Geographic Information Systems (GIS) for Disaster Management

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3

Geographic Information Systems

CHAPTER OBJECTIVES

Upon chapter completion, readers should be able to

1. understand the components of GIS,
2. understand the concept of layers in GIS,
3. be familiar with common GIS functions and how they relate to disaster management,
4. be familiar with common GIS data storage formats,
5. understand some of the limitations of GIS,
6. understand what GIS metadata is and why it is important, and
7. identify and discern a variety of specific GIS technologies that are relevant to disaster management.

INTRODUCTION

This chapter formally presents geographic information systems (GIS). The chapter starts with a discussion of what a GIS is and what it can and cannot do. In this discussion, specific GIS software product references are avoided as much as a possible to ensure you understand the underlying principles of GIS that are used in specific GIS technologies. The chapter then discusses the most important and time-consuming aspect of working with a GIS—GIS data. You will learn about conceptual differences in how the earth is digitally referenced and represented in various GIS data model formats. Additionally, you will learn about GIS *metadata*—a critical item to ensure that the GIS data you select is relevant to your GIS operational needs. The second half of the chapter is devoted to specific GIS technology. In this part of the chapter, you will learn about commercial, open-source, and open/web-based GIS software. This part of the book is the one that is most likely to change quickly as specific GIS technology is constantly and rapidly changing, and you will need to keep track of these changes. However, the foundational

concepts learned in the beginning of this chapter should serve to keep your skill and knowledge set relevant even as specific GIS software products change. The first section presents an overview of GIS.

WHAT IS GIS?

To understand what a GIS is, let's first take a closer look at what the acronym means. Remove the "G" from GIS and you have *IS* or an *information system.* Information systems have been defined as "combinations of hardware, software, and telecommunications networks that people build and use to collect, create, and distribute useful data, typically in organizational settings" (Valacich and Schneider, 2010, 8). Additionally, like any system that is a whole constructed of parts, a GIS can also be viewed as an amalgam of several parts that create the overall system. Although variations exist in what exactly those parts might be, a GIS is generally considered to be composed of the following interrelated parts that follow the information systems definition closely:

1. **Software:** Software is used for running GIS operations. For example, commercial GIS software packages such as Esri's ArcMap or open-source web mapping environments such as Open Layers.
2. **Hardware:** Hardware is the platform in which software is run and/or data is stored. In today's increasingly interconnected world, hardware can range from traditional PCs to smartphones to massive computing infrastructures for hosting cloud computing resources.
3. **People:** People include those who work with GIS in a variety of capacities such as using GIS to make decisions, organizations like the United Nations Geographical Information Working Group (UNGIWG - http://www.ungiwg.org/) that advocate for GIS, or students learning about GIS.
4. **Knowledge:** Knowledge is perhaps the most abstract part of GIS but as equally important as the other parts. Knowledge, in the context of this discussion, refers to the variety of training, education, skills, and experience that are applicable to GIS. For example, by reading this book, you are gaining new knowledge in GIS, cartography, spatial analysis, and spatial perspectives on how these and other ideas in this book are applied to the disaster management domain.
5. **Data:** Data will always be the more important component of a GIS. Representation of the earth's features, which is the conceptual core of GIS, is fundamentally based on data and hence why significant discussion of GIS data is made in this chapter.
6. **Network:** The network can be considered the element that connects all the other parts together. For example, the Internet that connects people to GIS data websites or connecting GIS software with web-based data services or social networks that connect people who use GIS with one another through things like GIS user communities.

Figure 3.1 depicts a graphical representation of the components of GIS with disaster management items added to illustrate the components in the context of GIS for Disaster Management.
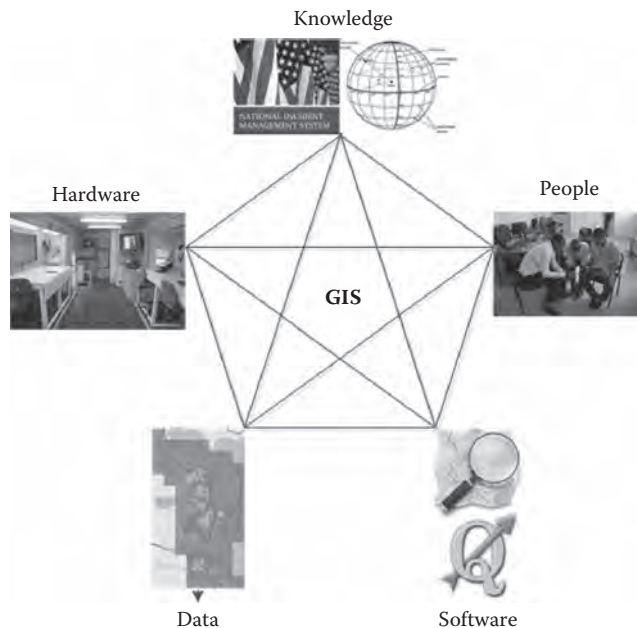
Figure 3.1 The components of GIS. The lines represent networks that connect all of the other components. Each component requires elements of the other components. For example, the *hardware* in the GIS truck requires *people* with *knowledge* of disaster management practice and fundamentals of geographic information to use *software* that consumes *data* to support disaster management activities. (Illustration © OpenStreetMap contributors.)

A Brief History of GIS

Although maps have existed for millennia, the origins of what we now consider GIS are usually attributed to what actually might be considered a disaster (or emergency) management scenario. During the London cholera outbreak of 1854, physician Dr. John Snow famously mapped cholera outbreak instances to find spatial clusters that led him to the conclusion that cholera was originating from a contaminated well (Figure 3.2).

The 1960s saw the beginning of the development of modern GIS. Creation of the term *geographic information systems* is credited to Canadian Dr. Roger Tomlinson (1933–2014) and development of the Canadian Geographic Information System, which was a first step in moving beyond computer mapping to include map layer overlays. The later 1960s and early 1970s were also when the Harvard Laboratory for Computer Graphics and Analysis began developing some of the first computer-based spatial analysis and computer cartography and graphics research and applications, and later, the ODYSSEY system, which was designed to process larger geographic datasets (Chrisman, n.d.). Jack Dangermond, president and founder of Esri, began his career at the Harvard Laboratory for Computer Graphics and Analysis. By the early 1980s, Esri was founded and the ArcINFO software product running on UNIX platforms was developed for

specialized application uses such as environmental management and demography via the Dual Independent Map Encoding (DIME), and later led to the Topologically Integrated Geographic Encoding and Referencing (TIGER) formats developed by the US Census Bureau, of which TIGER is still used today. By the 1990s, GIS technology then began a trend that continues to this day of closely following and being shaped by broader computing industry trends. For example, the 1990s saw the first graphical user interface (GUI) and mainstreaming of GIS technology to align with the rise of the PC and Windows, the 2000s saw increased use of web-based and Internet GIS and the time when the first edition of this book was written (2014) is currently the age of cloud computing, mobile computing, social media, and "big" datasets.
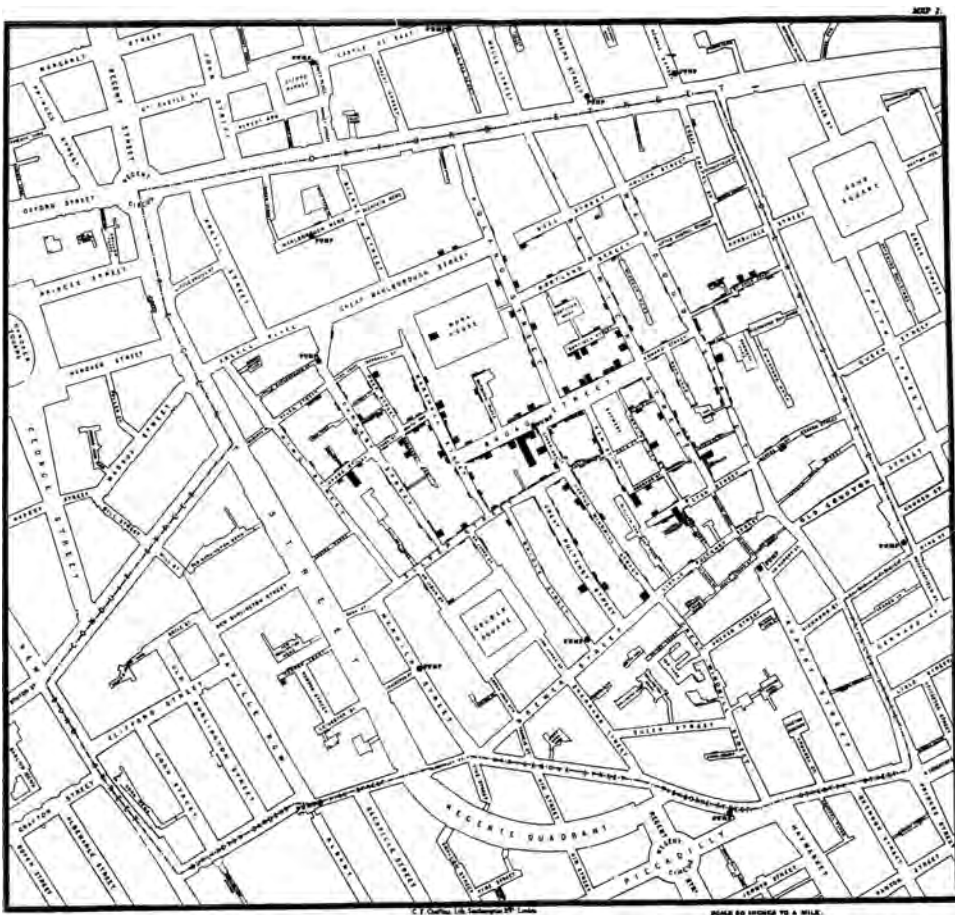
Figure 3.2 Excerpt of John Snow's famous 1854 map of cholera outbreaks. The cluster of cholera cases found near the pump of Broad Street (seen in the center of this image) led to the conclusion that this pump was the cholera source. (From John Snow, *On the Mode of Communication of Cholera*, 2nd ed., John Churchill, New Burlington Street, London, England, 1855.)
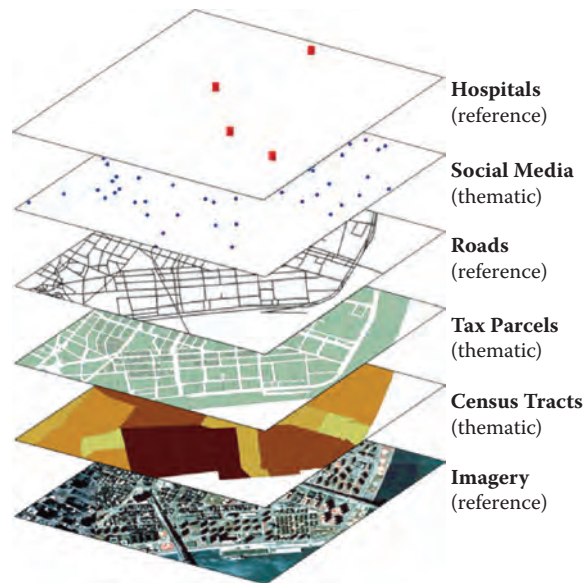
Organizing the World Geographically: Map Layers

The core of the power of GIS is its ability to organize data into one common geographic view. This simple statement may seem self-evident given the extensive discussion so far about maps and the principals of geographic information such as coordinate systems that provide a common geographic index. However, the key thing that GIS provides to the organization of data geographically is the concept of map layers. Figure 3.3 provides a graphical representation of the concept of map layers from the perspective of disaster management.

In Figure 3.3, a selection of real GIS datasets from Manhattan, New York, USA during Hurricane Sandy (2012) are shown to demonstrate how map layers are combined to support disaster management. Furthermore, the category of map data (reference vs. thematic) as per Chapter 2 discussions, are also shown to give you a sense of how different kinds of map layers are combined. For example, imagery provides a visual reference to the geographic region in question; the census tracks layer shows population thematic characteristics, tax parcels, and who owns what buildings; the roads layer provides reference to critical infrastructure; the social media layer represents locations of people who are tweeting about the hurricane; and the hospitals layer provides reference for medical issues.

The concept of map layers is itself not a new idea, as acetate map overlays existed for years before the advent of computers. What makes modern GIS-driven map layers so powerful is the ability to overlay any number of digital map layers together and reference them to a common geography, thus allowing for entities on the layers to be viewed and analyzed together with the interactive power that GIS offers such as quickly changing the map layer, symbology of the map layer or any of the other GIS functions discussed later in this chapter.

Hospitals (reference)

Social Media (thematic)

Roads (reference)

Tax Parcels (thematic)

Census Tracts (thematic)

Imagery (reference)

**Figure 3.3**   The layering of geographic information.

What Can You Do (and Not Do) with GIS Software?

GIS software contains many powerful tools that can serve numerous functions. The following sections discuss some of the important GIS functions within the context of disaster management.

Data and Spatial Asset Management

As discussed previously, data is the most important component within the overall system that is GIS. The management of data using GIS is thus a primary GIS function. Management of GIS data can come in many forms. For example, GIS is often used to *create* spatially referenced data. Creation of spatial data can involve many activities such as digitizing features from images (Figure 3.4).

In Figure 3.4, features from an area flooded after the 2011 Fukashima Tsunami in Japan are being digitized from a satellite image of the disaster zone. As can be seen in the middle-left of the image, a variety of construction tools such as Polygon, Rectangle, Circle, and others are available to create features in two categories—flooded areas and standing structures (seen in Figure 3.4 in the construction tools). On the image itself, flooded area polygons have been digitized (or traced) from the image and are shown as polygons with a slanted line fill and standing structures are shown as black-filled polygons. Digitizing features from satellite images that show a disaster impact is a very common technique used to create damage assessment reports such as amount of area flooded and buildings that are intact. Once GIS data are created (or while it is being created), it must be stored in some type of data repository so that it can later be queried, retrieved, disseminated, and updated. Data repositories for GIS data are as diverse as the GIS data itself.
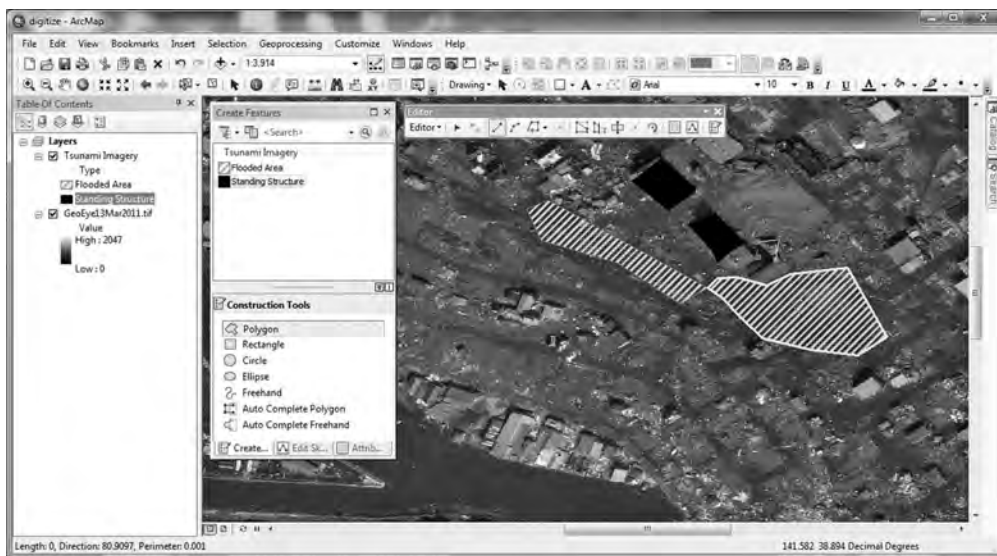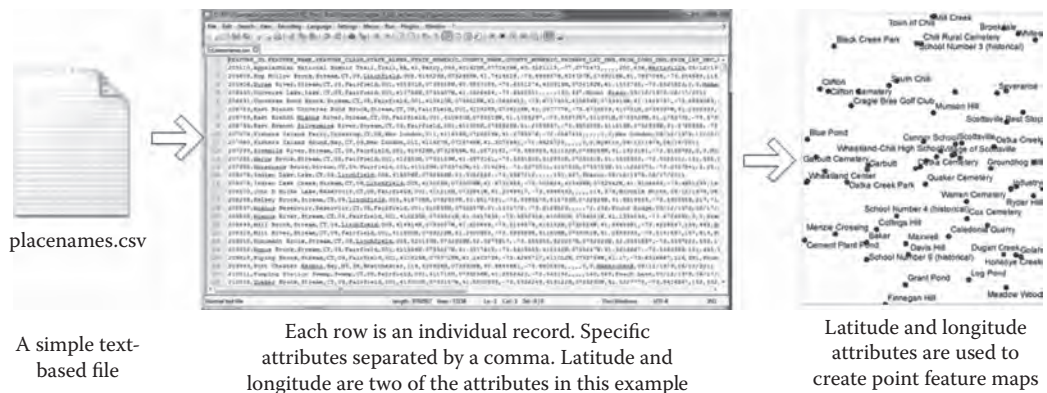

Figure 3.4 Digitizing features from images from the Fukashima, Japan, disaster of 2011. (Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)
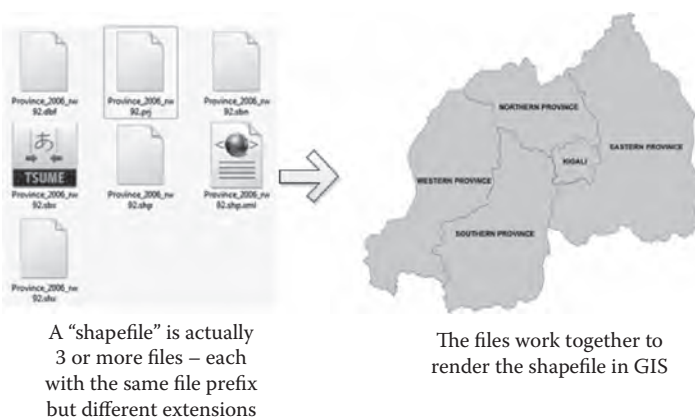
Figure 3.5 show one of the most basic yet still commonly used GIS data storage formats—the comma-separated values or CSV file.

CSV files are nothing more than ASCII-based text files where data in the file is structured using commas (,) to define data columns and each line in the file represents a single data record. Most often used for storing point features, specific geographic information is often represented as decimal degree, x,y coordinate numbers in the file that can then be parsed or read by GIS software for rendering on a map. CSV files are a common data storage format used by GIS data providers such as the US Census Bureau and the United States Geological Survey (USGS). Additionally, other characters such as a pipe (|) or tab can be used to structure text-based data like a .csv file.
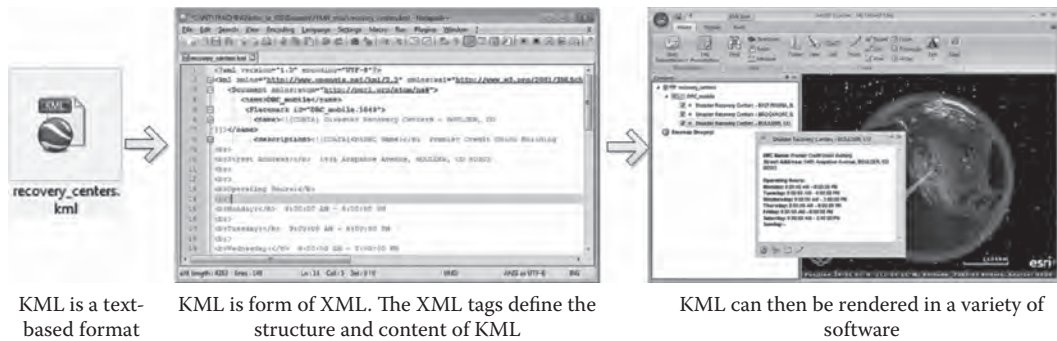
Figure 3.6 shows a shapefile.

placenames.csv

A simple text-based file

Each row is an individual record. Specific attributes separated by a comma. Latitude and longitude are two of the attributes in this example

Latitude and longitude attributes are used to create point feature maps

Figure 3.5   A CSV file containing geographic information. This example shows place name features.

A "shapefile" is actually 3 or more files – each with the same file prefix but different extensions

The files work together to render the shapefile in GIS

Figure 3.6   An example of the specific files that comprise a shapefile and what the contents of a shapefile look like when displayed in GIS, using Rwandan provinces as an example.

| KML is a text-based format | KML is form of XML. The XML tags define the structure and content of KML | KML can then be rendered in a variety of software |

Figure 3.7 An example of the KML format. In this example, FEMA disaster recovery centers are shown. (ArcExplorer screen shot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)

A proprietary spatial data format created by Esri in 1997, a *shapefile* is actually a collection of three or more files for storing vector GIS data (discussed later in this chapter) and has been a de facto (although not official) spatial data standard for many years due to Esri's large GIS market share and publication of the shapefile format (Environmental Systems Research Institute, 1998). Although Esri is deemphasizing shapefile data format in favor of their geodatabase file format, it is still a widely used format and many GIS datasets published by government entities in the United States, such as US Census Bureau TIGER files, and is thus important to mention. Shapefiles also store geographic information in a matrix (i.e., rows and columns) format, but raw shapefile data can only be viewed using special software unlike CSV files, which can be viewed using a basic text file viewing program like Notepad++ (http://notepad-plus-plus.org/).

Figure 3.7 shows the Keyhole Markup Language (KML) data storage format.

Originally developed by Google for use in Google Earth, KML has seen increasing popularity in recent years due to its ease of creation using Google Earth and the fact that KML is now an Open Geospatial Consortium (OGC) data standard (Open Geospatial Consortium, 2014). KML is an eXtensible Markup Language (XML) format and is thus an ASCII-based file format viewable in a text editor, making it useful for GIS applications that can read XML. As seen in Figure 3.7, KML contains both raw geographic information such as coordinates, but also the *presentation* of the geographic information such as colors used to display map features, text to display when a feature is clicked, and a wide variety of items such as time series and three-dimensional (3D) database solutions also exist.

OGC and Open Data Standards

The Open Geospatial Consortium (OGC; http://www.opengeospatial.org/) is an international standards body that maintains numerous geospatial and locational standards for a wide variety of application domains and industries. For example, the Web Map Services (WMS; http://www.opengeospatial.org/standards/wms) standard allows

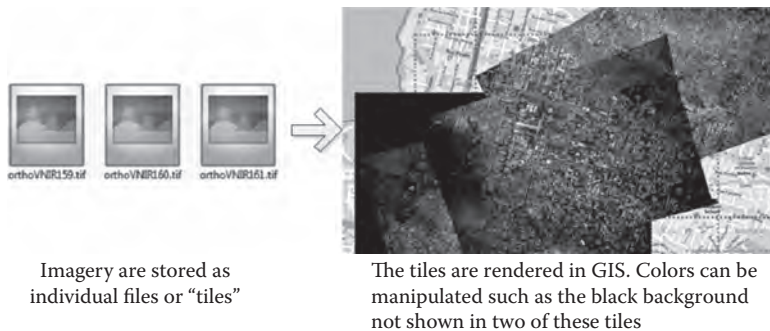different GIS applications to share georegistered images with one another using a simple HTTP protocol. The Geography Markup Language (GML; http://www.open-geospatial.org/standards/gml) standard defines an XML-based grammar to define geographic features and is often used in streaming geographic data services. OGC standards are particularly important for disaster management applications as the standards can ideally allow for greater discovery, sharing, and interoperability of geographic information across different GIS technology platforms, data formats, and organizations. For more information on OGC disaster management activities, see the OGC website at http://www.opengeospatial.org/domain/eranddm (Figure 3.8).
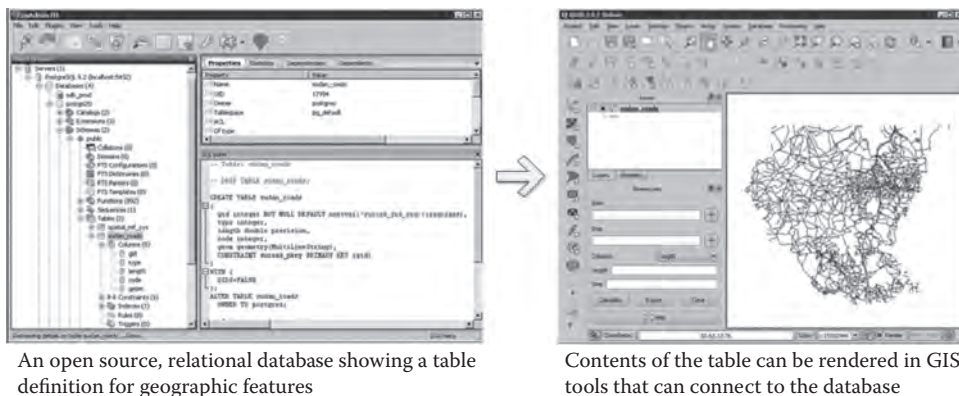
Figure 3.9 shows imagery files.

Imagery, such as satellite or aerial imagery, is commonly used as reference data in GIS (refer back to Chapter 2 for discussion of reference maps and data). However, during disaster response, rapid image acquisition from a disaster zone can become critical to situation awareness and understanding and quantifying damage impacts (van Aardt et al., 2011). Imagery can be considered a form of *raster-type* geographic information, which is discussed later in this chapter. Imagery can be stored in a variety of file formats such as.tiff, geotiff, .jpg, .sid, and others. Some image files can be viewed in standard image software such as Adobe Photoshop. However, to view the geographically referenced images requires GIS software or other software designed for handling

Figure 3.8 The OGC Emergency Response and Disaster Management webpage. Used with permission.

Imagery are stored as individual files or "tiles"

The tiles are rendered in GIS. Colors can be manipulated such as the black background not shown in two of these tiles

Figure 3.9 A sample of imagery files collected after the 2010 earthquake in Haiti. These images were very valuable for viewing damage done to buildings in Port-au-Prince. (Imagery files from Rochester Institute of Technology, http://ipler.cis.rit.edu/projects/haiti; base map data behind the images, © OpenStreetMap contributors.)

An open source, relational database showing a table definition for geographic features

Contents of the table can be rendered in GIS tools that can connect to the database

Figure 3.10 Storing GIS data in a relational database. In this example, the open-source database postegreSQL/postGIS (left side of the figure) show geographic content in QGIS (right side of the figure).

geographically referenced imagery or other raster data such as Erdas Imagine or ENVI. Rather than handling large repositories of image files, images are increasingly being disseminated via web services.

Figure 3.10 shows storage of GIS data in a relational database.

The relational database is a very broad category of GIS data storage and entails keeping geographically referenced information inside structures that normally store other types of nongeographic information. Storage of GIS data inside of relational databases is typically used in large-scale operations where there are large volumes of GIS data that have complex modeling requirements and need to be shared with many people. Most professional-grade GIS technology offers support for storing GIS data inside relational databases such as Microsoft SQL Server. However, as seen in Figure 3.10, open-source GIS enterprise database environments are also available.

Analysis

Analysis refers to the use of GIS to investigate geographically or spatially oriented questions or problems. An important point in this regard is that GIS software contains methods or tools designed to assist in understanding spatial patterns or processes. Disaster management lends itself well to providing specific examples of GIS analysis due to the fundamentally spatial nature of disasters.

As a hypothetical yet real GIS analysis example, based on events that happened in 2012 Hurricane Sandy, a disaster manager may wish to understand how to reduce the risk of people who are vulnerable to a flood hazard (Parry, 2013). She hypothesizes that a large storm swell will likely affect a larger number of elderly people than has been currently accounted for and are unlikely to seek shelter (Saul, 2012). To test her hypothesis, she starts by bringing census data into her GIS that indicates how many elderly people are living in a flood zone and next to a shoreline. She then uses a buffer tool to calculate distances from the shoreline to spatially understand how many elderly people may be affected by different storm surge extents (Figure 3.11).

GIS Programming

GIS programming refers to the use of computer programming languages to build custom software applications or tools to accomplish tasks that out-of-the-box GIS software might not be able to accomplish. In the early days of GIS, operations in GIS software were all
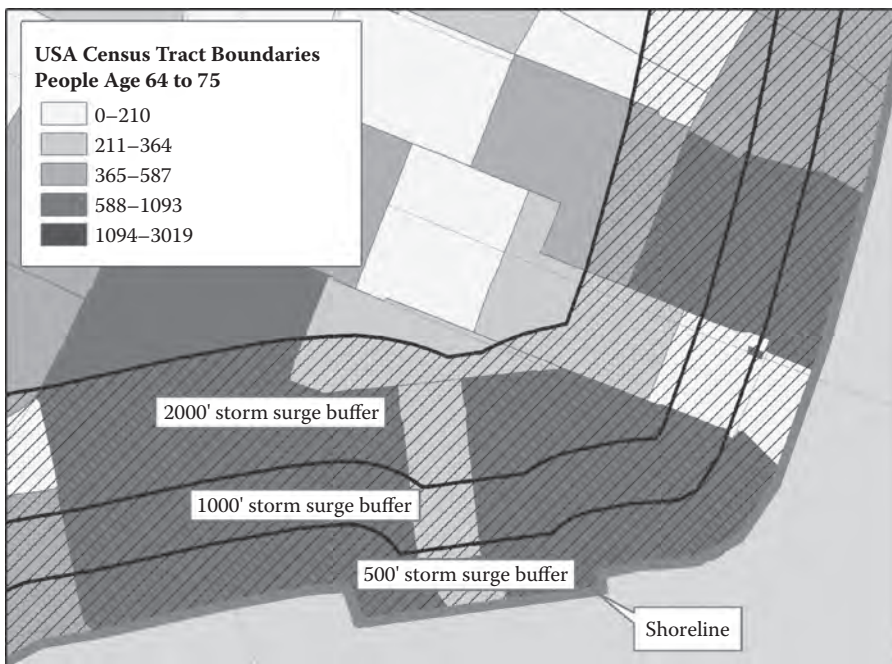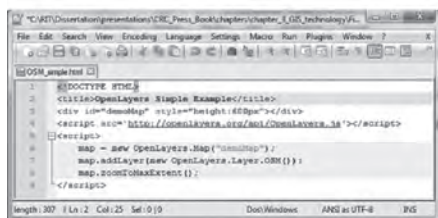

Figure 3.11   Buffer example; calculating distances from a shoreline to understand potential impacts on vulnerable populations.

conducted using programming languages such as FORTRAN and AML (ArcMacro Language) to send commands to the software. With the rise of Windows and personal computers in the 1990s, GIS software evolved to allow operations and interactions based on GUIs and the mouse. GIS programming thus evolved to become a more specialized task requiring interdisciplinary computing and information technology knowledge and skills such as computer programming that could be matched with GIS software tasks and principals. GIS programming is still a highly valued skill, knowledge of which makes one very valuable in terms of employability. A GIS programmer may write computer code for tasks ranging from batch data processing and automation to the development of modern-day *mapping mashups* that use complex algorithms for integrating heterogeneous data sources to solve unique problems (Batty et al., 2010; Liu and Palen, 2010). At the time of this writing, important computer programming languages to know for GIS programming are JavaScript for development of web-based GIS applications, Python for scripting tasks inside of major commercial GIS packages such as Esri's ArcGIS, and languages such as Java, C# or .Net for development of desktop GIS applications or native mobile device applications.

Mapping APIs

GIS programming is often based on the use of mapping application programming interfaces or APIs. Mapping APIs allow computer code to be written that utilizes objects, methods, and functions with the APIs. The following block of JavaScript code from the popular OpenLayers API demonstrates these ideas:
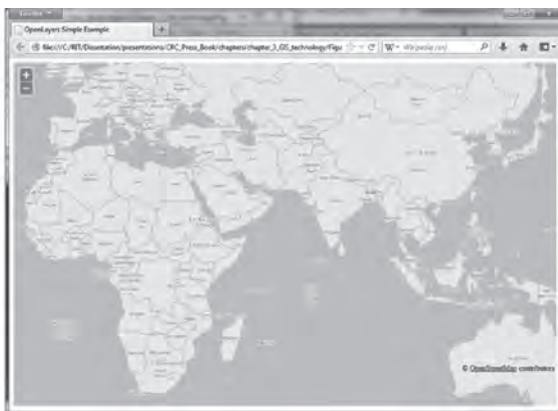

JavaScript code used to create web map. Note line 4 which connects the code to the OpenLayers API

JavaScript code creates this map when opened in web browser.

Figure 3.12 Using the OpenLayers API to create a simple web map using OpenStreetMap data. Code based on example from http://wiki.openstreetmap.org/wiki/OpenLayers_Simple_Example.

Many mapping APIs exist that can be used to support GIS programming tasks based on the underlying technology that will be programmed. A nonexhaustive collection of mapping APIs for web environments as of 2014 include:

Google Maps API for web, phone, and tablet environments: https://developers.google.com/maps/

Esri APIs for JavaScript, Flex, and Silverlight development platforms: http://www.esri.com/software/arcgis/apis

Microsoft Bing Maps API: http://www.microsoft.com/maps/choose-your-bing-maps-api.aspx

Like any specific technology, make sure to review any updates to these technologies and their corresponding URLs since the printing of this book.

Modeling

Much like model trains or cars give us a scaled representation of a real-world entity, modeling in the context of GIS is the idea of using GIS to simulate conditions in the real world to answer what-if questions. For example, a GIS-based model could be developed to simulate possible storm surge conditions and outcome scenarios. Furthermore, a powerful analytical capability of GIS-based models is the ability to tweak parameters within a model to evaluate different conditions and test relationships between different model parameters (Maguire, Batty, and Goodchild, 2005). Using the storm surge example, parameters that might be modified and observed to evaluate different scenarios including the strength of the storm surge and the time of day when the storm surge is happening to understand population impacts. For example, a model with a 3-meter storm surge within a city at 11:00 a.m. on Wednesday will produce vastly different results than the same model run on Saturday at 10:00 a.m. due to the effects of differing populations with a city between weekday and weekend work schedules of people. As we will see in later chapters, GIS-based models can be developed for almost any aspect of the disaster management cycle.

GIS-Based Disaster Modeling Tools

Several GIS-based modeling tools have been developed by US government agencies. Three important spatial modeling environments for disaster management are as follows:

HAZUS: This model focuses on estimating loss from natural hazards, specifically earthquakes, floods, and hurricanes. Through GIS-based modeling, HAZUS can estimate social, physical, and economic disaster impacts. Visual representations are a key component of HAZUS as the power of maps are utilized to show spatial relationships between a natural hazard and items such as populations or other resources (see http://www.fema.gov/hazus for more details).

Areal Location of Hazardous Atmospheres (ALOHA): This model is designed to model the spatial distribution of hazardous gases. ALOHA can model parameters relevant to the release of toxic, gas-based substances such as the pressure of the container holding the gas, the size of the opening in the gas container, gas storage temperature, wind speed and parameters to determine exactly what type of gas plume would be generated from the release. The gas plume that ALOHA generates can then be overlaid in a GIS to answer what-if questions about the plume such as, "What if the plume spreads over a residential area when people are home?" (Figure 3.13).

Standard Unified Modeling, Mapping and Integration Toolkit (SUMMIT): SUMMIT is a modeling environment supported by the US Department of Homeland Security "that enables analysts, emergency planners, responders, and decision makers to seamlessly access integrated suites of modeling tools & data sources for planning, exercise, or operational response" (Standard Unified Modeling Mapping, and Integration Toolkit, n.d.).

ALOHA generates plume model
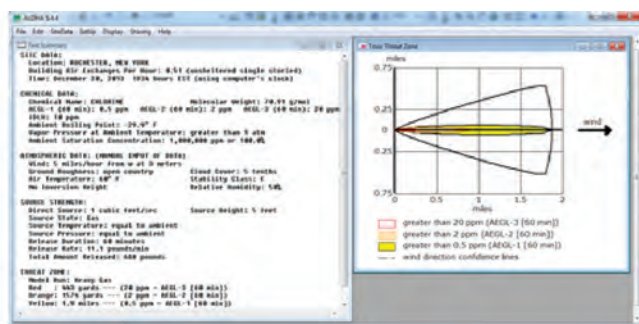
Plume model added to a GIS to answer "what if" questions about toxic gas release in a city

Figure 3.13 A plume generated in ALOHA (top of figure) that is then imported as a KML file into a GIS and layered on a map to show how the plume would affect the area of interest. ALOHA is US government software. For more on using ALOHA with GIS, see http://response.restoration.noaa.gov/aloha and Tomaszewski, Brian. 2003. Emergency response and planning application performs plume modeling. *ArcUser*, 10–12. (Figure base map data © OpenStreetMap contributors.)
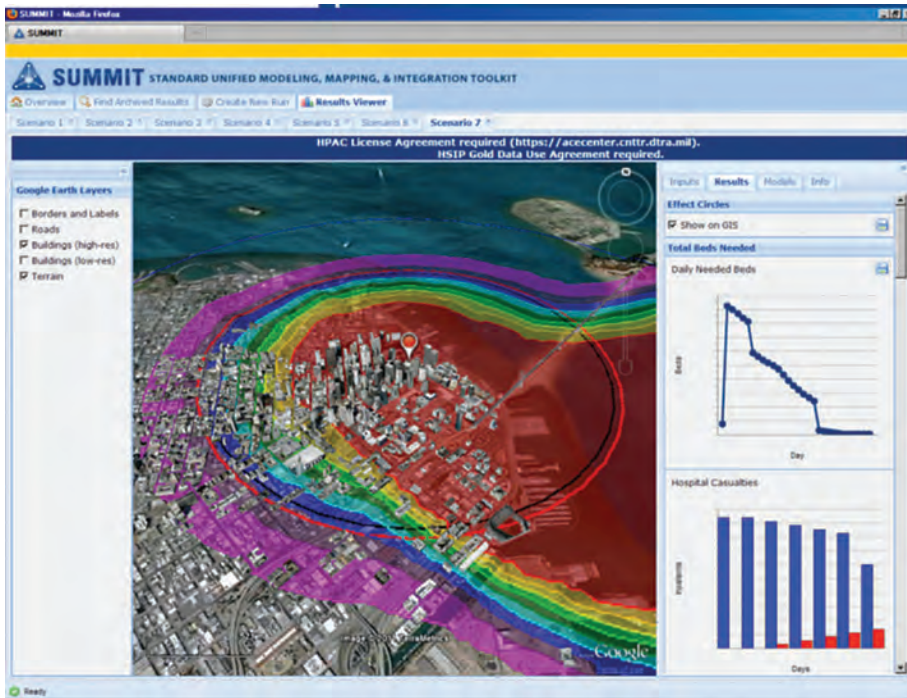
Figure 3.14 SUMMIT screenshot. For more information, visit: https://dhs-summit.us/.

Cartography, Visualization, and Map Production

As you saw in Chapter 2, important GIS functions are map production and cartography support tools. In essence, map production can be seen as the final process related to the other functions previously discussed in this chapter. For example, a map can be used to represent the final results of a GIS analysis to give to a decision maker or be used to represent different parameters, scenarios, and outcomes from GIS-based modeling to make modeling results easier to understand. Commercial desktop GIS tools such as Esri's ArcMap come with comprehensive tool sets to support the processes behind the art and science of cartography as well as numerous tools for final map product outputs for printing, use as static digital graphics, or map tiles within dynamic, web-based reference maps. The rise of online mapping tools like Google Maps is also changing long-held conventions about cartography and map production as these types of technologies in some way limit the cartographic process as the map maker is restricted, for example, to only using the Google base map as a reference map, which may not always be the best choice (Field and O'Brien, 2010). However, arguments for using mapping tools like Google Maps and Google Earth for cartographic and map production in disaster management cases, especially disaster response, are compelling when one considers the speed and ease of use by which these tools can produce maps. For example, quick situation awareness maps can be made by plotting point features on top of Google Earth's visible satellite imagery maps (Figure 3.15).
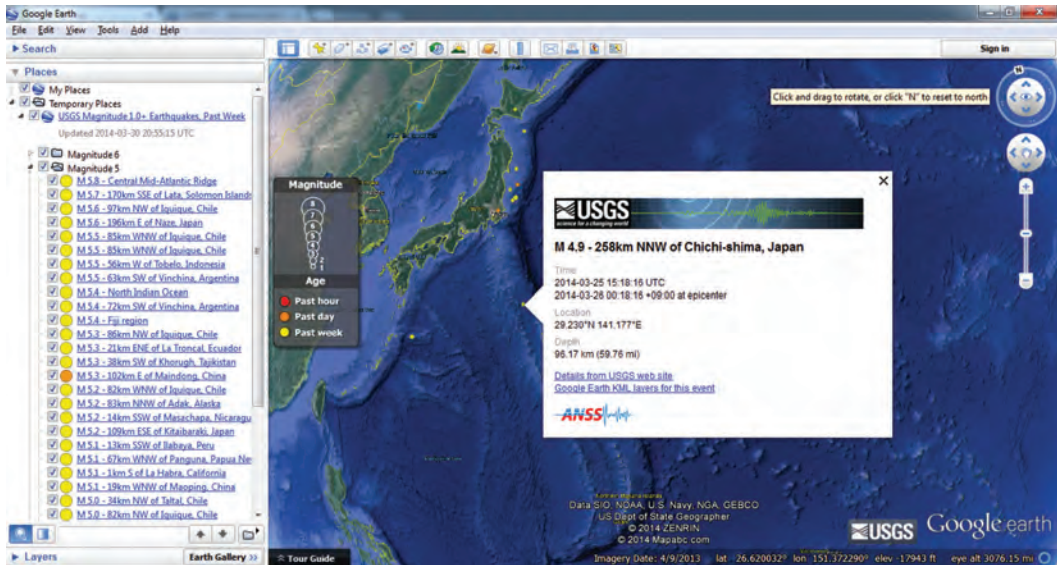
Figure 3.15   Viewing a USGS Earthquake KML feed inside Google Earth.

Geocoding

Geocoding is the idea of taking text-based input such as a place name or street address and converting it to a coordinate representation. For example, "1600 Pennsylvania Avenue, Washington, DC" would be geocoded to 38.897881, –77.036530 in decimal degree coordinates. A common, everyday example of geocoding is entering the name of a place, business, or address in a tool like Google Maps that can then quickly geocode the item entered and show its location on a map. Geocoding has numerous important uses for disaster management that include, but are not limited to, geocoding (or more accurately, geo-tagging) picture locations, geocoding tax parcels in relation to flood zones, and address searching for missing people (Schradin, 2013).

Limitations of GIS

Although the overall intent of this book is to inspire and help you learn about GIS for disaster management, it is important to also consider the limitations of GIS in disaster management. Technology in general is often seen as a miracle cure for existing problems, but it is important to manage the expectations about what GIS can do. The following are some points to keep in mind in terms of the limitations of GIS.

GIS software is not a miracle technology that can automatically answer all questions. Although this may seem obvious, it is important to keep in mind that GIS is limited by the numerous components of the system that comprises GIS, as discussed previously. For example, the answers you get are only as good as the software used, the quality of the data used in the software, and the skills of the people operating the software, conducting the analysis, and modeling and producing the final maps. GIS can strongly support answering questions, but it is still human reasoning and critical thinking that must make final decisions.

Overreliance and overexpectation of the technology coupled with lack of proper GIS education and training and lack of good human judgment, reasoning, and critical thinking, can all lead to dire consequences.

The acquisition, creation, editing, and duration of data is the most costly aspect of GIS. Anyone who is experienced with GIS has most likely learned this lesson the hard way. If you are new to GIS, it is very important to understand the importance of data for being successful at utilizing GIS technology for disaster management. GIS operations, analysis, modeling, and cartography are fundamentally data driven. Acquiring GIS-ready data is both financially costly in terms of hours spent collecting and editing data, or perhaps spending money on purchasing GIS data from a data vendor such as Navteq (http://www.navteq.com/). In my own teaching experiences, I have seen many great student research project ideas fail or have to undergo major modifications due to lack of data to support the investigation. Thus, if you are new to GIS, pay close attention to how you will find data that can support your investigation and how much time and possibly money you are willing to spend to acquire data. In the disaster management context, data handling must be done during planning (discussed in Chapter 5), because when it comes time for a disaster response, there is no time to acquire data and spatial deluge may occur (discussed in Chapter 6). At the end of this chapter, a list is provided of free GIS data sources relevant to disaster management.

The following sections discuss GIS data models and specific GIS software technology.

UNDERSTANDING GIS DATA MODELS

An important concept to understand when working with GIS data are GIS data models. A GIS data model can be thought of as a way in which geographic-scale features or phenomena are represented in a digital manner. Remember that digital representations ultimately reduce the item being represented to binary 1s and 0s. Reducing geographic reality to 1s and 0s is problematic, and many of the nuances, subtleties, and idiosyncrasies are lost in digital representations—a problem that really has existed since the beginning of mapping. For example, in a disaster management context, how does one represent the shifting nature of an eroding shoreline or differences in vulnerability that do not lend themselves to simple polygon-based representation. Thus, GIS data models have been developed to address these representational issues in a variety of manners (and varying degrees of success). The two most common forms of data GIS models are *vector* and *raster*.

Vector Models

The vector GIS data models represent geographic features as discrete, vertex-based shapes. Each vertex in a vector shape is referenced to a specific *x,y* Cartesian or geographic coordinate location. By using a discrete, vertex-based approach, the vector data model is generally advantageous for representing geographic features that have *discrete* boundaries or edges or can be reduced to representation as a single *x,y* coordinate pair. In practical terms, this means that the vector GIS data model is typically used to represent geographic
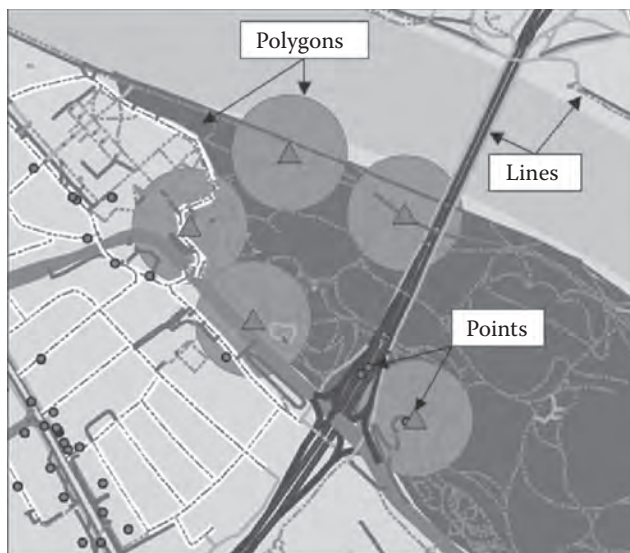
Figure 3.16 An example of vector points, lines, and polygons in a disaster management context. In this hypothetical scenario, toxic waste barrels have washed up on shore from a river and are presented as points using triangle symbols. A 500-foot buffer has been generated around the points to create polygons that show the toxicity threats of the barrels in relation to line features such as roads and bridges. (Map by Brian Tomaszewski.)

features as points, lines, and polygons as these geometric primitives intuitively lend themselves to representation of features or phenomena that have discrete edges or boundaries. Figure 3.16 graphically represents a disaster management example of vector-based points, lines, and polygons to illustrate these ideas.

An important aspect of vector-based GIS datasets from a technical perspective is that for any given geographic feature stored in a vector dataset, nonspatial attribute data can be stored along with the data that describes the vertices of the point, line, or polygon shape itself. Figure 3.17 demonstrates this idea.

Having nonspatial attributes associated with geographic features, as per the vector GIS data model, is one of the fundamental analytical features of GIS. For example, thematic maps can be based on qualitative or quantitative attributes (as discussed and shown in Chapter 2) or nonspatial attributes can be queried using Structured Query Language (SQL) statements to ask questions of GIS data (Figure 3.18).

In most GIS software packages, the actual specific data that defines the point, line, or polygon contents are hidden from the end user and the GIS software itself takes care of editing the vertices. However, the increased use of text-based, XML-structured GIS data formats such as KML or GeoJSON demonstrate how vector shape vertices coordinates are in fact human-readable. Having vector shape vertices coordinates in human-readable, text-based format is significant because GIS software-readable data can, in many cases, be created and edited without specialized GIS tools (Figure 3.19).
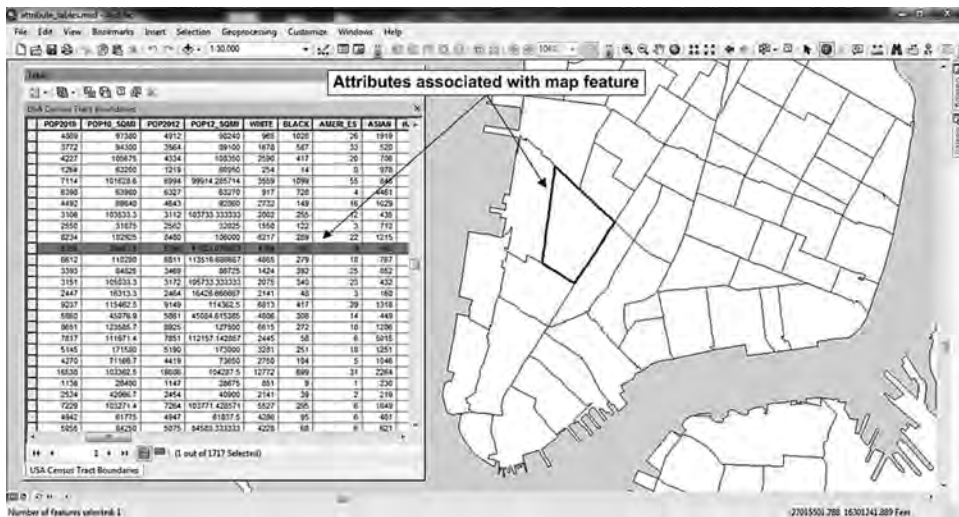
Figure 3.17 Attributes associated with a vector polygon. In this example using US Census tract boundaries, one record from the attribute table has been selected and the corresponding map feature associated with this record is outlined in black. Make note of how the attribute table contains a variety of different attributes that can be associated with a feature such as population counts or racial composition. (ArcMap screenshot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)
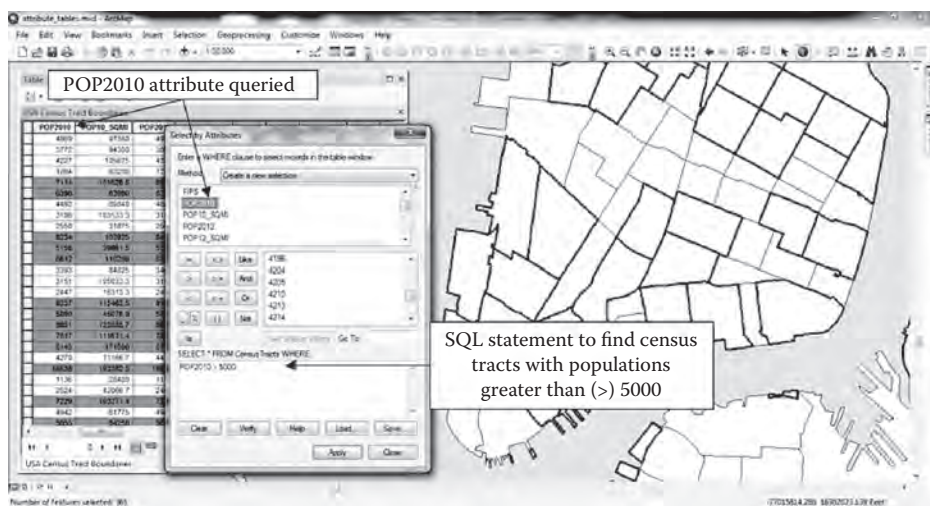
Figure 3.18 Querying attribute tables with SQL statements to answer questions. In this example, a query was made to find census tracts whose population in 2010 was greater than 5,000 people (as specified in the POP2010 column). The left side shows how 361 features matched this query criteria and the map on the right side correspondingly shows a variety of selected features. (ArcMap screenshot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)
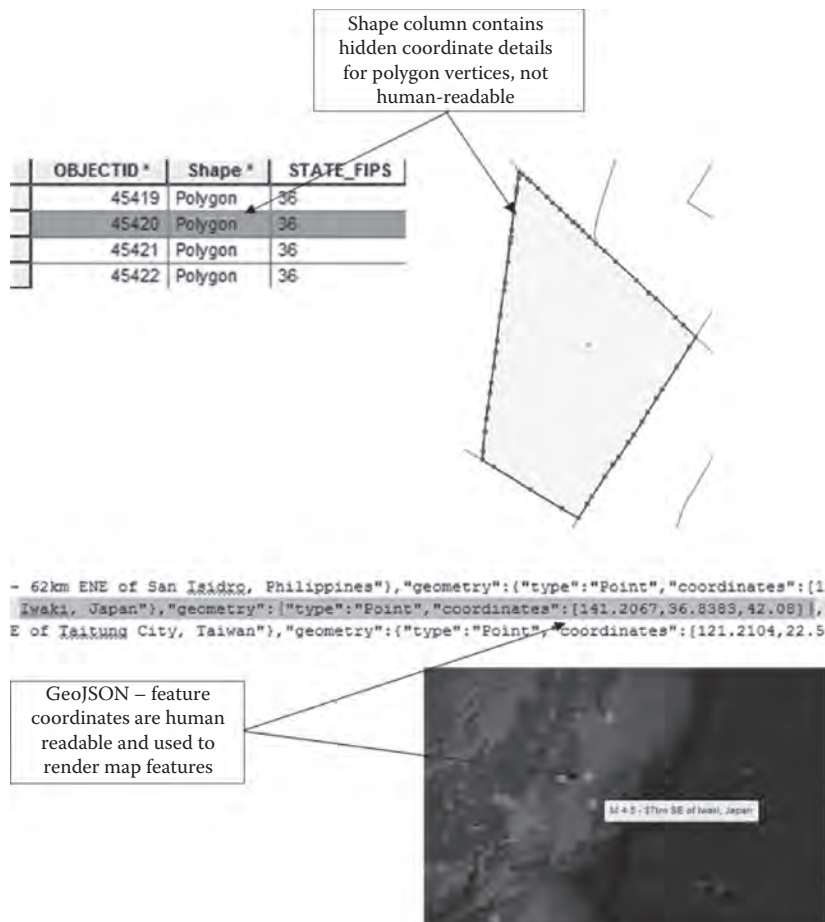
Figure 3.19 Coordinate information in vector features. In the top-right part of this figure, a polygon feature and the vertices that define its shape are shown. Note how the attribute table has a shape column that only indicates "polygon" and does not display any vertices coordinate details. The middle of this figure shows an excerpt of earthquake location GeoJSON code. Note how the coordinate values are human-readable, and thus potentially editable with a text editor, and can be used to create vector point features like those shown on the map in the bottom right of this figure.

Raster

The raster GIS data model represents geographic features and phenomena as a grid of individual cells. As opposed to vector, raster is typically used for modeling geographic entities that are *continuous* in nature and have no discreet boundaries or edges. Typical examples of continuous phenomena that would be represented in the raster data model include temperature and elevation. Raster data is also the format used for imagery ranging from aerial photography to space-based images that can be can be incorporated into GIS software.

Figure 3.20 provides specific disaster management examples of raster GIS data.
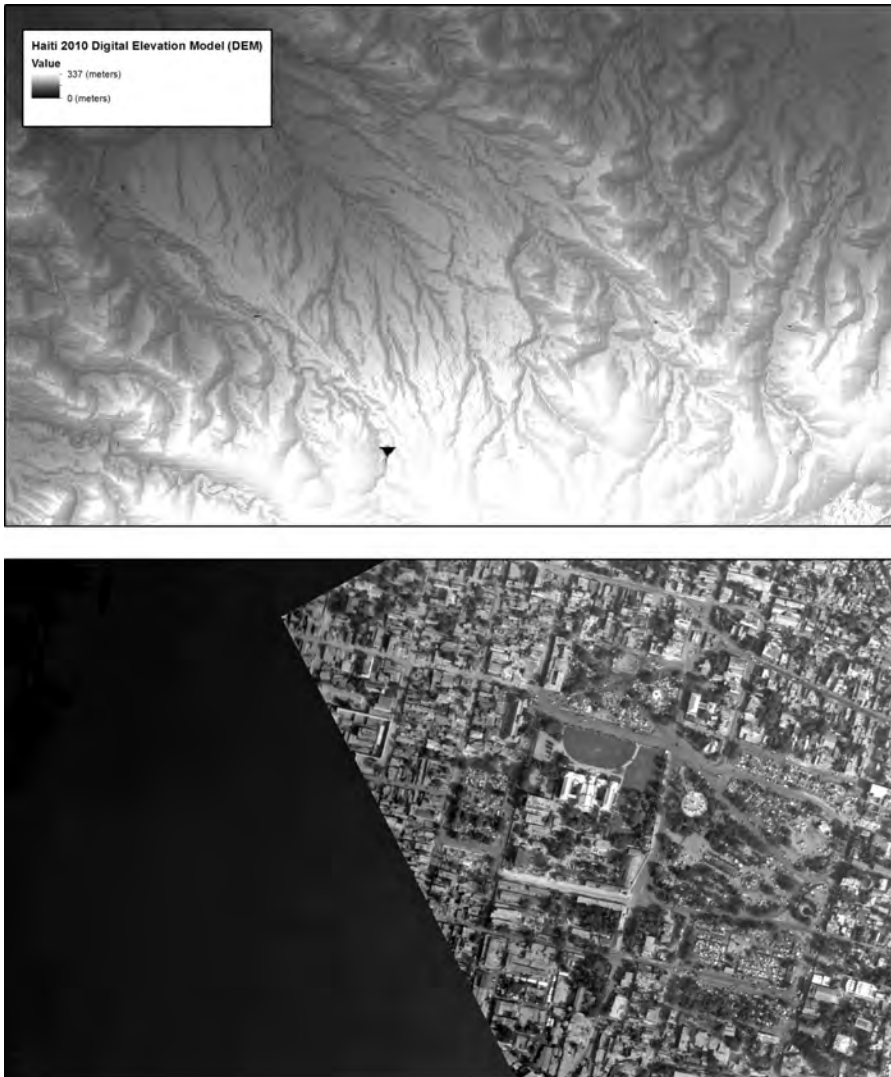
Figure 3.20 Disaster management raster data examples. The top part of this figure shows a digital elevation model (DEM) captured during the 2010 Haiti earthquake. Note how the grid of cells shows the varying landscape elevation—a representation technique that is difficult to achieve with vector data. In the bottom portion of of the figure, two raster datasets are shown side by side. On the bottom figure, left side, a DEM is shown; note how the individual cells can be seen. On the bottom figure, right side, an image of the presidential palace is shown. For imagery, each pixel in the raster grid represents a color in the image. DEMs and imagery are often combined in disaster management to understand how the underlying landscape interacts with the built environment, for example, the relationship between water runoff from slopes and building locations. Also differing from the vector data model, the raster data model stores numerical values associated within each grid cell; for example, the elevation of a given cell or its temperature.

An important concept with raster data is *spatial resolution*. Spatial resolution is fineness of detail of a raster dataset and is based on the size of each cell within the grid. For example, the smaller each grid cell, the finer the spatial resolution of the raster dataset. This idea is no different than that of digital camera picture pixel resolution. Spatial resolution is an important concept to be aware of with raster data, much like the discussion of map scale in Chapter 2. Spatial resolution is an important consideration for determining the appropriateness of a raster dataset for a given purpose. For example, too coarse a spatial resolution may not provide enough detail for a given task, while too fine a resolution may not provide enough coverage of a given area. Figure 3.21 provides examples of specific raster datasets to illustrate these points.

Now that you have learned about GIS data model basics, the next important concept to understand is GIS metadata.
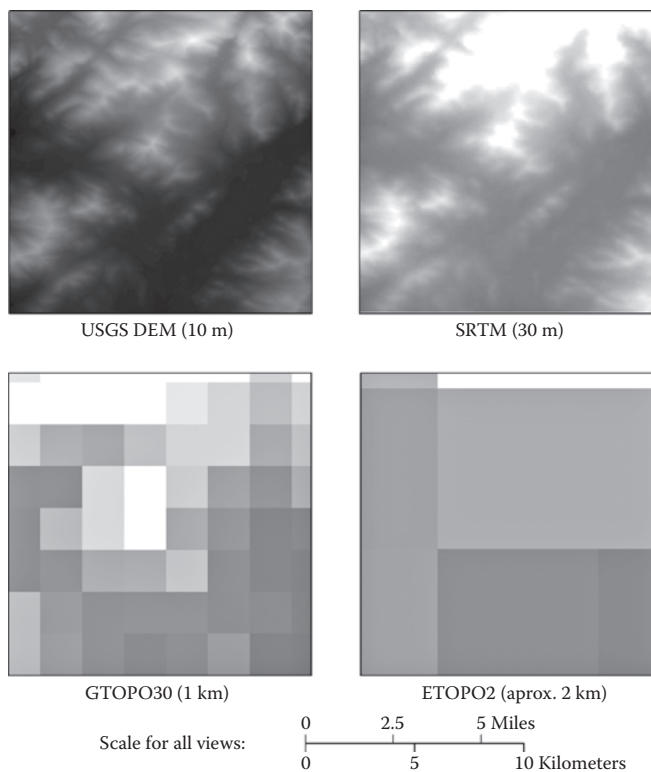
Figure 3.21   Examples of different raster dataset spatial resolutions. In this figure, the same overall geographic extent is shown in each view (as per the scale bar shown in middle). However, each view shows how spatial resolution varies. For example, the top left view shows the USGS DEM at 10-meter spatial resolution, the top right view shows data from the Shuttle Radar Topography Mission (SRTM) at 30-meter spatial resolution, the bottom left view shows data from the Global 30 Arc-Second Elevation (GTOPO30) at 1-kilometer spatial resolution and the bottom right view shows data from the Global Digital Elevation Model (ETOPO2) at approximately 2-kilometer spatial resolution. Note the striking contrast seen when using different raster spatial resolutions.

GIS METADATA

Metadata is *data about data*, or more precisely, data records that describe the contents, characteristics, lineage, or anything else about another dataset. For example, when you go grocery shopping, you typically do not buy canned items that do not have labels on them, as you would have no idea what is inside of the can. Metadata is the label on the can. This same idea works with digital GIS datasets whether they are raster or vector. For example, metadata for a vector GIS dataset might describe the geometry type used (point, line, or polygon), the attributes found in each record, and who initially created the dataset. Metadata for a raster dataset might describe the spatial resolution of the individual cells and the geographic extent of the overall grid, as well as the specific data format used for storing numerical information in each cell such as integer or floating point numbers. The structure and physical storage of GIS metadata is as varied as GIS data itself. For example, in the United States, the US federal government Federal Geographic Data Committee (FGDC; http://www.fgdc.gov/) has a specific metadata standard to which all GIS datasets created by the US federal government agencies must adhere. FGDC-compliant metadata must contain descriptions such as the following:

1. *Identification Information:* This identifies who created the data.
2. *Data Quality Information:* This information concerns how the data was created and any quality control issues encountered during the creation such digitization errors and the data lineage (i.e., who has worked on the data).
3. *Spatial Data Organization Information:* If the data is being organized under some type of formal organizing structure such as the Federal Information Processing Standards (FIPS) used in the united States.
4. *Spatial Reference Information:* Spatial reference Identifies the coordinate system and geodetic model (i.e., datum) used.
5. *Entity and Attribute Information:* Entity and attributes include descriptions of what attributes are used in the dataset and what the values of the attributes mean (in cases where a code is used instead of an actual value).
6. *Distribution Information:* This information tells how the data can be distributed and whom to contact to obtain a copy of the data.
7. *Metadata Reference Information:* This identifies the standard the metadata itself is using.

Figure 3.22 is a screen shot of a metadata file in HTML format containing each of these description categories.

Metadata plays a particularly important role in GIS for disaster management. This importance is due to the fact that metadata is critical to coordination and collaboration activities, as discussed in Chapter 1. For example, increases in larger disasters that span multiple jurisdictional or even national boundaries make it vitally important that disaster managers know what data they have to work with and how appropriate a given dataset is to a task at hand. In time-sensitive situations, there is no time to evaluate the usefulness or fit of a dataset. Proper, updated documentation of GIS datasets through metadata is vital in making informed decisions about GIS data.
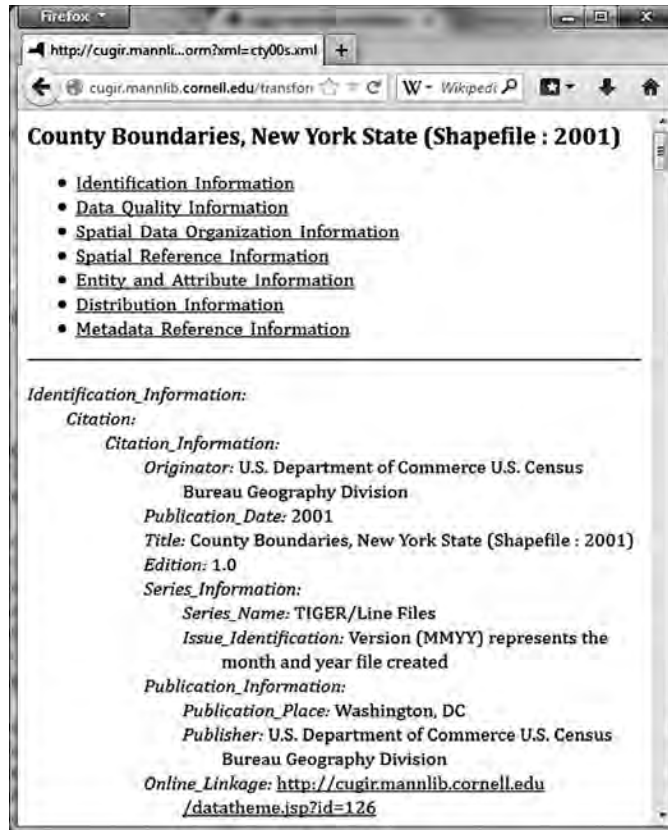
Figure 3.22   Example of HTML-based GIS metadata.

SPECIFIC GIS TECHNOLOGY

Now that you have a solid background in GIS concepts, the following section presents specific GIS technology. This is perhaps the one part of the book where you will need to be most careful in checking that specific items mentioned are still in existence and available, and that URLs listed here have not changed. Even though all technology changes, every effort has been made to ensure that the technology discussed in this section will likely be available for at least five years after this book is published. More specifically, the criteria used to include specific GIS technology in this section include:

- the technology has been around for at least 10 years prior to publication of this book;
- the technology is being actively supported through ongoing maintenance and support by a corporation that sells it or an actively supported open-source software development community; and
- the technology has documented use in disaster management practice.

Please note that are numerous types of GIS technology applicable to disaster management and that many volumes could be published on the many technologies that exist. The technologies listed here are meant as a guide to the general varieties that exist, and you are encouraged to do your own research or create your own technologies to fit your GIS for disaster management needs.

GIS Technology Platforms and Disaster Management

In today's ever-increasing interconnected world, GIS is available for all types of computing platforms ranging from traditional desktop systems, to phones and tablets, to virtual, cloud-based environments that provide GIS functionality through web interfaces. It is important, however, to distinguish which technology platform is appropriate for which aspect of disaster management work. For example, developing a complex flood hazard model will be very difficult to accomplish on an iPhone due to limited computing resources and screen space. Conversely, viewing simple point locations where relief stations are located does not require a supercomputer cloud cluster. Thus, GIS is evolving to where different technology platforms are being used for specific tasks and needs of specific consumers of GIS data, services, and products, such as maps. For example, desktop computers are still best suited for core analytical and data management tasks for disaster management due to the heavier computing power that is available. In the past ten years, with the decrease in demand for specialized desktop GIS software and the increased demand for more lightweight tools focused on the viewing of GIS and map-based data for things like location-based services, GIS technologists have begun to offer GIS technology on what are known as "thinner" (i.e., less CPU/RAM and overall computing power) clients such as mobile and web-based platforms. For disaster management, mobile platforms are increasingly showing their benefit for allowing disaster management practitioners to access GIS data contained within larger systems and to collect data from the field using simple point collection procedures that utilize the GPS receiver common to most mobile platforms.

An advantage of web platforms is that they can be accessed anywhere that there is an Internet connection; they are (usually) not restricted by operating systems, plug-ins, or choice of web browser if they conform to various W3C (World Wide Web Consortium) standards for coding HTML pages. A very interesting development at the time of this book's writing is the advent of HTML5. HTML5 is allowing for more interaction and functionality in web browsers. In the past, web browsers typically required the use of a plug-in, such as the Java or Flash Player, which was often a barrier to web application use. For example, with HTML5, an application can be designed so that it can run either in a web browser or on a mobile device, and all from a single code base.

In the following sections, specific GIS technologies are discussed from the dual perspectives of technology platform and disaster management tasks and end users.

ArcGIS

ArcGIS is an umbrella term for a wide range of GIS technologies created and maintained by Esri, the world's largest commercial GIS software company. Esri GIS technology is used in countless disaster management organizations around the world as evidenced by

the numerous disaster management and homeland security success stories Esri maintains (Environmental Systems Research Institute, n.d.; Kataoka,2007). Esri offers a comprehensive range of GIS technology relevant to all modern technology platforms and disaster management tasks and end users.

For *desktop* applications, there is the ArcGIS/ArcMap (http://www.esri.com/software/arcgis) application that has numerous, powerful features. Select examples of features with strong relevance to disaster management are illustrated in the following series of screen shots (Figures 3.23–3.25) taken from ArcMap:

The very rich feature set and overall complexity of the software make ArcMap a somewhat challenging tool to use. Often, those who are most competent in its use have received specialized training and education.

For *mobile platforms* such as Android and iPhone-based operating systems, Esri offers a variety of APIs for software developers to build custom GIS applications. Furthermore, Esri offers several free apps that the public can download view data and perform some analytical procedures such as map overlay and changing map displays.

For web platforms, Esri also offers several APIs that software developers can use to build custom web-based GIS applications (as discussed previously). At the time of this writing, APIs for JavaScript, Flex, and Silverlight web development environments are offered, but be sure to check which ones are still supported if you are interested in examining web-based technology from Esri.

In recent years, Esri has strongly emphasized its ArcGIS Online technology. ArcGIS Online is a paid, subscription-based service that provides access to many functionalities
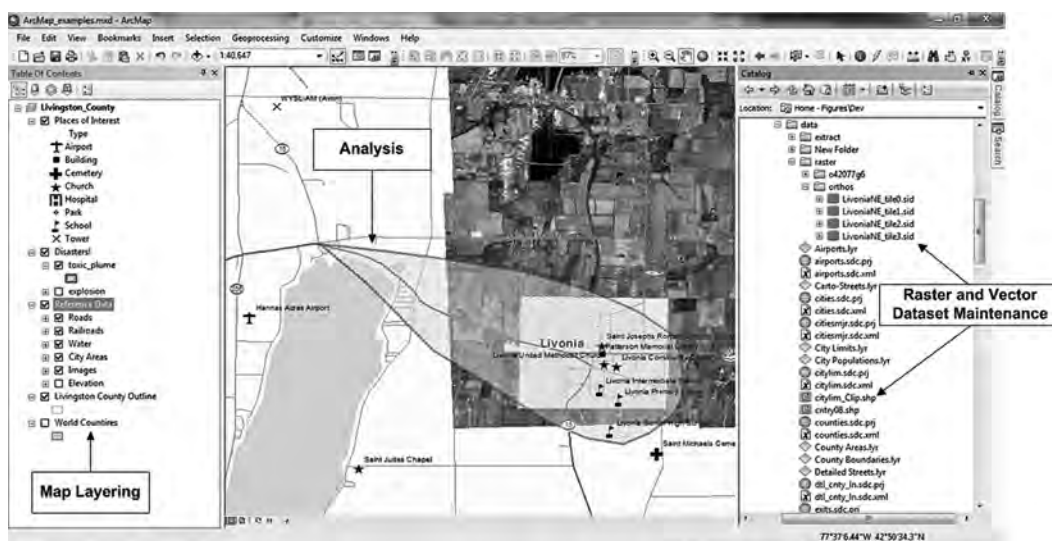
Figure 3.23 A disaster management example of map layering, vector and raster dataset maintenance, and analysis in ArcMap. In this example, impacts from a toxic plume cloud are being investigated. (Screenshot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)
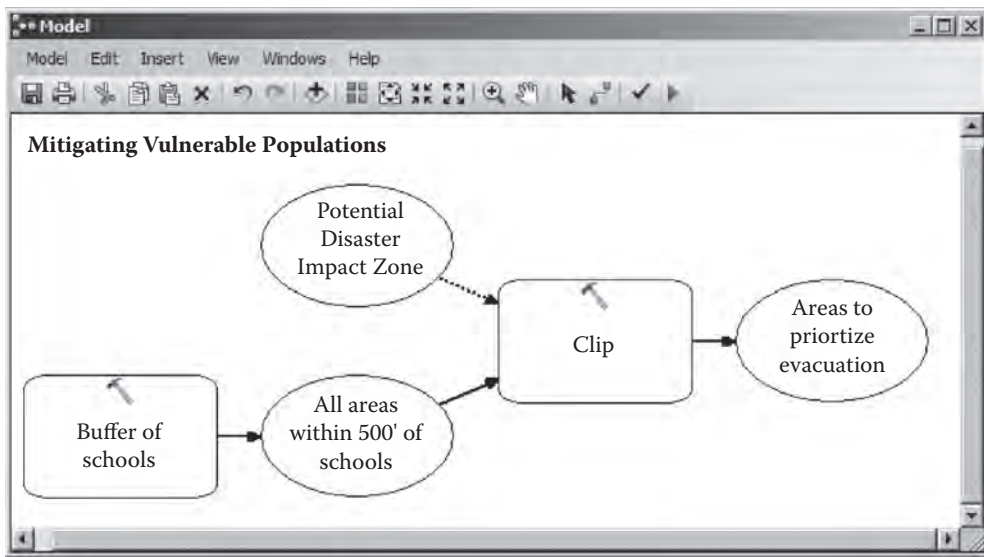
Figure 3.24 A disaster management example of modeling tools available in the ArcMap model-builder tool. ArcMap models allow a series of GIS processes and datasets to be combined in one workflow. In this simple example, a model is used to determine areas to prioritize for evacuation. (Screenshot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)
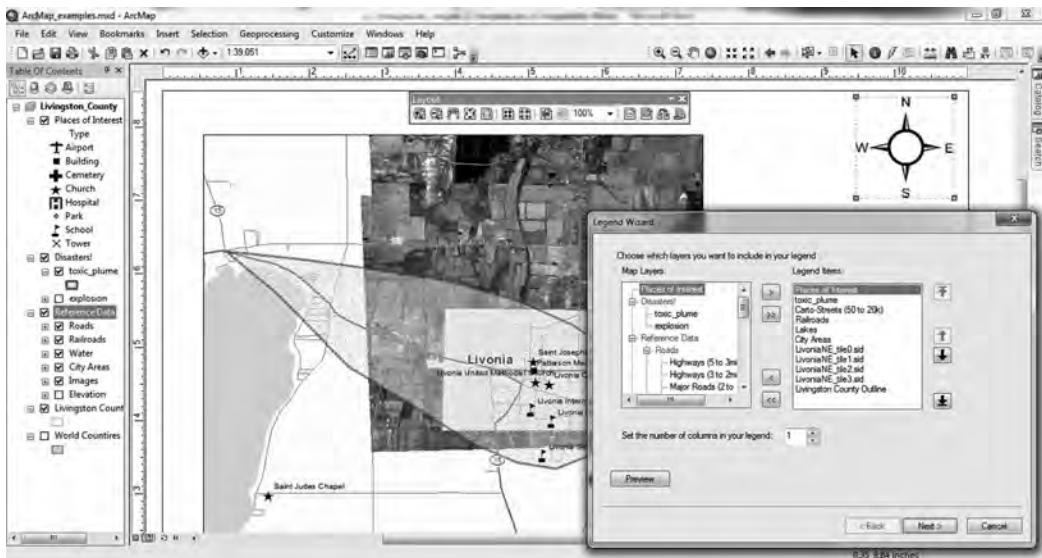
Figure 3.25 A disaster management example of select cartographic production tools available in ArcMap. ArcMap's map layout functions make it easy to produce maps using tools such as a legend wizard and automated scale bar and north arrow generation. (Screenshot Copyright © 2014 Esri, ArcGIS, ArcMap. All rights reserved. Used with permission.)

offered through desktop ArcMap, but in a web environment. Furthermore, ArcGIS Online offers an impression range of premade reference maps, apps, and analytical tools that allow users to quickly start using GIS functionality and to interact and share data with one another within the ArcGIS Online community. ArcGIS Online is also a cloud-based environment, meaning that its capacities are very scalable and available wherever there is an Internet connection and across all types of hardware platforms.

In disaster management applications, ArcGIS Online is seeing increased use for the sharing and display of disaster-related situational information. For example, the Federal Emergency Management Agency (FEMA) GeoPlatform (http://fema.maps.arcgis.com/home/; discussed further in Chapter 4) uses ArcGIS Online to display a wide range of GIS data from FEMA projects such as cyclone impacts, flood hazards, risk assessment, and more. Esri's increased emphasis on their ArcGIS Online technology is part of a growing trend in cloud-based, web-driven applications that provide GIS analytical functionality, maps, and datasets to end users for a wide variety of disaster management contexts ranging from simple maps that display point locations to complex analytical prediction models. Perhaps the most visible and widely recognized company, outside of the traditional GIS world, that has been developing web-driven technology for disaster management is Google.

Google Maps and Other Google Geospatial Technology

As an Internet search company that "grew up" on the web, Google has a well-established record of developing web-driven applications that work with the massive datasets that comprise the web. Their flagship geospatial technology, Google Maps, is perhaps the most recognized mapping technology in the world. For example, when I teach introductory geospatial technology students, at the start of each semester, few to none of have heard of Esri, but all of them are familiar with Google and many report using Google Maps almost every day. Of course, Google's geospatial technology goes far beyond Google Maps to include the virtual globe Google Earth, mapping APIs, location-oriented services, and even the entire Android operating system, the world's most widely used mobile device operating system, which contains native location functionality for GPS receiver access and more. Google has also made their mapping tools more accessible to nontechnical experts through technology such as Google Maps Engine (https://mapsengine.google.com), which allows end users to create content on top of the Google base map without having to use computer programming languages such as JavaScript to do so.

Google is also consistently part of major worldwide disaster response and relief efforts. Specifically, Google's philanthropic division (google.org) has Google Crisis Response (http://www.google.org/crisisresponse/), a team dedicated to using the Internet to collect data and build tools during major disasters. A very common approach that is used by the Google Crisis team for disseminating crisis data is to host a *crisis response map* that displays thematic data related to a given crisis inside a Google Map interface (Figure 3.26). Furthermore, Google makes data for a given crisis available in the KML format, which allows for the easy sharing of geographic data across multiple GIS platforms such as Google Earth, but other technology as well, such as ArcMap.
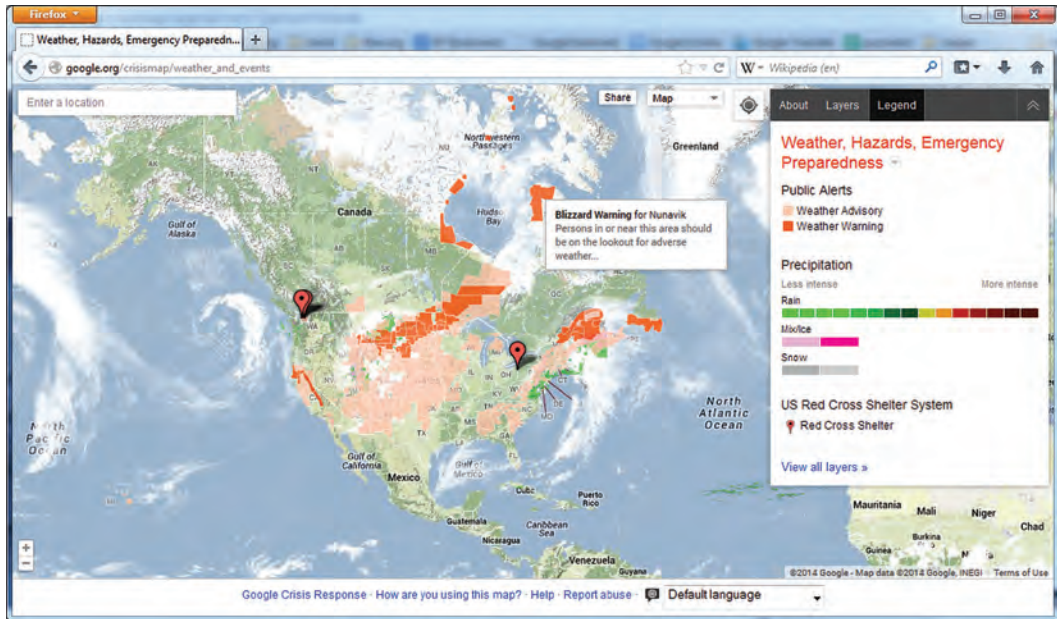
Figure 3.26   Google crisis map.

Google technologies continue to see increased use for disaster management applications due to the ubiquitous nature of Google technology in general, ease of use, familiarity that people have with using Google technology, and the fact that there is (usually) no cost involved in using tools like Google Maps and Google Earth. However, other *free and open-source* GIS technology solutions exist, many of which provide a better technology solution for disaster management practice based on limited financial resources, unreliable Internet connectivity, or a general desire to avoid commitment to a particular software company that ultimately has control over critical technological assets. In the open-source GIS world, numerous options exist; the following are a few of the most widely used.

QGIS

QGIS (http://www.qgis.org/en/site/) is perhaps the most widely known and used open-source GIS package. QGIS offers many of the same features as found in commercial GIS tools such as ArcMap (Figure 3.27).

For example, QGIS can handle raster and vector data, map production, and offers a range of spatial analysis tools and modeling capabilities. Additionally, QGIS offers a Python-based scripting environment that allows for custom scripting and specialized GIS tools to be developed inside the QGIS environment. QGIS is also capable of working with other popular open-source GIS tools such as Geographic Resources Analysis Support System (GRASS) (http://grass.osgeo.org/) and the Geospatial Data Abstraction Library (GDAL) (http://www.gdal.org/).

101
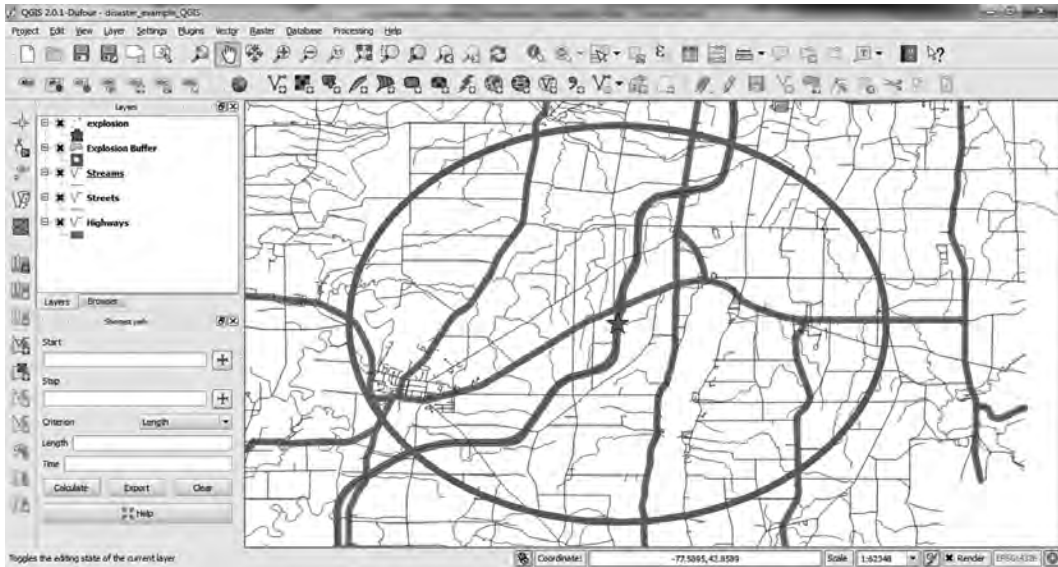
Figure 3.27   A disaster management example in QGIS. In this example, an explosion has occurred and the extent of the explosion has been buffered. Note how QGIS has a similar look to ArcMap and offers many of the same functionalities. QGIS is covered under Creative Commons Attribution-ShareAlike 3.0 license (CC BY-SA) http://creativecommons.org/licenses/by-sa/3.0/.

In terms of QGIS and disaster management activities, QGIS is commonly used around the world for disaster management training and an Internet search on the terms "QGIS disaster management" will reveal numerous training opportunities and information on open-source GIS disaster management solutions that feature QGIS.

Other Commercial, Free, and Open-Source or Openly Available GIS Technologies

The GIS technologies that were discussed so far in this chapter represent some the most widely used and well-known GIS technologies. However, they are not the only available options. The following sections outline a variety of other GIS technologies that are used in disaster management.

OpenStreetMap

As discussed in Chapter 2, OpenStreetMap (OSM) provides a platform for users to create and edit a freely editable world map. The data provided through OSM continues to serve a vital role in disaster management activities for areas where reference data is not available. OSM and the Humanitarian OpenStreetMap Team (HOT; http://hot.openstreetmap.org/) will be revisited once again in Chapter 4, which discusses various organizations involved in disaster management.

Other GIS Technologies

The following general GIS technologies could also be used for or could support a variety of disaster management activities:

- *OpenLayers* (http://openlayers.org/) is an open-source, web-based map client similar to the Google Maps API.
- *Mapbox* (https://www.mapbox.com/) is a free commercial map service that utilizes OpenStreetMap data and places particular emphasis on cartography and design of maps created in the MapBox system.
- *MapServer* (http://mapserver.org/) is a free and open-source publishing service that allows map data to be served over the web.
- GeoServer (http://geoserver.org/display/GEOS/Welcome) is similar to MapServer in that it is a free and open-source service to publish map-based data over the web.
- *PostGIS* (http://postgis.net/) is an open-source spatial database that works with postgreSQL (http://www.postgresql.org/) to provide geographic objects and spatial queries
- *NASA World Wind* (http://worldwind.arc.nasa.gov/java/) is an open-source virtual globe tool that is particularly suited for viewing datasets created by NASA, such as the Landsat series.
- *MapInfo* (http://www.mapinfo.com/) is commercial GIS technology by Pitney Bowes, and is similar to Esri technology in that it offers desktop, web, and server-based GIS tools.

Free and Open-Source Datasets Relevant to Disaster Management

The following is a nonexhaustive list of reference and thematic sources of GIS datasets that are relevant to disaster management and can be downloaded and used in the technologies previously mentioned:

- *The National Map* (http://nationalmap.gov/) provides access to numerous reference and thematic data layers for the United States.
- *USGS Global Visualization Viewer* (http://glovis.usgs.gov/) provides free access to numerous NASA and USGS products such as LANDSAT, MODIS, ASTER, and TERRA.
- *Global Administrative Areas* (http://www.gadm.org/) provides free access to worldwide administrative boundaries.
- *GeoNames* (http://www.geonames.org/) provides free worldwide gazetteer (place name) data; a good source for geocoding applications.   .
- *FEMA GIS Data Feeds* (http://gis.fema.gov/DataFeeds.html) provides a collection of FEMA's disaster declarations and support offices relative to the United States.
- *US Census Bureau American FactFinder* (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml) is relevant to the United States, and can be used to find a wide variety of census indicator data (discussed again in Chapter 8).
- *US Census Bureau TIGER* (http://www.census.gov/geo/maps-data/data/tiger.html) is relevant to the United States, and provides a variety of vector features that can be used with American FactFinder data.

- *USGS Earthquake Hazards Program* (http://earthquake.usgs.gov/earthquakes/feed/v1.0/) provides a variety of feeds (including KML and GeoJSON) related to worldwide earthquake instances.
- *World Bank Data* (http://data.worldbank.org/) provides economic and social country-level indicators; data is in CSV, XML, and Excel formats.

Finding GIS Data on the Internet

As stated previously, finding or creating data is the most time-consuming aspect of GIS. A very important skill to learn is how to use the Internet to find GIS data. In the United States, most states have *GIS clearinghouses*, which (often) allow free access to public GIS data. At the US federal level, spatial data infrastructures (SDIs) such as GeoPlatform.gov provide access to a wide variety of GIS and other data produced by the federal government (Figure 3.28).

Depending on where you live, you may need to do some "hunting" on the Internet to find the right GIS datasets for your disaster management needs. Always be sure to look for metadata that describes the dataset and make sure that the GIS technology you are using can work with the dataset. For example, many datasets created in the old ArcINFO coverage format can still be found on the Internet, but will not work in a tool like Google Earth unless using special data conversion software.

Figure 3.28 The GeoPlatform.gov website.

How to Choose the Right GIS Technology for Disaster Management

There is no single guideline or set of principles to determine the right GIS technology to use for disaster management. There are several interconnected factors to consider and tie back to the components of GIS discussed in the beginning of this chapter.

First and foremost is cost; does your organization have the financial resources to afford purchasing and maintaining licenses with commercial software like MapInfo or Esri? (It is important to note that Esri does offer their software for free to nonprofit organizations; see http://www.esri.com/nonprofit.) If it does not, does your organization have the technical capacity to work with open-source software that often requires information technology–oriented knowledge of how to install and host open-source tools? Furthermore, how important is it that your organization have immediate technical support when technology problems arise? Commercial GIS software does give the advantage of a stable, reliable company that supports the products it creates and it can be quite reassuring to make an old-fashioned telephone call to get technical support versus posting a question to an online discussion forum for an open-source or openly available tool with no guarantee of getting a response (even in large communities like Google).

Second, what are the specific disaster management tasks you will have to conduct and how might those tasks change over time? For example, a small community disaster training organization might find Google Maps Engine or CrowdMap (discussed in Chapter 6) to be sufficient technologies for creating simple maps to show where disaster shelters are located for planning that can then can be used to monitor relief request locations during an actual disaster versus a large government organization that needs the computing power of robust GIS tools to develop flood hazard models that in turn have to be disseminated to millions of people via the web.

Third, how integral is GIS to your overall organizational mission? If GIS and maps only play a minor role in your overall activities, using robust and comprehensive GIS technology like desktop ArcGIS might not be the best choice. Technologies like these are difficult to learn and knowledge of how to operate them can be quickly lost if not maintained or the consultant or student intern hired to work with them has moved on from the organization. In the case of disaster response, the last thing that should be a factor in a response situation is trying to scramble around and learn (or relearn) how to use a technology that has been dormant for a long time. Besides these general items, there are myriad things to consider when choosing a GIS technology solution. Many GIS consulting firms provide GIS needs assessment consulting services that can help with making the right decisions; that is an option to consider if your organization has the resources to purse this route, or you can review sources such as Tomlinson (2007).

Getting Started with GIS Technology and GIS Technology Configuration Ideas

The sheer number of GIS technologies available coupled with the numerous tasks for which GIS can be applied in disaster management can make the process of getting started with GIS for disaster management a daunting task. The following section is written for those that are brand new to GIS or are looking to expand their use of GIS technology for disaster management beyond simple point mapping on Google Maps. Please note that

step-by-step instructions and training on specific GIS technology is not within the scope of this book. For detailed steps on how to use a specific GIS technology, consult the help guides and tutorials that often accompany the software in question. If you find a technology that is not well documented or does not offer tutorials, that might help you determine if the technology is worth your time.

If you are brand new to GIS (i.e., you have never taken a class on the topic and have done minimal to no web searching on GIS), I recommend you first start with a free tool like ArcGIS Explorer (http://www.esri.com/software/arcgis/explorer). ArcGIS Explorer will give you a sense of map layering and working with raster and vector datasets. Using ArcGIS Explorer, try downloading a vector dataset from one the sources listed previously in this chapter and explore how to change the symbols used on the map and think about how these datasets might work for disaster management tasks. I recommend a technology like ArcGIS Explorer over other free technologies like Google Earth as ArcGIS Explorer has more GIS-specific features such as basic spatial analysis through querying, a wider variety of base map choices so you can explore different cartographic conventions, and integration of standard GIS datasets such as shapefiles and KML than general map-based data viewing like the free version of Google Earth offers.

Working with a tool like ArcGIS Explorer will help you become comfortable with basic GIS operation, for example, adding data layers to a map. Learn how to reorder the map layer drawing levels, explore attribute data associated with vector datasets, and learn general digital map interaction such as panning and zooming. When you are comfortable with these tasks, try working with a more robust GIS technology. In this regard, and depending on your circumstances, options might include trying the 60-day free trial version of ArcMap (http://www.esri.com/software/arcgis/arcgis-for-desktop/free-trial) or QGIS (which was listed previously). If you are student and your initial activities with a technology like ArcGIS Explorer has peaked your interest, look into taking an introductory GIS class (if your university offers one). With a more robust GIS tool, begin to explore the analytical functions of these tools such as buffer, clip, and union (search the help system of the tool you are using for these functions), practice making maps with these tools (see Chapter 2), try creating your own spatial data or editing existing data, and develop metadata for datasets you create. In general, work at becoming more proficient with operating a robust GIS technology; this will allow you to be more competent at using GIS for disaster management tasks (and make you more employable).

For those of you who are looking for ideas on how to set up a *geospatial stack* (i.e., a series of technology combined to provide various functions and services) for disaster management, here are some ideas from the perspective of some of the open-source technologies listed previously. Please note that implementing technology solutions like these requires a substantial amount of IT knowledge in areas such as web servers, databases, system administration, and programming. This is why technologies such as ArcGIS Online and Google cloud-based mapping have become very popular in the past few years as they have eliminated technical barriers to creating a geospatial stack. Thus, if you are unfamiliar with the IT areas needed to create a geospatial stack, make sure to find the right people that can help you if you choose to go this route or consider one of the completely integrated solutions previously mentioned. Also note that the following discussion is not intended to be a definitive guide, but rather a loose set of recommendations for you to follow if you are new to working with open-source geospatial technology in general and want to create your own geospatial stack.
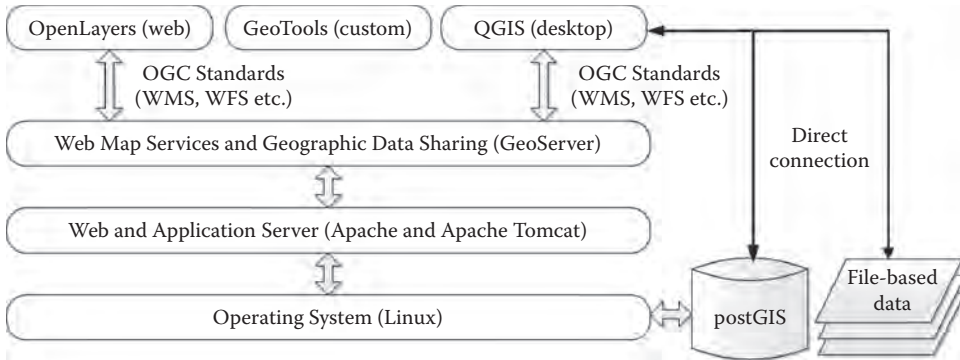
Figure 3.29   An open-source geospatial stack.

A very common and popular combination of technologies to create a stack is the LAMP configuration. *LAMP* refers to the combination of the *L*inux operating system, the *A*pache web and application server, *M*ySQL as the database, and *P*hP as the scripting language. However, each of these components are not set in stone. For example, postgreSQL with postGIS might offer a better choice as a spatial database solution than MySQL, and Python can offer a better choice for scripting related to GIS technology than PhP. Thus, the following list and accompanying Figure 3.29 outlines ideas for an open-source GIS technology stack:

- *Operating system:* Linux (many choices, see: http://www.linux.org/ and http://www.ubuntu.com/download)
- *Web server and application server:* Apache (http://www.apache.org/) and Apache Tomcat (http://tomcat.apache.org/)
- *Web map services and geographic data sharing:* GeoServer (http://geoserver.org/display/GEOS/Welcome)
- *Database:* postgreSQL and postGIS (http://postgis.net/)
- *Web client and presentation:* Open Layers (http://openlayers.org/)
- *Desktop support and data management:* QGIS
- *Custom application development libraries:* GeoTools (open-source Java libraries http://www.geotools.org/), Android API

CHAPTER SUMMARY

In this chapter, you were introduced to GIS on conceptual and technical levels. The chapter began with a discussion about the individual components of the system that comprises GIS. Next, you were shown the various functions that GIS can do such as data and spatial asset management, which is the core of any GIS; analysis to help answer questions and derive insight into spatial problems; programming for developing custom applications and tools to extend the capabilities of GIS; modeling for creating scaled representations of reality and to answer what-if questions; cartography; visualization

and map production, which connects modern-day GIS with the millennia-old practice of map making and representation of geographic features; and geocoding, which is the idea of taking textual inputs such as an address or a place name and converting it to coordinates. You also learned a little bit about what GIS cannot do—points that are important to keep in mind as you learn more about GIS and the need to manage technology expectations.

The chapter then provided a technical discussion of GIS data models, which are the ways geographic and spatial entities are represented in digital formats. Specifically, you learned about the two most common data models—vector data, which represents discrete entities as points, lines, and polygons, and raster data, which represents continuous entities as a grid of pixels with varying spatial resolution. Of great importance to all types of GIS data is metadata, or data that describes the contents, structure, lineage, or anything else pertinent to a dataset. Metadata is vitally important for determining the usefulness and relevance of a dataset for a given task or application.

The chapter then discussed specific technologies relevant to disaster management applications. As stated several times in this chapter, this is one part of the book where you will need to be careful to check for updates on specific URLs listed because technology is always changing. However, the specific technologies listed such as Esri, Google and QGIS were chosen given their stability, popularity, and wide user communities. A list of free and open-source datasets relevant to disaster management were also provided to give you some ideas for where to find both reference and thematic data that could be of use for disaster management tasks.

Finally, the chapter gave you some ideas on what to think about when deciding which technologies to use for disaster management and how to get started working with GIS technology if you are new to GIS and learning GIS independently (i.e., you are not taking classes at a university of some other type of training). The chapter concluded with a loose set of guidelines for building a GIS technology stack using open-source GIS technology, if you are interested in the more technical aspects of building a complete GIS solution to support disaster management tasks.

In the next chapter, the relationship between disaster management and GIS is discussed in more detail starting with an overview of the general disaster management cycle (response, recovery, mitigation, planning), the role of GIS within disaster management policy at different scales within the United States (i.e., town, county, state, and federal), and how the international community such as the United Nations and other entities engage in international disaster risk reduction, response, and recovery.

DISCUSSION QUESTIONS

1. What if, anything, might you add to the components of GIS in terms of disaster management areas?
2. With the further increase of 3D virtualization worlds like Google Earth, do you think the concept of map layers is still relevant for disaster management?
3. What other types of GIS data storage formats can you find, besides the ones listed in this chapter, that are used for disaster management applications?

4. From what you've learned about GIS and disaster management so far, what other GIS disaster management analysis scenarios you can think of?
5. What other GIS limitations you can think of and how might those limitations be relevant to disaster management?
6. What are some disaster management features you would represent as vector? As raster? Are there disaster management cases you can think of where either raster or vector could be used?
7. Why is metadata important?
8. If you could use any technology, which GIS technologies might you use for specific disaster management tasks and why?
9. Try downloading some of the datasets listed at the end of this chapter. What were your experiences? For example, were the datasets easy to find and download or did you have problems?

RESOURCES

During the creation of this book, the great Dr. Roger Tomlinson passed away. See http://www.npr.org/2014/02/13/276522411/tech-innovator-and-master-of-maps-dies-at-80 for a discussion of this important person in the history of GIS.

For more information about the Dual Independent Map Encoding (DIME) format, see http://www.census.gov/history/www/innovations/technology/dual_independent_map_encoding.html.

For information about the Esri File Geodatabase format, see http://www.esri.com/news/arcuser/0309/files/9reasons.pdf.

More information on ERDAS IMAGINE, see http://www.hexagongeospatial.com/products/ERDAS-IMAGINE/Details.aspx.

For more information on ENVI, see http://www.exelisvis.com/ProductsServices/ENVI/ENVI.aspx.

For examples of Imagery Services available from the US National Map, see http://viewer.nationalmap.gov/example/services/serviceList.html.

For more information on application development with Esri technology, see https://developers.arcgis.com/en/.

For more information about Tiled Map Services, see http://wiki.osgeo.org/wiki/Tile_Map_Service_Specification.

For more information on GeoJSON, see http://geojson.org/.

For more information on the Shuttle Radar Topography Mission (SRTM), see http://www2.jpl.nasa.gov/srtm/.

For more information on Global 30 Arc-Second Elevation (GTOPO30), see https://lta.cr.usgs.gov/GTOPO30.

For more information on Global Digital Elevation Model (ETOPO2), see http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html.

For more information on Android location services, see http://developer.android.com/reference/android/location/package-summary.html.

For more on HTML5, see http://www.w3schools.com/html/html5_intro.asp.

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