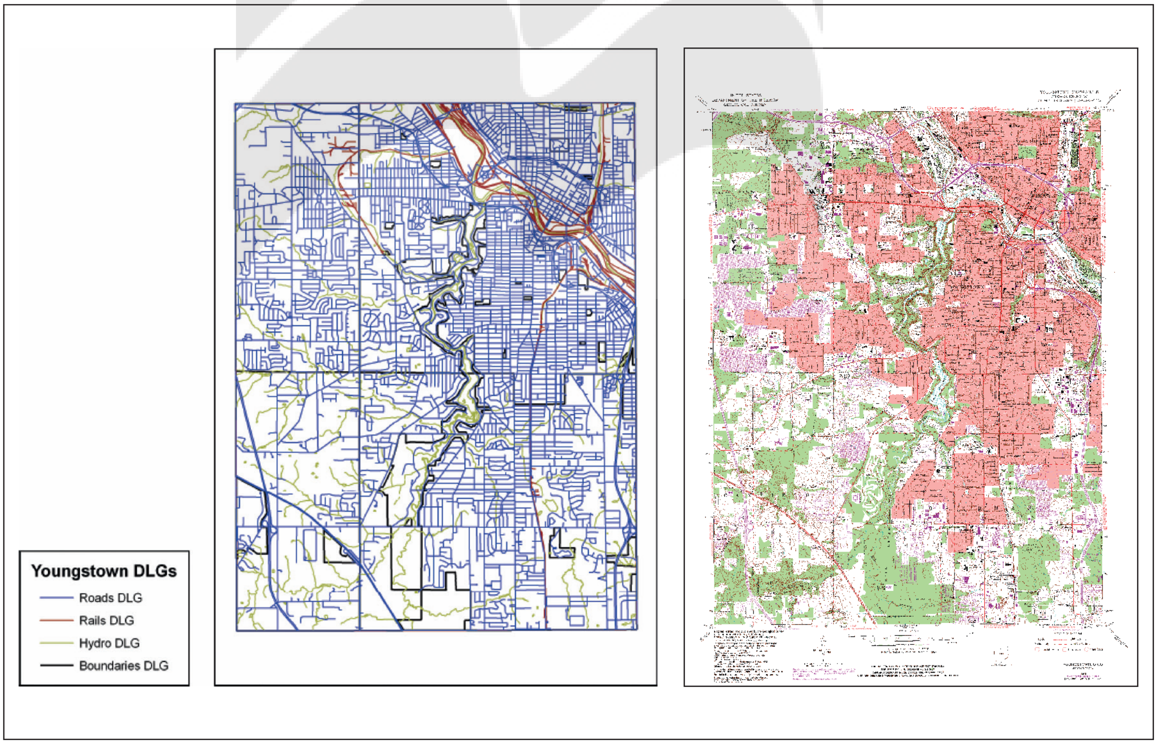


FIGURE 13.2

1:24000 DLG data showing roads, railroads, boundaries, and hydrologic features of Youngstown, Ohio, along with the corresponding 1:24000 DRG of Youngstown.

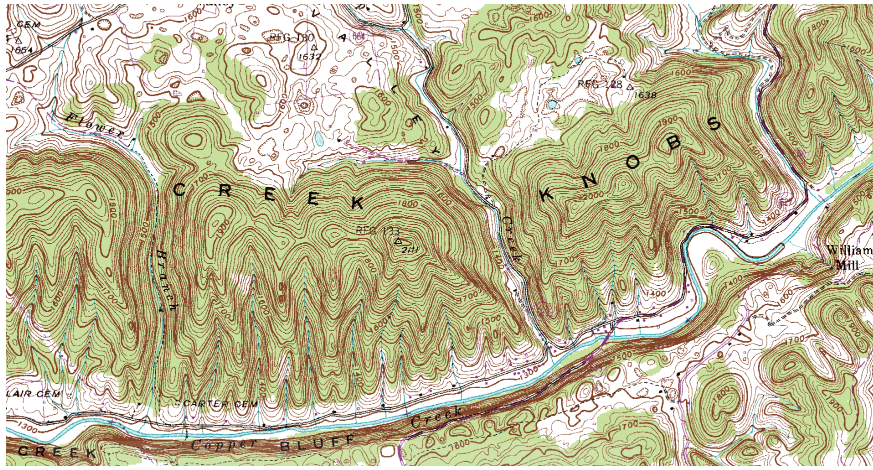


FIGURE 13.3

Contour lines as shown on a DRG (at a 20-foot contour interval). *[USGS]*

contour interval the vertical difference between two adjacent contour lines drawn on a map

This elevation or vertical difference between contour lines is called the **contour interval** and is set up according to the constraints of the map and the area being measured. In general, a wider contour interval is selected when mapping more mountainous terrain (since there are numerous higher elevations), and a narrower contour interval is used when mapping flatter terrain (because there are fewer changes in elevation and more details can be mapped). Small-scale maps (see Chapter 7) tend to use a wider contour interval because they cover a larger geographic area and present more basic information about the terrain, whereas large-scale maps generally utilize a narrow contour interval for the opposite reason (they show a smaller geographic area and thus can present more detailed terrain information).

A big thing to keep in mind when dealing with topographic maps is that they are no longer being produced by the USGS. The original USGS topographic mapping project lasted until 1992, with sporadic revisions made to a small percentage of the maps for a few years after that. The topographic map program was replaced by The National Map (see Chapter 1) to deliver digital geospatial data (including contour line data) for the United States. Since these topographic maps are no longer being produced, neither are their corresponding DRGs or DLGs. However, see *Hands-On Application 13.1: The Historical Topographic Map Explorer* for an online tool for examining series of historic USGS topographic maps.

US Topo a digital topographic map series created by the USGS to allow multiple layers of data to be used on a map in GeoPDF file format

Printed or scanned topographic maps haven't been produced for several years, however the next generation of digital topographic mapping is available through the **US Topo** series. Like the old topographic maps, the US Topos are delivered in 7.5 minute quad sections, but in GeoPDF file format (see Chapter 7). A US Topo has multiple layers of data stored on the same

Hands-On Application 13.1

The Historical Topographic Map Explorer

The Historical Topographic Map Explorer is a great USGS online tool for examining historic topographic maps over time. To get started, go to **http://historicalmaps.arcgis.com/usgs**. When the Website opens, you'll need to type in a location. Start with Orlando, FL. When the basemap of Orlando appears, click on it to open the historical timeline of topographic maps at the bottom of the screen. In the timeline, the dates of available topographic maps (and their map scales) are shown. By clicking on one of the dates, the corresponding topographic map will be added to the view in its georeferenced position. By clicking on a second date, that map will be added as well.

In the table of contents on the left side of the screen, maps can be reordered (the map at the bottom of the stack is drawn first and maps at the top of the stack are drawn over it), removed (by clicking the *X* for the map) or made semi-transparent (with the slider bar under each map). First add the 1:24000 scale topographic map for 1956, then add the map for 1970. Use the slider bar to make the 1970 map semi-transparent to see the changes from one time period to the other. Next add the 1980 map and compare it to the 1970 map, then add and compare the 1995 map to the 1980 map.

Expansion Questions

- How has Orlando changed and where has it expanded as a city over time from 1956 to 1970? From 1970 to 1980? From 1980 to 1995? And also from 1956 to 1995?
- Look for your own local area and see what historical topographic maps are online for your location. What map dates are available to view? How has your area changed significantly on the maps from the earliest time period available to the latest available time period?

map, which can be turned on and off according to what features you want to display on the map. US Topo maps include contours, recent transportation features (roads, railroads, airports), transportation names, contours, boundaries, and orthophoto images, all as separately accessible layers. A US Topo also contains a lot of data (including the scale, the dates of map creation, and similar information) in the white border that surrounds the map. This information-filled border is referred to as the map's **collar**, and like the other layers in the US Topo it can be displayed or hidden. See **Figure 13.4** for an example of a US Topo.

collar the white, information-filled border around a US Topo

The data contained in the US Topos (such as the contours or transportation layers) is derived from the national GIS data. The USGS produces over 100 US Topos per day and each US Topo is on a three-year revision cycle. Also, historic topographic maps are being converted over to the GeoPDF format as part of the Historic Topographic Map Collection (HTMC) and freely distributed online.

As a GeoPDF, each US Topo is a stand-alone product that can be used on a computer or on a mobile device. The GeoPDF can also store coordinate information for each location on the map, and a set of tools

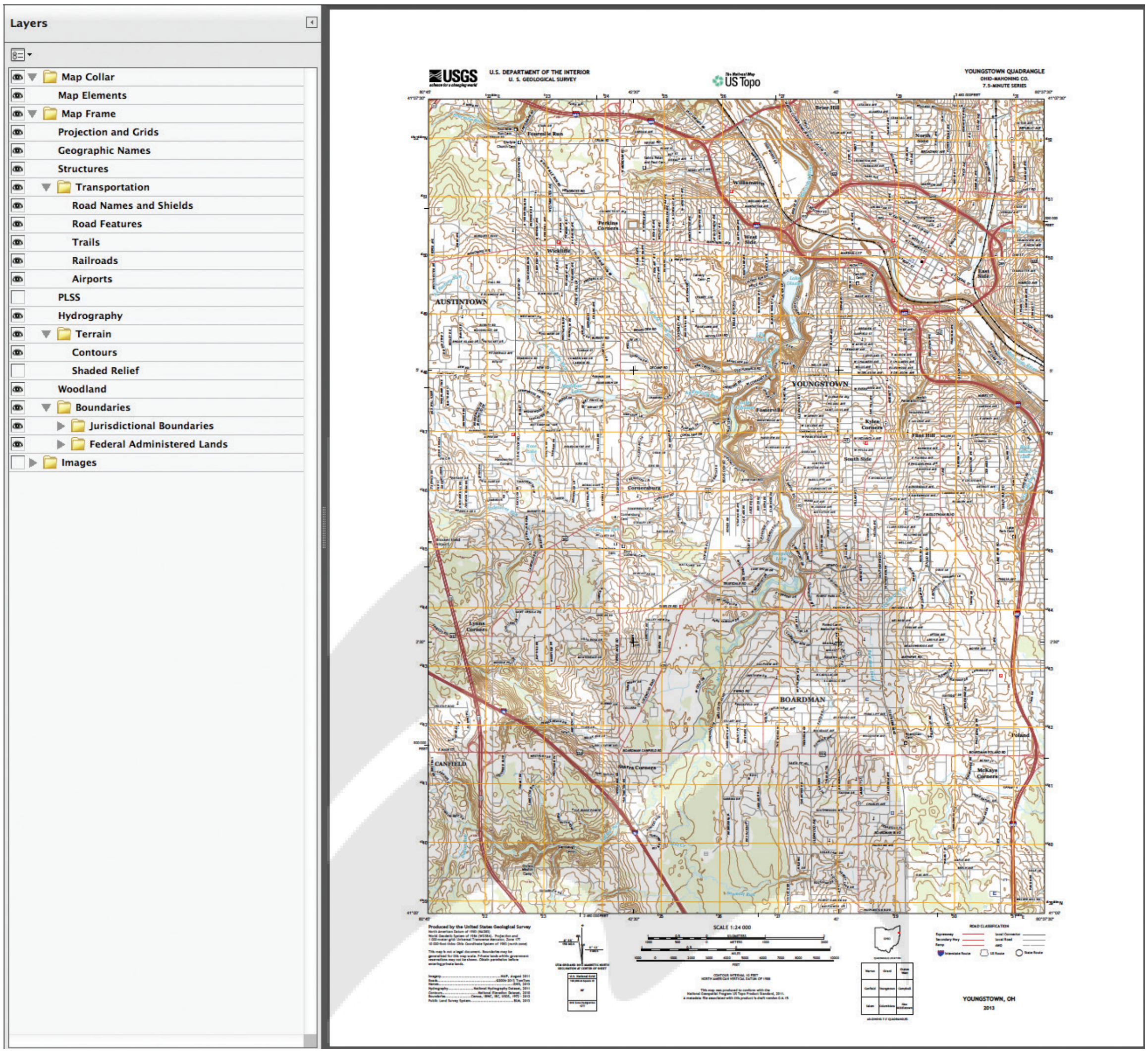


FIGURE 13.4

A 2013 US Topo of Youngstown, Ohio, showing the available layers for the map. *[USGS]*

available from a special free plug-in allows you to measure distances, calculate the size of areas, and also connect the US Topo to a GPS device for obtaining your current location information (see *Hands-On Application 13.2: US Topos as GeoPDFs* for how to obtain and work with US Topos).

Hands-On Application 13.2

US Topos as GeoPDFs

Before working with US Topos, you'll need to install the TerraGo Toolbar in order to take advantage of all of the GeoPDF features available with the US Topo. The TerraGo Toolbar can be downloaded directly from **http://www.terragotech.com/products/terrago-toolbar**. With the GeoPDF downloaded and the toolbar installed, now it's time to get some US Topos to work with.

US Topos can be obtained easily through The National Map (see Chapter 1) in the same way you would get other data layers. An alternative way to browse current and historic US Topos is through the USGS Store at **http://store.usgs.gov**. Click on the link for Map Locator & Downloader and you'll be taken to a separate Website to search for available maps. At this point, you can first type the name of a place to search for available US Topos. For instance, search for East Lansing, Michigan, and the display map will shift to show that. Next, click on the blue marker in the center of the East Lansing view and a new pop-up box will appear to show you all of the available maps for that location. For each of the maps labeled as 7.5 × 7.5 GRID, click on the circular icon with the blue-and-white cross on it to add that map to the download cart.

As you add the 7.5 maps (these will be US Topos or Historic Topographic Map Collection maps) to the download cart, you'll see your cart begin to fill. Once you have the 7.5 × 7.5 GRID maps for all available dates, click on Download All Cart Items. A zip file will download to your computer containing all of the GeoPDFs that you have added to the cart. When the zip file finishes downloading, unzip the US Topos and open the one with the most recent date. For further information on accessing and using US Topos, see the Quickstart guide from the USGS, online at **http://nationalmap.gov/ustopo/quickstart.pdf**.

Expansion Questions

- What dates of US Topos and historical topographic maps are available for East Lansing, Michigan?
- What is the approximate elevation of Spartan Stadium on the Michigan State University campus? (*Hint:* You can use the information on the Orthoimage and Geographic Names layers to locate the campus and stadium and the Contours layer for elevation.)
- What is the contour interval of the US Topo? What is the highest elevation shown on the map?

Thinking Critically with Geospatial Technology 13.1

If Everything's Digital, Do We Still Need Printed Topographic Maps?

A similar question was raised back in Chapter 2: If all of the historic USGS topographic map products are available digitally and in easily accessible formats that can be used on a desktop, laptop, or tablet, is there still a need to have printed copies (at a variety of map scales) on hand? Keeping in mind that the topographic mapping program ran through 1992 and only a small percentage of the maps were updated after that (and the estimated median date for the currentness of a map was 1979), are the available printed maps up-to-date enough to be of use? Do surveyors, geologists, botanists, archeologists—or any other professionals who require topographic information for fieldwork—need to carry printed topo quads with them? Is there a need for geographers to have printed versions of several quads when seamless digital copies (which can be examined side by side) are so readily available? Are there situations in which a printed topo map is necessary?

How Can Geospatial Technology Represent Terrain?

DTM a representation of a terrain surface calculated by measuring elevation values at a series of locations

two-and-a-half–dimensional (2.5D) model a model of the terrain that allows for a single *z*-value to be assigned to each *x*/*y* coordinate location

three-dimensional (3D) model a model of the terrain that allows for multiple *z*-values to be assigned to each *x*/*y* coordinate location

TIN Triangulated Irregular Network; a terrain model that allows for non-equally spaced elevation points to be used in the creation of the surface

DEM digital elevation model; a representation of the terrain surface, created by measuring a set of equally spaced elevation values

In geospatial technology, terrain and landscape features can be represented by more than just contour lines on a map. A digital terrain model (**DTM**) is the name given to a model of the landscape that is used in conjunction with GIS or remotely sensed imagery. The function of a DTM is both to represent the features of the landscape accurately and to be a useful tool for analysis of the terrain itself. The key to a DTM is to represent a *z*-value for *x* and *y* locations properly. With a *z*-value, the model can be shown in a perspective view to demonstrate the appearance of the terrain, but this doesn't necessarily make it a three-dimensional model. In fact, a DTM is usually best described as a two-and-a-half–dimensional model. In a 2D model, all coordinates are measured with *x* and *y* values, without a number for *z* at these coordinates. In a **two-and-a-half–dimensional (2.5D) model**, a single *z*-value can be assigned to each *x*/*y* coordinate as a measure of elevation at that location. In a full **three-dimensional (3D) model**, multiple *z*-values can be assigned to each *x*/*y* coordinate. Most DTMs have one elevation value measured for the terrain height at each location, making them 2.5D models (**Figure 13.5**).

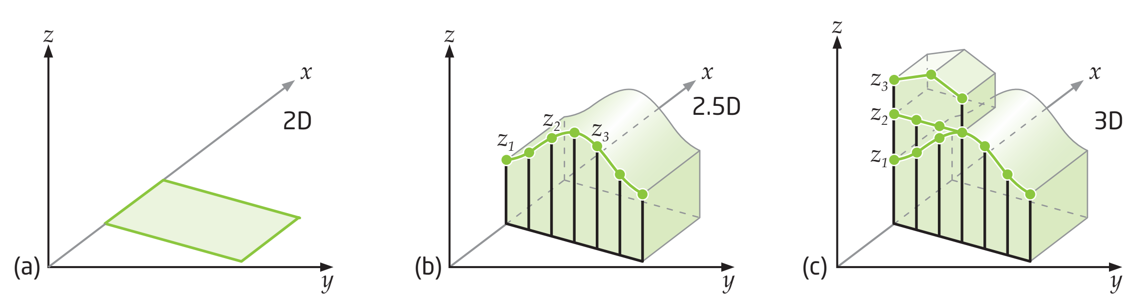
An example of a type of DTM that's used in terrain modeling is a **TIN** (Triangulated Irregular Network), in which selected elevation points of the terrain, those that the system deems the "most important," are used in constructing the model. Points are joined together to form nonoverlapping triangles, representing the terrain surfaces (see **Figure 13.6**). While TINs are often used in terrain modeling in GIS, another very widely used type of digital terrain model is the DEM.

What Is a DEM?

A **DEM** is a digital elevation model, a specific type of model of the terrain and landscape, produced by the USGS and others. A DEM is based on regularly spaced point data of elevations, but it can be converted to a raster

FIGURE 13.5

A comparison of (a) 2D, (b) 2.5D, and (c) 3D models of terrain.



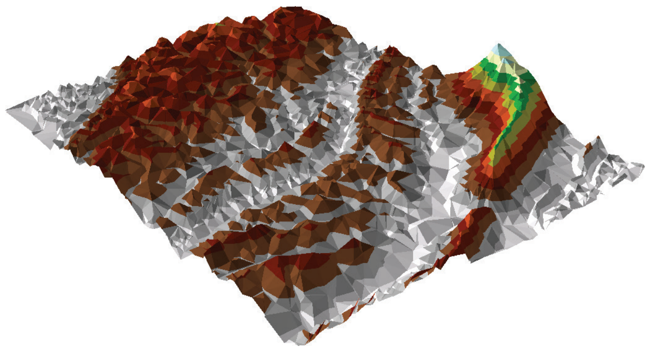


FIGURE 13.6

A TIN representation of the terrain around Gate City, Virginia.

grid representation (see Chapter 5) for use with other geospatial data, such as satellite imagery or GIS layers. In grid format, the elevation values are represented by the grid cell value, while the grid resolution represents the size of the cell being measured. Thus, DEM resolution is measured in much the same way that we measure the resolution of a remotely sensed image (see Chapter 10). If a DEM has 30-meter resolution, then each of the DEM's raster grid cells is set up at 30 meters in size.

DEMs have been created through a variety of methods, including using DLG contour information, photogrammetry, and remotely sensed data and stereo imagery (see Chapter 14). The ASTER sensor onboard the Terra satellite (see Chapter 12) was used to create a global DEM at 30-meter resolution. Another source of terrain data is the Shuttle Radar Topography Mission (**SRTM**), which originated as a part of a mission of the space shuttle *Endeavor* in February 2000. For 11 days, *Endeavor* used a special radar system to map Earth's terrain and topographic features from orbit, and the result was a highly accurate digital elevation model. At the mission's close, roughly 80% of Earth was examined and modeled as 90-meter DEMs (30-meter DEM data is also available for the United States). Updates and edits to the initial SRTM dataset are available as well.

SRTM the Shuttle Radar Topography Mission, flown in February 2000, which mapped Earth's surface from orbit for the purpose of constructing digital elevation models of the planet

An additional remote sensing method of terrain mapping is called **lidar** (a mashup of the words "light" and "radar" but also an acronym for Light Detection and Ranging). Rather than firing a microwave pulse at a ground target as a radar system would, lidar uses a laser beam to measure the terrain. In lidar, a plane is equipped with a system that fires a series of laser beams (between 30,000 and 250,000 pulses per second) at the ground. The laser beams are reflected from the ground back to the plane, and based on the distance from the plane to targets on the ground, the elevation of the landscape (as well as objects on the surface of the terrain) can be determined. GPS (see Chapter 4) is used in part to determine where the beams are striking the ground. See **Figure 13.7** for an example of how lidar data is collected.

lidar a process in which a series of laser beams fired at the ground from an aircraft is used both to create highly accurate elevation models and also to measure the elevation of objects from the ground

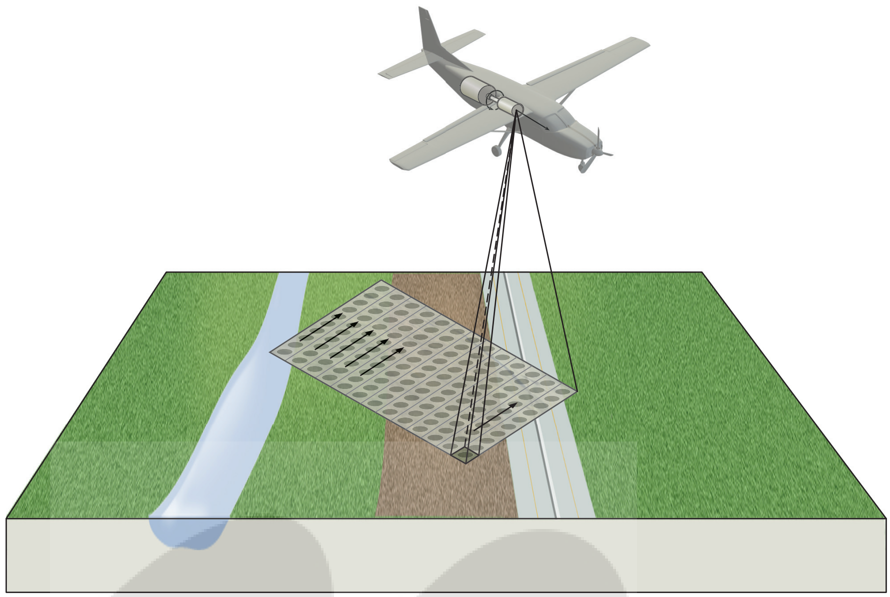


FIGURE 13.7

Gathering point cloud data: the process behind measuring terrain heights using lidar.

point cloud the name given to the massive number of elevation data measurements collected by lidar

DSM digital surface model; a measurement of the heights of ground elevations as well as the objects on top of the ground as captured by lidar

LAS the industry standard data format used for lidar data

The data collected by lidar is often referred to as **point cloud** data, owing to the high volume of point locations measured (you could potentially measure millions of locations in a single flight). After the data is collected and processed, the end result of a lidar mission is a highly accurate set of *x*/*y* locations with a *z*-value (see **Figure 13.8** for an example of a lidar-derived elevation model). These "bare earth" elevation models of open terrain have a high degree of accuracy for their vertical measurements (between 15 and 30 centimeters), and today lidar equipment is also attached to UAS drones and can achieve 3- to 5-centimeter vertical accuracy.

However, Earth is covered by more than just open terrain. Lidar points will also measure the heights of features such as tree canopies or roofs of buildings and can be used to create realistic-looking 3D models of these objects on Earth's surface. We'll get to 3D visualization in Chapter 14, but these digital surface models (**DSMs**) can be developed using lidar to measure the heights of all types of things on Earth's surface, not just the ground. The heights of objects like trees or buildings are removed to create an elevation model of the actual Earth's surface. As such, lidar has become a very versatile remote sensing tool that is used extensively in both government and private sector fields. A **LAS** file is the industry standard for storing lidar data, and many software packages (such as ArcGIS) are able to generate elevation models and calculate object heights using this data.

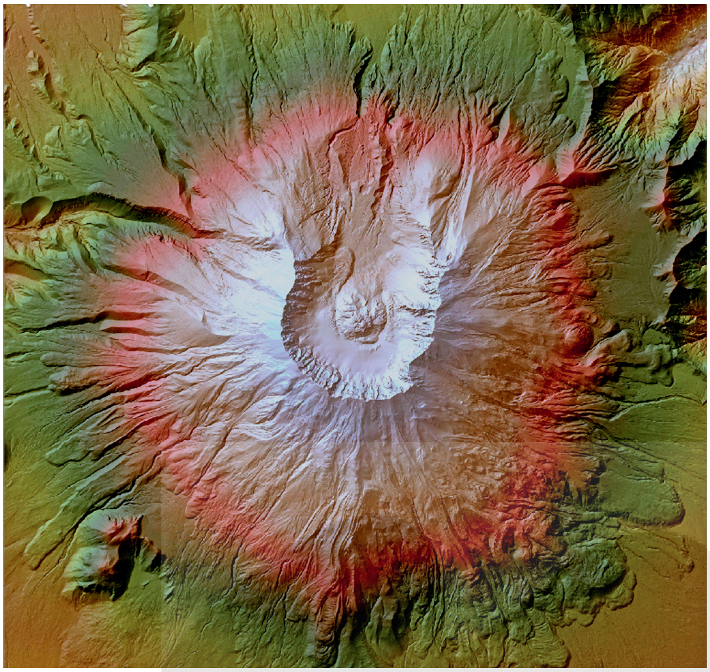


FIGURE 13.8

Mount St. Helens as viewed from lidar data. *[USGS]*

Digital elevation data is available from the USGS through the **3DEP** (3D Elevation Program) initiative. 3DEP data is available as a free download from The National Map (see *Hands-On Application 1.3: The National Map* on page 11 of Chapter 1 for instructions on how to obtain various geospatial datasets). The purpose of 3DEP is twofold: to have a digital elevation product that covers the entire United States at the best possible resolution, and to eliminate any gaps in the data. 3DEP is designed to be "seamless", insofar as its data uses the same datum, projection, and elevation unit. With 3DEP, users select which sections of the national elevation dataset they need and then download those areas. 3DEP data is available at 1 arc second (about 30-meter), 1/3 arc second (about 10-meter), and 1/9 arc second (about 3-meter) resolutions, depending on the region. At the time of writing, some areas around the United States also had 1-meter resolution 3DEP data available. To see what's available for 3DEP data for your own area, see *Hands-On Application 13.3: U.S. Elevation Data and The National Map*. 3DEP draws from a variety of different sources for its elevation data. Lidar is a key method used to derive the DEMs that comprise 3DEP data, as well as radar remote sensing in areas such as Alaska. Point cloud data for areas as well as derived DSMs are also part of the 3DEP data sets.

3DEP the 3D Elevation Program, a U.S. government program that provides digital elevation data for the entire United States

Hands-On Application 13.3

U.S. Elevation Data and The National Map

The USGS distributes 3DEP data through The National Map. To see what types of elevation data are available, go to the TNM download viewer platform at **http://viewer.nationalmap.gov/basic**. Under the options for Data on the left side, put a checkmark in the box next to Elevation Products 3DEP. This will allow to you see all of the available elevation resolutions for 3DEP. Under this, click on the option for Product Availability and a series of radio buttons will appear, allowing you to see what 3DEP elevation data resolutions are available at areas across the United States. Then click on Show Availability to see what DEM data is available. For instance, clicking the radio button for DEM 1-meter will show you which areas of the country have available 1-meter 3DEP elevation data.

Next, you can go to a particular location to see what elevation data is available. For instance, in the Search location box, type in Topeka, Kansas. The Viewer will center on Topeka, but you may also need to zoom out a little bit from the initial search area to see the entire area. Select each of the radio buttons to see the kinds of 3DEP data available for download for Topeka.

Expansion Questions

- What resolutions of 3DEP elevation data are available for Topeka, Kansas?
- For your own local area, what types of elevation data and which resolutions of data are available?

How Can Digital Terrain Models Be Utilized?

viewshed a data layer that indicates what an observer can and cannot see from a particular location due to terrain

slope a measurement of the rate of elevation change at a location, found by dividing the vertical height (the rise) by the horizontal length (the run)

slope aspect the direction that a slope is facing

With terrain data, many different types of terrain analysis can be performed. DTMs are used in geospatial technology for creating **viewsheds**—maps that show what can be seen (or not seen) from a particular vantage point. A viewshed is used for determining how far a person's visibility is (that is, what they can see) from a location before his or her view is blocked by the terrain. A viewshed can be created by selecting a vantage point and then computing how far a person's line of sight extends in all directions until something blocks the view. DTMs are also used for a variety of hydrologic applications, for example calculating the accumulation of water in an area or delineation of stream channels or watersheds.

DTMs can be used to derive a new dataset of **slope** information—rather than elevation values, slope represents the change of elevations (and the rate of change) at a location by calculating the rise (vertical distance) over the run (horizontal distance). When a slope surface is created from a DTM, information can be derived not just about heights, but also about the steepness or flatness of areas. Similarly, a surface of **slope aspect** can be computed, which will show the direction that the slope is facing for each location. Now, you not only have information about where the

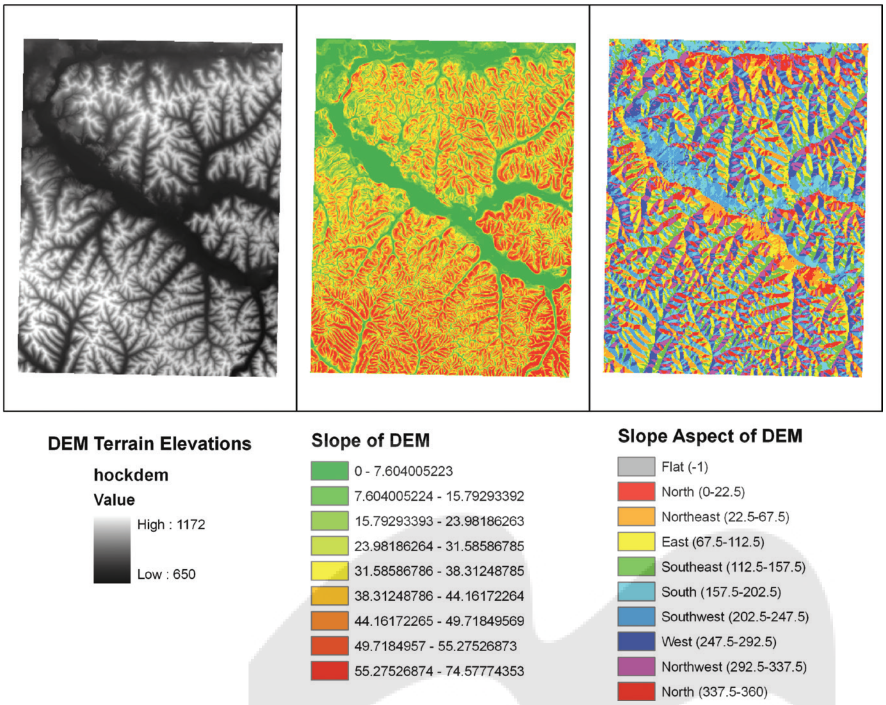


FIGURE 13.9

A DEM of a portion of the Laurelville/Hocking region of Ohio and the slope and slope aspect grids derived from it.

steepest slopes are located, but also about whether they are north-facing, east-facing, and so on. **Figure 13.9** shows a comparison of a DEM with the slope and slope aspect maps derived from it.

Digital terrain models aren't just limited to flat images on a computer screen or a paper map—remember, constructs like DTMs are 2.5D models, and because they have a *z*-value, that *z*-value can be visualized in a 3D view. It's more accurate to say these types of visualizations are really **pseudo-3D** views because they're really 2.5D, but they are not really full 3D models. Setting up a pseudo-3D view of a digital terrain model involves examining it at a **perspective view** (or an oblique view). Points or raster cells are elevated to the height of their *z*-value, and the resultant model is shown from an angular view. In this way, mountain peaks can be seen jutting up from the surface, and a meteor crater looks like a depression in the ground.

pseudo-3D a term often used to describe the perspective view of a terrain model because it is often a 2.5D model, not a full 3D model

perspective view the oblique angle view of a digital terrain model from which the model takes on a three-dimensional appearance

In many geospatial technology applications, the model becomes interactive, allowing the user to move or "fly" over the terrain, skimming over the surface and banking past mountains. Beyond viewing the terrain in perspective view, there are numerous ways of artificially altering the appearance of the terrain to make it more realistic looking. One way is to drape imagery over the surface (see **Figure 13.10** for an example of a terrain surface shown in perspective view with a digital topographic

FIGURE 13.10

A pseudo-3D view of a digital terrain model enhanced with a digital topographic map displayed over the terrain.

map overlaid to show off the contour lines in relation to the pseudo-3D model).

Remember that a DTM is just a map or grid of elevation surfaces. Like any other map, it can be displayed with various color ramps to show the differences in elevations, but there are several ways to make the terrain model look more realistic (and start to resemble that image of Mount Everest at the beginning of this chapter). The first of these techniques is called a **hillshade**, which models how the terrain would look under different lighting conditions (based on the location of the Sun in the sky). When you're constructing a hillshade, you can calculate where the light source (that is, the Sun) will be located at different times with respect to the terrain and simulate the effects of shadows cast on the landscape by the various terrain features.

hillshade a shaded relief map of the terrain created by modeling the position of the Sun in the sky relative to the landscape

By setting two parameters for the Sun, you can determine different appearances of the terrain at different times of day. The first parameter is the **Sun altitude**, a value between 0 and 90 representing the angle of the Sun in the sky between 0 degrees (directly at the surface) and 90 degrees (directly overhead). The second parameter is the **Sun azimuth**, a value between 0 and 360 that shows where its rays are coming from. The values represent a circle around the landscape, with 0 being due north, 90 being due east, 180 being due south, and 270 being due west (the values are measured clockwise from due north). By setting values for Sun altitude and Sun azimuth, the terrain can take on various appearances to simulate how the

Sun altitude the value between 0 and 90 used in constructing a hillshade to model the Sun's elevation above the terrain

Sun azimuth the value between 0 and 360 used in constructing a hillshade to model the Sun's position in the sky to show the direction of the Sun's rays striking the surface landscape looks at different times and in different conditions during the day. A hillshade using a Sun altitude of 45 degrees and a Sun azimuth of 315 degrees is shown in **Figure 13.11**.

Hillshading provides a good shaded map of what the terrain will look like under various lighting conditions, but there are plenty of features on the landscape (for instance roads and land cover) that aren't shown with a hillshade. In order to see these types of features, we can use a process called **draping**, which essentially shows the terrain model with a remotely sensed image (or another dataset) on top of it. **Figure 13.12** shows an example of a Landsat TM image draped over a DEM. Draping is achieved by first aligning the image with its corresponding places on the terrain model, then

draping a process in which an image is given *z*-values to match the heights in a digital terrain model

FIGURE 13.11

A DEM of Columbiana County, Ohio, and a hillshade of the DEM made using a Sun altitude of 45 degrees and a Sun azimuth of 315 degrees. *[Source: USGS/Esri]*

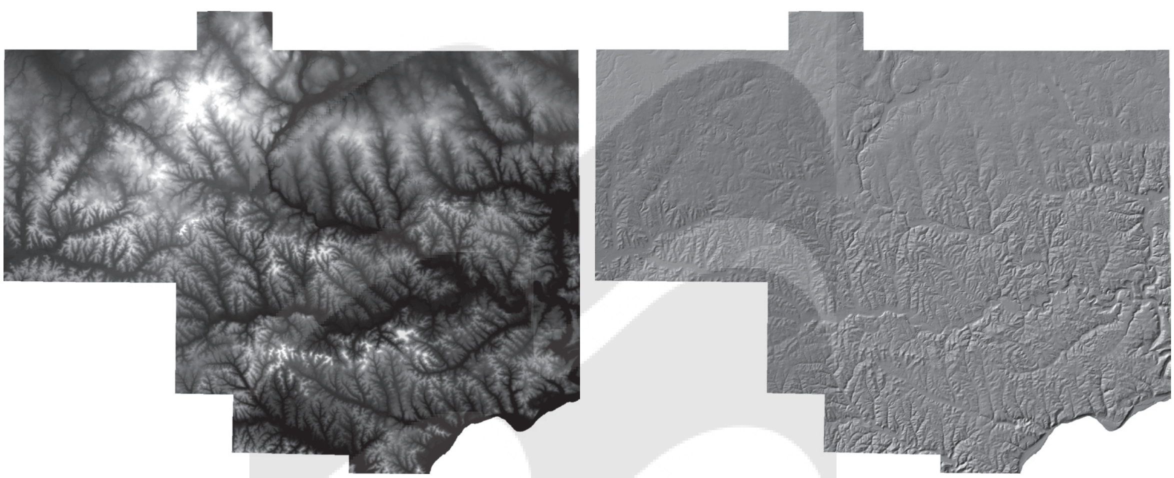
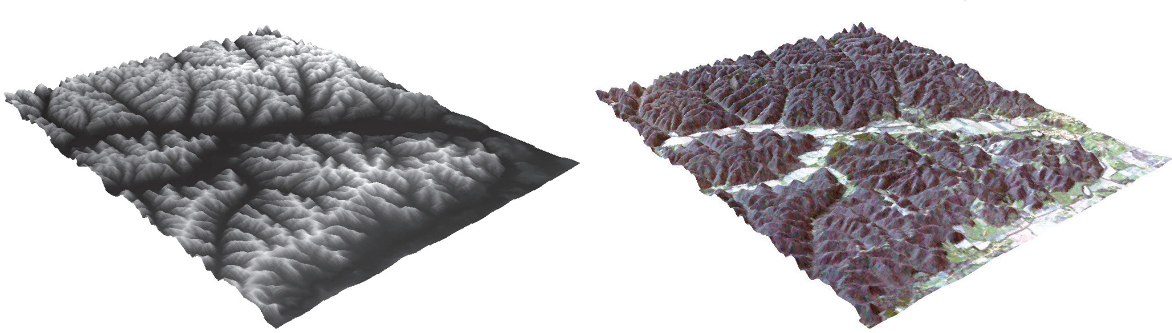


FIGURE 13.12

A DEM of the Laurelville/Hocking region of Ohio and a Landsat TM image draped over the DEM.



base heights the *z*-values of a digital terrain model that can then be applied to an image in the process of draping

assigning the *z*-values from those locations on the terrain (in Esri terminology, these are referred to as **base heights**) to those locations on the image. In essence, locations on the image are assigned a *z*-value that corresponds with the terrain model.

Draping is a common technique to show remotely sensed imagery on terrain features (the terrain model of Mount Everest in Figure 13.1 on page 472 appears in this way). Programs such as Google Earth and Google Earth Pro can show pseudo-3D landscapes by draping imagery over the underlying terrain models (see **Figure 13.13**). By creating a new draped image

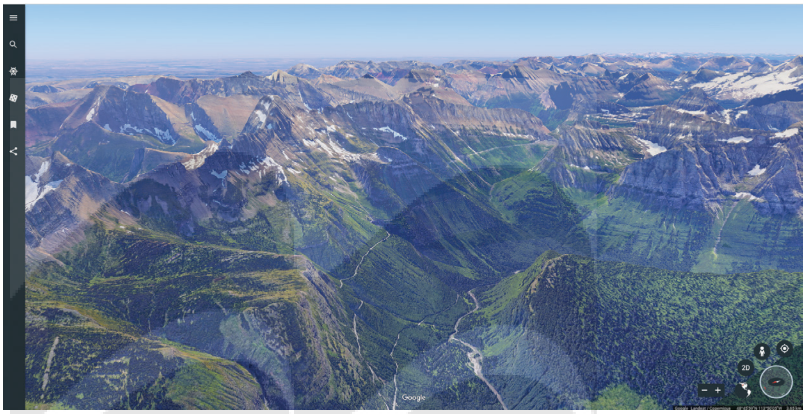


FIGURE 13.13

Examining imagery on a digital terrain model of Glacier National Park in Google Earth.

Hands-On Application 13.4

Terrain and Imagery Examples in Google Earth

To see some examples of three-dimensional terrain, go to **earth.google.com** and start using Google Earth. Use the search function to look for Glacier National Park, MT. When Google Earth arrives at Glacier, click on the 3D button to change to a perspective view of the national park to see the mountains and terrain. By double-clicking on the red and white arrow button, you'll gain access to the navigation controls for Google Earth. You can use the controls to tilt the view up or down, then navigate and spin the view. Use the mouse and/or the arrow keys on the keyboard to fly around the landscape. Remember that what you're examining here is imagery that has been draped over a digital terrain model representing the landscape of this section of the country. Fly around the Glacier area (see Figure 13.13 for an example) and get a feel for navigation over draped imagery. You'll be doing more of this (among many other things) in Geospatial Lab Application 13.1 but using Google Earth Pro.

Expansion Questions

- Try using Google Earth to fly to other areas and view their terrain, such as Mount Everest, Death Valley, and Machu Picchu. How does the addition of draped remotely sensed imagery on the terrain add to your sense of visualizing the features of the terrain?
- From examining Glacier as well as the other three options above, you'll see that in some locations some features on the landscape (such as trees or buildings) may just be shown flat and not in 3D. Why is this?

in perspective view, we can get new visual information about the appearance of the landscape that's not directly obtainable through an examination of contours or non-perspective DTMs (see *Hands-On Application 13.4: Terrain and Imagery Examples in Google Earth* for more information). For example, draping a dataset of contours over a DTM and looking at it in perspective can demonstrate visually how contour lines match up with the elevations that they represent.

Even with hillshading or draping to improve the terrain's appearance, there's no getting around the fact that some sections of terrain don't have much variety in terms of changing elevations and features. In these cases, differences in landscape elevations or slopes may be difficult to see when viewing or interacting with a digital terrain model. The solution is to enhance the differences between elevations artificially so that the landscape can be better visualized. **Vertical exaggeration** is the process of artificially altering the terrain model for visualization purposes so that the vertical scale of the digital terrain model is larger than the horizontal scale. If the model's vertical exaggeration is "5×," then the vertical scale (the *z*-values) will be five times that of the horizontal scale. These types of artificial changes can really enhance certain vertical features (for example, valleys appear deeper and peaks appear higher) for visual purposes. The downside to vertical exaggeration is that it alters the scale of the data and should be used only for visualization. For a comparison of different vertical exaggerations applied to a DTM, see **Figure 13.14**.

vertical exaggeration a process whereby the *z*-values are artificially enhanced for purposes of terrain visualization

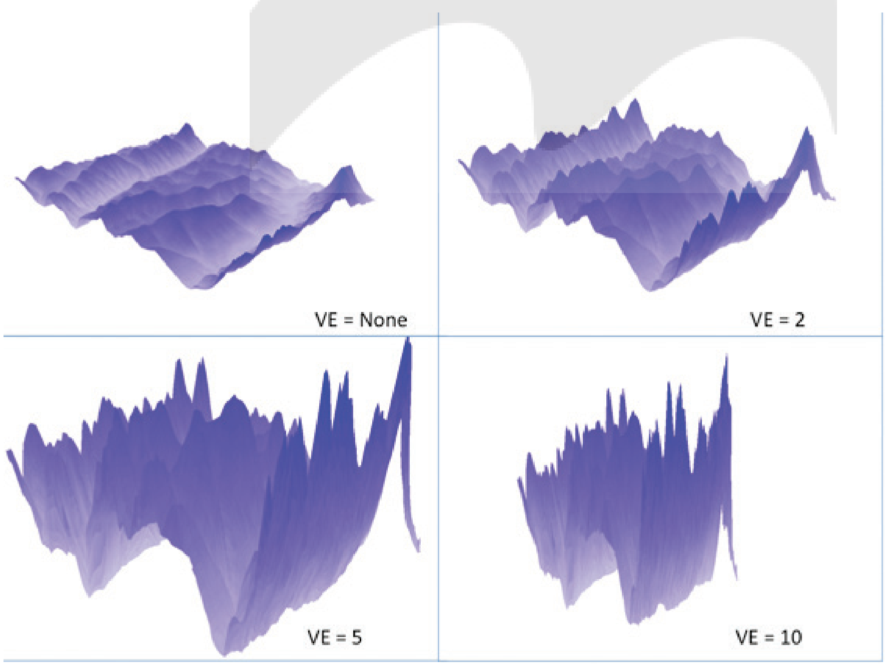


FIGURE 13.14
Different levels of vertical exaggeration for a DEM (values of none, 2, 5, and 10).

Chapter Wrap-Up

This chapter has explored both methods of modeling and ways of visualizing the landforms on Earth's surface. In the next chapter, we'll do a lot more with the 3D aspect of visualization. After all, there's more than just the terrain that can be viewed in 3D—there are plenty of structures, buildings, and natural growth that can be added to a pseudo-3D terrain model to improve the realism of the scene. Chapter 14, which picks up where this one leaves off, continues pursuing new avenues of 3D visualization.

Before then, check out *Terrain and Topography Apps* for some downloadable apps that will allow you to use topographic maps on your mobile device. Also take a look at *Digital Terrain in Social Media* for information from Twitter and Instagram accounts as well as some YouTube videos related to this chapter's concepts. This chapter's lab will allow you to implement the chapter topics using Google Earth Pro.

Important note: The references for this chapter are part of the online companion for this book and can be found at **www.macmillanlearning.com/catalog/shellitoigt4e**.

Terrain and Topography Apps

Here's a sampling of available representative terrain apps for your smartphone or tablet. Note that some apps are for Android, some are for Apple iOS, and some may be available for both.

- **Avenza Maps:** An app that allows you to purchase maps, and also to import GeoPDF maps for use on a mobile device
- **NP Maps:** An app that allows you to download and view topographic maps of the U.S. National Parks

Digital Terrain in Social Media

Here's a sampling of some representative Twitter and Instagram accounts, along with some YouTube videos related to this chapter's concepts.

Become a Twitter follower of:

- **OpenTopography:** @OpenTopography
- **USGS (United States Geological Survey):** @USGS
- **USGS News about Mapping:** @USGSNewsMapping

Become an Instagram follower of:

- **OpenTopography:** @OpenTopography
- **USGS:** @usgs

On YouTube, watch the following videos:

- **How does LiDAR remote sensing work?** (a basic introduction to lidar): **www.youtube.com/watch?v=EYbhNSUnIdU**
- **How to use a GeoPDF** (a video from TerraGo about GeoPDFs): **https://www.youtube.com/watch?v=XUI_FFiv1kg**
- **Using US Topo and Historic Topo Maps on your Mobile Device** (a USGS video about using US Topos): **https://www.youtube.com/watch?v=nbCGoYJJwZs**
- **US Topo** (a USGS video concerning the development of US Topos): **www.youtube.com/watch?v=hv0jxsW3qgY**
- **What is the USGS 3DEP Program?** (a video interview concerning the 3DEP program): **https://www.youtube.com/watch?v=GBdGWWMvO-Y**

Key Terms

3DEP (p. 481)
base heights (p. 486)
collar (p. 475)
contour interval (p. 474)
contour line (p. 473)
DEM (p. 478)
DLG (p. 473)
draping (p. 485)
DRG (p. 472)
DSM (p. 480)
DTM (p. 478)
GeoTIFF (p. 472)
hillshade (p. 484)
LAS (p. 480)
lidar (p. 479)
NAVD88 (p. 471)
perspective view (p. 483)
point cloud (p. 480)
pseudo-3D (p. 483)
slope (p. 482)
slope aspect (p. 482)
SRTM (p. 479)
Sun altitude (p. 484)
Sun azimuth (p. 484)
three-dimensional (3D) model (p. 478)
TIN (p. 478)
topographic map (p. 472)
two-and-a-half–dimensional (2.5D) model (p. 478)
US Topo (p. 474)
vertical datum (p. 471)
vertical exaggeration (p. 487)
viewshed (p. 482)
z-value (p. 471)

13.1 Geospatial Lab Application

Digital Terrain Analysis

This chapter's lab will introduce you to some of the basics of digital terrain modeling—working with DTMs, slope, viewsheds, and imagery draped over the terrain model. You'll be using the free Google Earth Pro for this lab.

Objectives

The goals for you to take away from this lab are:

- To examine pseudo-3D terrain and navigate across it in Google Earth Pro
- To examine the effects of different levels of vertical exaggeration on the terrain
- To create a viewshed and analyze the result
- To create an animation that simulates flight over 3D terrain in Google Earth Pro
- To create an elevation profile for use in examining a DTM and slope information

Using Geospatial Technologies

The concepts you'll be working with in this lab are used in a variety of real-world applications, including:

- Civil engineering, in which slope calculations from digital elevation models are utilized to aid in determining the direction of overland water flow, a process that contributes to calculating the boundaries of a watershed
- Military intelligence, which makes use of terrain maps and digital elevation models in order to have the best possible layout of real-world areas (as opposed to two-dimensional maps) when planning operations involving troop deployments, artillery placements, or drone strikes

[PATRICK HERTZOG/AFP/Getty Images]

Obtaining Software

The current version of Google Earth Pro (7.3) is available for free download at **https://www.google.com/earth/download/gep/agree.html**.

Important note: Software and online resources can change fast. This lab was designed with the most recently available version of the software at the time of writing. However, if the software or Websites have changed significantly between then and now, an updated version of this lab (using the newest versions) will be available online at **www.macmillanlearning.com/catalog/shellitoigt4e**.

Lab Data

There is no data to copy in this lab. All data comes as part of the Google Earth Pro data that is installed with the software or is streamed across the Internet when using Google Earth Pro.

Localizing This Lab

The lab can be performed using areas close to your location, as Google Earth Pro's terrain and imagery covers the globe.

13.1 Examining Landscapes and Terrain with Google Earth Pro

1. Start **Google Earth Pro (GEP)**. By default, GEP's Terrain option will be turned on for you. Check in the **Layers** box to be sure that there is a checkmark next to **Terrain** (and don't uncheck that for the remainder of the lab). Having this layer turned on activates the DTM that underlies the imagery within GEP.
2. Next, as this lab is focused on digital terrain modeling, we'll want to use the most detailed DTM possible. From the **Tools** pull-down menu, select **Options**. In the Google Earth **Options** dialog box that appears, choose the **3D View** tab and place a checkmark in the box next to **Use high quality terrain (disable for quicker resolution and faster rendering)**. Next, click **Apply** and then click **OK** to close the dialog box and return to GEP.
3. For this lab, we'll be using GEP to examine a terrain model of Zion National Park in Utah—in the **Search** box, type **Zion National Park, UT**. GEP will zoom down to the area of Zion National Park. In the **Layers** box, expand the **More** option and place a checkmark next to **Parks/Recreation Areas**. This will show you the outline of Zion in green. Zoom out so that you can see the entire layout of Zion in the view. For more information about Zion National Park, check out **www.nps.gov/zion/index.htm**.
4. You will see a question mark symbol labeled as "Visitor Center" next to a label for "Park Headquarters." Center the view on this area of Zion.
5. From the **Tools** pull-down menu, choose **Options**. In the dialog box that appears, click on the **Navigation** tab and make sure that the box that says **Automatically tilt when zooming** has its radio button filled

in. This will ensure that GEP will zoom in to areas while tilting to a perspective view. Next, click **Apply** and then click **OK** to close the dialog box and return to GEP.

6. Use the **Zoom Slider** to tilt the view down, so that you have a good perspective view on Zion (see *Geospatial Lab Application 1.1* for more info on using this tool). Basically, push down the **plus** button on the Zoom Slider, and your view will zoom in and tilt down to a perspective where you can see the sides of the mountains and canyons in Zion in pseudo-3D. You can also hold down the **Ctrl** key on the keyboard while moving the mouse forward or backward to tilt the view.
7. Use your mouse wheel to move the view in and out (do this instead of using the Zoom Slider, because otherwise you'll keep tilting backward as well) as well as holding the **Ctrl** key until you can position the view as if you were at the park headquarters/visitor center and facing south (see below for an example).

8. There are two references to heights or elevation values in the bottom portion of the view:
   - The heading marked "elev" shows the height of the terrain model (that is, the height above the vertical datum) where the cursor is placed.
   - The heading marked "Eye alt" shows GEP's measurement for how high above the terrain (or the vertical datum) your vantage point is.

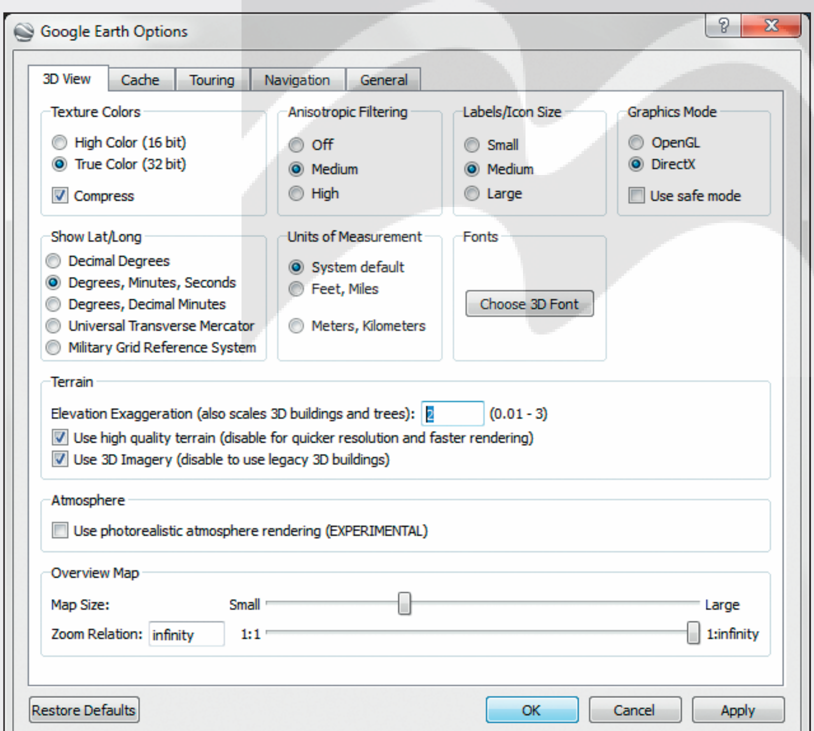
   Maneuver your view so your Eye alt is a good level above the terrain (perhaps about 4100–4200 feet), and you'll be able to see the mountain area that surrounds the park headquarters in Zion.

Question 13.1 How does the pseudo-3D view from this position and altitude aid in bringing out the terrain features of Zion (compared to what you originally saw in the overhead view earlier)?

13.2 Vertical Exaggeration and Measuring Elevation Height Values in Google Earth Pro

Google Earth Pro also allows you to alter the vertical exaggeration of the terrain layer. As we discussed on page 487, vertical exaggeration changes the vertical scale but keeps the horizontal scale the same, therefore it should be used for visualization purposes only.

1. To look at different levels of vertical exaggeration, select **Options** from the **Tools** pull-down menu. Select the **3D View** tab.
2. In the box marked Elevation Exaggeration, you can type a value (between 0.01 and 3) for vertical exaggeration of GEP's terrain. Type a value of **2**, click **Apply** and **OK**, and then reexamine the area surrounding the park headquarters in Zion.



Question 13.2 How did the vertical exaggeration value of 2 affect the view of Zion?

Question 13.3 Try the following values for vertical exaggeration: 0.5, 1, and 3. How did each value affect the visualization of the terrain? In addition to the value of 2 you examined in Question 13.2, which value of vertical exaggeration was the most useful for a visual representation of Zion and why?

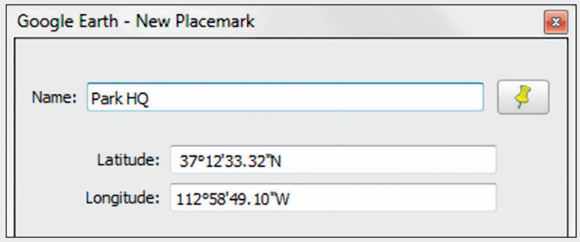
3. Reset the Elevation Exaggeration to a value of 1 when you're done.
4. From here, we'll examine the elevation values of the terrain surface itself. Although Google Earth Pro will always show the imagery over the terrain model, elevation information of each location is available. Wherever you move the cursor on the screen, a new value for elevation is computed in the elev option at the bottom of the view. By zooming and placing the cursor on its symbol on a spot on the screen, you can determine the elevation value for that location.

Question 13.4 At what elevation is the height of the park headquarters/visitors center?

13.3 Working with Viewsheds in Google Earth Pro

Now that you have a pretty good idea of how the landscape of Zion looks in the areas near the park headquarters, we'll now create a viewshed that will allow you to see what is visible and what is blocked from sight at a certain location.

1. To begin, we'll see what areas of Zion can be seen and cannot be seen from the park headquarters. Zoom in closely on the question mark symbol that GEP uses to mark the park headquarters. This symbol is what we'll use as the location for creating a viewshed.
2. Select the **Add Placemark** icon from the toolbar and put the placemark right on the park headquarters question mark symbol (see *Geospatial Lab Application 1.1* for how to do this).
3. In the **New Placemark** dialog box, name this new placemark **Park HQ**. Click **OK** in the New Placemark dialog box to accept the new name and close the dialog box.



4. You'll see the new **Park HQ** placemark in the Places box. Right-click on it and select **Show Viewshed**. When prompted about the placemark being too low, click on **Adjust automatically**.
5. GEP will compute the viewshed. Zoom out a bit to see the extent of the viewshed—all of the areas covered in green are the places that can be seen from the location of the Park HQ placemark and the areas not in green cannot be seen from there. After zooming out, look at the areas immediately south and southeast of the Park HQ placemark.

Question 13.5 Can the ranger station, the campground, or the two picnic areas just south and southeast of the park headquarters be seen from the Park HQ vantage point?

6. Click on **Exit viewshed** to remove the viewshed layer.
7. About 2 miles to the northeast of the park headquarters is a scenic overlook. Its symbol in GEP is a small green arrow pointing to a green star. Move over to that location so that you can see it in the view and zoom in closely on the overlook symbol.
8. Put a new placemark directly on the green star and name this placemark **Zion Overlook**.
9. Create a viewshed for the Zion Overlook point and answer Questions 13.6 and 13.7. Exit the viewshed once you're done.

Question 13.6 Can the area labelled as parking to the immediate north of your Zion Overlook point be seen from the overlook?

Question 13.7 What is blocking your view of Sand Beach trail from the overlook? Be specific in your answer. *Hint:* You may want to zoom in closely to your Zion Overlook placemark and position the view as if you were standing at that spot and looking in the direction of Sand Beach trail.

13.4 Flying and Recording Animations in Google Earth

Google Earth Pro allows you to record high-definition videos of the areas you view in GEP. In this section, you'll be capturing a video of the high-resolution imagery draped over the terrain to record a virtual tour of a section of Zion. Before recording, use the mouse and the Move tools to practice flying around the Zion area. You can fly over the terrain, dip in and out of valleys, and skim over the mountaintops. Don't forget you can also hold down the Ctrl key and move the mouse to tilt your view. It's important to have a good feel of the controls, as any movements within the view will be recorded to the video. When you feel confident in your skills for flying over 3D terrain in Google Earth Pro, move on to the next step.

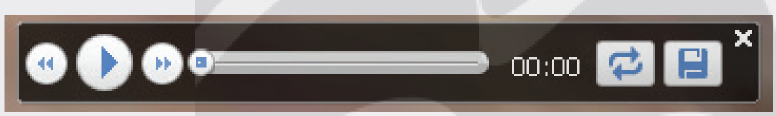
1. The tour you will be recording will start at the park headquarters (your Park HQ placemark), move to the scenic overlook (your Zion Overlook placemark), and then finish at the lodging/parking area about a mile to the north of the overlook. We'll do a short "dry run" of this before you record. To begin, double-click on the **Park HQ** placemark in the Places box and the view will shift there.
2. Next, double-click on the **Zion Overlook** placemark in the Places box and the view will jump to there.
3. Lastly, use the mouse and **Move** tools to fly manually over the terrain a mile north of the overlook to the parking and lodging area and end the tour there.
4. If you need to, try this dry run of maneuvering among the three points so that you feel comfortable prior to recording. When you're ready to make your tour video, double-click on the **Park HQ** placemark in the Places box to return to the starting point of the tour. Also, take away the checkmarks next to the **Park HQ** and **Zion Overlook** placemarks in the Places box so that the two placemarks will not appear in the view (and thus not appear in the video) and that all you will see is the GEP imagery and terrain.
5. On Google Earth's toolbar, select the **Record a Tour** button.

6. A new set of controls will appear at the bottom of the view:

7. To start recording the video, press the red record button.

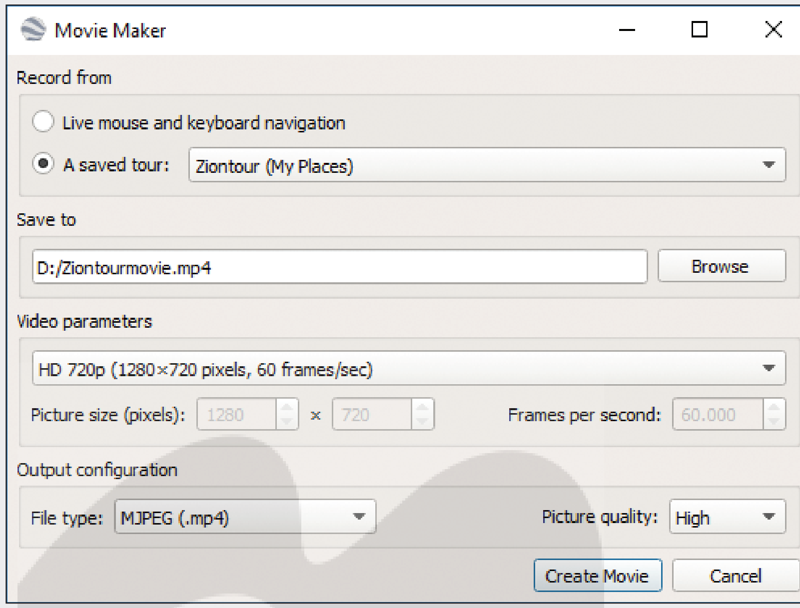
   Important note: If you have a microphone hooked up to your computer, you can get really creative and narrate your tour—your narration or sounds will be saved along with your video.

8. After showing the park headquarters in the view for a couple seconds, double-click on the **Zion Overlook** placemark in the Places box to jump to there. Show the overlook for a few seconds, then use the mouse and move commands to fly to the lodging/parking area to the north.
9. When you're done, press the **red** record button again to end your recording of the tour.
10. A new set of controls will appear at the bottom of the screen, and Google **Earth Pro** will begin to play your video.



11. Use the **rewind** and **fast-forward** buttons to skip around in the video, and also the **play/pause** button to start or stop. The button with the two arrows will repeat the tour or put it on a loop to keep playing.
12. If the tour is how you want it, save the tour by pressing the **disk icon** (Save Tour) button. Call it **Ziontour** in the dialog box that opens. The saved tour will be added to your Places box (just like all other GEP layers). If the tour is not looking how you want it, return to Step 4 and remake the tour.
13. Right now, the tour can only be played in GEP. You'll want to export your tour to a high-definition video that can be watched by others or shared over the Web. To start this process, first close the DVR control box in the view by clicking on the **x** in the upper right-hand corner of the controls.

14. Next, from the **Tools** pull-down menu, select **Movie Maker**.

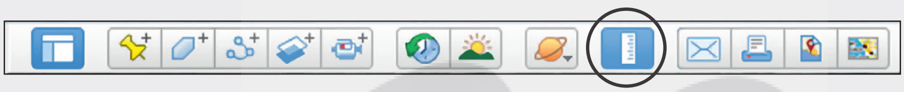


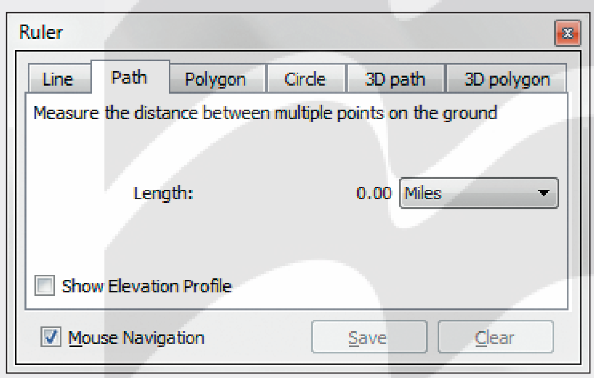
15. In the **Movie Maker** dialog box, choose **1280 × 720 (HD)** for **Video parameters**. This will create a high-definition (HD) video of your tour.
16. Next, under **Record from…** choose the radio button for **A saved tour** and choose **Ziontour (My Places)**. This will be the source of your video.
17. From the pull-down menu next to File type, choose **.MJPEG (.mp4).** If you are using Windows, you may want to instead choose **Windows Media (.asf).**
18. Under **Save to…** use the **browse** button to navigate to the drive to which you want to save your video and call it **Ziontourmovie**.
19. Leave the other defaults alone and click **Create Movie**. A dialog box will appear showing the conversion process to create your video.
20. Return to the folder where you saved your movie (either as .mp4 or .asf) and view it using your computer's media player.

> **Question 13.8** Show (or submit) your final video file of your video tour of Zion to your instructor, who will check it over for its quality and completeness for you to get credit for this question.

13.5 Measuring Profiles and Slopes in Google Earth Pro

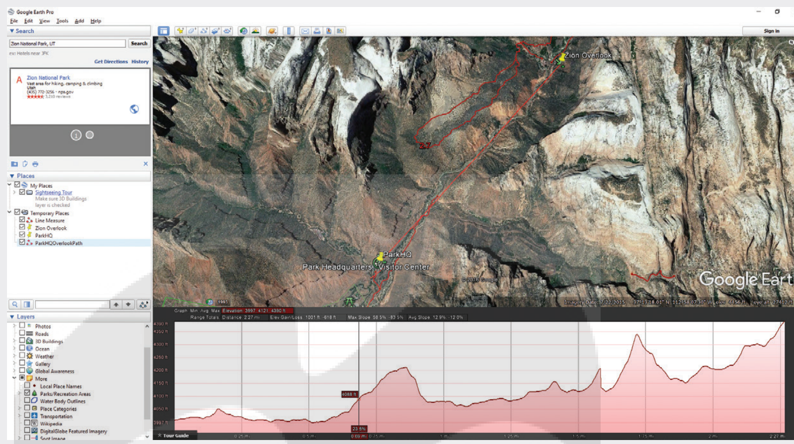
1. In the last part of this lab, you will be examining profiles of the digital terrain model and examining the slope information. To begin, return the view to the **Park HQ** placemark.
2. Zoom out so that you can see both the Park HQ and the Zion Overlook placemarks clearly in the view. What we'll do next is construct a profile (a two-dimensional view) of the digital terrain between the two placemarks and then examine the elevations and slope of the terrain.
3. To examine the terrain profile, you must first draw a path between the two points. To begin, choose the ruler tool from the GEP toolbar.





4. In the **Ruler** dialog box that opens, select the **Path** tab.
5. In the view, you'll see that your cursor has changed to a crosshairs symbol. Left-click once on the **Park HQ** placemark location and then click the left mouse button once on the **Zion Overlook** placemark position. You'll see a yellow line drawn between them and the Length of this line will be shown in the Ruler dialog box.
6. In the Ruler dialog box, click **Save**.
7. A new dialog will open and allow you to give this path you've drawn a name. Call it **ParkHQOverlookPath** and click **OK** in the **naming** dialog.

8. You'll see a new item added to the Places box called ParkHQOverlookPath. Right-click on it and select **Show Elevation Profile**.
9. A new window will open below the view, showing the elevation profile between the two points. This profile will show you, in two dimensions, the outline and elevations of the terrain in between the two points.



10. As you move your cursor along the outline of the terrain in the profile, information will appear about the elevation and the slope at the location of your cursor. You'll see the corresponding location highlighted in the view as well. The slope information is in a positive percentage as you move uphill from the park headquarters to the overlook and a negative percentage as you move downhill. Carefully examine the profile (and the digital terrain) and answer Questions 13.9, 13.10, and 13.11.

Question 13.9 What is the average slope for the 2.2-mile path between the park headquarters and overlook (both uphill and downhill)?

Question 13.10 What is the steepest uphill slope between the two points and where is this located?

Question 13.11 What is the steepest downhill slope between the two points and where is this located?

11. You can also select a small section of the path and only examine the profile of that small subset. To do so, click the mouse at a place in the profile you want to begin. Hold down the left mouse button and move

the mouse to the place in the profile where you want to end. Release the mouse button and you will see that small section of the profile you chose in a darker red. Statistics for the elevation and slope of that subset will be shown in a red box at the top of the profile.

12. We're going to examine one small part of the profile. On the far right side of the profile (the terrain nearest the overlook), you'll see that a section of the landscape drops off sharply (this should be around the 1.6-mile mark between the Park HQ and the overlook). Using the method described above, highlight the subset of the profile from the location at the bottom of the drop-off to the overlook itself, then answer Question 13.12.

> **Question 13.12** For this section of the terrain, what is the maximum uphill and downhill slope? What is the average uphill and downhill slope?

Closing Time

Google Earth Pro is a very powerful program with a lot of functionality and options for working with DTMs and digital terrain analysis. Google Earth Pro's detailed terrain model under the draped imagery can be used as the base for many different types of analysis. When you're finished, exit GEP by selecting the **File** pull-down menu and choosing **Exit**. There's no need to save any of your temporary places data for this lab.