

# 1

## Planning maps

**COMMUNICATION SKILLS ARE CRUCIAL TO EVERY professional's work. Verbal skills are not enough to effectively present geographic information—you also need graphic skills. This book helps you develop the graphic skills needed for mapmaking. Cartographic expertise allows you to communicate geographic information clearly with maps. Amateur-looking maps can undermine your audience's ability to understand important information and weaken the presentation of a professional data investigation.**

**Designing better maps means thinking carefully about each aspect of the map-design process. When creating a page layout, you should size each map element relative to its importance for the map's purpose. The positions and sizes of empty spaces between elements are as important to layout as the elements themselves. This chapter presents map-design essentials that will help you produce clear, meaningful maps that invite reading.**

**Choosing a map projection is also a design decision that depends on the purpose of the map. Projecting the round earth onto the flat page creates unavoidable distortions in the geography of your map. By choosing an appropriate map projection, you can manage the distortion so that it has minimal effect on the message and purpose of your map. The choice of projection partly determines the shape of the map as well as its layout.**

**Here are the essentials of planning better maps:**

- **linking layout to the map's purpose and using visual hierarchy**
- **planning a layout, balancing empty spaces, refining alignments in layout, and valuing experimentation and critique**
- **selecting map projections to suit the map's purpose**

## Designing for map purpose

The impetus to design better maps comes from a desire to make maps that are clear and convincing. A successful design begins with knowing why the map is being made. Cartographers begin planning maps by asking themselves and their clients several questions:

- What information is being mapped?
- Who will be reading the map?
- Is the map content coordinated with written text or other graphics?
- What size and medium will be used to display the map?
- What are the time and budget constraints on map production?

The topic and intended audience will dictate many of a map's characteristics. It may be necessary to refer to related research or to other maps in the same field to gauge the amount of detail and relevant symbol conventions for the project. Researchers who make their own maps have the advantage of familiarity with their data and how it is typically portrayed. They will still benefit by asking themselves the same set of questions before they begin design work.

The purpose of your map will determine what parts of it are most important. Which elements of your map do you want people to notice first and remember after they finish reading the map? This ordering of importance—or visual hierarchy—is created by designing some parts of the map to appear as background information and others to take prominence in the foreground. You should design map elements that supply supporting information by decreasing visual importance, echoing their role in understanding the mapped information.

## Audience

If you are laboring over map design, you are probably making a map for people beyond your immediate workgroup. Who are these map readers? If the audience is new to the information mapped, they may require a simpler presentation. Likewise, if they are people who are too busy to spend much time reading, they will also need a simple map that summarizes the information. Maps that have a simple purpose, such as a navigation display you check while driving, demand a simple design. Maps for nonexperts or busy people will have a similar look. They should have a single message that focuses the attention of the reader. In contrast, maps

for people who already know about the topic can be more complex. If they are experts on the data that is mapped, they will expect a rich and multilayered presentation of information that adds to their knowledge or thoroughly supports your (the mapmaker's) contention. The more knowledge and time the map reader brings to the task of reading your map, the more information you will be able to include. More complex maps will motivate advanced map readers to spend more time examining a map on a topic of interest. Detailed information on the map will support their map reading rather than distract from it.

When designing a map, you should also consider your audience's physical ability to read. If the map will be used by older people and others likely to have reduced vision, keep the map text large enough to be legible. If the map will be read in dim or otherwise difficult viewing conditions, use exaggerated lightness contrasts. You may even choose to design your maps to accommodate color-blind readers, who comprise 4 percent of the population. A map can be tailored to the knowledge level of its audience by reducing the number of categories of data shown. Figure 1.1 shows two municipal water maps made for different purposes. The map in figure 1.1*A* shows water mains along with hydrants, meters, fittings, valves, laterals, road centerlines and edges, and sewage mains. This level of detail is suitable for a knowledgeable map reader. The map in figure 1.1*B* uses portions of the same dataset, but the map has been simplified to show just the water mains and hydrants. This map would be suitable for a lay audience or a busy city mayor.

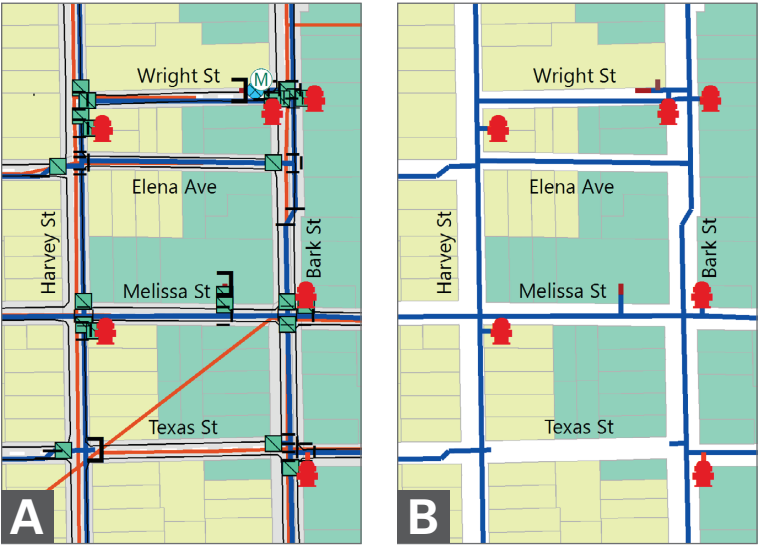
The same set of data can be used to make two maps with different purposes by emphasizing different categories of features. The two maps in figure 1.2 are derived from the Placitas quadrangle geologic map in New Mexico. The map in figure 1.2*A* emphasizes the road to a recreation site, nearby mines, and the network of faults in the area. This map would be suitable as a location map for a group who wanted to plan a field trip to the area to examine these mines. The map in figure 1.2*B* would be suitable for a more expert group who is familiar with geologic mapping conventions, the names and ages of geologic formations, and information on strike and dip.

Maps for different purposes may also have similar levels of detail. The two maps in figure 1.3 are designed from the same data, but they have different purposes, and so they should have different emphases. They show the same set of lines from a map of Joshua Tree National Park in Southern California symbolized two

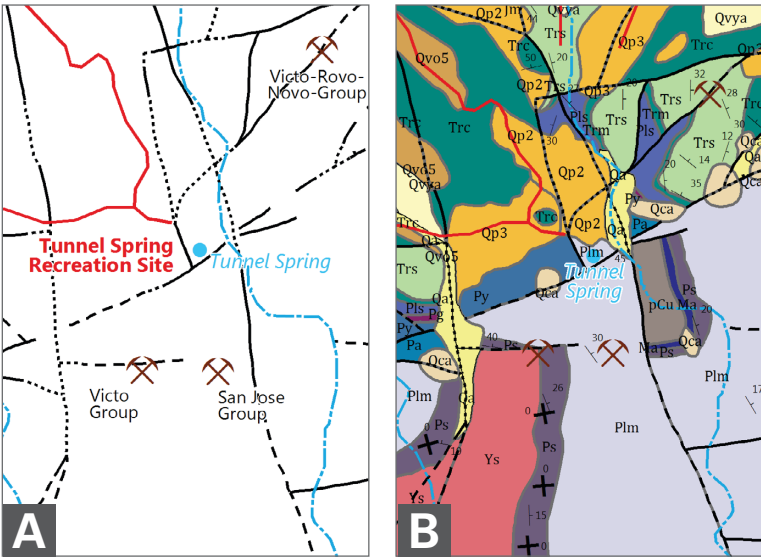
different ways. In figure 1.3A, the emphasis is on physical features near Joshua Tree: the San Andreas Fault (dashed), the transition zone between the Mojave and Colorado Deserts (brown), and sea level (blue). The map in figure 1.3B emphasizes cultural features near the park: roads (thin red), the interstate highway (thick red), and populated places (yellow).

### Visual hierarchy in layout

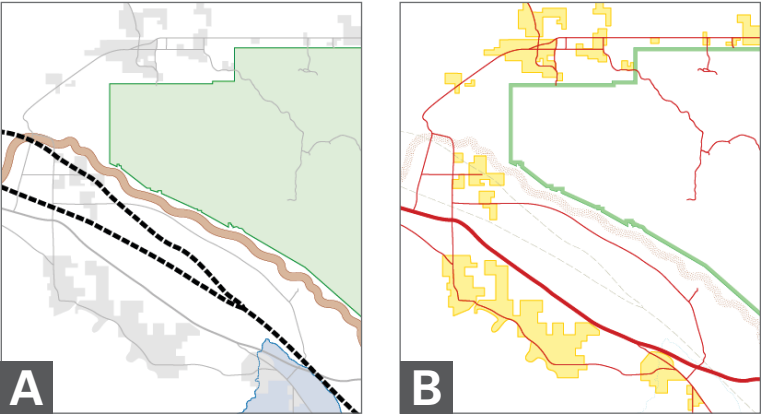
A map’s purpose determines which of its elements are the most important and should be displayed most prominently in the visual hierarchy. The title and key features on the main map are highest in the visual hierarchy. Base or background geography is lower in the visual hierarchy. Chapter 2 introduces basemap themes common for supporting the main map content. Supporting information, such as source notes, should be lowest in the hierarchy. These are often along the margins of the display and called *marginal elements*. Chapter 3 elaborates on the design of marginal elements, such as text wording, legends, scale bars, and direction indicators. But first, you need to understand map layout overall.



**Figure 1.1** Two maps of city water mains. The first (A) includes detail suitable for an expert audience, while the second (B), with fewer symbols, is appropriate for a novice or busy audience. Map updated by P. Limpisathian, Department of Geography, The Pennsylvania State University (Penn State Geography).



**Figure 1.2** Two maps showing a portion of the Placitas quadrangle, New Mexico. The first (A) simply shows faults as well as mining and recreation sites. The second (B) is designed for an expert audience. Source: New Mexico Bureau of Mines and Geology, Placitas Quadrangle. Map updated by P. Limpisathian, Penn State Geography.



**Figure 1.3** Two maps of Joshua Tree National Park emphasizing physical features (A) and cultural features (B). Source: National Park Service, <http://www.nps.gov/carto>.

Map design is largely a process of deciding how prominent to make each element of your map layout. Numerous graphic effects can be produced using GIS software. Your decisions whether to use them or change them are guided by the visual hierarchy of information in your map. A clear understanding of the hierarchy of the map's elements to suit its purpose is the essence of good

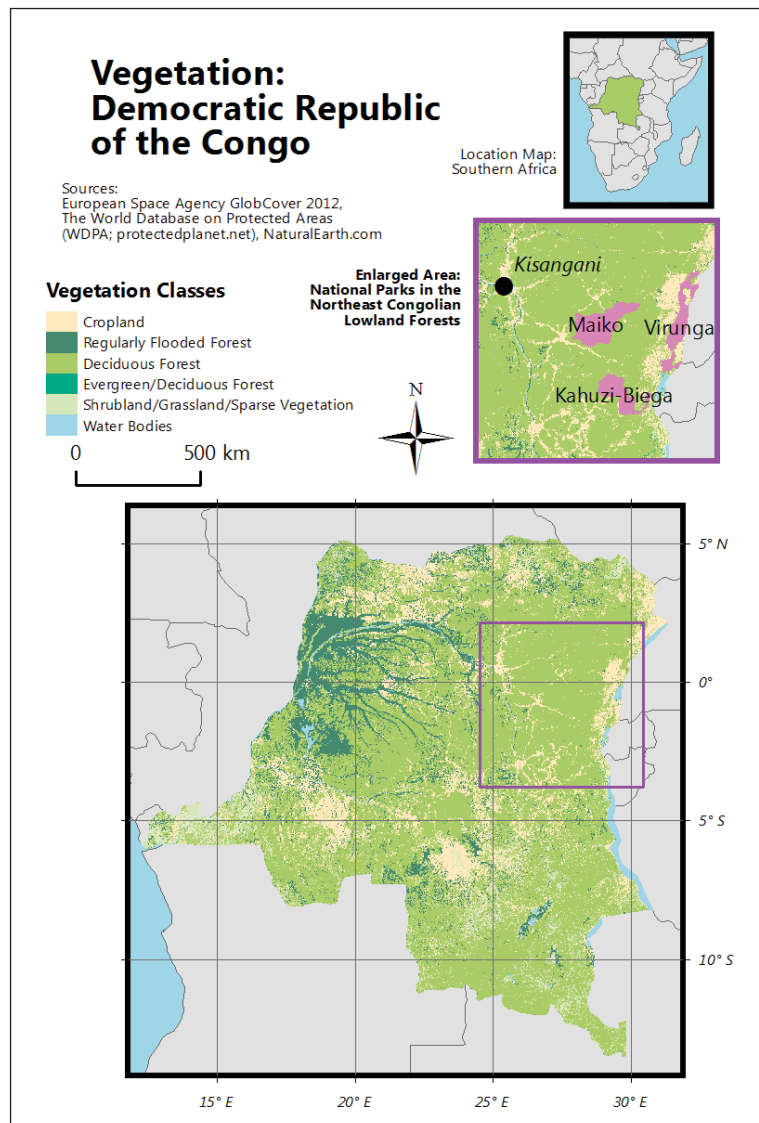
design. Designs that do not follow a logical hierarchy are cluttered, confusing, and hard to read. Map designs that do are crisp, organized, inviting, and to the point.

The list of elements to consider can be extensive for a complex project, though most maps will not include every element:

- main map
- smaller-scale location map
- larger-scale inset maps showing detail
- insets of locations outside the area of the main map
- title
- subtitles
- legends
- scale indicators
- orientation indicators
- graticule (lines of latitude and longitude)
- extent indicators
- explanatory notes
- source note
- publisher credit and copyright notice
- author credit
- neatline
- additional graphics (photos, graphs)

Hierarchy is established by an element's position in the map layout, its size, and the amount of open space around it. A note in small text in the lower left corner will be lower in the hierarchy than a title in large text that is centered across the top of the map. Contrasting colors, line weights, and line detail also establish hierarchy. The elements of a vegetation map of the Democratic Republic of the Congo in figure 1.4 are not arranged in any particular order within the layout. This lack of planning produces a cluttered and unclear product. From top to bottom, the elements are the following:

- title and location map
- source note and subtitle for detailed inset map
- legend and detailed inset map
- scale for main map
- orientation indicator (north arrow) and
- main map with graticule



**Figure 1.4** Example map with a set of basic map elements haphazardly arranged. Data sources: UNEP-World Conservation Monitoring Centre, World Wildlife Fund via ProtectedPlanet; ESA GlobCover and the Université Catholique de Louvain; made with Natural Earth. Map updated by P. Raposo, Penn State Geography.



Figures 1.5 and 1.6 show two organized layouts of the same vegetation map. In addition to the different arrangement of the elements, the visual hierarchy of these layouts is also different. The first map (figure 1.5) emphasizes vegetation distributions for the entire country, while the second (figure 1.6) emphasizes parks located in one forest type. The difference in visual hierarchy

between the two maps is established mainly by changing the sizes of elements and repositioning them within the layout.

In figure 1.6, the country vegetation map is an inset rather than the main map. It is smaller and positioned in a less prominent location than in the previous layout. Because this difference changes the apparent purpose of the map, it has been suitably retitled.

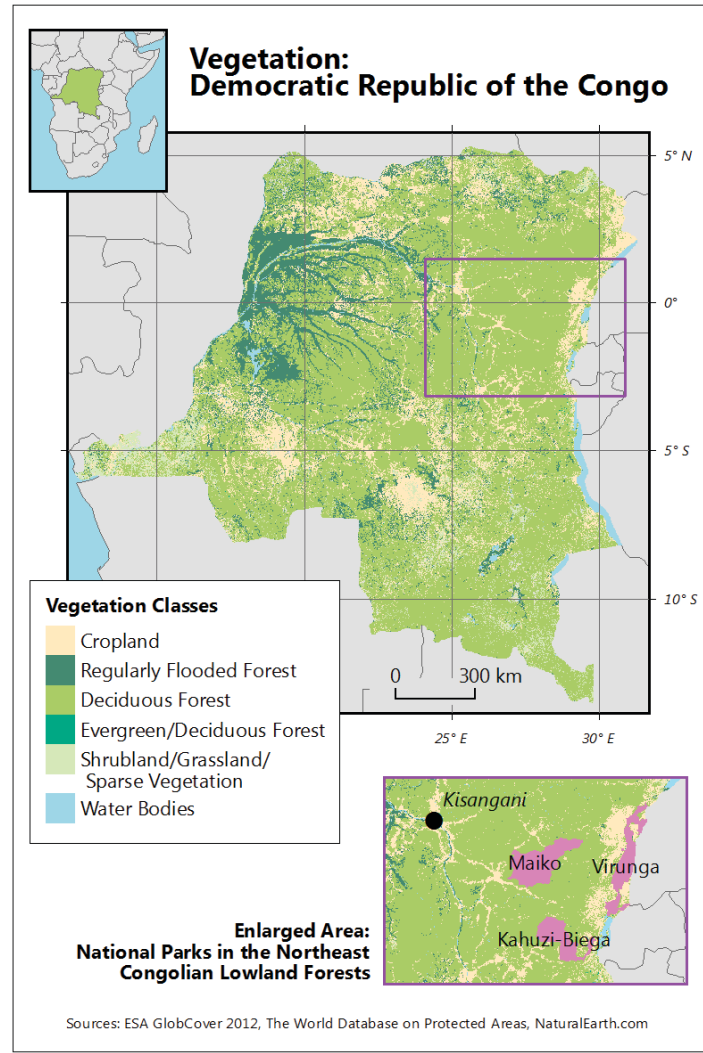


Figure 1.5 Layout emphasizing Congo vegetation.

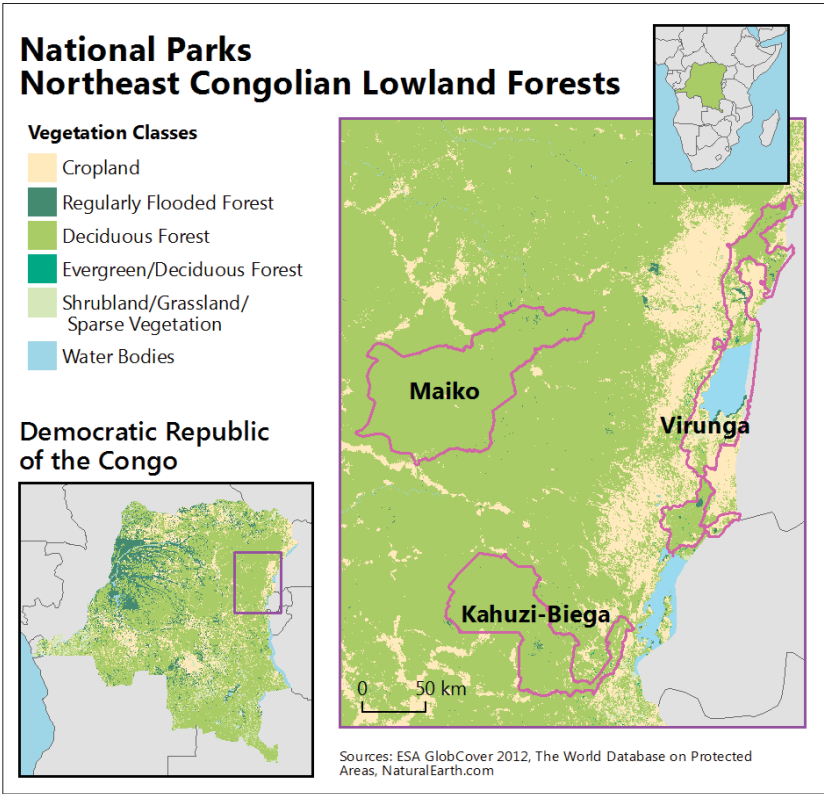
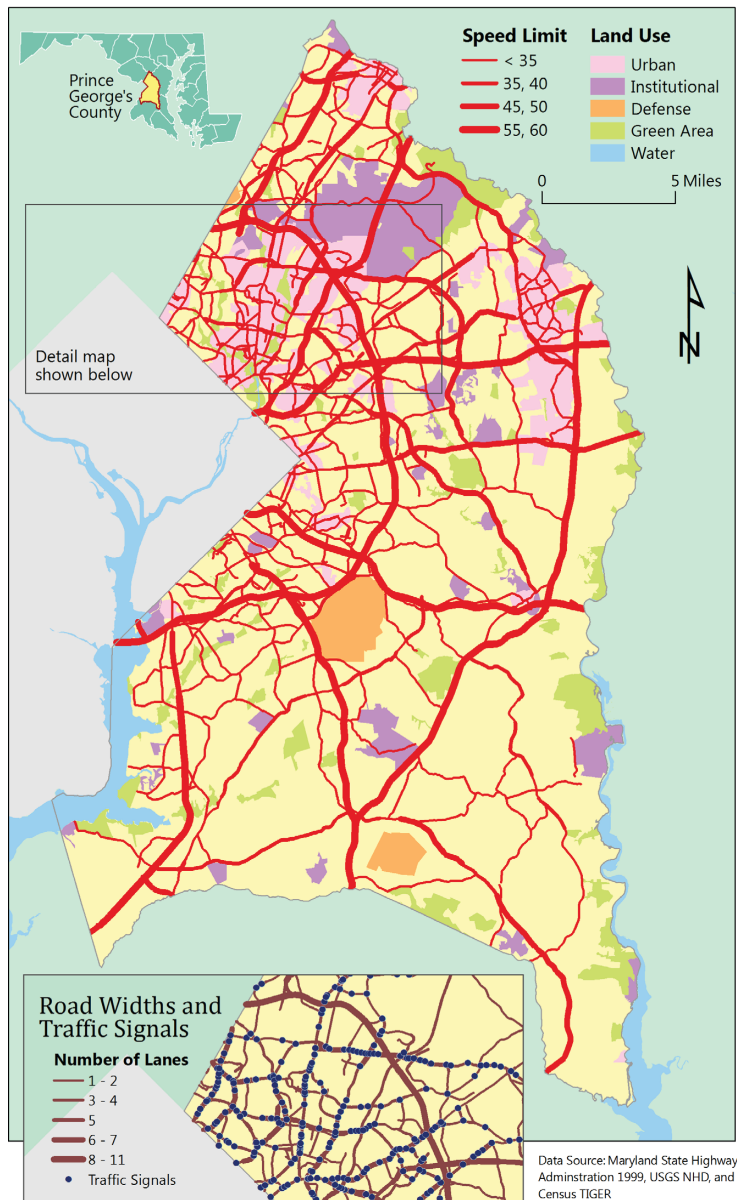


Figure 1.6 Layout emphasizing parks in Congo forest.

Data sources: UNEP-World Conservation Monitoring Centre, World Wildlife Fund via ProtectedPlanet; ESA GlobCover and the Université Catholique de Louvain; made with Natural Earth. Maps updated by P. Raposo, Pennsylvania State University Geography.

# Transportation and Land Use

## Prince George's County, Maryland



**Figure 1.7** Compact layout of map elements for Prince George's County, Maryland. Data source: Maryland State Highway Administration, Prince George's County. Map updated by P. Limpisathian, Penn State Geography.

## Planning a layout

Once you have decided the hierarchy of importance for your map elements, position them within the display. Then step back, squint your eyes, and look at the arrangement of empty spaces on your page. Designing the positions and shapes of those empty spaces is a key to good page layout. Experimenting with design can reveal new and more effective arrangements of elements in a map layout.

Geographic areas are often irregularly shaped, and a novice designer may be tempted to fill the corners and voids in a display with the remaining elements of the map. Unfortunately, some designs evolve like this: a map designer says, "I see a big hole in a lower corner of my map, so I will use a large compass rose to fill in that problem area." If that sounds like familiar thinking, your future maps will benefit from design practice. The problem with the "fill-in" strategy is the resulting overly large or bold map elements that are at the wrong level in the visual hierarchy of the map.

## Balancing empty spaces

If the goal of page layout is not consistent filling in, what is it? Page layout is an act of balancing empty spaces. If you have an empty space on the page in one corner, you can position other map elements to produce empty spaces that are similar in size in other parts of the page to balance that gap. These open areas are useful too; they offer a welcome break from the visually dense information of your map and text blocks. They can open up a complex page by separating groups of elements so that their relationships can be better understood.

Two maps of transportation and land use in Prince George's County, Maryland, provide examples of a densely arranged layout and a more loosely arranged layout. Both layouts are suitable for the elements and purpose of the map (figures 1.7 and 1.8).

# Transportation and Land Use

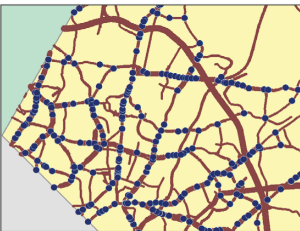
Prince George's County, Maryland

Land Use	Speed Limit
Urban	< 35
Institutional	35, 40
Defense	45, 50
Green Area	55, 60
Water	

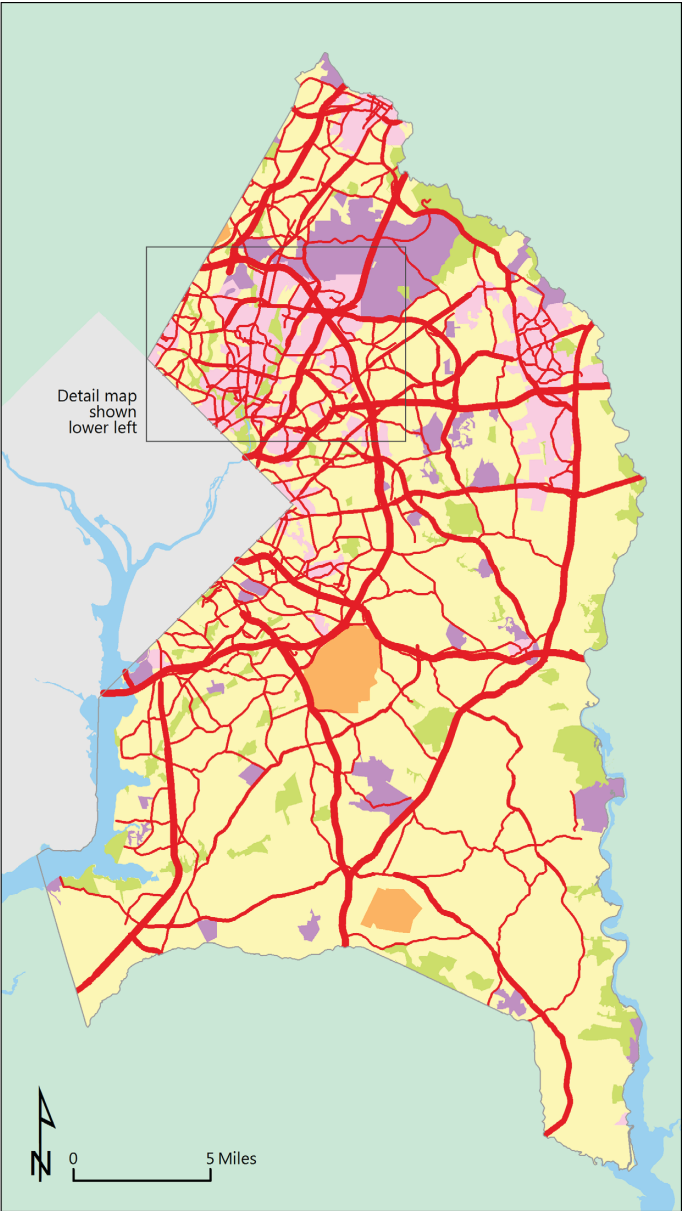
Maryland Counties



Road Widths and Traffic Signals	Number of Lanes
	1 - 2
	3 - 4
	5
	6 - 7
	8 - 11
• Traffic Signals	



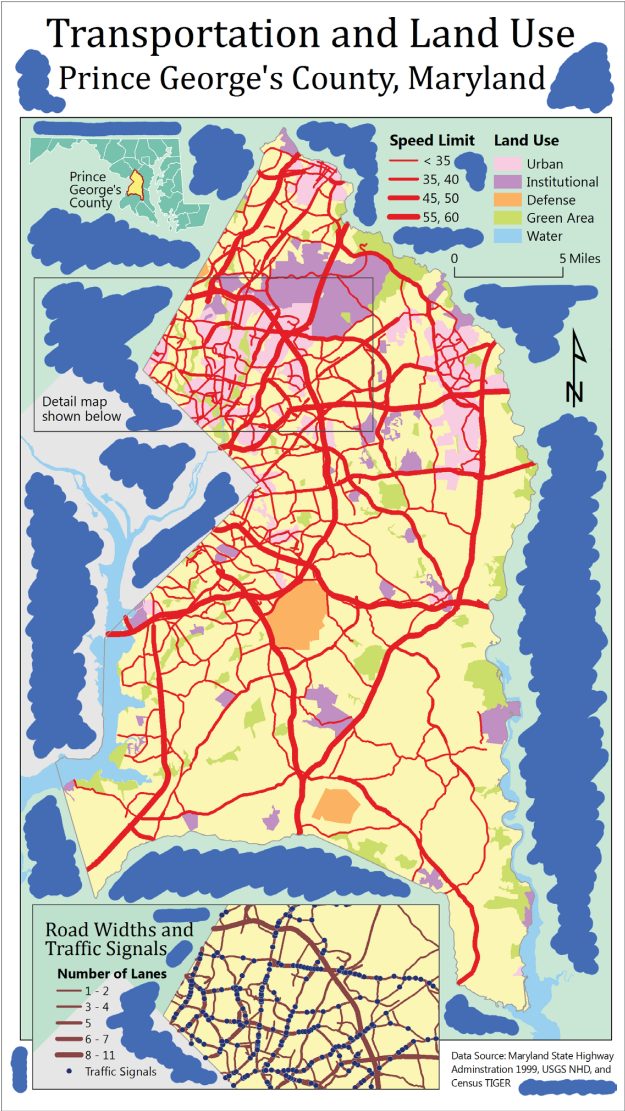
Data Source: Maryland State Highway Administration 1999, USGS NHD, and Census TIGER



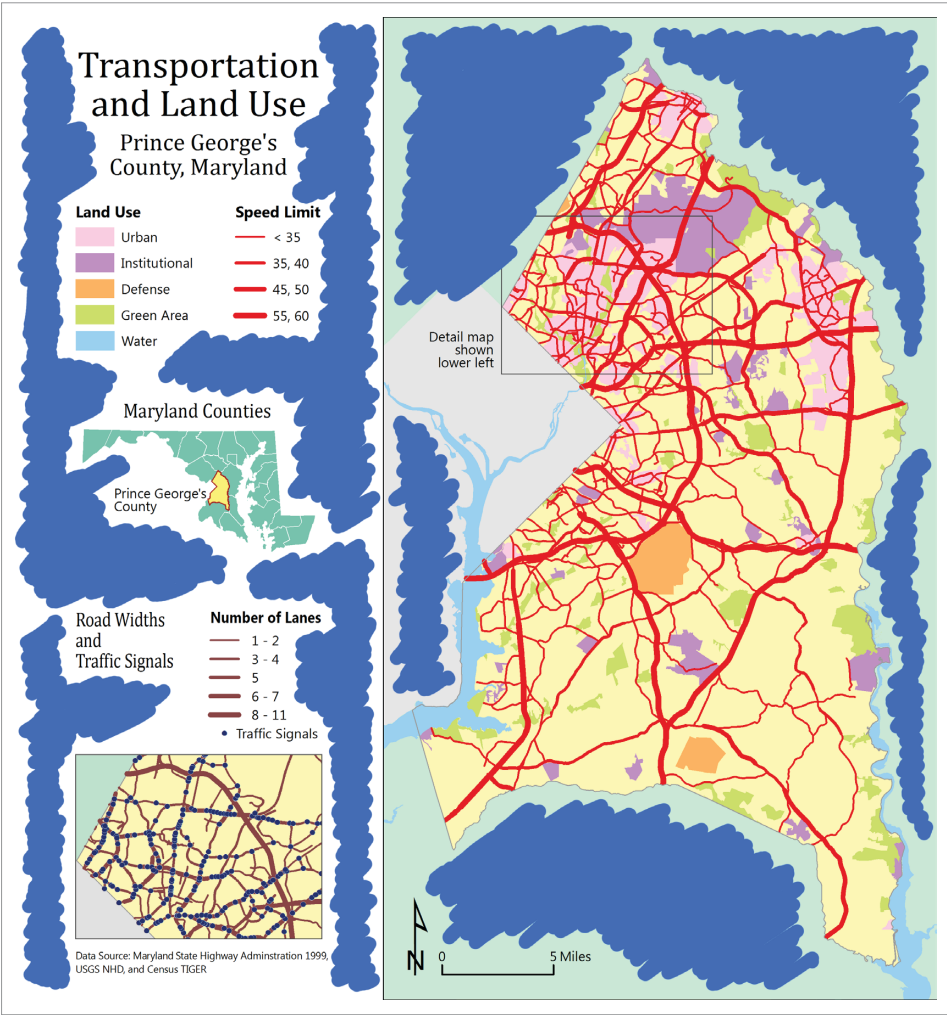
**Figure 1.8** Looser layout of map elements for the same map of Prince George's County. Data source: Maryland State Highway Administration, Prince George's County. Map updated by P. Limpisathian, Penn State Geography.

The same maps are marked up to encourage you to focus on the empty spaces in the layouts (figures 1.9 and 1.10). In figure 1.9, the blue highlights are small and similar in size throughout the map. In figure 1.10, the blue highlights are larger but are still balanced in their arrangement on the page. You can improve your map layouts by learning to see these empty places, create them, move them around, and use them as design elements.

Drawing boxes around map elements makes designing with empty space more difficult. A box is not a “bad” design choice for a map, but it can dissect empty space into distinctive shapes—inside the box and outside the box—that become difficult to incorporate into a design. The shape of the empty space outside the box may crowd adjacent parts of the map. Inside the box, the gaps between text and the edge of the box can create distracting shapes that are difficult to work with. With no box, these shapes coalesce to form a looser space around the text, which has a less distinctive shape and is easier to balance with other empty space in the design.



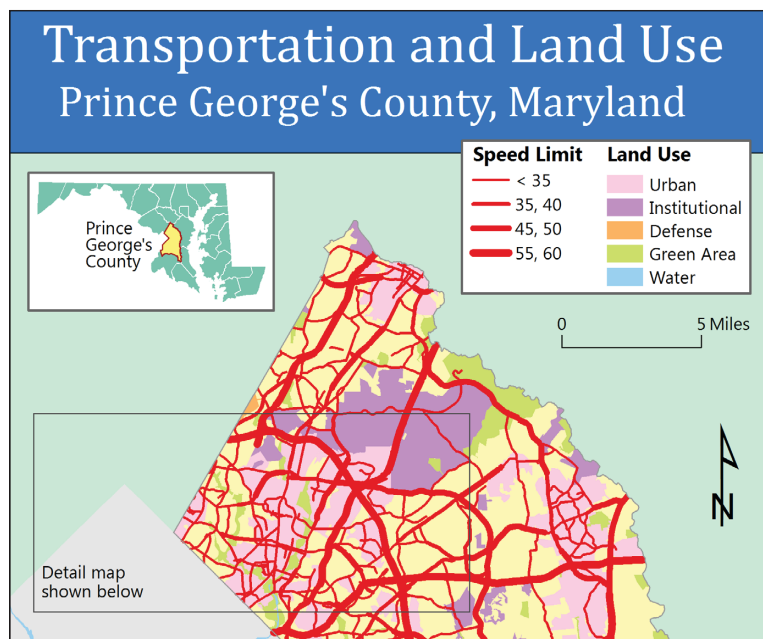
**Figure 1.9** Blue is used to highlight empty spaces in the compact layout.



**Figure 1.10** Blue highlights larger empty spaces in the looser layout.

Data source: Maryland State Highway Administration, Prince George's County. Maps updated by P. Limpisathian, Penn State Geography.



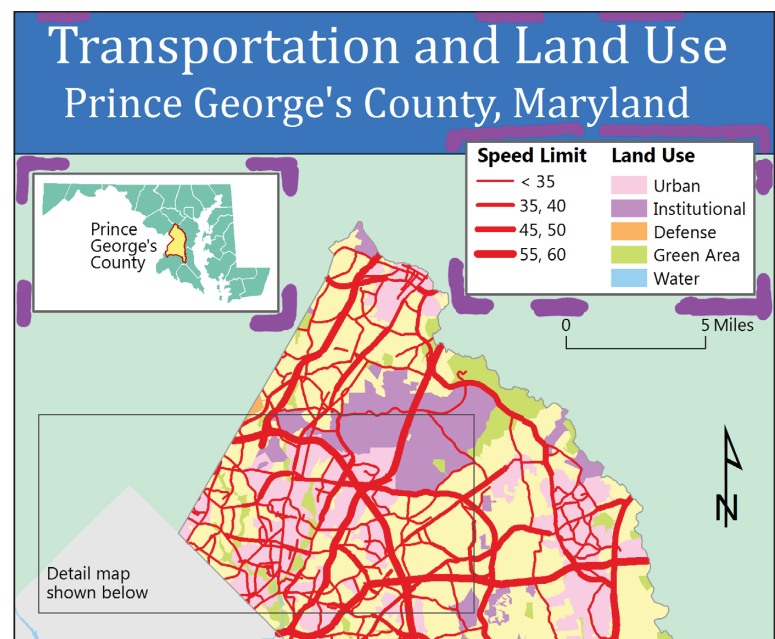


**Figure 1.11** Boxed elements in the layout of Prince George's County. Boxes move the legend and inset higher in the visual hierarchy of the map.

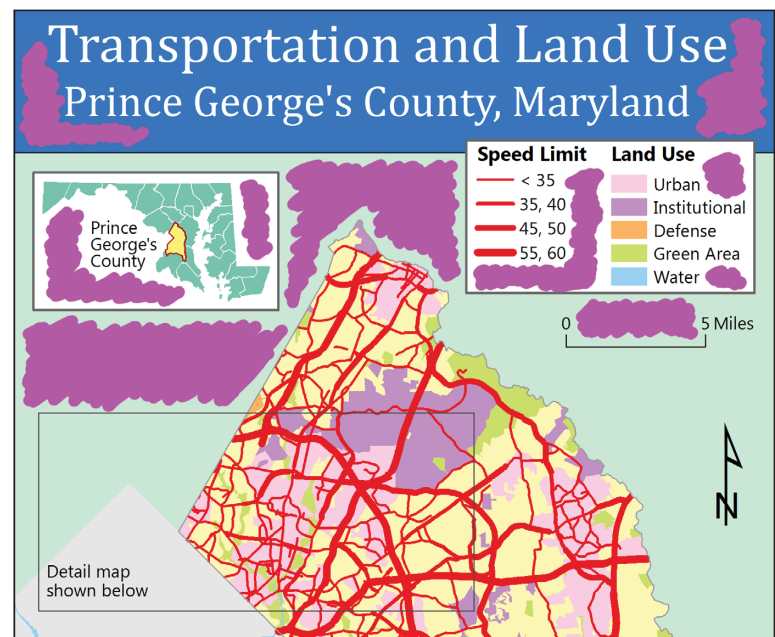
The top portion of a third layout of the Prince George's County map uses boxes around the inset map, the legend, and the title (figure 1.11). Compare this design to the two previous designs.

Purple highlights have been placed in the many crowded and tight spaces created by these boxes in a marked-up version of this same design (figure 1.12). These tight spaces can be arranged, but it will be harder to produce a balanced layout.

The purple highlights in the map in figure 1.13 emphasize the empty spaces inside and outside the boxes. Notice how little control the designer has over the shapes of these spaces because they are dictated by the boxes.



**Figure 1.12** Purple highlights the tight spaces in this boxy layout.



**Figure 1.13** Purple highlights the numerous empty spaces in the boxy layout.

Data source: Maryland State Highway Administration, Prince George's County. Maps updated by P. Limpisathian, Penn State Geography.

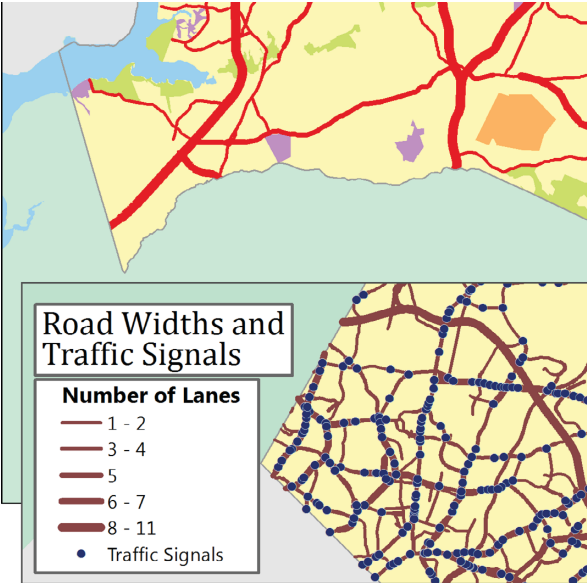


In the next example, the boxes create a difficult and distracting set of pinched angles near the center of the detailed inset map from the bottom part of the map layout (figure 1.14).

Empty spaces that flow into each other are much easier to work with when the boxes are removed from the design. Notice also that removing the strong geometric box shapes pushes the legend back in the visual hierarchy where it belongs as supporting information (figure 1.15). Strong geometric shapes like rectangles can

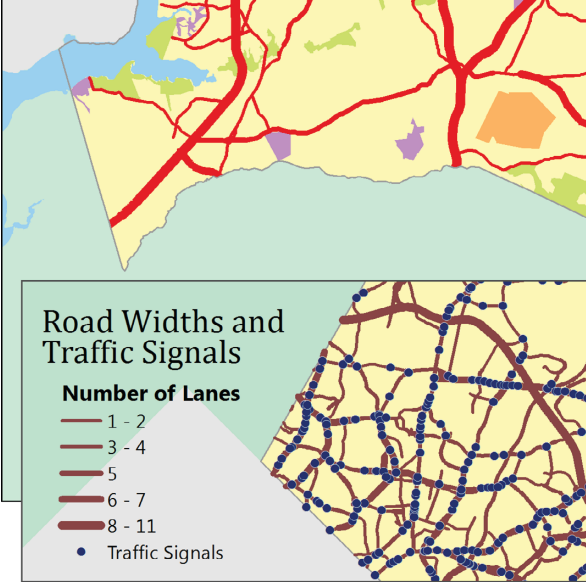
unintentionally elevate an element in the visual hierarchy of the layout.

Learn to see and use the empty spaces between elements when you are designing a page layout. Unnecessary boxes around map elements produce gaps and spaces that interfere with the design of an attractive and balanced layout of map elements. It is better to group elements with effective manipulation of empty space rather than containing them in restrictive and visually dominant boxes.



**Figure 1.14** Boxy layout within inset map of transportation details.

Data source: Maryland State Highway Administration, Prince George's County. Maps updated by P. Limpisathian, Penn State Geography.



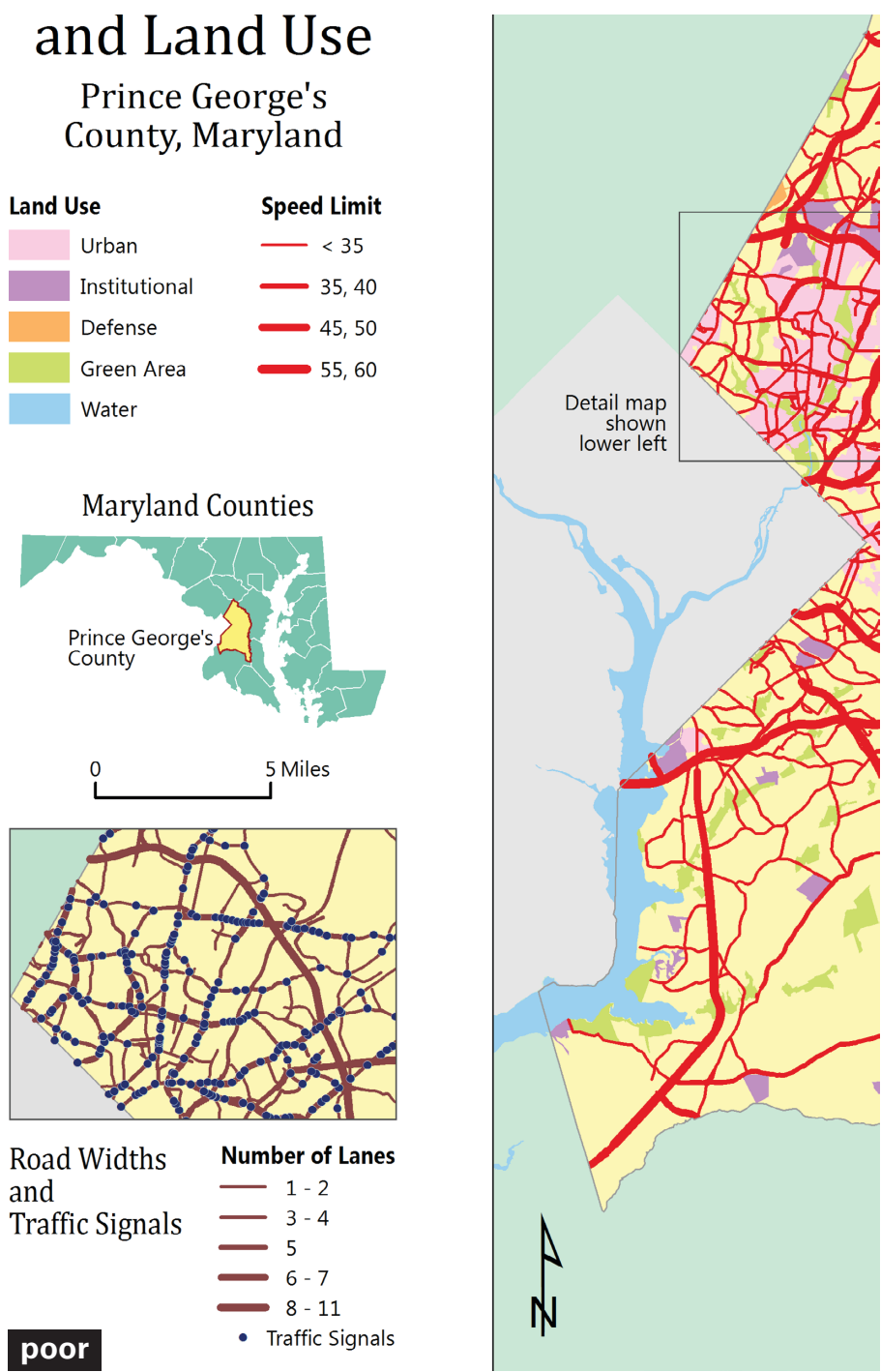
**Figure 1.15** The layout of the inset map is much improved when the boxes are removed.

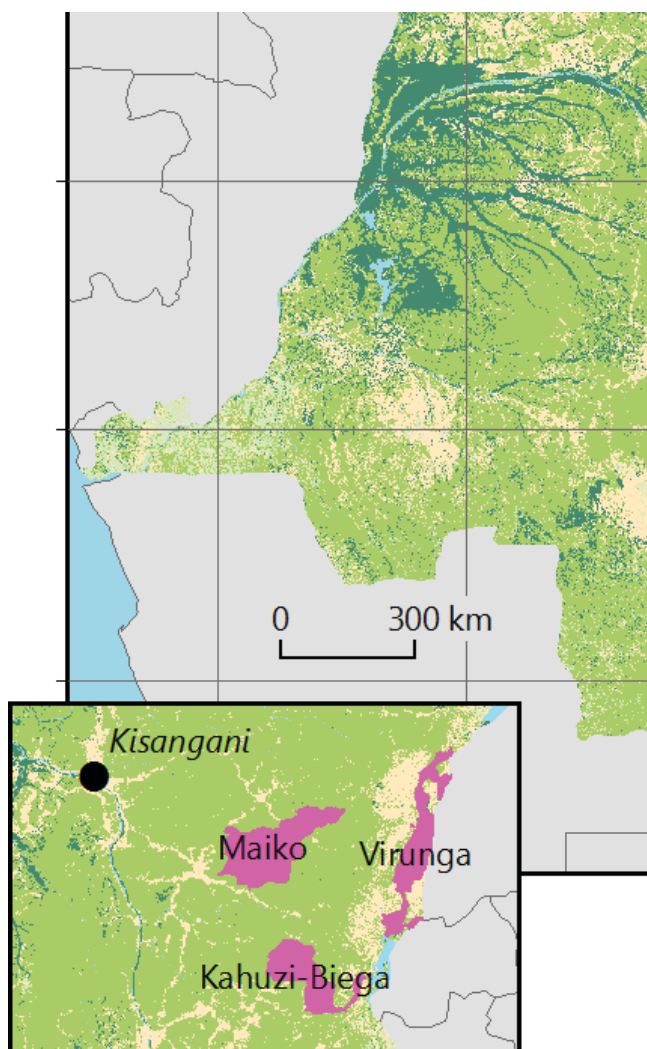
Refining a layout

A map layout works best when elements that are conceptually related are placed physically near one another. This seems obvious, but in a layout with many map elements, it can be difficult to accomplish. For example, a confusing association can result if a scale bar is placed closer to an inset map than the main map to which it refers.

A layout with many maps, each with explanatory text, is designed well if surrounding empty space unambiguously groups each text block with the map it describes. A general explanation for the entire layout functions well if it stands on its own—not necessarily isolated, but not visually associated with one particular element through proximity.

The location of the scale bar in figure 1.16 is confusing because it is close to three maps, each at a different scale. This layout fails because the importance of proximity is not considered.



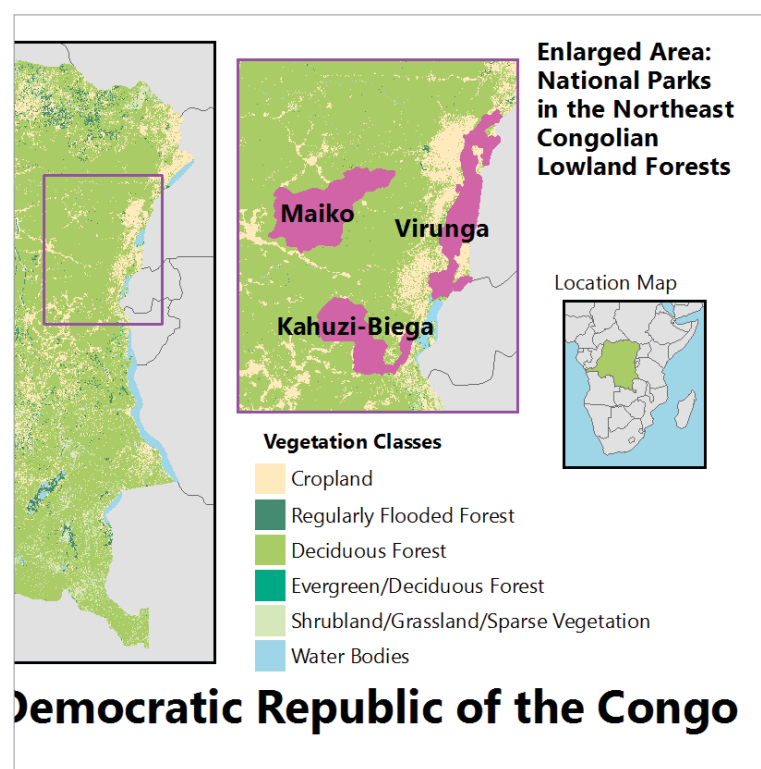


**Figure 1.17** The scale bar is ambiguous because of its close proximity to the inset.

Data sources: UNEP-World Conservation Monitoring Centre, World Wildlife Fund via ProtectedPlanet; ESA GlobCover and the Université Catholique de Louvain; made with Natural Earth. Maps updated by P. Raposo, Penn State Geography.

An enlargement of a portion of the Congo map, redesigned, shows a scale bar positioned within the main map (figure 1.17). The scale bar is still quite close to the inset map and, therefore, might be misconstrued as pertaining to it.

As you decide how adjacent objects will be positioned, examine the details of how they align both vertically and horizontally. Look for linear elements that are almost aligned. Do you want them to be perfectly aligned or do they need to be placed intentionally out of alignment? You do not want to unthinkingly align everything; that strategy may produce a display that is more structured and static than is suitable for your map's purpose. Adjusting alignments so that they are either perfectly aligned or obviously not

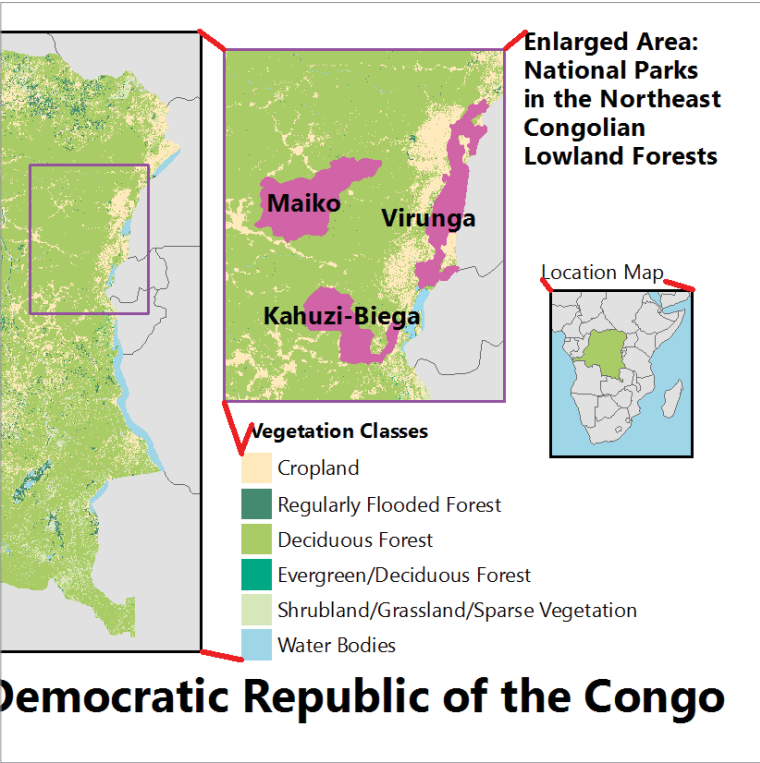


**Figure 1.18** The slight misalignments of elements produce an unpolished layout of this vegetation map.

aligned confirms that your positioning is intentional, not accidental. Ambiguous alignments look like errors.

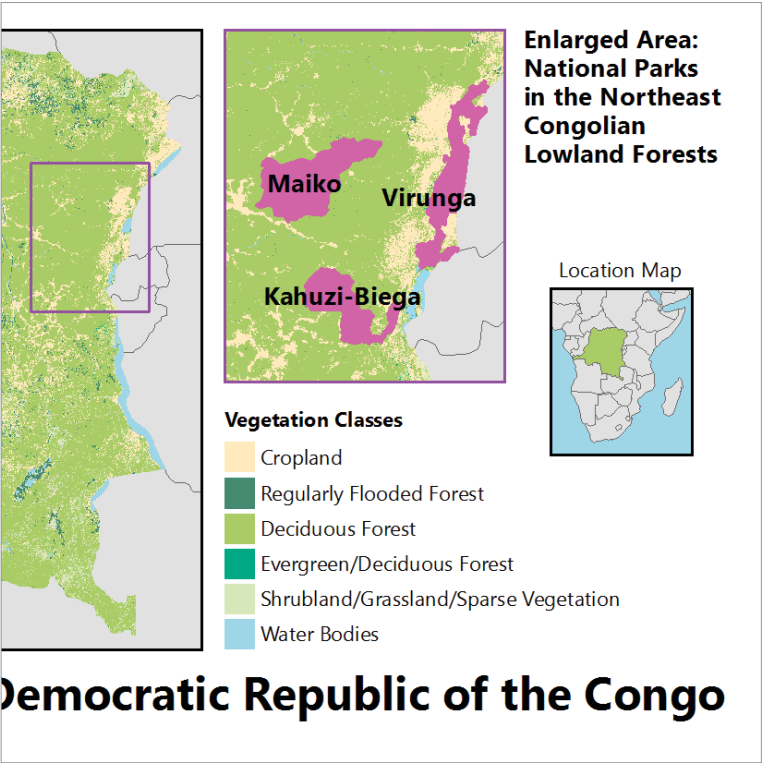
The portion of the Congo vegetation map (figure 1.18) has many elements that are only slightly out of alignment. Though the elements have been positioned reasonably, the map has a messy appearance because these details are not purposeful in their organization. The missed alignments are highlighted in red in the next map (figure 1.19).

Figure 1.20 pulls the elements into an organized arrangement with intentional alignments. The result is a clear, professional presentation.



**Figure 1.19** The misalignments are highlighted in red.

Careful alignment can also remedy extraneous or distracting shapes where geographic data coincides awkwardly with graphic frames. These intersections can misleadingly connect the geography to its frame to produce geometric shapes that draw the reader's attention away from the body of the map. For example, if a state line runs directly to the corner of the frame, the three lines radiating from that one point become more visually dominant. Because you can control the position of the geography within its frame, a slight adjustment will usually solve the problem. Choosing different line styles for frames and geographic features can also reduce these effects.



**Figure 1.20** The elements have been aligned to improve the layout of the map.

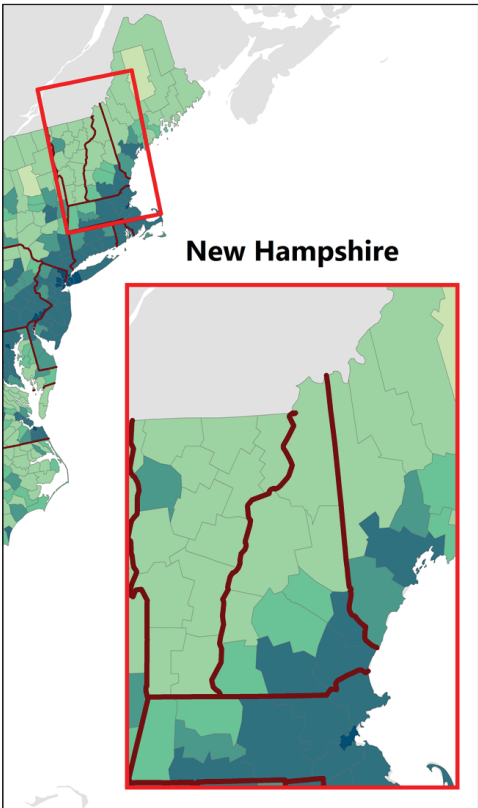
Data sources: UNEP-World Conservation Monitoring Centre, World Wildlife Fund via ProtectedPlanet; ESA GlobCover and the Université Catholique de Louvain; made with Natural Earth.  
Maps updated by P. Raposo, Penn State Geography.

Figure 1.21 shows a few problem intersections between the vivid red graphic frame and the dark red state boundary lines. The problems (highlighted in blue in figure 1.22) include state lines that run along the frame and one that runs directly into the lower left corner. The small tip of Cape Cod that pokes into the inset area at the lower right erroneously resembles an island rather than a peninsula.

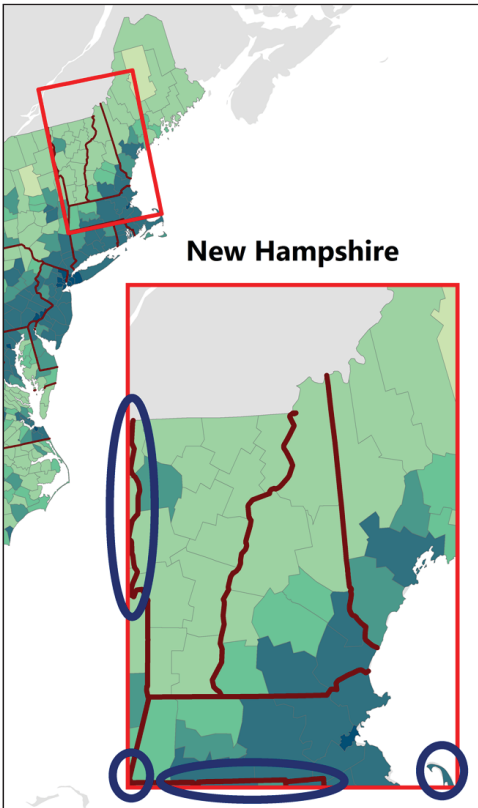
The geography is not wrong, but the frame positioning is sloppy. Figure 1.23 shows that a slight shift in the frame position

relative to the geography solves these problems without compromising the intent of the frame—to show the population density of New Hampshire.

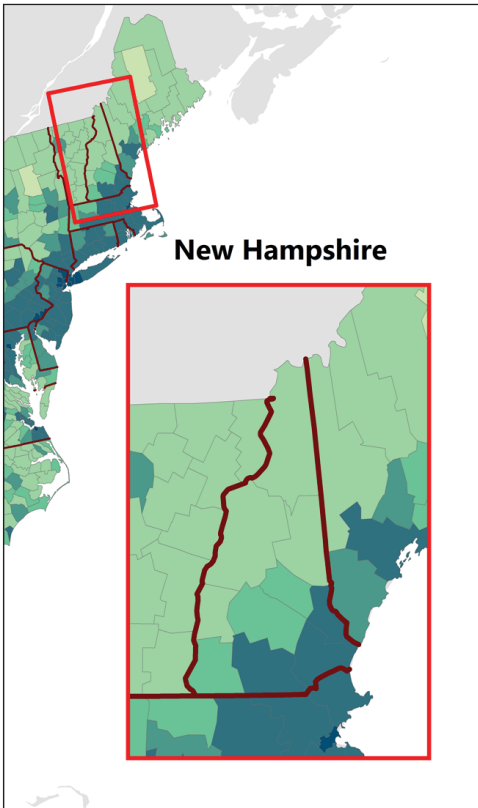
Alignment adjustments are the finishing touches that allow you to create a professional-looking page. You can adjust them endlessly, so seeing potential problem areas at the start of a project and using guides on-screen and other alignment tools can help you complete your design work efficiently.



**Figure 1.21** This map contains distracting intersections between the frame and the state lines and coastline.



**Figure 1.22** The intersections that can be improved by alignment adjustments are highlighted with blue.



**Figure 1.23** Slight adjustments in the relationship between the frame and the geography refine the layout.

Data sources: US Census Bureau, Natural Earth. Maps updated by P. Limpisathian, Penn State Geography.



# Experimentation and critique

In addition to planning hierarchies and balancing empty spaces, a good dose of experimentation often improves a map design. Novice designers tend to place map elements in positions that seem obvious and workable. They may adjust these positions or change the sizes of elements slightly to improve the layout, but they do not question the initial arrangement of elements on the page.

Before you start making small adjustments to improve a layout, push yourself to think of some arrangements radically different from the first one you are assuming will work. Change the page orientation from portrait (tall) to landscape (wide) and see how elements fit together. Move elements from the top of the page to the bottom. Try pulling them into a more compact arrangement with overlapping elements. Overlay titles and text blocks on some

conveniently open areas within the map. You may come back to the first layout in the end, but this experimentation is an important first step in map design.

The vegetation map seen in previous examples is shown in portrait and landscape orientations (figures 1.24 and 1.25). Both arrangements are well-balanced with similar visual hierarchies.

Equally important to experimentation is asking other people to judge your draft map layout. When you ask a person to critique your work, your job is to be quiet and let them do what you have asked. A critique is not an opportunity to explain or defend your decisions. You may adjust or discard many of their suggestions, but do that only after you hear them out. During the critique, ask them to elaborate on reasons behind their ideas and interpretations, but do not spend time debating them.

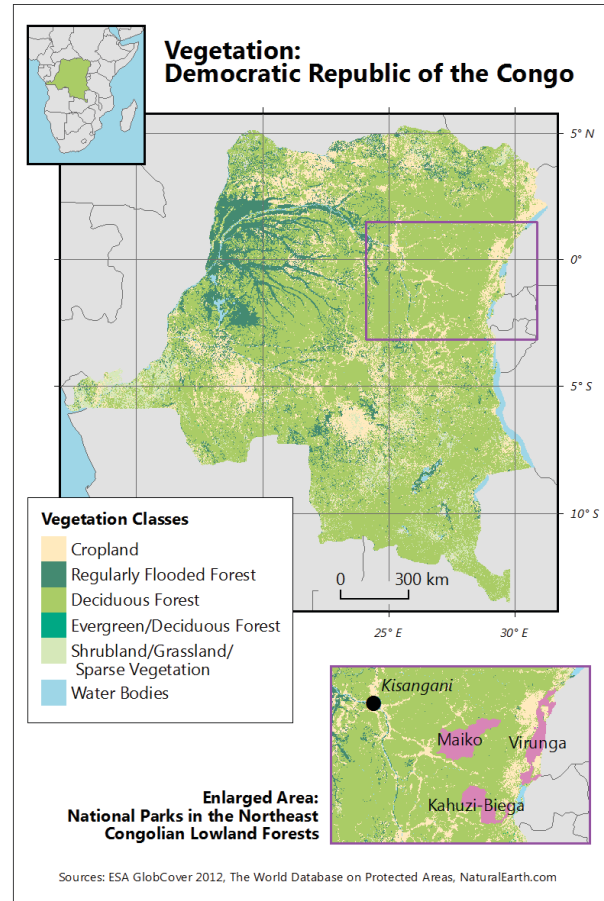


Figure 1.24 (left) Vegetation map of the Congo in portrait orientation.

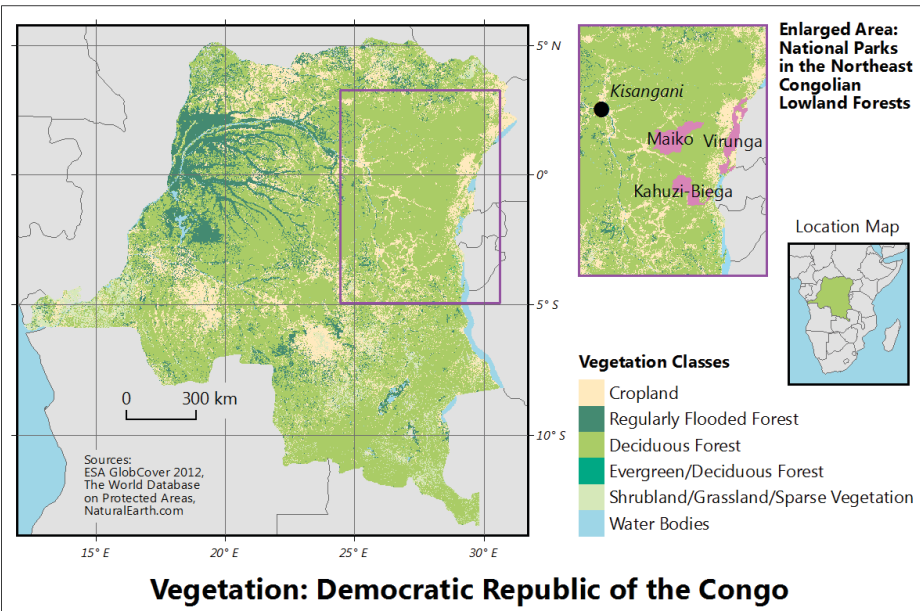


Figure 1.25 (above) Vegetation map of the Congo in landscape orientation.

Data sources: UNEP-World Conservation Monitoring Centre, World Wildlife Fund via ProtectedPlanet; ESA GlobCover and the Université Catholique de Louvain; made with Natural Earth. Maps updated by P. Raposo, Penn State Geography.

A draft map usually has unfinished aspects, such as incomplete text, nonsense colors, or errors. The person doing the critique will often zero in on these details first. Acknowledge that the work is a draft and encourage them to look at the big picture, the overall layout. Help them get past the details; details are easier to critique than the larger scope of a project.

You should ask a few people for suggestions and balance their critiques. Pay attention to their reasoning and recommendations, but be aware that points of confusion can sometimes be improved by making changes other than the ones suggested. For example, one critic may suggest that legend boxes be made larger so they are more visible, and another may suggest spacing the boxes. You may decide that changing the position of the legend so the boxes are not as close to the colorful main map makes them more visible, addressing both concerns without making either suggested change.

A critique is raw material that pushes you to experiment and to refine your decisions. It also keeps you honest—it prevents you from going forward with convoluted adjustments when the overall layout (which seemed perfect at first) has become unwieldy and is ill-suited to the project's current goals.

## Map projections in design

Many mathematicians have been entranced by the interesting puzzle of projecting the spherical globe onto the flat page (or screen). My students and I had fun physically acting this out using an old globe that I found on the roadside one day. We stomped and pulled and tore this poor old carcass into a flat surface. We illustrated that all projected maps are distorted in some way (and more kindly). Your job as a mapmaker is to choose a projection that relegates those distortions to places on the map that are not important

for your message. This challenge makes projection selection a design decision because it depends on the purpose of the map.

## Shape within layout

If you are making a detailed map of a small amount of land (a large-scale map), the particulars of map projection will not be crucial unless map readers will be taking detailed measurements from the map. If you are mapping larger areas—all the US states, for example—you should put more thought into the map projection. For continental, oceanic, or hemispheric mapping, projection becomes a critical decision. If you see a map of the United States that looks like a rectangular slab, with a straight-line US–Canada border across the west, be suspicious of the mapmaker's knowledge of map projection and of interpretations of the mapped data.

For example, if you want to understand the road network on a map with a poorly chosen map projection, you will not know whether roads look sparse in an area because it is underdeveloped or because the map is distorted in a way that happens to expand that part of the map. Likewise, maps of point patterns or area densities need equal-area projections for accurate interpretation.

Figure 1.26 shows a map of western Canada produced with a plate carrée projection. The length of one degree of latitude on the page is equal to the length of one degree of longitude, forming a square grid. This projection is sometimes misnamed “no projection.” Plate carrée seems like a fine idea until you remember that the length of degrees of longitude gets smaller as you near the poles. (The length of one degree of longitude is half the length of a degree of latitude at 60 degrees north.) The provinces, and especially the northern islands of Canada, appear stretched horizontally because they are distorted by the projection. East-west scale (degrees of longitude) gets larger as you go north on this

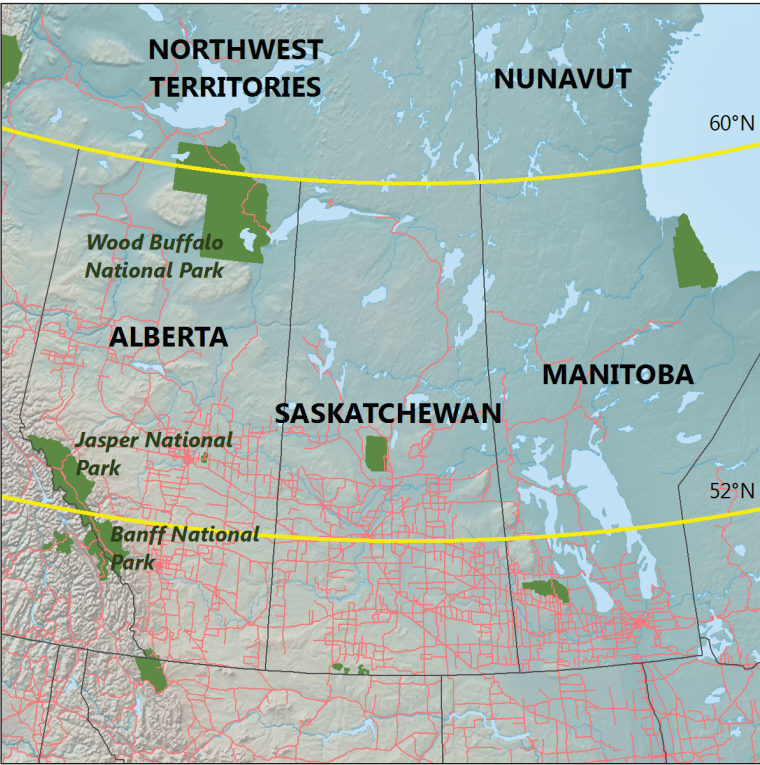
map. Judging the density of roads or the size of national parks is difficult with a projection that results in such distortions.

A more suitable projection of the same area of Canada is shown in figure 1.27. This map is made using an Albers equal-area projection with two standard parallels (lines of true scale) running through the area of interest at 52 degrees and 60 degrees latitude.



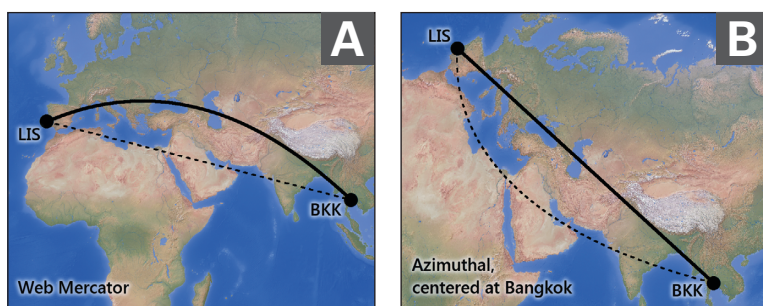
**Figure 1.26** The plate carrée map projection distorts this portion of Canada.  
Data source: Made with Natural Earth. Map by P. Raposo, Penn State Geography.

The provinces are proportioned quite differently on this map compared to the map in figure 1.26. Wood Buffalo National Park is correctly shown much larger than Jasper or Banff, as is the sparseness of the northerly road network. Areas are correct all over this map, so density of features, such as roads and small lakes, can be accurately judged.

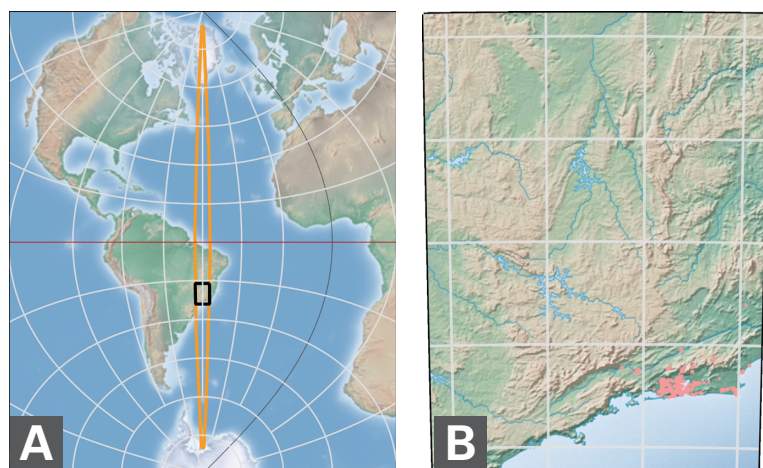


**Figure 1.27** Albers equal-area map projection of a portion of Canada with standard lines at 52 and 60 degrees north latitude shown as curved yellow lines. Data source: Made with Natural Earth. Map updated by P. Raposo, Penn State Geography.





**Figure 1.28** A web Mercator projection (A) and an azimuthal projection (B), each plotting real-world straight paths differently. On both maps, the solid line is the great circle route from Lisbon and Bangkok, and the dashed line is the rhumb, a line of constant compass bearing.



**Figure 1.29** UTM Zone 23, North and South, is shown in orange in the large map (A). A subsection of the zone that contains Rio de Janeiro is shown (B), as well as a larger scale map of the city (C). Distortion within the zone is minimal, even though distortion is severe elsewhere, such as in Africa (see map A). In this projection, the Rio de Janeiro map has very little distortion, which is good enough for most uses.

Data source: The Shaded Relief website, <http://www.shadedrelief.com>. Maps by P. Raposo, Penn State Geography.

Projection affects the shape of geographic areas, which, in turn, constrains the size and layout of the map. You can see how much of northern Canada is not shown in figure 1.27 that was present in the first example. If northern Canada was relevant for this map, a larger frame or a smaller scale would be needed to suit the map's purpose.

Shape differences with projection choices can also affect the map theme in addition to display layout. Figure 1.28 illustrates distorted directions, or azimuths, with a flight path between Bangkok and Lisbon. In both cases, the true shortest path is the solid black line. If you were hoping to snap a photo of the Nile River out the window as you fly along the northern edge of Africa, as the dashed straight line in the web Mercator map suggests, you will be disappointed—the direct flight path on the earth instead passes over the Caspian and Black Seas. The second map has an azimuthal projection chosen specifically to position this straight line across the surface of the earth as a straight line on the map.

## Projections affect scale

As we saw in figures 1.26 and 1.27, the size of areas on the map can be shrunk or enlarged by projections, so it is important to choose a projection that offers the best representation of portions of the earth you are mapping. The universal transverse Mercator (UTM) system of projections is designed to make maps with minimal distortion for any given small portion of the earth. The system uses the Mercator projection flipped sideways. It divides the earth into sixty zones, each using a specially positioned transverse Mercator projection, rendering the area within a narrow zone with negligible distortion. The configuration of the projection in each zone suits large-scale mapping in that zone only. Figure 1.29 shows an example of a UTM zone and how a map of a small area within it can be made with minimal distortion, even though distortion is severe outside of the UTM zone.

At the time of writing this, many interactive web maps use the web Mercator projection (which has minor technical differences from a Mercator projection). You might have noticed, while planning your route for a weekend trip, that these mapping tools are often compiled at various scales from which you can zoom in and out. Each of those scales can be described by a representative fraction (for example, 1:72,223, meaning 1 inch of screen is worth 72,223 inches, a little over a mile, in the real world).

For a Mercator projection, that ratio can only be correct along one or two lines near or on the equator (depending on a technical, geometric choice the cartographer makes). As you move north or south toward the poles, areas and distances get more and more blown out of proportion (figure 1.30). A useful rule is the 60-degree latitude lines are half the length of the equator on the sphere. Angular relationships are maintained within local views of the web Mercator map, with equal exaggeration north-south and east-west, for example. The common “no-projection” (plate carrée) choice would show an east-west stretch to these local views.

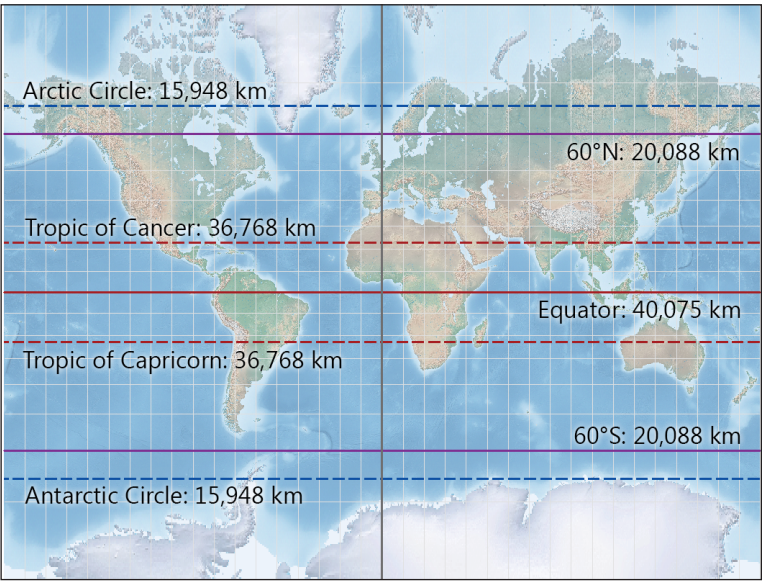
This area and distance distortion does not matter when the map shows you that the closest coffee shop is a 5-minute walk, because you are likely zoomed in to a very large scale to see the local route on a Mercator map. But when you are mapping something roughly the size of a US state or larger, this projection seriously distorts distance and area. This is a significant issue for something like a choropleth map, with the world’s countries as units—countries at high latitudes, like Russia and Canada, will look much larger than they really are relative to equatorial countries, like Ecuador or Kenya. Greenland is about an eighth the size of South America, but on a Mercator map, they look about the same size.

### Choosing projection properties

If you are making thematic maps—special purpose or statistical maps of geographic phenomena, such as population density—choose an *equal-area map projection* for most topics. Despite all the fun we could have with projection distortions, this is the important piece of information to remember: if you are mapping data distributions, choose an equal-area projection.

If you are mapping the continental United States, the Albers equal-area projection customized to the United States is a common projection choice. You should also make use of additional customized Albers projections for Alaska and Hawaii. Each projection has repositioned standard parallels so that no part of the area of interest gets far from these lines, where there is no distortion.

Large-scale reference maps often use another category of projection called *conformal projections*. These projections are better for showing routes and locations because they preserve angles and shapes at points. These advantages come at the expense of preserving areas, and they will misrepresent densities of features in parts of the map distorted by the projection.



**Figure 1.30** Distance and area distortion on a Mercator projection become increasingly severe toward the poles. Approximate circumferences for the equator, the Tropics, 60-degree lines, and the polar circles are listed, though the projection draws each line at the same length. Data source: The Shaded Relief website, <http://www.shadedrelief.com>. Map by P. Raposo, Penn State Geography.