Copyrighted Materials
Copyright © 2015 John Wiley & Sons Retrieved from app.knovel.com

Cartography and Map Production

This chapter is the first of a series of chapters that examine geographic information (GI) system outputs; the next, Chapter 12, deals with the closely related but distinct subject of visualization. This chapter reviews the nature of cartography and the ways that users interact with GI systems in order to produce digital and hardcopy reference and thematic maps. Standard cartographic conventions and graphic symbology are discussed, as is the range of transformations used in map design. Map production is reviewed in the context of creating map series, as well as maps for specific applications. Some specialized types of mapping are introduced that are appropriate for particular applications areas.

LEARNING OBJECTIVES

After studying this chapter, you will understand:

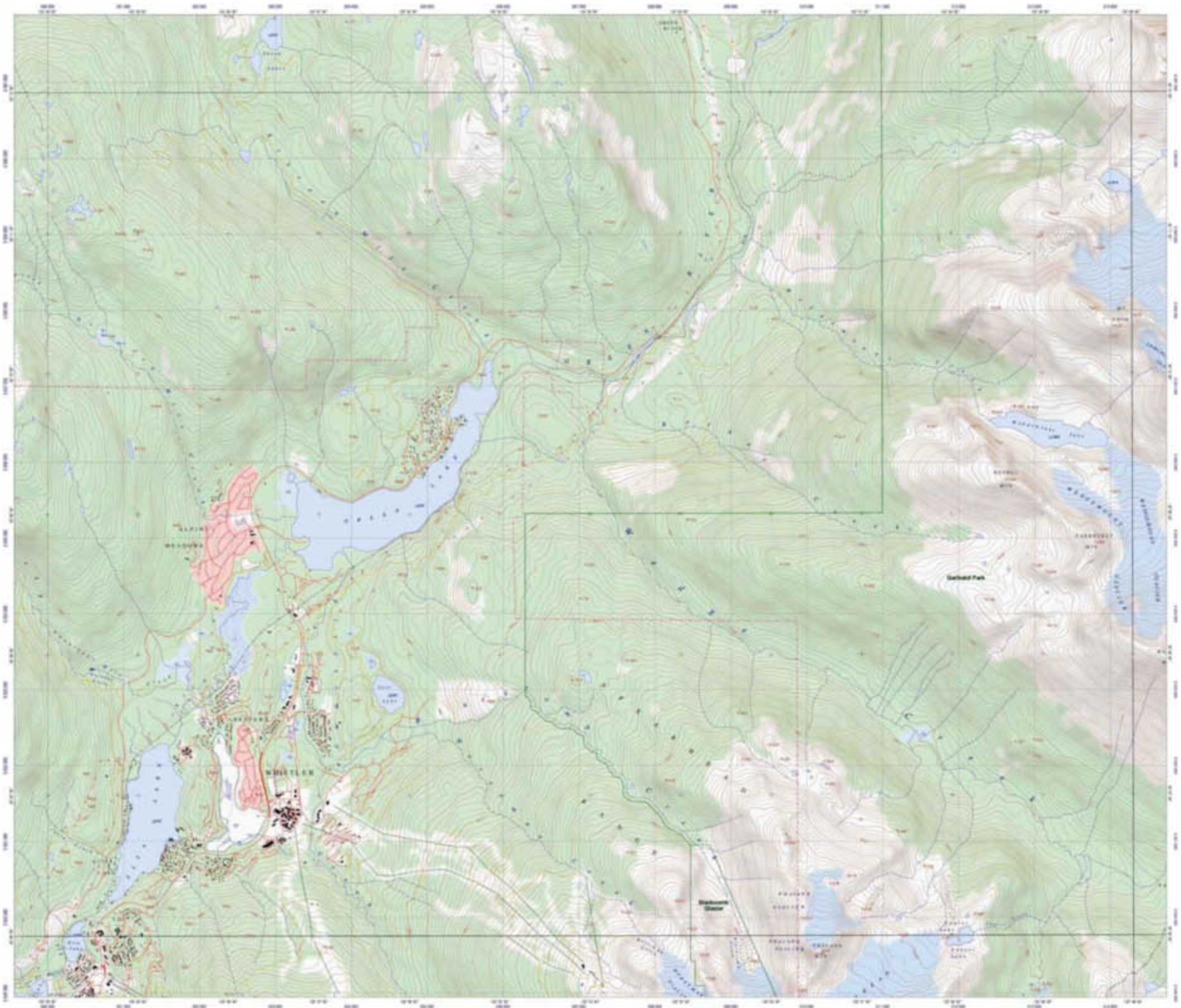
- The nature of maps and cartography.
- Key map-design principles.
- The choices that are available to compose maps.
- The many types of map symbology.
- Concepts of map-production flow lines.

11.1 Introduction

System outputs such as maps represent the pinnacle of many GI projects. Because the purpose of information systems is to produce results, this aspect of GI systems is vitally important to many managers, technicians, and scientists. Maps are the most important type of output from most GI systems because they are a very effective way of summarizing and communicating the results of GI system operations to a wide audience. The importance of map output is further highlighted by the fact that many consumers of geographic information only interact with GI systems through their use of map products.

For the purposes of organizing the discussion in this book, it is useful to distinguish between two types of GI system output: formal maps, created according to well-established cartographic conventions, that are used as a reference or communication product (e.g., a military mapping agency 1:250,000-scale topographic map, or a geological survey 1:50,000-scale paper map—see Box 11.3); and transitory map and map-like visualizations, used simply to display, analyze, edit, and query geographic information (e.g., results of a database query to retrieve areas with poor health indicators viewed on a desktop computer, or routing information displayed on a mobile device). Both can exist in digital form on interactive display devices or in hardcopy form on paper and other media. In practice, this distinction is somewhat arbitrary, and there is considerable overlap, but at the core the motivations, tools, and techniques for map production and map visualization are quite different. The current chapter will focus on maps and the next on visualization.

Cartography is concerned with the art, science, and techniques of making maps or charts. Conventionally, the term *map* is used for terrestrial areas (Figure 11.1) and *chart* for marine areas (Figure 11.2), but they are both maps in the sense the word is used here. In statistical or analytical fields, statistical graphics provide the pictorial representation of data, but this does not form part of the discussion in this chapter. Note, however, that statistical graphics can



Courtesy: ESRI

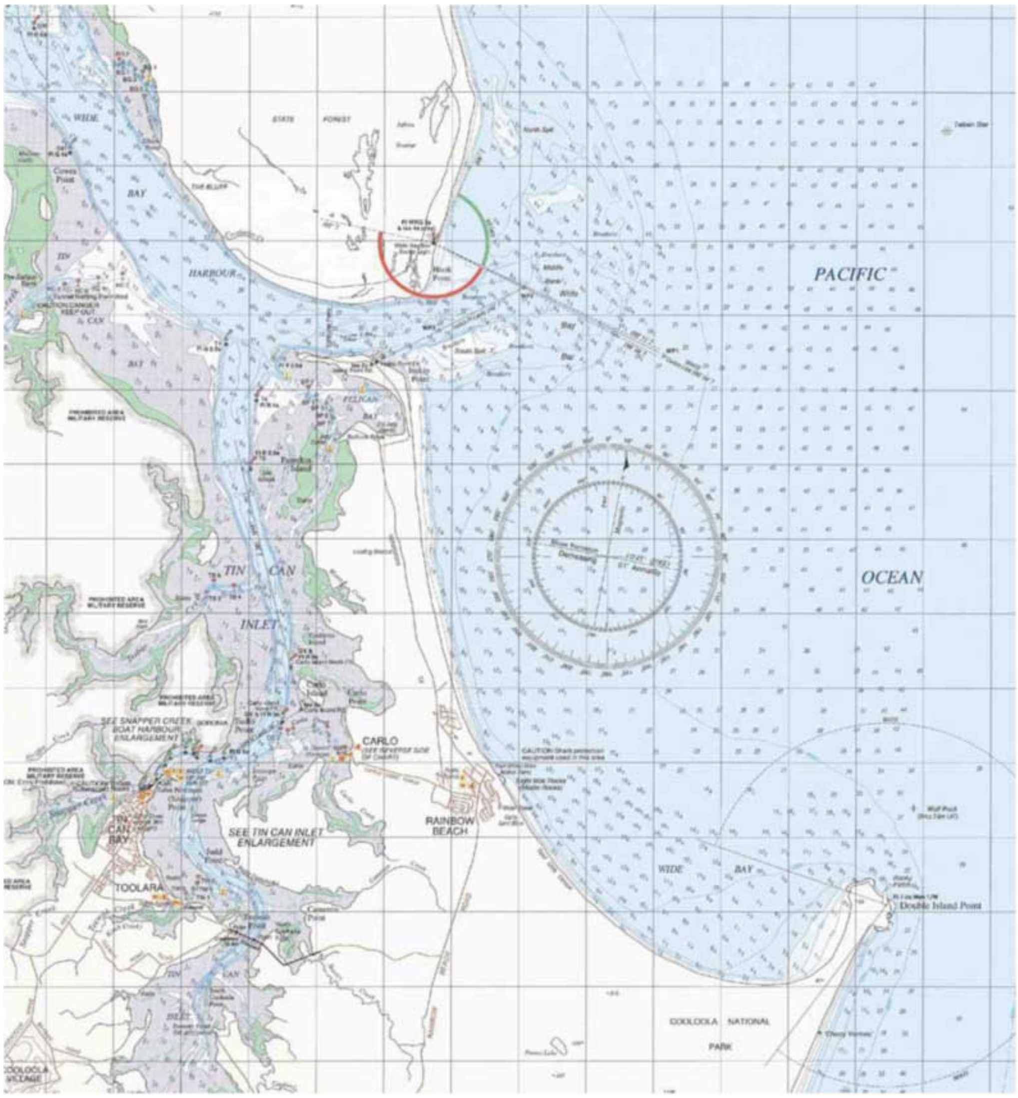
Figure 11.1 Terrestrial topographic map of Whistler, British Columbia, Canada. This is one of a collection of 7016 commercial maps at 1:20,000 scale covering the province.

be used on maps (e.g., Figure 11.3A, B). Cartography dates back thousands of years to a time before paper, but the main visual display principles were developed during the paper era; thus many of today's digital cartographers still use the terminology, conventions, and techniques from the paper era. Box 11.1 illustrates the importance of maps in a historic military context.

Maps are important communication and decision support tools.

Historically, the origins of many national mapping organizations can be traced to the need for mapping for "geographical campaigns" of infantry warfare, for colonial administration, and for defense. Today such organizations fulfill a far wider range of needs of many more user types (see Chapter 17). Although the military remains a heavy user of mapping, such territorial changes as arise from today's conflicts reflect a more subtle interplay of economic, political, and historical considerations—though, of course, the threat or actual deployment of force remains a pivotal consideration. Today, GI system–based terrestrial mapping underpins a wide range of activities, such as the support of humanitarian relief efforts (Figure 11.3) and the partitioning of territory through negotiation rather than force (e.g., GI systems were used by senior decision makers in the Darfur Peace Agreement in 2006). The time frame over which events unfold is also much more rapid: It is inconceivable to think of politicians, managers, and officials being able to neglect geographic space for months, weeks, or even days, never mind years.

Paper maps remain in widespread use because of their transportability, reliability, ease of use, and the routine application of printing technology. They are also amenable to conveying straightforward



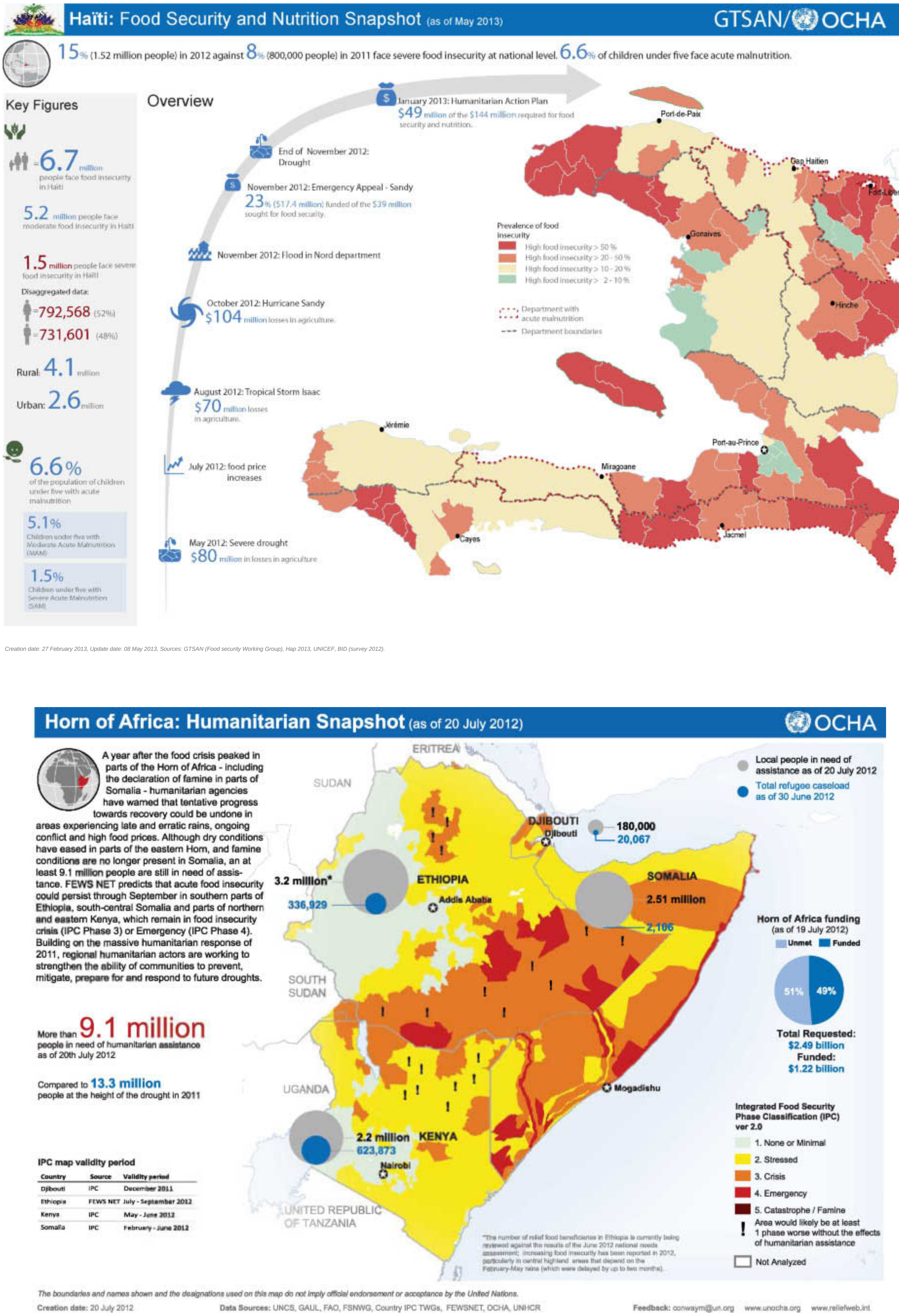
Courtesy: ESRI

Figure 11.2 Marine chart of Great Sandy Strait (South), Queensland, Australia Boating Safety Chart. This chart conforms to international charting standards.

Applications Box 11.1

Military Maps in History

"Roll up that map; it will not be wanted these ten years." British Prime Minister William Pitt the Younger made this remark after hearing of Napoleon's victory over Austria and Russia at the Battle of Austerlitz in 1805, when it became clear that the prospects of a British military campaign in Continental Europe had been thwarted for the foreseeable future. The quote illustrates the crucial historic role of mapping as a tool of decision support in warfare, in a world in which nation–states were far more insular than they are today. It also identifies two other defining characteristics of the use of geographic information in 19th-century society. First, the principal, straightforward purpose of much terrestrial mapping was to further national interests by infantry warfare. Second, the time frame over which changes in geographic activity patterns unfolded was, by today's standards, incredibly slow—Pitt envisaged that no British citizen would revisit this territory for a quarter of a (then) average lifetime! In the 19th century, printed maps were available in many countries for local, regional, and national areas, and their uses extended to land ownership, tax assessment, and navigation, among other activities.



Courtesy: United Nations Office for the Coordination of Humanitarian Affairs

Figure 11.3 Humanitarian relief maps: (A) Haiti food security and nutrition; (B) Horn of Africa Food Crisis.

messages and supporting decision making. Yet our increasingly detailed understanding of the natural environment and the accelerating complexity of society mean that the messages that mapping can convey are increasingly sophisticated and, for the reasons set out in Chapter 5, uncertain. Greater democracy and accountability, coupled with the pervasive use of maps on smartphones and increased spatial reasoning abilities that better education brings, indicate that more people than ever feel motivated and able to contribute to all kinds of spatial policy. This makes the decision-support role immeasurably more challenging, varied, and demanding of visual media. Today's mapping must be capable of communicating an extensive array of messages and emulating the widest range of what-if scenarios (see Section 15.1.1).

Both paper and digital maps have an important role to play in many economic, environmental, and social activities.

The visual medium of a given application must also be open to the widest community of users. Technology has led to the development of an enormous range of devices to bring mapping to the greatest range of users in the widest spectrum of decision environments. In-vehicle displays, smartphones, and wearable computers are all important in this regard (see Chapters 6 and 10 for examples). Most important of all, the development of the Web makes societal representations of space a real possibility for the first time. That is to say, it is now very easy to create cartographic products that represent everything from consumer preferences about how they will vote in an election to indicators of social deprivation, and ethnicity. For example, each month Google creates over 1 billion maps for users. The technology and applications of transient maps and other visualizations are explored more fully in the next chapter.

11.2 Maps and Cartography

There are many possible definitions of a map; here we use the term to describe digital or analog (softcopy or hardcopy) output from a GI system that shows geographic information using well-established cartographic conventions. A map is the final outcome of a series of GI processing steps (Figure 11.4) beginning with data collection, editing, and maintenance (Chapter 8), extending through data management (Chapter 9) and analysis (Chapters 13–15), and concluding with a map. Each of these activities successively transforms a database of geographic information until it is in the form appropriate to display on a given technology.

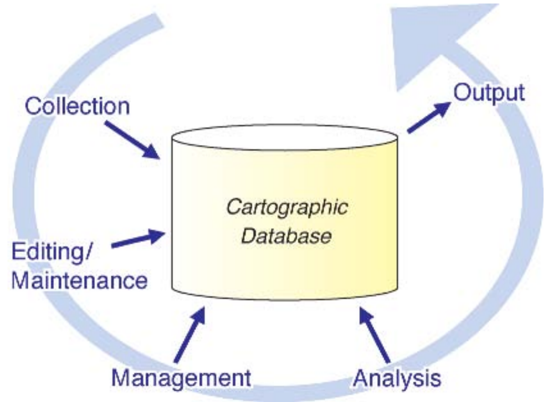


Figure 11.4 GI system processing transformations needed to create a map.

Central to any GI system is the creation of a data model that defines the scope and capabilities of its operation (Chapter 7) and the management context in which it operates (Chapters 16–18). There are two basic types of map (Figure 11.5): reference maps, such as topographic maps from national mapping agencies (see also Figure 11.1), that convey general information; and thematic maps that depict specific geographic themes, such as population census statistics, soils, or climate zones (see Figures 11.14 and 11.15 for further examples).

Maps are both storage and communication mechanisms.

Maps fulfill two very useful functions, acting as both storage and communication mechanisms for geographic information. The old adage "A picture is worth a thousand words" connotes something of the efficiency of maps as a storage container. The modern equivalent of this saying is "A map is worth a million bytes." Before the advent of GI systems, the paper map was the database (see Section 3.7), but now a map can be considered merely one of many possible products generated from a digital geographic database. Maps are also a mechanism to communicate information to viewers. They can present the results of analyses (e.g., the optimum site suitable for locating a new store, or analysis of the impact of an oil spill). They can communicate spatial relationships between phenomena across the same map, or between maps of the same or different areas. As such they can assist in the identification of spatial order and differentiation. Effective decision support requires that the message of the map be readily interpretable in the mind of the decision maker. A major function of a map is not simply to marshal and transmit known information about the world, but also to create or reinforce a particular message.

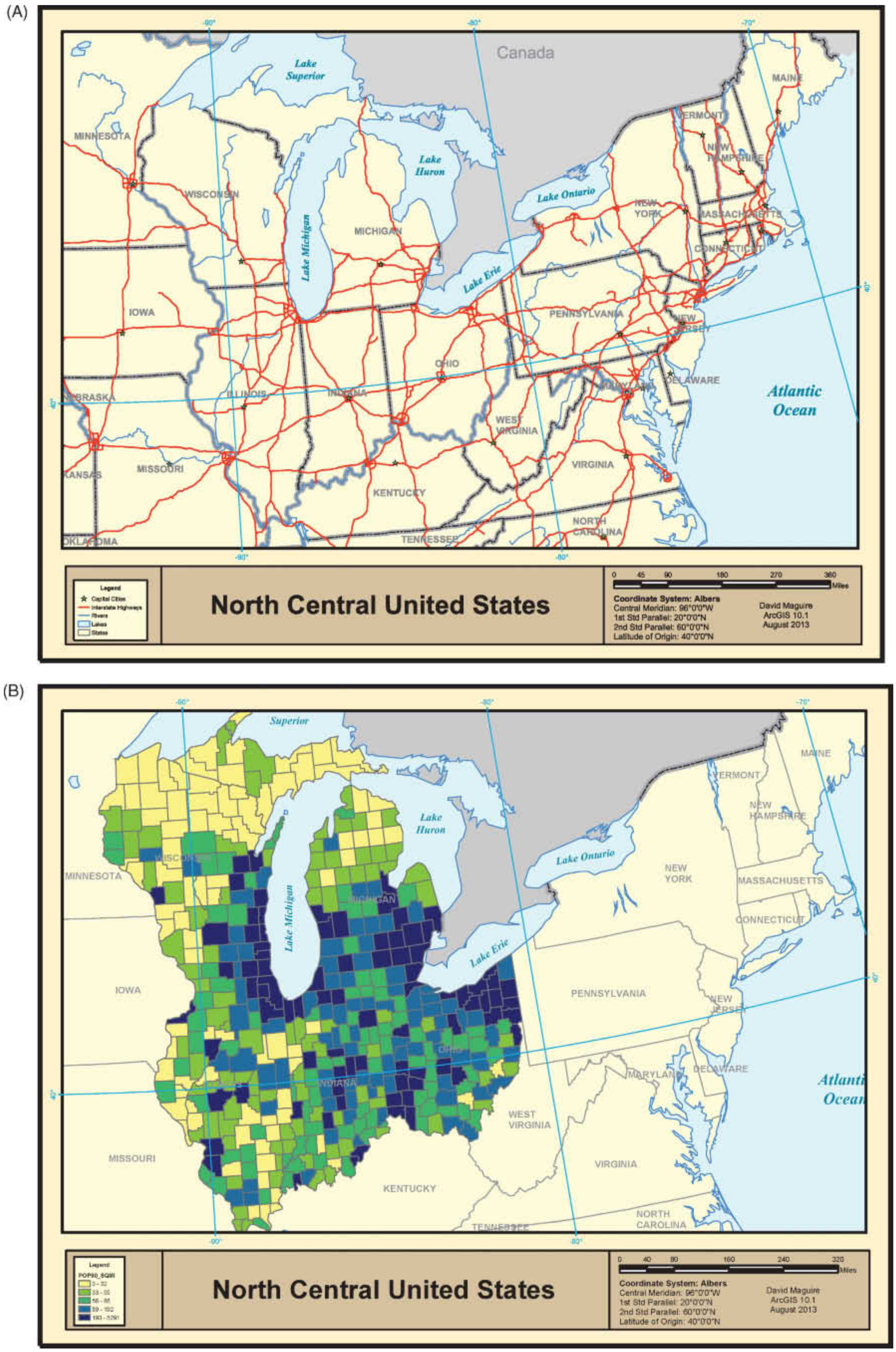


Figure 11.5 Two maps of North Central United States: (A) a reference map; and (B) a thematic map showing population density.

Box 11.2 concerns the work of Ferjan Ormeling, who has written extensively on the importance of maps.

Maps also have several limitations:

- Maps can be used to miscommunicate or obfuscate either accidentally or on purpose. For example, incorrect use of symbols can convey a misleading message to users by highlighting one type of feature at the expense of another (see Figure 11.14 for an example of different choropleth map classifications of the same data).
- Maps are a single realization of a spatial process. If we think for a moment about maps from a statistical perspective, then each map instance represents the outcome of a sampling trial and is therefore a single occurrence generated from all possible maps on the same subject for the same area (see Section 5.4.2). The significance of this is that other sample maps drawn from the same population would exhibit variations, and consequently, we need to be careful in drawing inferences from a single map sample. For example, a map of soil textures is derived by interpolating soil

Biographical Box 11.2

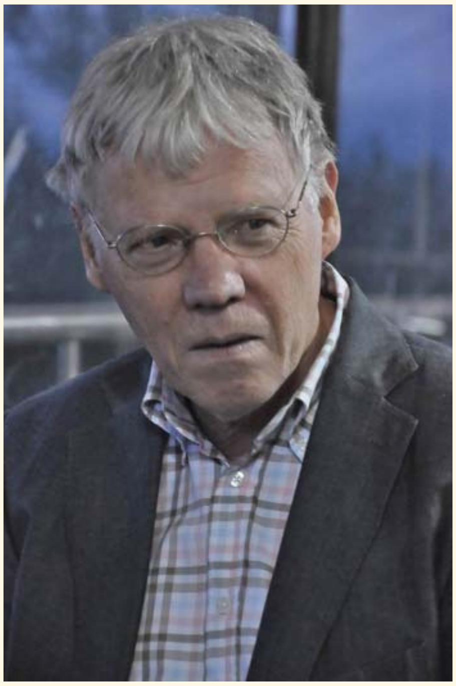
Ferjan Ormeling, Cartographer

Ferjan Ormeling (Figure 11.6) received his graduate degree in geography from Groningen University, the Netherlands; he paid for his studies by working for Wolters-Noordhoff Atlas Productions as a part-time assistant atlas-editor from 1961–1968. In Utrecht University from 1969 onward he cooperated in setting up a graduate program in cartography, from 1985 as a professor.

After an earlier focus on map perception research, he specialized in atlas cartography and toponymy. He helped produce two editions of the national atlas of the Netherlands, in 1977 and 1991. He edited two cartographic manual series, *Basic Cartography* (4 volumes with Roger Anson) and *Cartography, visualization of geospatial data* (with Menno-Jan Kraak), both translated widely. Ferjan has been vice chair of the United Nations Group of Experts on Geographical Names (UNGEGN, 2007–2017) and as such produced an online toponymy Web course in 2011. Since 2000 he has been a member of the Explokart research group on the history of Dutch cartography (now located at the University of Amsterdam) and has published books on the development of Dutch colonial cartography (of the area of present Indonesia) and on the history of Dutch school atlases.

Ferjan believes that without names maps are no use, but if names are used, they should be standardized (Figure 11.7). As can be seen in Figure 11.7, national standardization is not enough, however, and conversion systems between different writing systems should be standardized as well, making sure that every name uniquely refers to one specific topographic object only (this principle is called univocity). Even then, the standardization work should be sustained as name versions for specific topographic objects may quickly be superseded, so updating is required regularly.

Ferjan is concerned with the post-1990 mass resurgence of exonyms in Central and Eastern Europe, which he considers as detrimental to cartographic communication,

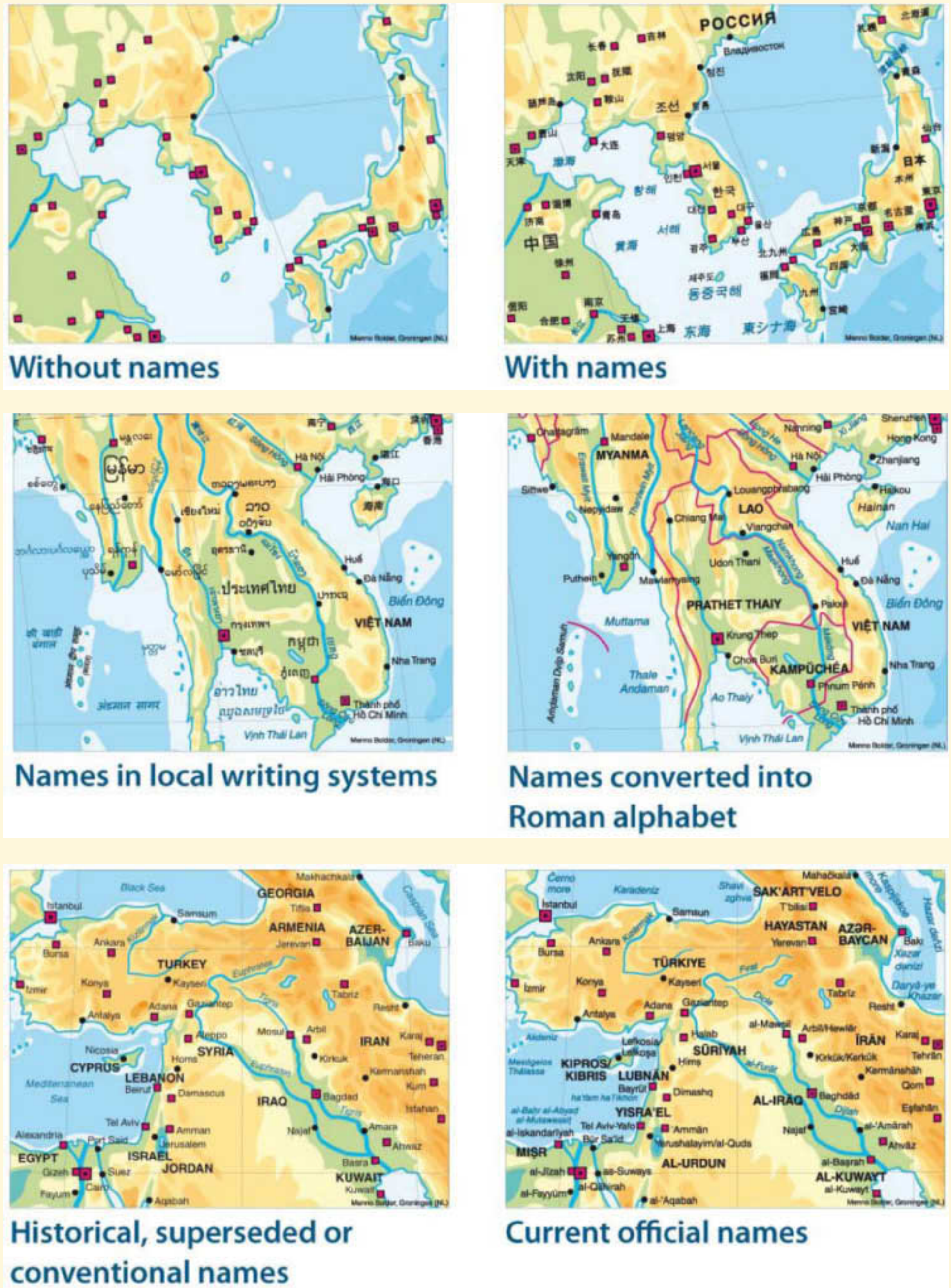


Courtesy: Ferjan Ormeling

Figure 11.6 Ferjan Ormeling, Cartographer.

although he has supported the right of minority language groups (like the Welsh, Frisians, Basques, etc.) to have their own geographical name versions also rendered on topographic maps; currently this has also been recognized as a crucial aspect of one's cultural heritage. Through the EU EuroGeoNames project he has helped to shape the geographical names model in INSPIRE, Europe's exchange format for geospatial data files.

The inclusion on maps of the proper geographical names renders these maps suitable for use as decision support tools. Ferjan's other concern is that decision makers need to be sufficiently trained to interpret map names. A course on map analysis for decision makers is long overdue!



Courtesy: Ferjan Ormeling

Figure 11.7 The importance of standardized, up-to-date names on maps.

sample texture measurements. Repeated sampling of soils will show natural variation in the texture measurements.

- Maps are often created using complex rules, symbology, and conventions and can be difficult to understand and interpret for the untrained viewer.

This is particularly the case, for example, in multivariate statistical thematic mapping where the idiosyncrasies of classification schemes and color symbology can be challenging to comprehend.

Uncertainty pertains to maps just as it does to other geographic information.

11.2.1 Maps and Media

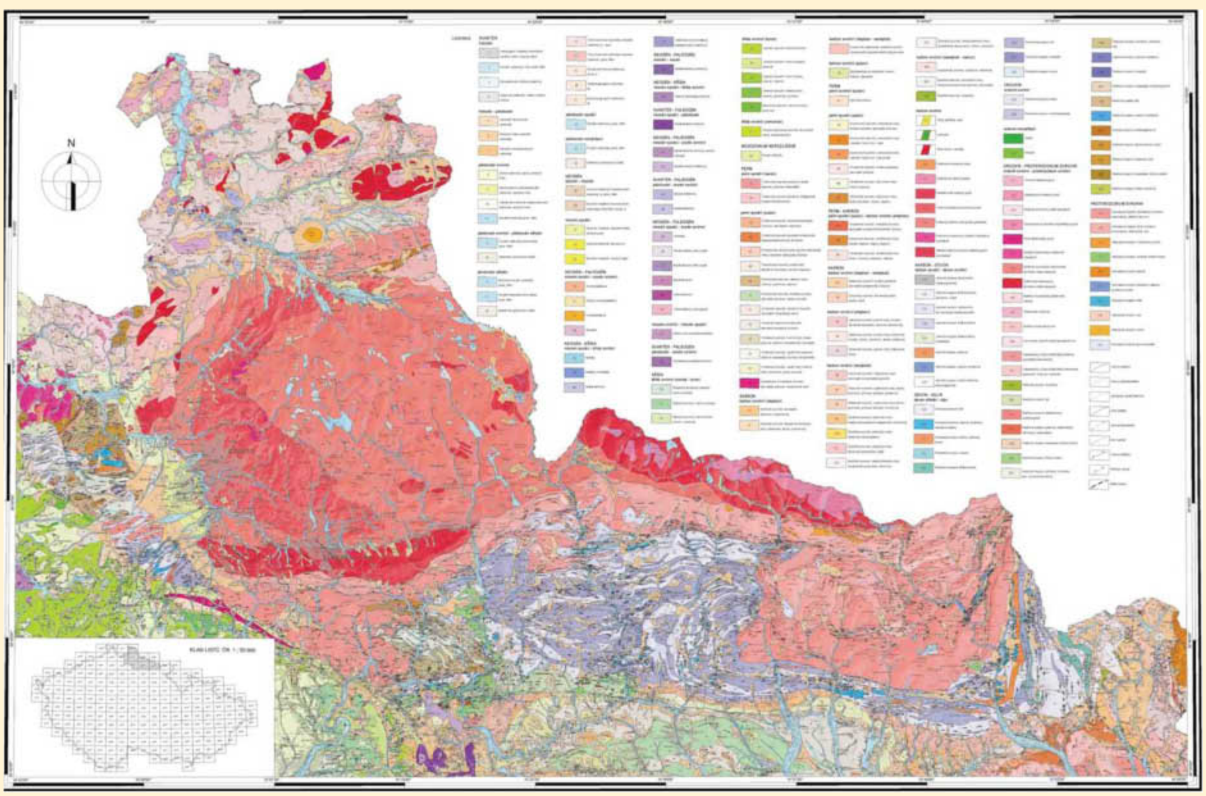
Without question, GI systems and science have fundamentally changed cartography and the way we create, use, and think about maps (see Box 11.3). The digital cartography of GI systems frees mapmakers from many of the constraints inherent in traditional paper mapping (see also Section 3.7).

- The paper map is of fixed scale. Generalization procedures (Section 3.8) can be invoked in order to maintain clarity during map creation. This detail

Applications Box 11.3

Czech Geological Survey (CGS) Map Production

In 1994, the Czech Geological Survey (CGS) began extensive use of GI technology to meet the increasing demand for digital information about the environment. GI systems in the CGS focus on the methods of spatial data processing, unification, and dissemination. Digital processing of geological maps and the development of GI systems follows standardized procedures using common geological dictionaries and graphic elements. Recently, the main objective has been to create and implement a uniform geological data model and provide the public and the scientific community with easy access to geographic data, via a Web map server (www.geology.cz). CGS has a unique geographic information system containing more than 260,000 mapped geological objects from the entire Czech Republic. The fundamental part of this geographic database is the unified national geological index (legend), which consists of four main types of information—chronostratigraphical units, regional units, lithostratigraphical units, and lithological description of rocks. The database has been under revision since 1998, leading to the creation of a seamless digital geological map of the Czech Republic. This database has already been used for land-use planning by government and local authorities. The geological map of the Krkonose–Jizera Mountains shown in Figure 11.8 is a cartographic presentation of one part of the CGS database. The overview map in the bottom left corner shows the extent of all maps in the series.



Courtesy: Esri

Figure 11.8 A 1:50,000 geological map of the Krkonose–Jizera Mountains, Czech Republic.

is not recoverable, except by reference back to the data from which the map was compiled. The zoom facility of GI systems can allow mapping to be viewed at a range of scales and permit detail to be filtered out as appropriate at a given scale.

- The paper map is of fixed extent, and adjoining map sheets must be used if a single map sheet does not cover the entire area of interest. (An unwritten law of paper map usage is that the most important map features always lie at the intersection of four paper map sheets!) GI systems, by contrast, can provide a seamless medium for viewing space, and users are able to pan across wide swaths of geography.
- Most paper maps present a static view of the world, whereas conventional paper maps and charts are not adept at portraying dynamics. GI representations are able to achieve this through animation.
- The paper map is flat and hence limited in the number of perspectives that it can offer on three-dimensional data. 3-D visualization is much more effective within GI systems, which can support interactive pan and zoom operations (see Figure 8.15 for a 3-D view example).
- Paper maps provide a view of the world as essentially complete. GI system-based mapping allows the supplementation of base-map material with further data. Data layers can be turned on and off to examine data combinations.
- Paper maps provide a single, map-producer-centric, view of the world. GI system users are able to create their own, user-centric map images in an interactive way. Side-by-side map comparison is also possible in GI systems.

GI systems offer flexible ways to produce many types of maps.

11.3 Principles of Map Design

Map design is a creative process during which the cartographer, or mapmaker, tries to convey the message of the map's objective. The primary goals in map design are to share information, highlight patterns and processes, and illustrate results. A secondary objective is to create a pleasing and interesting picture, but this must not be at the expense of fidelity to reality and meeting the primary goals. Map design is quite a complex procedure requiring the simultaneous optimization of many variables and harmonization of multiple methods. Cartographers must be prepared to compromise and balance choices. It is difficult to define exactly what constitutes a good design, but the general consensus is that a good design is one that looks good, is simple and elegant, and most important, leads to a map that is fit for its purpose.

Robinson et al. identify seven controls on the map-design process:

- *Purpose*. The purpose for which a map is being made will determine what is to be mapped and how the information is to be portrayed. Reference maps are multipurpose, whereas thematic maps tend to be for a single purpose (Figure 11.5). With the digital technology of GI systems, it is easier to create maps, and many more are digital and interactive. As a consequence, today's maps are increasingly created for a specific purpose.
- *Reality*. The phenomena being mapped will usually impose some constraints on map design. For example, the orientation of the country—whether it be predominantly southwest–northeast (Japan) or north–south (Chile)—can determine layout in no small part.
- *Available data*. The specific characteristics of data (e.g., raster or vector, continuous or discrete, or point, line, or area) will affect the design. There are many different ways to symbolize map data of all types, as discussed in Section 11.3.2.
- *Map scale*. Scale is an apparently simple concept, but it has many ramifications for mapping (see Box 2.3 for further discussion). It will control the quality of data that can appear in a map frame, the size of symbols, the overlap of symbols, and much more. Although one of the early promises of digital cartography and GI systems was scale-free databases that could be used to create multiple maps at different scales, this has never been realized because of technical complexities.
- *Audience*. Different audiences want different types of information on a map and expect to see information presented in different ways. Usually, executives (and small children!) are interested in summary information that can be assimilated quickly, whereas advanced users often want to see more information. Similarly, those with restricted eyesight find it easier to read bigger symbols.
- *Conditions of use*. The environment in which a map is to be used will impose significant constraints. Maps for outside use in poor or very bright light will need to be designed in ways different to maps for use indoors where the light levels are less extreme.
- *Technical limits*. The display medium, be it digital or hardcopy, will impact the design process in several ways. For example, maps to be viewed in an Internet browser or on a smartphone, where resolution and bandwidth are limited, should be simpler and based on fewer data than equivalents to be displayed on a desktop PC monitor.

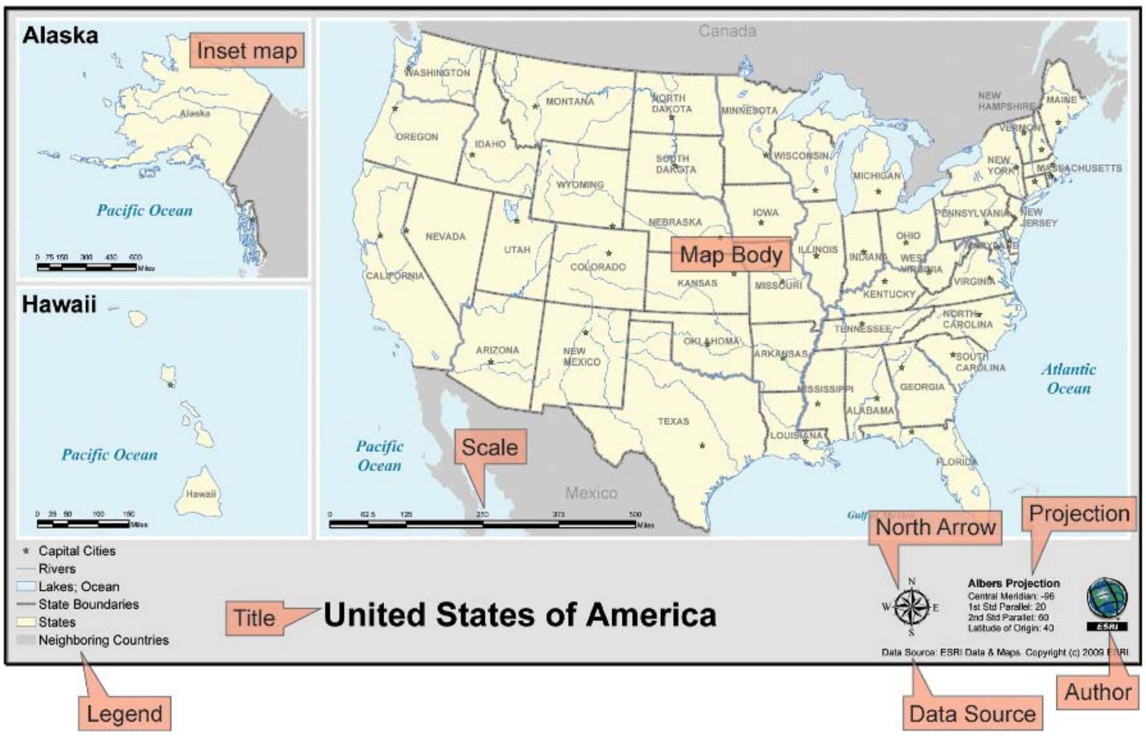
11.3.1 Map Composition

Map composition is the cartographic design process of creating a map comprising several closely interrelated elements (Figure 11.9):

- *Map body*. The principal focus of the map is the main map body, or in the case of comparative maps there will be two or more map bodies. It should be given the necessary space and use symbols appropriate to its significance.
- *Inset/overview map*. Inset and overview maps may be used to show, respectively, an area of the main map body in more detail (at a larger scale) and the general location or context of the main body.
- *Title*. One or more map titles are used to identify the map and to inform the reader about its content.
- *Legend*. This lists the items represented on the map and how they are symbolized. Many different layout designs are available, and a considerable body of information is available about legend design.
- *Scale*. The map scale provides an indication of the size of objects and the distances between them. A paper map scale is a ratio, where one unit on the map represents some multiple of that value in the real world. The scale can be symbolized numerically (1:1,000), graphically (a scalebar), or texturally ("one inch equals 10,000 inches"). The scale is a representative fraction (see Section 3.7), and so a 1:1,000 scale is larger (finer) than 1:100,000. A small- (coarse-) scale map displays a larger area than a large- (fine-) scale map, but with less detail. See also Box 2.3 for more discussion of the many meanings of scale.
- *Direction indicator*. The direction and orientation of a map can be conveyed in one of several ways, including grids, graticules, and directional symbols (usually north arrows). A grid is a network of parallel and perpendicular lines superimposed on a map (see Figure 11.1). A graticule is a network of longitude and latitude lines on a map that relates points on a map to their true location on the Earth (see Figure 11.5).
- *Map metadata*. Map compositions can contain many other types of information, including the map projection, date of creation, data sources, and authorship (see also Section 10.2).

A key requirement for a good map is that all map elements are composed into a layout that has good

Figure 11.9 The principal components of a map composition layout.



Courtesy: Esri

visual balance. On large-scale maps, such as 1:10,000 national mapping agency topographic series, all the contextual items (everything in the preceding list except the map body) usually appear as marginal notations (or marginalia). In the case of map series or atlases (see Section 11.4), some of the common information may be in a separate document. On small- or medium-scale maps this information usually appears within the map border (Figure 11.9).

11.3.2 Map Symbolization

The data to be displayed on a map must be classified and represented using graphic symbols that conform to well-defined and accepted conventions. The choice of symbolization is critical to the usefulness of any map. Unfortunately, the seven controls on the design process listed in Section 11.3.1 also conspire to mean that there is not a single universal symbology model applicable everywhere, but rather one for each combination of factors. Again, we see that cartographic design is a compromise reached by simultaneously optimizing several factors.

Good mapping requires that spatial objects and their attributes can be readily interpreted in applications. In Chapter 2, attributes were classified as being measured on the nominal, ordinal, interval, ratio, or cyclic scales (see Box 2.1). Also, in Chapter 3 points, lines, and areas were described as types of discrete objects (see Section 3.5.1), and surfaces were discussed as a type of continuous field (see Section 3.5.2). We have already seen how attribute measures that we think of as continuous are actually discretized to levels of precision imposed by measurement or design (see Chapter 5). The representation of spatial objects is similarly imposed: cities might be captured as points, areas, mixtures of points, lines, and areas (as in a street map: Figure 6.12) or 2.5-D and 3-D objects (see Section 12.4.2), depending on the base scale of a representation and the importance of city objects to the application. Measurement scales and spatial object types are thus one set of conventions that are used to abstract reality. The choice of output format, digital or paper, may entail reclassification or transformation of attribute measures.

The process of mapping attributes frequently entails further problems of classification because many spatial attributes are inherently uncertain (Chapter 5). For example, in order to create a map of occupational type, individuals' occupations will be classified first into socioeconomic groups (e.g., "factory worker") and perhaps then into supergroups, such as "blue collar" (see Figure 1.17). At every stage in the aggregation process, we inevitably do injustice to many individuals who perform a mix of white- and blue-collar, intermediate, and skilled functions, by lumping them into a single group. In practice, the validity and usefulness of an occupational or geodemographic classification will have become established over repeated applications, and the task of mapping is to convey thematic variation in as efficient a way as possible.

11.3.2.1 Attribute Representation and Transformation

Humans are good at interpreting visual data—much more so than interpreting numbers, for example—but conventions are still necessary to convey the message that the mapmaker wants the data to impart. Many of these conventions relate to the use of symbols (such as the way highway shields denote route numbers on many U.S. medium- and fine-scale maps) and colors (blue for rivers, green for forested areas, etc.) and have been developed over a period of hundreds of years. Mapping of different themes (such as vegetation cover, surface geology, and socioeconomic characteristics of human populations) has a more recent history. Here too, however, mapping conventions have developed, and sometimes they are specific to particular applications.

Attribute mapping entails the use of graphic symbols, which (in two dimensions) may be referenced by points (e.g., historic monuments and telecoms antennae), lines (e.g., roads and water pipes), or areas (e.g., forests and urban areas). Basic point, line, and area symbols are modified in different ways in order to communicate different types of information. The ways in which these modifications take place adhere to cognitive principles and the accumulated experience of application implementations. The nature of these modifications was first explored by Jacques Bertin in 1967 and was extended to the typology illustrated in Figure 11.10 by Alan MacEachren. The size and orientation of point and line symbols are varied principally to distinguish between the values of ordinal and interval/ratio data using graduated symbols (such as the divided pie symbols shown in Figure 11.11). Figure 11.12 illustrates how orientation and color can be used to depict the properties of locations, such as ocean current strength and direction.

Hue refers to the use of color, principally to discriminate between nominal categories, as in agricultural or urban land-use maps (Figure 11.13). Different hues may be combined with different textures or shapes if there are a large number of categories, in order to avoid difficulties of interpretation. The shape of map symbols can be used to communicate information about either a spatial attribute (e.g., a viewpoint or the start of a walking trail), or its spatial location (e.g., the location of a road or boundary of a particular type: Figure 11.13), or spatial relationships (e.g., the relationship between subsurface topography and ocean currents). Arrangement, texture, and focus refer

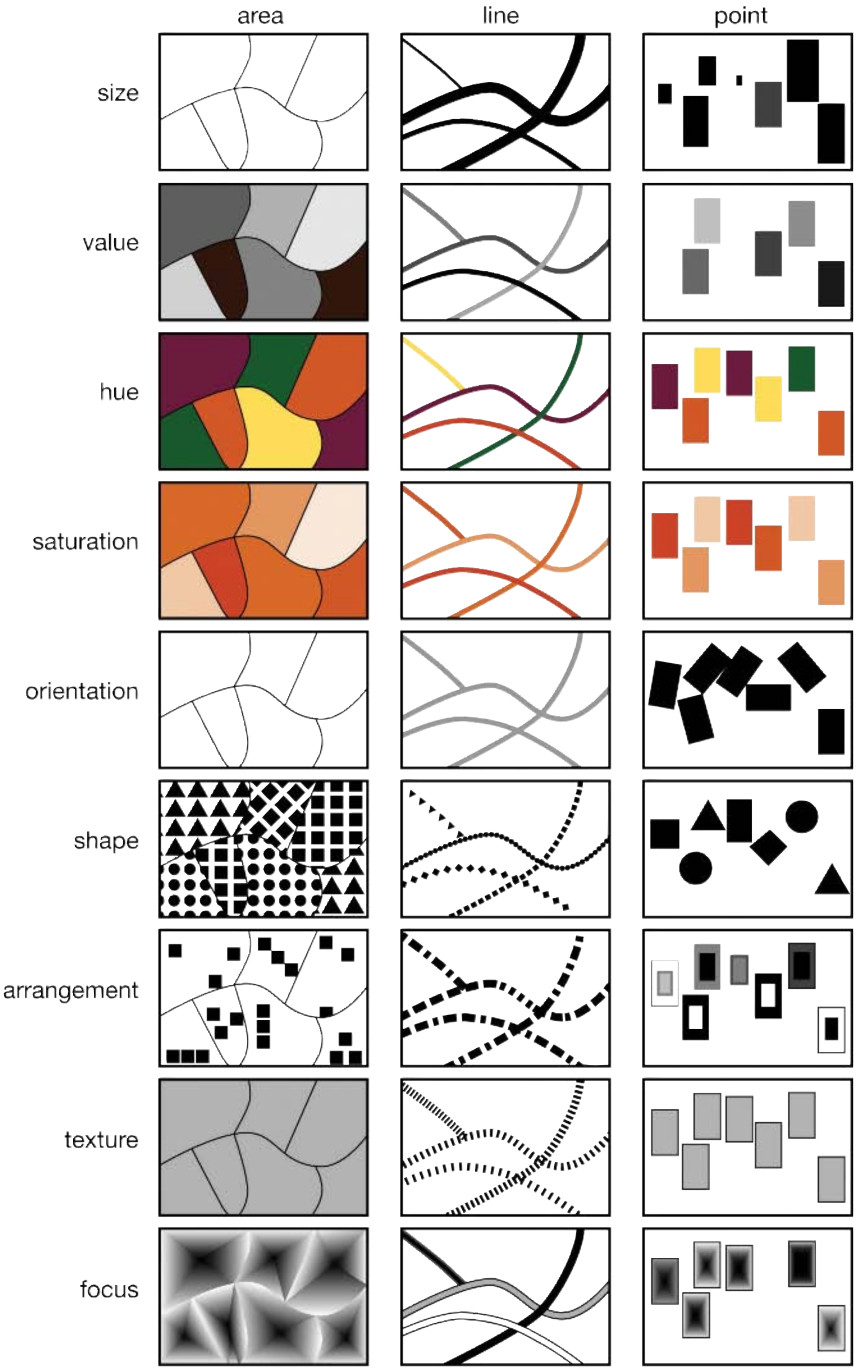
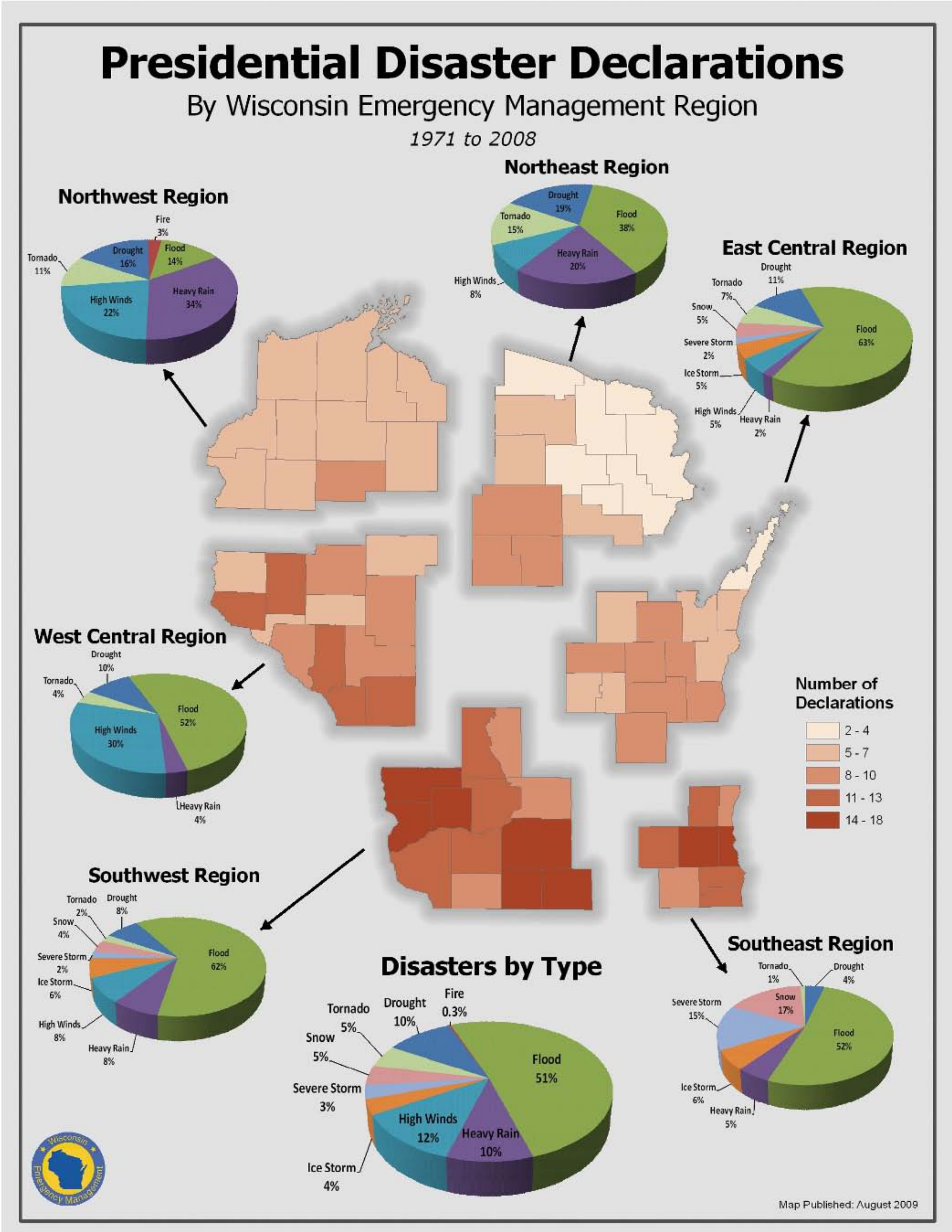


Figure 11.10 Bertin's graphic primitives, extended from seven to ten variables (the variable location is not depicted).

Source: MacEachren 1994; from *Visualization in Geographical Information Systems*, Hearnshaw H. M. and Unwin D. J. (eds.). Reproduced by permission of John Wiley & Sons, Ltd.

to within- and between-symbol properties that are used to signify pattern. A final graphic variable in the typologies of MacEachren and Bertin is location (not shown in Figure 11.10), which refers to the practice of offsetting the true coordinates of objects in order to improve map intelligibility, or changes in map projection. We discuss this in more detail later in this section. Some of the common ways in which these graphic variables are used to visualize spatial object types and attributes are shown in Table 11.1.

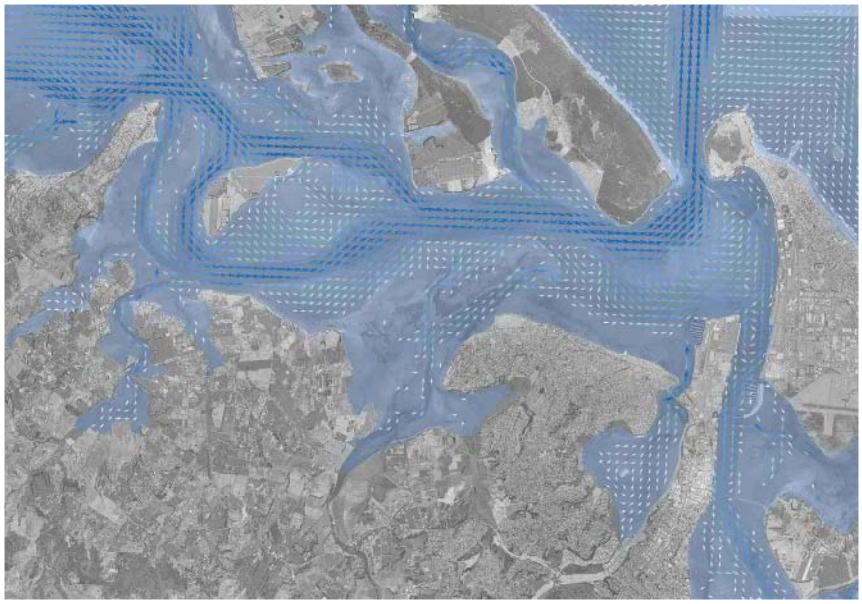
The selection of appropriate graphic variables to depict spatial locations and distributions presents one set of problems in mapping. A related task is how best to position symbols on the map to optimize map interpretability. The representation of nominal data by graphic symbols and icons is apparently trivial, although in practice automating placement presents some challenging analytical problems. Most GI system software packages include generic algorithms for positioning labels and symbols in relation to geographic objects.



Courtesy: Esri

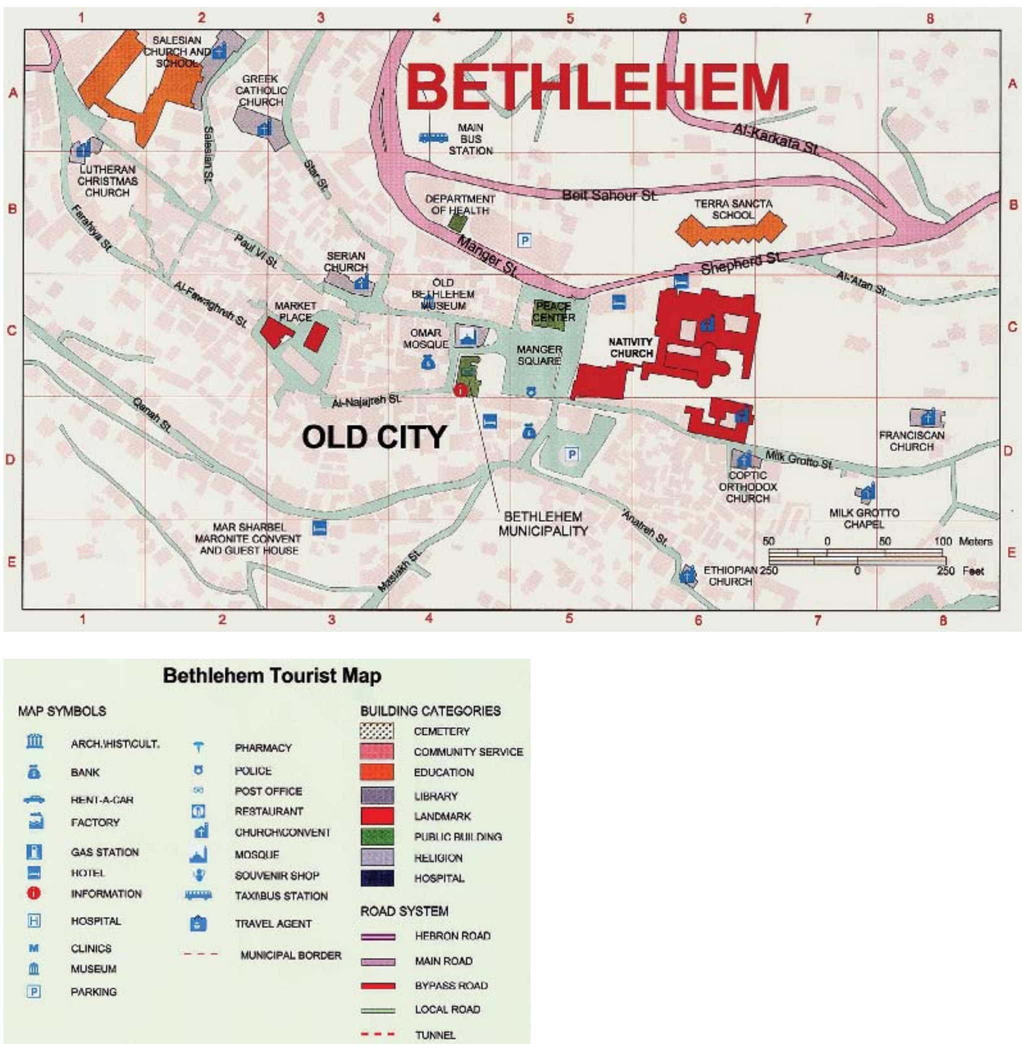
Figure 11.11 Wisconsin Presidential Disaster Declarations 1971–2008.

Figure 11.12 Tauranga Harbor Tidal Movements, Bay of Plenty, NZ. The arrows indicate speed (color) and direction (orientation).



Courtesy: Esri

Figure 11.13 Use of hue (color) to discriminate between Bethlehem, West Bank, Israel urban land-use categories and use of symbols to communicate location and other attribute information.



Courtesy: Esri

Next Page

Table 11.1 Common methods of mapping spatial object types and attribute data, with examples.

Spatial object type	Attribute type		
	Nominal	**Ordinal**	**Interval/Ratio**
Point (0-D)	Symbol map (each category a different class of symbol—color, shape, orientation), and/or use of lettering: e.g., presence/absence of building type (Figure 11.13)	Hierarchy of symbols or lettering (color and size): e.g., small/medium/large depots, city size (Figure 11.7)	Graduated symbols (color and size): e.g., disease incidence (Figures 11.3, 11.16)
Line (1-D)	Network connectivity map (color, shape, orientation): e.g., presence/absence of connection (Figure 6.1)	Graduated line symbology (color and size): e.g., road classifications (Figure 6.12)	Flow map with width or color lines proportional to flows (color and size): e.g., traffic flows (Figure 11.24)
Area (2-D)	Unique category map (color, shape, orientation, pattern): e.g., soil types or geology (Figure 11.8)	Graduated color or shading map: e.g., timber yield low/medium/high, name concentration (Figure 1.7)	Continuous hue/shading, e.g., dot-density or choropleth map: e.g., percentage of retired population (Figure 11.14)
Surface (2.5-D)	One color per category (color, shape, orientation, pattern), e.g., relief classes: mountain/valley, children's activity plots (Figure 3.1)	Ordered color map, e.g., areas of gentle/steep/very steep slopes, land use risk (Figure 7.14)	Contour map (e.g., isobars/isohyets: e.g., topography contours, diabetes contours (Figure 5.2)

Point labels are positioned to avoid overlap by creating a window, or mask (often invisible to the user), around text or symbols. Linear features, such as rivers, roads, and contours, are often labeled by placing the text using a spline function to give a smooth, even distribution, and distinguishing by use of color. Area labels are assigned to central points (see Figure 11.9), using geometric algorithms similar to those used to calculate geometric centroids (Section 14.2.1). These generic algorithms are frequently customized to accommodate common conventions and rules for particular classes of application, such as topographic (Figure 11.1), utility, transportation, and seismic maps. Generic and customized algorithms also include color conventions for map symbolization and lettering.

Ordinal attribute data are assigned to point, line, and area objects in the same rule-based manner, with the ordinal property of the data accommodated through use of a hierarchy of graphic variables (symbol and lettering sizes, types, colors, intensities, etc.). As a general rule, the typical user is unable to differentiate between more than seven (plus or minus two) ordinal categories, and this provides an upper limit on the normal extent of the hierarchy.

A wide range of conventions is used to visualize interval- and ratio-scale attribute data. Proportional circles and bar charts are often used to assign interval- or ratio-scale data to point locations (Figures 11.11 and 11.16). Variable line width (with increments that correspond to the precision of the interval measure) is a standard convention for representing continuous variation in flow diagrams.

A variety of ways can be used to ascribe interval- or ratio-scale attribute data to areal entities that are predefined. In practice, however, none is unproblematic. The standard method of depicting areal data is in zones (Figure 11.5B). However, as was discussed in Box 2.5, the choropleth map brings the dubious visual implication of within-zone uniformity of attribute value. Moreover, conventional choropleth mapping also allows any large (but possibly uninteresting) areas to dominate the map visually. A variant on the conventional choropleth map is the dot-density map, which uses points as a more aesthetically pleasing means of representing the relative density of zonally averaged data—but not as a means of depicting the precise locations of point events. Proportional circles provide one way around this problem; here the circle is scaled in proportion to the size of the quality being mapped, and the circle can be centered on any convenient point within a zone. However, there is a tension between using circles that are of sufficient size