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Guidelines for Developing Historic Urban Growth Series for Military Installation Risk Assessment

Diane M. Timlin, Douglas M. Johnston,
and Brian M. Deal

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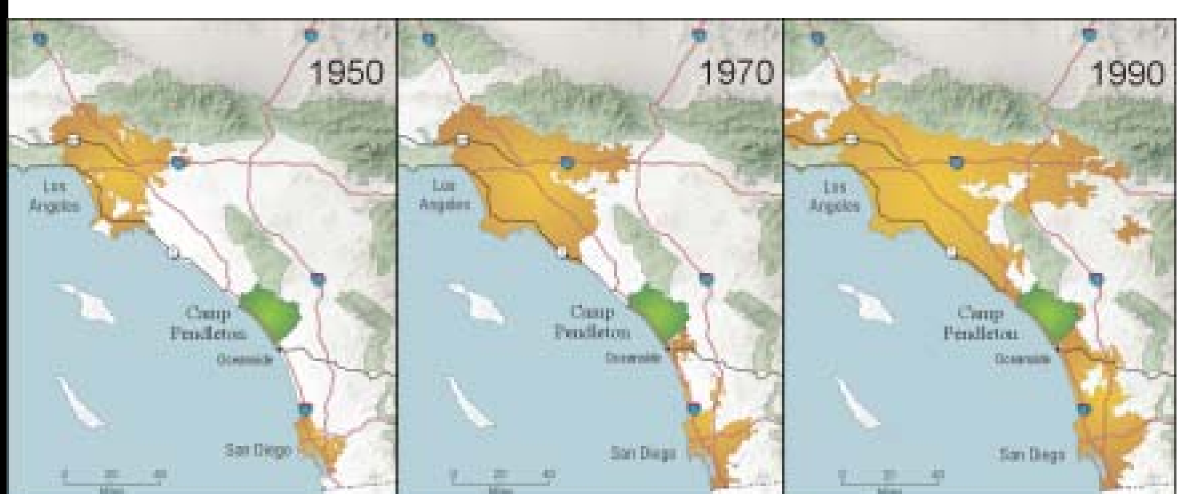

Construction Engineering
Research Laboratory

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Foreword

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 622720A896, "Base Facilities Environmental Quality"; Work Unit, CFE-T141FF "Environmental Indices & Metrics." The technical monitor was William D. Goran, CEERD-CV-T.

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Brian M. Deal. Dr. Thomas J. Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CVT. The technical editor was William J. Wolfe, Information Technology Laboratory—CERL. The Director of CERL is Dr. Alan W. Moore

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1 Introduction

Background

It has become common for population centers that neighbor military installations to expand and approach installation boundaries. When civilian and military centers operate in close proximity, the military installations are increasingly asked to alter activities within their boundaries to alleviate conflicts. For example, in response to conflicts with local communities, Camp Pendleton, CA has restricted flight routes, Fort Sill, OK has eliminated firing ranges, and Fort Carson, CO has faced threats to firing operations. Such restrictions to operations can limit installations' abilities to meet vital mission requirements. One possible approach to the problem is to track historical urban growth in areas surrounding military installations so that both military and civilian planners can anticipate and devise appropriate strategies to avoid or otherwise deal with potential conflicts before they occur.

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL), Champaign, IL has engaged in several research projects investigating tools for such risk assessment. One approach developed is an installation-specific historic urban growth series. An historic urban growth series is a set of cartographic illustrations that depict the changes in land use around an installation. This visual presentation quickly conveys the potential for conflicts as the separation between military lands and the neighboring community disappears. Each series consists of several snapshots of the physical environment of an installation and its surrounding region. Each snapshot, the cartographic product for a specific year in the series, is called a "frame" (Figure 1). The series, formed when these frames are consistently formatted and presented together, is a powerful tool for showing the changing conditions around an installation.

A case study for the original series was designed for Fort Carson, CO and its neighboring community, Colorado Springs, with six full-page frames incorporated into a PowerPoint™ presentation and displayed with automation to animate the change over time. A second format was designed to improve the series' use in fact sheets and other printed materials. Figure 2 shows a condensed (three-frame) example of the print format for the Fort Benning series.

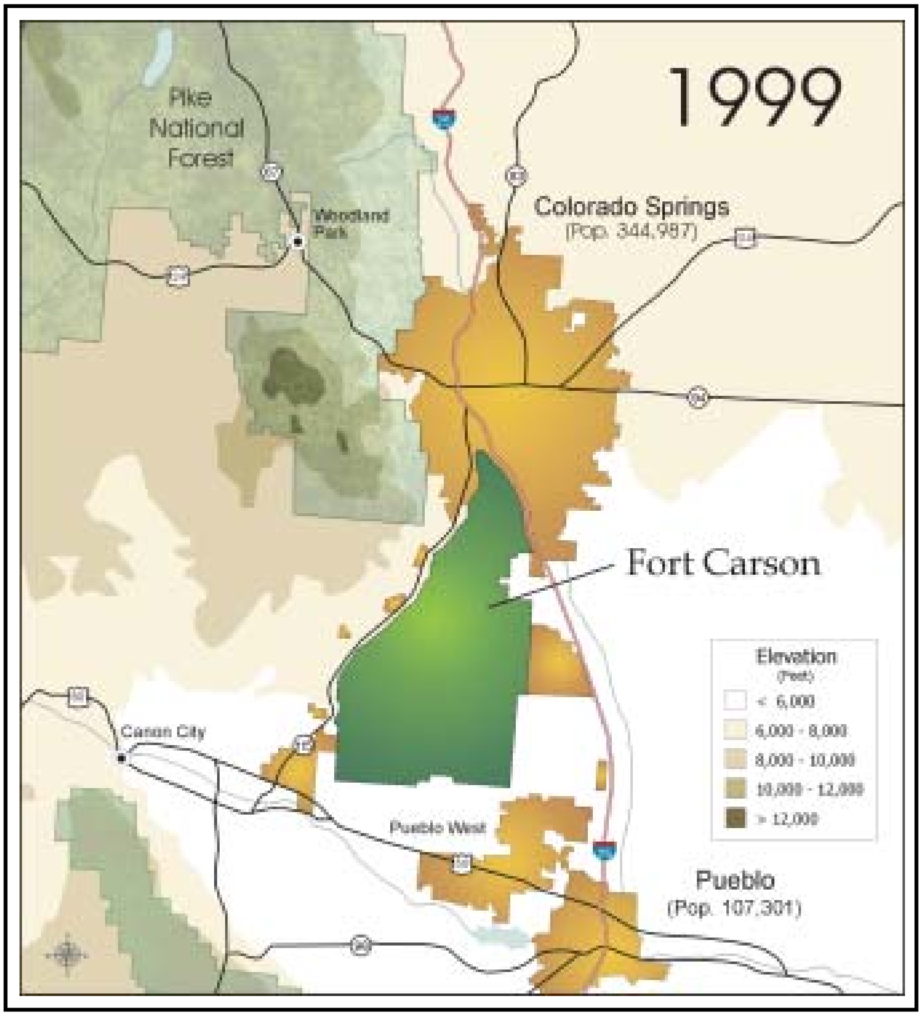

Figure 1. 1999 Frame from historic urban growth series for Fort Carson Area.

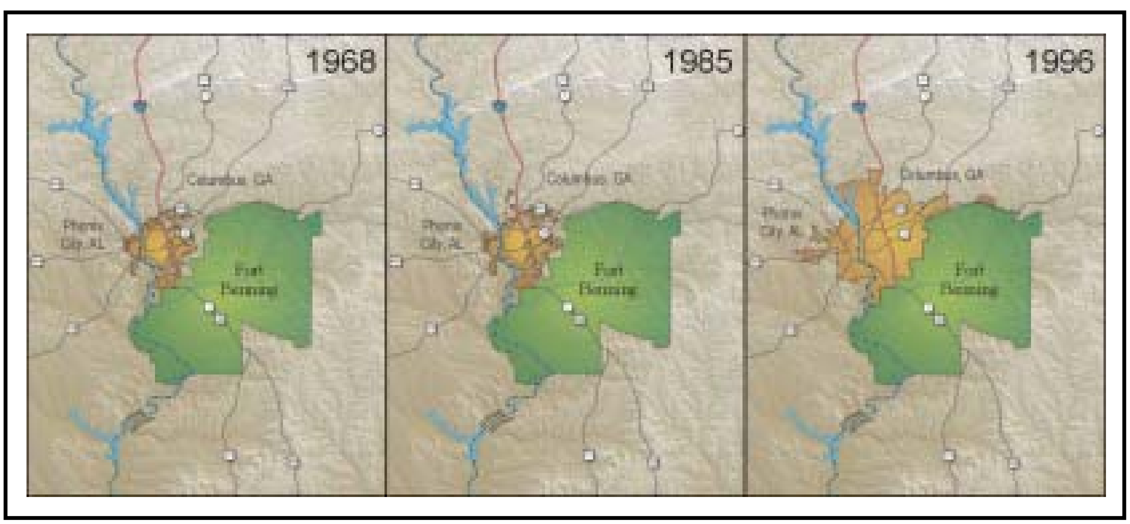

Figure 2. Print format example of historic urban growth series, Fort Benning area (1968–1996).

Historic urban growth series were created for the regions around Fort Carson, CO, Camp Pendleton, CA, Fort Benning, GA, and Fort Hood, TX. These "visual aids" series initiate an effective, general process that can visually highlight the rapid urban growth (local or regional) that may become a source of conflict and that may threaten continued training activities on military lands.

Objectives

The overall objective of this study was to develop a process that would help incorporate local knowledge of regional trends and plans through the use of "frames" that can predict future growth patterns, and ultimately, to foster proactive planning between the installation and its neighboring or regional communities. Specific goals of this work were to:

1. Discover issues related to the data gathering process required to produce accurate graphical frames.
2. Identify a specific process to graphically document the historical growth of communities.
3. Develop formatting techniques to successfully develop case studies at four military installations:
   a. Fort Carson, CO
   b. Camp Pendleton, CA
   c. Fort Benning, GA
   d. Fort Hood, TX.

Approach

The application of the historic urban growth series software to Army installations involved specifying and testing the following five general tasks:

1. *Inventory available data*. It is important to take an inventory of all available sources before any data is actually collected. Data describing the historic pattern of development in a region may vary both in quality and availability. Discovering the data issues up-front will enable a comprehensive decision about what data will produce the best series analysis, and will minimize time wasted in collecting inappropriate data. Chapter 2 presents issues to consider in inventorying data and in setting the parameters for the analysis; it also identifies types of data relevant to a historic growth series and some known sources.

2. *Select frames and source data for the series*. From the inventory, the developer can set the parameters for the analysis:

   a. the extent of the area to be examined

   b. the source data that will best capture land use change over time

   c. the set of features that will describe the land use issues

   d. the specific dates for the individual frames.

3. *Gather selected source data*.

4. *Assimilate source data*. Chapter 3 describes two tools for developing the series, and the tasks that may need to be performed to assimilate the source data into the final cartographic product. Chapter 4 gives specific guidance related to identifying urban development.

5. *Format map products*. Chapter 5 describes the formatting and presentation techniques used in the four case study examples. Appendix A to this report presents the series produced for the four case studies produced by the GMS Lab. Appendix B includes instructions on one method for developing a terrain background for a series.

Mode of Technology Transfer

It is anticipated that the capture and distribution of this information will enable the development of more historic growth series, such that this data may be incorporated into a geographic information system (GIS) for other spatial analysis work. Ultimately, this technology would be used on individual Army installations, who would operate the system, develop these data series (and timely updates), and maintain and improve data collection and accuracy.

This report will be posted to the World Wide Web (WWW) at URL:

www.cecer.army.mil

and will also be linked to the “Room to Maneuver” and to the University of Illinois (Urbana campus) Geographic Modeling Systems (GMS) laboratory websites. This report will also be distributed at relevant professional and organizational meetings.

2 Data Collection

Collecting appropriate data sources for a time series is the most critical step in the map production process. This chapter provides important information on data collection to enable the building of an historic urban growth series. It identifies basic data needs, sets the framework for defining the specific approach that might be taken for each series, and provides some references to data sources.

Source Data Needs

Four categories of data are used in illustrating the growth issues for the series maps: (1) installation extent, (2) urban area extent, (3) context information, and (4) natural features. These are described below, along with any specific issues that might affect data collection and map design.

- *Installation Extent* – the location and extent of the installation lands at a given point in time. If the time series is focused on a single installation, but there are additional DoD holdings in the map extent, the developer can decide whether to include any secondary holdings. The developer should also determine whether the installation boundaries have changed significantly, within the map extent and the timeframe selected. Describing changes to the installation extent can be important in illustrating combined land use changes in the area (see Fort Carson time series). A component that has not been incorporated in previous growth series, but should be considered for future analyses, is the identification of land use types within the installation boundaries. Depiction of general types such as cantonment, ranges, and maneuver areas might assist in visual assessment by highlighting locations for obvious potential land use incompatibilities.
- *Urban Areas* – for a given point in time, the location and extent of the urban areas surrounding the installation. Urban areas will be depicted in different ways in source cartographic data (for example, municipal boundaries, developed areas, etc.), and determined using different criteria. For consistency within and between series, it is important that these differences are taken into consideration to reduce the possibility of faulty interpretation. Alternatively, urban area extent can be interpreted from aerial photography, in conjunction with supporting information such as the known locations of existing cities or towns, specifically for use in the time series. Population estimates representing the developed area for each analysis year will also be needed.

These may be listed on cartographic products, or obtained and summarized from census data. However, population estimates may be derived from analysis units (e.g., Census Tracts) that do not necessarily conform to municipal or other boundaries.

- *Context Information* – data features that would aid the viewer in understanding the location or relationship between elements of the map display. Context information includes highways and major roads, political boundaries (counties, States, etc.) and major land holdings (e.g., Bureau of Land Management holdings). Selection of individual features will vary depending on map scale and extent. Like urban areas, context features may change over the timeframe of the analysis (e.g., the building of a highway). Such changes should also be represented by modifications to specific frames as appropriate.
- *Natural Features* – the location and extent of natural features in and around the installation. These include water bodies, streams, nature or other land preserves (e.g., National or State Parks, Fish and Wildlife Refuges), and significant topography (optional). As with context information, selection of features will vary based on map scale and extent, and may change over time (for example, the building of a reservoir). In addition to providing context information, these features may also indicate constraints on development that results in current and future spatial patterns of urban development.

Data Selection Issues

Because these series are to be used to understand past, and possibly to envision future growth patterns, some fundamental issues arise about the quality and documentation of any source data used to determine these time series. First, the date of data collection actually determines the relevance of the depicted information, rather than the date of publication. While long intervals between frames will minimize this effect, rapid changes may not be captured. Second, the standards by which data are interpreted or classified may vary between data sources. An area denoted as urban in one data source may be classified as something else in another data source depending on the rules used. Third, the spatial accuracy and completeness of data sources will influence interpretation. Since most digital data are derived from hardcopy sources at this point in time, a digital product should not be considered better data.

Choosing appropriate data for an historic urban growth time series involves achieving a balance between:

- accuracy, amount of detail and type of output desired in the final product
- type of source data and processing requirements for that data
- time (budget) available for map production.

Constraints on any of these aspects will affect the final quality of the series. Specific data are selected to: minimize the amount or complexity of the data translation processes, maximize the amount of data that could be available for spatial analysis with GIS, or maximize the area of study in anticipation of addressing regional scale (rather than only local scale) effects.

The two map data formats used for the growth series development are digital and hardcopy. Since the final map product is produced in digital media, digital source map data has some basic advantages. First, it eliminates at least one processing step of scanning or digitizing. If it is georeferenced (tied to a mapping coordinate system), it can eliminate several additional processing steps to integrate it with other data, especially if using a GIS tool. Digital data should not be automatically considered a better data source, however. These products are often larger scale than available hardcopy data, that is, they record features in more detail, but cover smaller geographic areas. This may require the collection of many individual files that will need to be joined together to include the area of interest for the time series. Even if digital data is georeferenced, it may require additional processing to translate the collected data into a single map projection or datum so that features from various data sources may be combined into a single image. If the data is an interpreted product, such as a land use map classified from imagery, it is important to know the date of the original source and to review the class definitions to determine if it can be integrated with other data.

Regardless of format, the task of choosing source data involves unique issues for every time series development project, because the availability of data will differ from location to location. Available source data will vary depending on the region of analysis: some areas have historically received more attention, in terms of cartographic products being produced and archived. For example, the map collections of a major university contained numerous historic maps for Colorado (to enable the depiction of growth around Fort Carson), but had few maps for southern California (Camp Pendleton area).

The physical extent of each study is unique, as the impacts of urbanization may occur at differing scales. This is evident in a comparison of the growth series produced for Camp Pendleton, where the urban impacts occur across a large spatial extent, and Fort Benning, where the urban impacts are more local. The larger spatial extent has to be addressed by either less-detailed information or more data integration (analyzing six USGS 1:250,000 scale topographic maps for a more summarized evaluation or 50 USGS 1:24,000 scale topographic maps for a detailed evaluation of urban growth). The larger the scale, the more difficult it becomes to find a set of historic maps to represent an area for any given year. Even standardized maps like the USGS topographic series are produced at different update cycles; some compromise will likely need to be made (using a 1967 and a 1969 map to build a “circa 1969” frame for a series).

Choosing Frames for the Series

In most instances, data availability will dictate the selection of frames for the series. With sufficient source data, the following guidance will help in choosing data that will be consistent with the analyses already developed, and best depict growth change over time:

- Historic growth series should include four to six frames of approximately 10-year intervals. The intervals should be as consistent as possible to avoid misinterpretation of rates of change.
- The first frame should represent the installation’s relationship with the surrounding communities before significant urbanization. From case studies, selection of a date around 1950 was sufficient to illustrate the original conditions, since substantial urban development around these installations seems to have arisen in the late 1970s. (This will vary from site to site.)
- The last frame should be as current as possible. Since cartographic and other digitally interpreted products can take several years to be released, the last frame may need to be derived from recent, unclassified (uninterpreted) imagery.
- Select frames for at least 1 year within each decade between the first and last frames. Available data in early decades will be more limited than in later decades, but there should be multiple years available in recent periods (1980s and 1990s).
- Select frames to point out periods of significant growth. These will vary for each location, so there is a lot of flexibility on the specific dates for intermediate frames.
- Perform a visual comparison of the possible sources and select the frames to best illustrate changes between periods. If frames are too close in time, land use changes will be too subtle and the result will be a reduction in the overall effectiveness of the series.

Potential Data Sources

A single producer of data for multiple years through a series is preferred. This will simplify data integration across the time series, because a producer is likely to use the same rules to identify physical features over time. Also, it is beneficial to minimize the number of sources for the different data categories (urban areas, rivers, etc.) to reduce data integration issues within a frame.

The following sections identify source data types and locations. Each of the sources identified were used in at least one of the four case study examples. The decision about which to use for any particular series is based mostly on availability, but an important consideration is maintaining consistency in representation throughout the series.

Digital Data

One source that proved very useful in developing the example series is the USGS digital raster graphic (DRGs). These are scanned, georeferenced images of the USGS topographic map series. Currently DRGs are only available at the 1:24000 scale (7.5 min quadrangles) so for larger study extents such as for Camp Pendleton, these might not be practical. The DRGs can be used to extract a number of features including roads, water features, major land holdings, political boundaries, and urban areas. The most recent versions are available online from several sources (http://mcmcweb.er.usgs.gov/drg/, http://gisdatadepot.com) with nationwide coverage, and can be downloaded at no cost. Unfortunately, historic versions are harder to find. An in-depth search of State geological surveys, department of natural resources, or other digital data repositories may locate some historical DRGs, but many of the older maps are not yet available in a digital format.

The USGS also provides access to various types and scales of georeferenced vector data through their general website, http://www.usgs.gov. These data sets are digital line graphics (DLGs), linear features extracted from the original USGS topographic map sheets. Data relevant to the growth series include roads, hydrography, and boundaries. Like the DRGs, DLGs will generally only be available for the most recent map data (the source data collection dates vary, even across adjacent sheets).

Environmental Systems Research Institute, Inc (ESRI) bundles a variety of data sets with their GIS software packages. Some data sets they provide include roads, rivers and lakes, political boundaries, parks and urbanized areas, for various time periods and scales. Their website (www.esri.com) provides references to other internet data sources. As with many commercially available datasets, however, documentation of data sources and modifications are often lacking.

The USGS and ESRI are partnering to develop the National Atlas of the United States (http://www.nationalatlas.gov). Of particular interest is a georeferenced data set of all U.S. Federal and Bureau of Indian Affairs lands. Developers may find other useful information here for the growth series or additional products.

Again, however, data quality assurance and control issues remain. In other aspects of this project, different data sources have included differing accounts of Federal and other properties.

Another data source for identifying urban areas are the 1:24000 scale georeferenced aerial photographs known as DOQs (digital orthoquadrangles). These photographs are primarily managed by State agencies and are frequently downloadable at no cost to the public. Unfortunately, many States have yet to convert their aerial photograph collection into a digital format, so photography may not be available for every study area. These images can provide important detailed information on development, but interpretation in a manner consistent with previous sources may be difficult.

Finally, the Microsoft TerraServer can be a source of historic imagery and DRGs (http://terraserver.microsoft.com/). Data is georeferenced and free for downloading. However, it was transferred as geo-jpegs when this data was acquired for the Fort Hood series; transformation to geo-tiff was necessary for use with ArcView.

Hardcopy Data

The USGS topographic maps, as mentioned earlier, are the paper source of the DRGs. The topographic maps are produced in several scales, and most State agencies, institutions, and/or colleges make them accessible. The 1:24,000 scale (7.5 min quads) are useful for smaller study areas, while the 1:250,000 scale (1 x 2 degree quads) are more practical for larger regions. One drawback to using the 1:250,000 scale maps is that there are fewer historic versions so it may be more difficult to obtain enough time intervals for a series.

Standardized maps depicting historic urban areas can be very difficult to locate. The developer may have to be creative in finding data for periods before 1980. One possible source is the decennial census, which historically tracked urbanized areas for large cities (now referred to as metropolitan statistical areas). The hard copy detailed census books contain maps that show the areas classified as urban and provide summary statistics. This data can be difficult to work with: the maps may be split over several pages, the pages can be difficult to piece together, the maps contain insufficient features for georeferencing, and even alignment with other data is difficult. Similarly, State- or commercially-produced (AAA, Rand McNally, etc.) road and tourist maps can be used to extract historic urban boundaries and features. Some map libraries carry road maps dating back 50 years. Significant processing may be required to render these useful.

3 Source Data Assimilation

Once the available data has been evaluated and a working set selected, it will need to be assimilated for the time series in one of two ways: (1) within a graphic-design program such as Corel Draw or Adobe Illustrator, or (2) within a GIS. This chapter describes the issues and decision criteria for choosing one approach over the other. It also identifies, for each approach, many of the processes that may be necessary to assimilate the source data as a coherent collection into the selected tool.

Graphical Tool vs. GIS Approach

As previously mentioned, selection of a data processing approach will depend on the available time for production, the format of the source data, and the desired end product. Table 1 lists the characteristics of the two approaches that may help a developer identify which is appropriate for a given series.

Table 1. GIS vs. graphical tool approach.

Issue	Graphic Tool	GIS
Data availability	Data representing historic conditions are most likely to be available as hard-copy maps, often with no projection or coordinate information for reference.	Data representing the current and recent conditions are most likely to be available as digital, georeferenced products.
Alignment	Alignment without geographic referencing is possible. This is important when georeferencing of scanned hardcopy data is impossible (no reference points exist, transformation makes image illegible).	With data in standard geographic referencing formats, data from different sources can be quickly and accurately aligned. Data that is not georeferenced cannot be aligned with data that is georeferenced in a GIS.
Graphic Representation	Because of the extensive graphic formatting tools, the quality of the cartographic product is better. Frames are more easily reformatted for different output mediums.	Formatting and display tools are limited, in most GIS software packages. Generally will need to use a additional graphic tool for post-production of produce high-quality frames for printed medium.
Analysis	No additional analysis is possible. Data integration approach results in accuracy issues.	Historic growth data is integrated with other GIS data, enabling spatial analyses such as area measurements, change detection, overlays, predictive modeling based on historic trends, etc.

Neither approach is faster or better in all circumstances. The development time-frame is dependent on how well the source data is described, how much of the data is already in a digital, georeferenced form, how comfortable the developer is with one tool versus the other, and how reusable versus attractive you want the series output to be.

The developer should make the choice between tools based on an understanding of the source data, the parameters for the series (e.g., study extent, classes of data being included, amount of historic variability across data classes) and the trade-offs between processing requirements of each method. If the only goal for developing the series is to have an attractive illustration to depict the urban growth issue, then using a graphic design program may be the best approach. Unless all the source data is georeferenced in the same projection, the graphics tool will likely be the most efficient method for completing a series.

If the end product of the series is intended to be more pictorial than cartographic (implying specific standards of accuracy, classification, completeness, etc.) then assimilation efforts may be simplified. It should be impressed on the developer, however, that just because data are digitized and included in a data set it does not inherit any improvements (and may in fact suffer additional degradation).

Processing with a Graphical Tool

Processing steps for assimilating data in a graphical tool may include:

- scanning of hardcopy source data
- conversion of digital source data
- importing data
- using layers to organize the data
- digitizing image data into feature data
- aligning feature and image data.

The first three steps are common to all digital graphic production tasks and will not be covered here. Hardcopy data must be translated to a digital form using a scanner to be used by either a graphics or GIS tool. Scanning at high resolutions is not a requirement, although a resolution of 200 to 300 dpi will make features more easily discernible when digitizing and is necessary for larger format printed output products. It is unlikely that graphics file conversions will be necessary as the graphic tools can interpret numerous formats, but there are a few exceptions (such as Unix formats). The import process is software specific, but does require that the developer have an organization scheme in mind (see later discussion on layering). At least one of the hardcopy maps should equal or exceed the spatial extent planned for the series, to help define the frame boundaries and identify a complete set of context features.

The use of the graphic tool's layering capability in data assimilation is very beneficial for reducing the potential for errors and helping track development decisions. Layering allows a designer to place different features (e.g., roads, rivers, urban boundaries for a year) on separate transparent "sheets," overlaid on the same "page" and stored within the same file. Organizing features by layers allows for easier editing and frame compilation, such as assigning a symbology to all the elements in one layer, having built-in documentation with the separation of features by year and class, or displaying and hiding layers to build a map frame for a particular year. It is also a good idea to create separate layers for each imported image.

A more time consuming task is the translation of selected portions of image data into feature data for the series: that is, determining and interpreting the elements (roads, rivers) represented in the image that should be included in the frames and digitizing those features as lines, polygons, or points. Translation of urban areas can be more complicated and is discussed in Chapter 4. Translation of context features such as roads and water bodies is done using the graphic package's draw tools. On separate layers, labeled by year and feature type, the developer uses the drawing tools to trace features from the image.

Start the graphic frame by translating one source image to create a "base map" definition. An appropriate image covers the full spatial extent of the area of analysis and has several features (roadways or rivers) that are common to the other images. Before continuing with the time series data, the developer should align the other images used to extract the time dependent data to the base map.

In a graphic tool, alignment is performed manually by visually aligning data. This is usually a difficult process because hardcopy sources are unlikely to be in the same scale or projection. The developer corrects the image's scale by enlarging or reducing it to match the scale of the base image. The developer can assess the rescaling by comparing the changed image to the base image (make one layer transparent) or to the digitized base features. In extreme cases where the data does not line up, images have to be rotated, shifted, stretched or distorted to fit. Note that these kinds of nonsystematic adjustments make the graphic map products inaccurate and inappropriate for subsequent quantitative spatial analysis.

Processing with a GIS Tool Approach

Processing steps for assimilating data in a GIS may include:

- conversion of digital source data
- importing
- georeferencing
- incorporating temporal attributes
- digitizing image data into feature data
- subselecting or clipping from a large feature set to derive an appropriate feature set for the series
- altering digitized data to correct feature mismatches and overlaps caused by scale, resolution, and accuracy differences.

The first three steps are typical tasks involved in collecting and preparing any data for use with GIS. The need for the task is dependent on what source data is being assimilated, and what GIS tool is being used. There are numerous formats for digital data (both raster/imagery and vector), and not all digital data is spatially referenced. GIS tools are equally varied in their support for digital formats, ability to operate on data in nonproprietary format, provision of import and translation tools, and ease of use and comprehensiveness for georeferencing. Finally, some GIS automatically handle projection reconciliation (for data that are fully and correctly described) while others require that the user transform all data to a common projection.

Devising an approach to incorporate the temporal issues of the data appropriate for each frame in the time series is an important design consideration for the GIS data sets. Temporality can be indicated in one of two ways: by creating separate data sets (also referred to as covers, layers, themes, etc., depending on the GIS) for each year of analysis, or by defining a date attribute(s) within a single data set. Choosing between approaches is dependent on what is most easily understood and manageable by the developer and other GIS data users. For a feature set such as roads, where features are introduced at points in time, but rarely change geography/topology, the attribute approach may be sufficient. For the urban areas data, where features change in extent and location, developing a data set for a specific year is required.

As with a graphical tool, image data translation into feature data is a time consuming task. GIS software typically includes on-screen digitizing tools to trace features from the image although usability may vary between products. The translation of context features is straightforward, requiring user judgments on what features to include, however. The translation of urban areas can be more complicated and is discussed in Chapter 4.

Some digital data sets may need to be subset or clipped to a smaller geographic region to increase efficiency in developing the series. For example, the location of an installation may involve acquisition of DLGs for four quadrangles to cover the spatial extent, but this may include many areas that will not be displayed in the series creating a data set that would slow down all aspects of display, editing, and graphic production. The developer is advised to clip and subset a large data set to the features that provide sufficient context for the growth series. While this may appear unnecessary, it is a typical technique used to improve processing times for other GIS operations.

Combined Graphical and GIS Tool Approach

An obvious disadvantage to a combined graphical and GIS approach, is that it requires additional software expertise and the eventual integration of all the data into the graphical tool. This approach may be necessary, however, because of the characteristics of the available data.

Using a graphical tool to combine nongeoreferenced data with georeferenced data can be useful for addressing geographic accuracy and consistency issues from data gathered from multiple sources, scales, resolutions and accuracies. The GIS data can serve as a consistent base map to which other data can be aligned. GIS vector features are transferred to a graphic tool through encapsulated postscript. This data is used to set the spatial extent and format of the graphic output. Images are imported into the graphic tool as bitmap graphic, aligned to the base data, and the desired features are digitized for integration into the series.

Three of the four examples of urban growth series produced by ERDC/CERL used a combined graphical and GIS tool approach. This approach was used because the original series for Fort Carson was initially developed without GIS data and with an entirely graphical approach; the Carson series presentation graphics set the standard for subsequent series. Almost every series required the use of nongeoreferenced source data, and developer judgment on the graphic quality of the output.

4 Determining Urban Areas

Delineation of urban areas is the primary objective of, and the most difficult task to accomplish in, developing an historic urban growth series. Urban areas are difficult to delineate because they are defined differently by each organization recording them, their boundaries change over time, and historic representations of them in GIS or digital formats are scarce. An historic growth series developer will almost certainly be required to assimilate several interpretations of urban areas or must interpret the area directly from imagery. This chapter describes issues and techniques for interpreting and combining interpretations of urban areas. It also discusses the identification and preparation of supporting population estimates for the delineated urban areas.

Principles for Delineation of Urban Areas

To represent urban areas, the data for each frame should be compiled using a common methodology. Ideally the source data for each frame will be in the same projection, at the same relative scale, and at the same level of generalization. Note that these rules are relevant not only for urban areas, but also extend to other data types having features that alter shape or size over the course of the map series (i.e., installation boundaries, roads, modified channels of streams/rivers, etc.).

In many instances, it will be impossible to find a single source of data for each frame in the series. In the case of cartographic products, the producers have likely used different methods for defining and constructing urban boundaries, and provided no documentation of their process. The end product of data integration from mixed sources will inevitably have a degree of inconsistency, uncertainty, and inaccuracy, not only because of the different methods used to define an urban area, but also because of the data processing procedures performed by the compiler. Guidance is proposed to aid in delineating the urban area.

Guidance for a Single Source

If the available data originates from one source, then the guidelines for developing a suitable multiple frame growth series are simple. The definition of the urban areas in the time series will be inherited from that source. No interpretation on the part of the developer is needed if the data are at a scale similar to the rest of the map product. Since map scale determines the minimal area of a feature to be included on a map, or the detail used in defining the boundary of features, if the map scales are highly variable between time periods, there can be problems with mismatched borders, sections of land disappearing, etc.

The problem of mismatched features also applies to projections and datums used by the source. If the data for each time frame in the series is produced using a different projection, then there will be similar issues of mismatching boundaries because of the varying distortion shaped from each projection. If the only data obtainable is at highly disparate scales or produced using different projections, then other sources should be examined as substitutes.

Guidance for Multiple Sources

When a growth series uses multiple sources, efforts to keep the data “true” to its original state become more complicated. Some adjustments will need to be made to create a logical representation of an urban area over time.

Discrepancies in the data from frame to frame will exist when using multiple sources. One source should be chosen as the principal definition to which all other sources will be compared and resolved. The base data should come from the most reputable source in the group. The features of the secondary sources are adjusted to conform to the principal definition. For example, these discrepancies may include:

1. An overlap or gap between the urban area boundaries and other base data. For example, the urban area may extent into a water body (Figure 3).
2. Conflicts in urban areas between time frames. For example, Source A labels an area as “Urban” in 1970, but Source B labels that same area as “Not Urban” in 1980 (Figure 4).
3. Shape or line work between frames is consistent, but still does not align properly. For example, the shape of the 1970 and 1980 urban areas appear to be consistent, but the 1980 area is stretched-out such that only one side of the urban area can be matched (Figure 5).
4. Changes in map generalization between time frames create the appearance of changed boundaries (Figure 6).

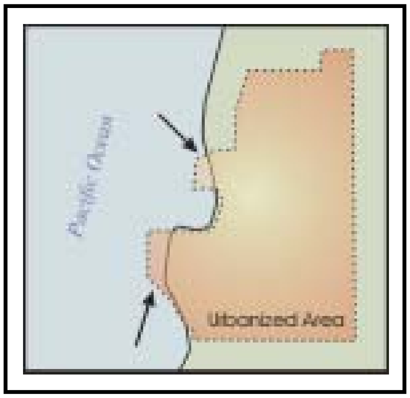

Figure 3. Overlapping boundary data.

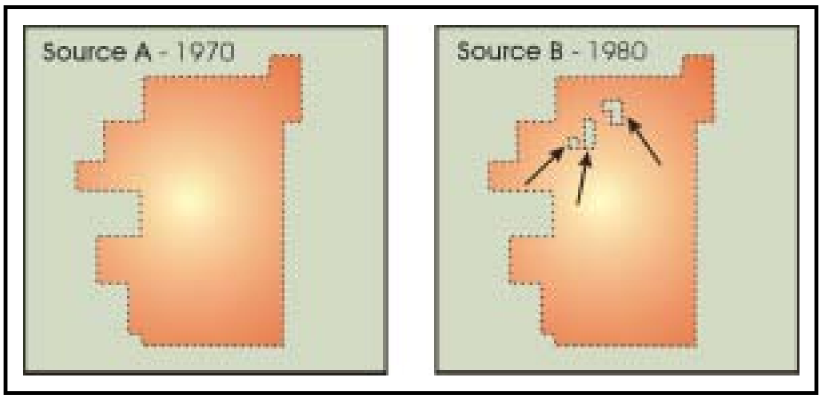

Figure 4. Conflicts in urban areas between time frames.

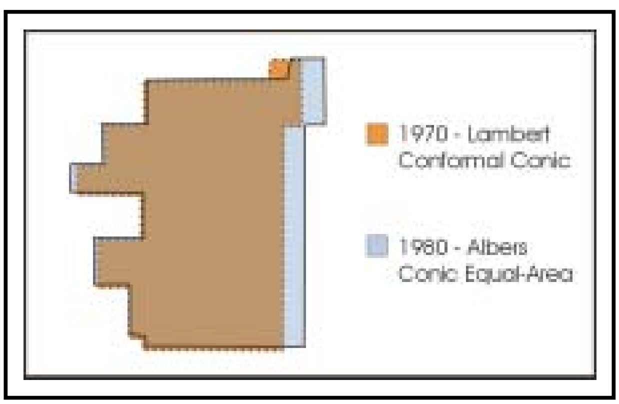

Figure 5. Inconsistent shape or line work between frames

To make features consistent with one another, some modifications of data must be made according to the developer's best judgment. It is inappropriate to arbitrarily add detail or fabricate data to improve the aesthetics or to exaggerate the growth. Data should be generalized to conform to the data from the selected principal source. Generalizing features can be accomplished by: (1) smoothing line work, (2) aggregating clusters of data into one feature, or (3) removing outliers that may be insignificant for the level of detail of a series. (Note that outliers should be removed with caution, since growth of small communities may represent an installation's greatest potential mission constraint.)

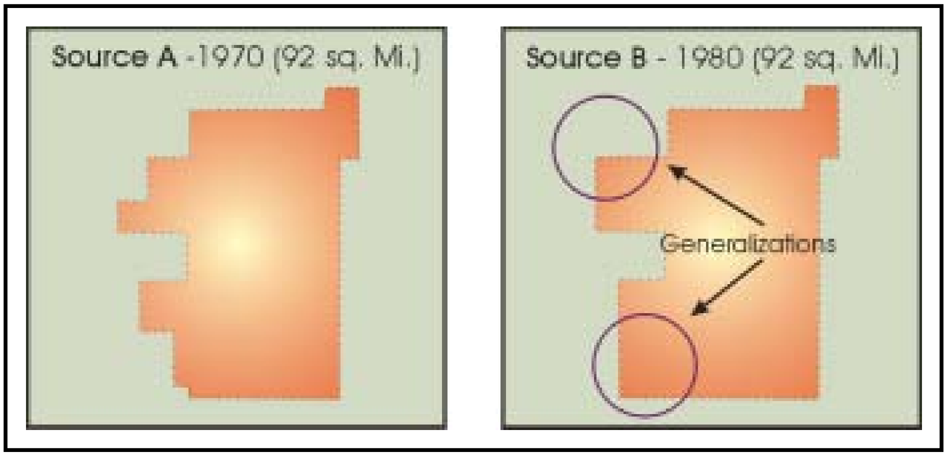

Figure 6. Changes in map generalization between time frames.

When discrepancies are the result of differences in projections, the data can be either (1) reprojected to one standard projection and datum if the data is being assembled in a GIS, or (2) stretched and rotated until it matches up with the other data in the series when a graphic design program is being used. The compiler should always attempt to adjust the size and rotation of the data object before attempting a free-hand stretch. This will distort the data and lower its accuracy and precision.

When aerial photography is used as a source to manually interpret urban areas, it is recommended that a supplementary source (such as a GIS point coverage of cities, towns, and villages) be used to identify the location of recognized urban areas. However, it is largely subject to the interpreter's training and judgment to define what areas may be considered urbanized. Image interpretation and classification is described in many textbooks. Whenever possible, interpretation should be based on accepted or applied standards used in other source data. For example, the USGS uses the following definition:

> Urban or built-up land is defined as areas characterized by buildings, asphalt, concrete, suburban gardens, and a systematic street pattern. Classes of urban development include residential, commercial, industrial, transportation, communications, utilities, and mixed urban. Political boundaries, such as city limits, are not used to define urban limits. Undeveloped land completely surrounded by developed areas, such as cemeteries, golf courses, and urban parks, is recognized within urban areas.

In addition, most mapping standards include minimum mapping area requirements defining the area a land use must occupy before it is recorded on a map.

The main objective for the series developer when using multiple sources is to make sure the data is consistent without having to sacrifice the accuracy of its original form. Any manipulations performed on the data should be kept to a minimum.

Preparing Supporting Population Estimates

Population numbers are added to each frame as a qualitative measure of the urban growth depicted in the series. These numbers should be consistent with the representation of the spatial data. For example, if the urban area definition for the frames was Census Bureau urbanized areas, than population numbers should also be for the urbanized area. The classification of population numbers should not change across frames in the series. All frames sho uld be annotated with a comparable number, such as a consistent city, county, or MSA.

The U.S. Census Bureau is the best source for population numbers for a variety of classifications, such as cities, urbanized areas, counties, and metropolitan statistical areas (MSAs). Current and some historic data is available on the Census website (www.census.gov). More extensive historical data can be gathered from the decennial census books available at University or government libraries.

Some published maps may be annotated with population; these can be used for a growth series frame as long as the source's identified urban area was not significantly modified during the assimilation process. Documentation on the source for these population figures is often not provided, so the series developer may have difficulty finding appropriate matching data for other frames.

When the growth series represents multiple urban areas, population numbers should be collected for each area within the frame and either added together or separately annotated. Also, because many of the frames in the series will not fall on the decade (Census population date), population estimates may need to be developed. For example, population numbers for a 1986 frame may be estimated by interpolating between the urbanized area populations for 1980 and 1990 (typically using a linear or nominal growth rate technique).

5 Presentation Techniques

The final step in developing a growth series is the selection of presentation techniques. This chapter presents various approaches that ERDC/CERL took to develop example series. The styles were adopted because they effectively emphasized the urban area feature over all other information, clearly and simply presented supporting information, and produced a series of illustrations that could be adapted as an animated presentation format or various print styles.

Color Conventions

The following color rendering techniques were used:

- Radial fills and highly saturated colors were used for the primary features (oranges for urban areas and greens for the installation) to highlight their importance in the map.
- High gray levels were used in color selections for all other features to lower their intensity and brilliance and de-emphasize their significance in the map.
- Interstate highways were colored with a double red line while all other U.S. and State highways were colored with a single black line.
- Natural colors were used for natural features such as water and forests.

Labeling

The following label rendering techniques were used:

- A feature's level of importance in the map is indicated by font type and size. The order of importance (from high to low) for feature types within the map are:
  - installation
  - urban areas (given multiple areas, then areas may be ranked according to their relative size)
  - other area features such as National and State parks
  - roads
  - hydrology
  - political boundaries.
- Highway shields were created using symbols from the ESRI shields font.

- The north arrow was created using the ESRI North font.
- If white text was used for labeling the year and population (map title), cast shadows were applied to the labels to separate them from the background.

For static features such as rivers or roads, the positioning of a label need only consider legibility and consistent placement rules within the frame (i.e., all labels appear to the right of and below their feature). For changing features such as the urban area, the positioning of the label needs to consider legibility both within the frame and across all frames. Generally labels are placed a uniform distance from the edge of the feature. As the urban area grows, the label will need to be repositioned; however, this can result in an awkward animation (when the frames are shown in a timed sequence). Repositioning of labels for features which change should be minimized.

Denoting Other Significant Area Features

To illustrate regional factors that may constrain growth patterns, the maps included other large features, namely topography and large public land holdings.

Rendering Techniques for Topography

A digital elevation model (DEM) was incorporated into some of the time series to illustrate how highly variable terrain (mountain ranges, plateaus, etc.) can have a significant affect on urban growth patterns. This issue is seen in the time series for Camp Pendleton and Fort Carson. Appendix B provides details on using a DEM to create a hill-shade relief background graphic for a series. When DEM data is not available, yet elevation is an important feature to illustrate, a simpler technique of displaying elevations from contour data can be substituted (see the Fort Carson series example in Appendix A).

Rendering Techniques for Public Land Holdings

Large land holdings that are expected to remain free from development, such as National parks and forests, Bureau of Land Management or Bureau of Indian Affairs lands, State parks or other natural areas, were incorporated into the time series. Like topography, these can show how protected lands can have a significant affect on urban growth patterns. These areas were simply rendered with an identifiable color, but with a transparency effect, to de-emphasize them relative to the main subjects and to integrate them with the topography.

Creating Thumbnails for Printed Materials

While the full-page frames are best for slide, poster or other larger format presentations, it is useful to develop thumbnails of some or all of the frames for side-by-side presentation in printed products (fact sheets, articles, reports). Using a simple resizing approach to reduce the full-page frames to smaller graphics results in a poor quality product with illegible text that will not reproduce well. The following steps, used to produce thumbnails for printed products from the example series, are suggested:

- For each frame graphic, remove all labels and produce an integrated raster image (e.g., export a jpeg, tiff, or bitmap) of the feature data to include in the thumbnails (areas, roads, rivers, topography, etc.).
- Re-import the images into a graphics tool. Crop, size and place the images to fit within the design of the target print format.
- These two steps may require several iterations to determine what feature set will be legible and relevant in the smaller presentation.
- For the resized and organized images, create new labels for the images, sized and emphasized appropriately. Use a separate layer for the text. Decide if the small images require a legend, title, or population numbers (since they are likely to appear with a caption and explanation).

6 Summary

This study has developed a process to help incorporate local knowledge of regional trends and plans through the use of "frames" that may predict future growth patterns and foster proactive planning between Army installations and their neighboring or regional communities. Some issues to consider when constructing frames are:

1. Collecting appropriate data sources for a time series is the most critical step in the map production process. This work has identified four categories of data are used in illustrating the growth issues for the series maps:
   a. installation extent
   b. urban area extent
   c. context information
   d. natural features.
2. Date of data collection (rather than the date of publication) actually determines the relevancy of the depicted information.
3. The standards by which data are interpreted or classified may vary between data sources. An area denoted as urban in one data source may be classified as something else in another data source depending on the rules used.
4. The spatial accuracy and completeness of data sources will influence interpretation. Since most digital data are derived from hardcopy sources at this point in time, a digital product should not be considered better data.

The specific documentation process should follow these general guidelines:

1. A single producer of data for multiple years through a series is preferred. Still, a number of data sources, both digital and hard copy, should be considered.
2. Frames should be constructed by the following criteria:
   a. Historic growth series should include four to six frames of approximately 10-year intervals.
   b. The first frame should represent the installation's relationship with the surrounding communities before significant urbanization.
   c. The last frame should be as current as possible.

   d. Select frames for at least 1 year within each decade between the first and last frames.

   e. Select frames to point out periods of significant growth and to best illustrate changes between periods.

3. Once the available data has been evaluated and a working set selected, it must be assimilated for the time series either within a graphic-design program such as Corel Draw or Adobe Illustrator, or within a GIS.

4. Delineation of urban areas is the primary objective of developing an historic urban growth series, and often involves a degree of interpretation of information from multiple data sources (e.g., matching populations and geographic data).

5. These principles were used to develop formatting techniques to develop and present case studies at four military installations (Appendix A), using established labeling conventions (Chapter 5)

Appendix A: Example Urban Growth Series

A.1 Fort Carson Historic Urban Growth Series

Source Data References

- 1956 frame interpreted from the USGS 1956 1:500,000 scale State of Colorado map (obtained from University of Illinois Map & Geography Library) (Figure A1).
- 1965 frame interpreted from the State of Colorado Department of Highways 1965 *Colorful Colorado* map (obtained from University of Illinois Map & Geography Library) (Figure A2).
- 1970 frame interpreted from the State of Colorado Department of Highways 1970 *Colorful Colorado* map (obtained from University of Illinois Map & Geography Library) (Figure A3).
- 1980 frame interpreted from the State of Colorado Department of Highways 1980 *Colorful Colorado* map (obtained from University of Illinois Map & Geography Library) (Figure A4).
- 1993 frame interpreted from H.M. Gousha's 1993 *Colorado Roadmap* map (obtained from University of Illinois Map & Geography Library) (Figure A5).
- 1999 frame (Figure A6) compiled from multiple sources:
    - 1992 Bureau of the Census Urbanized Area Boundaries (obtained from ESRI Data & Maps 2000 product).
    - Colorado Springs Boundary (undocumented GIS data, obtained from Fort Carson).
    - 1990s Housing development in Colorado Springs area (undocumented GIS data, obtained from Fort Carson).

Source Population Data

U.S. Bureau of Census Date	Colorado Springs Population	Pueblo Population
1950	45472	63685
1960	70194	91181
1970	135517	97774
1980	215150	101686
1990	280430	98640
1993 Estimates	305966	100626
1998 Estimates	344987	107301
Estimates for inter-census periods calculated using a nominal growth rate approach.		

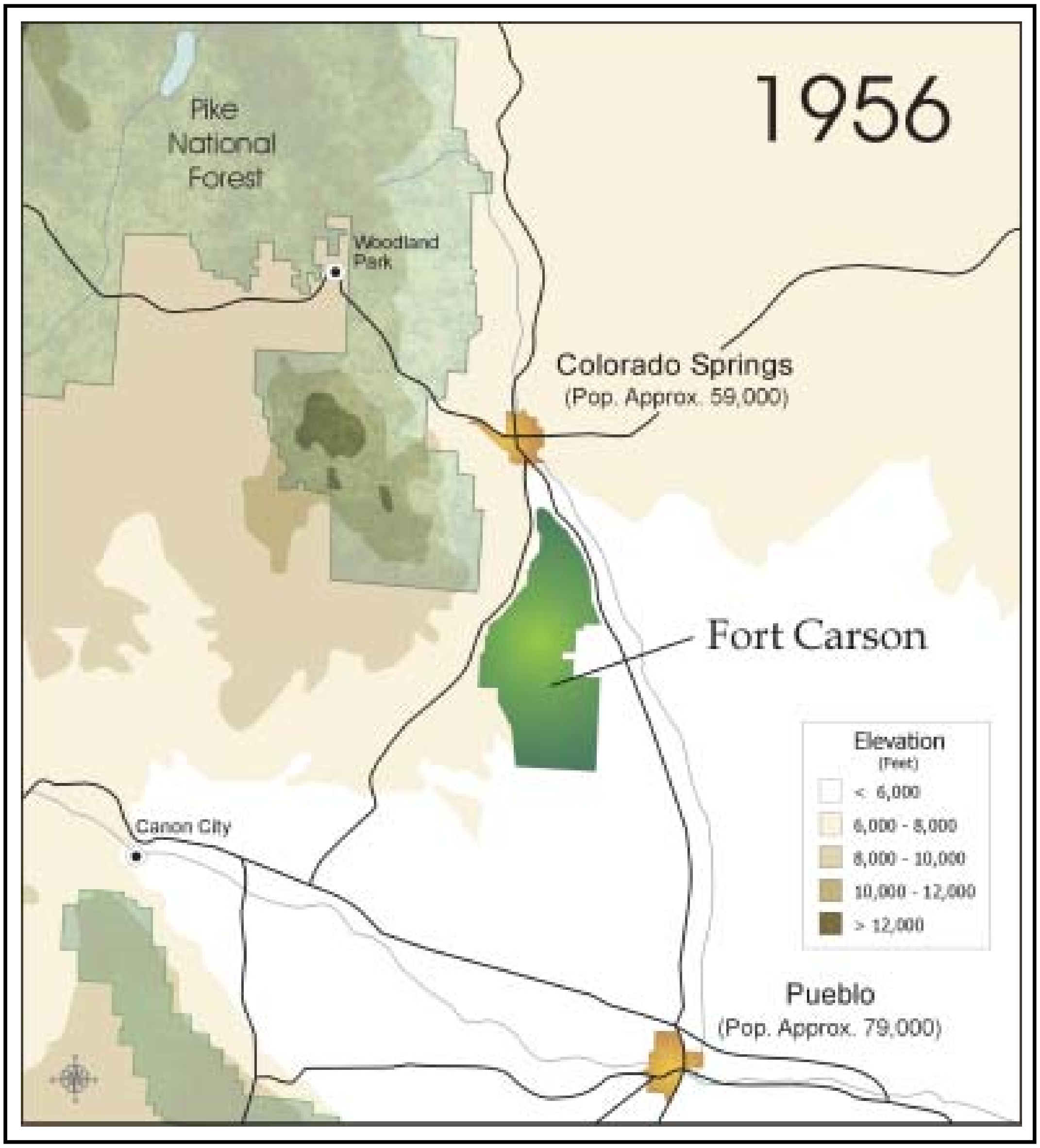

Figure A1. Fort Carson / Colorado Springs, frame 1 (1956).

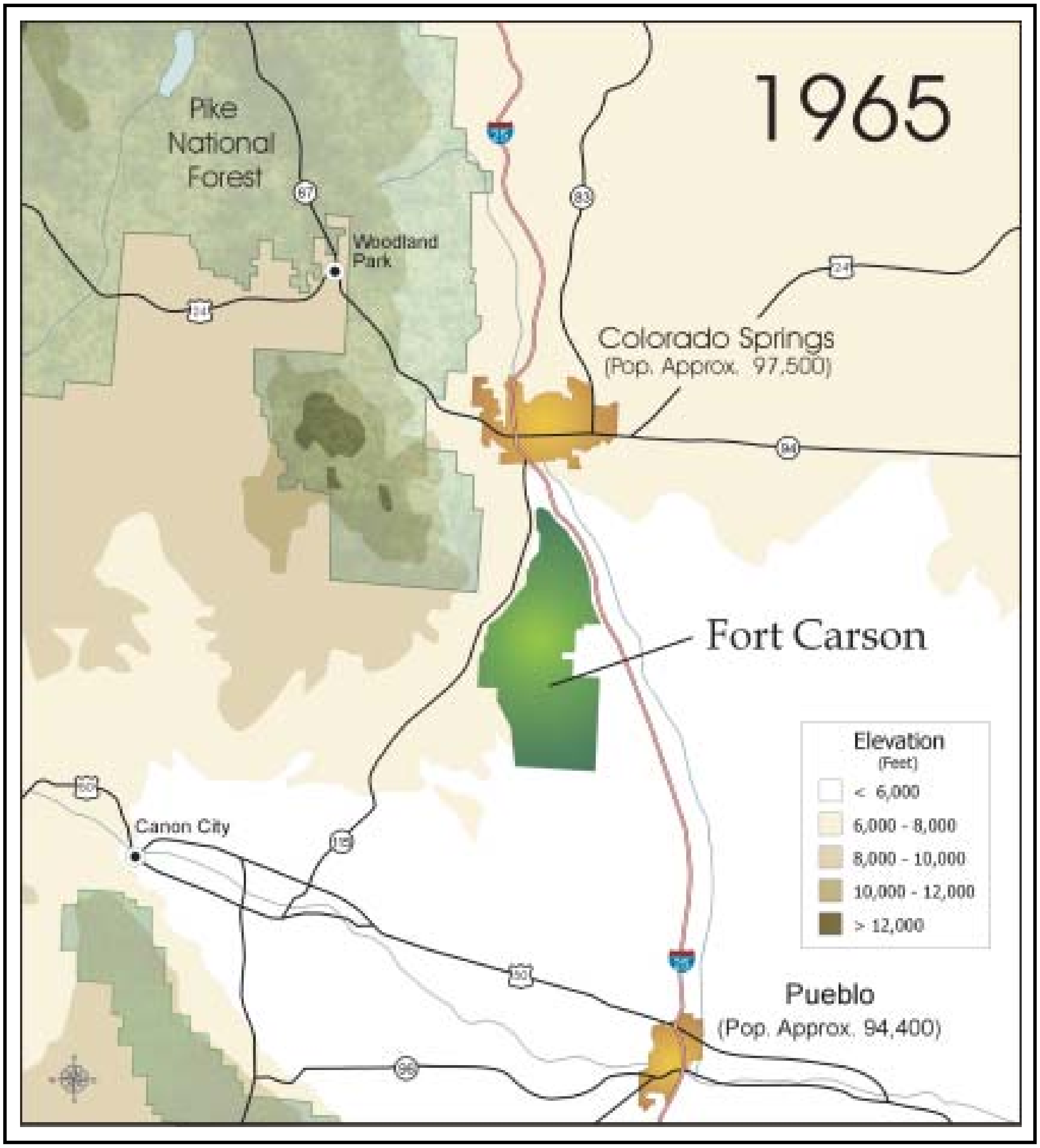

Figure A2. Fort Carson / Colorado Springs, frame 2 (1965).

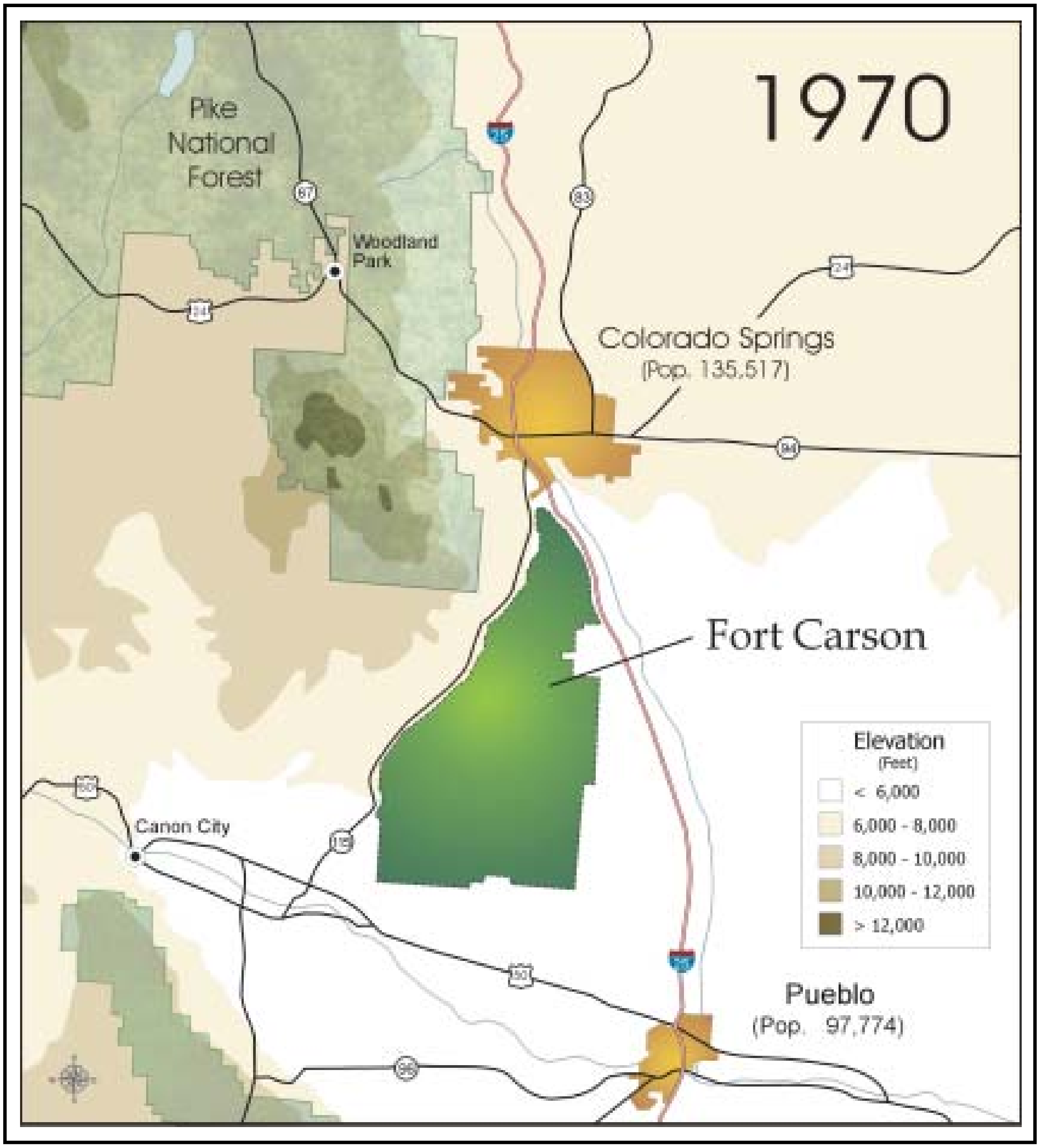

Figure A3. Fort Carson / Colorado Springs, frame 3 (1970).

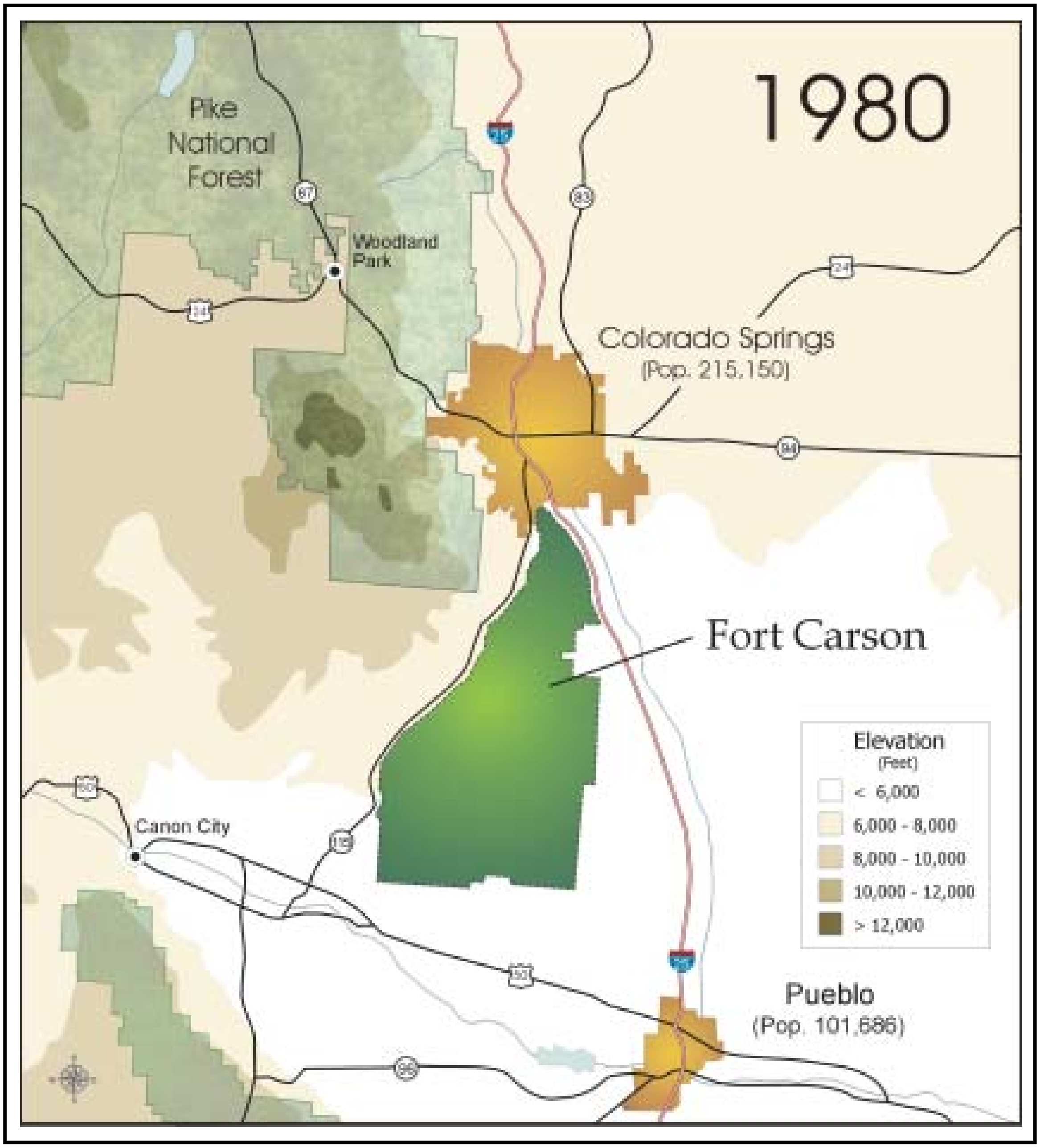

Figure A4. Fort Carson / Colorado Springs, frame 4 (1980).

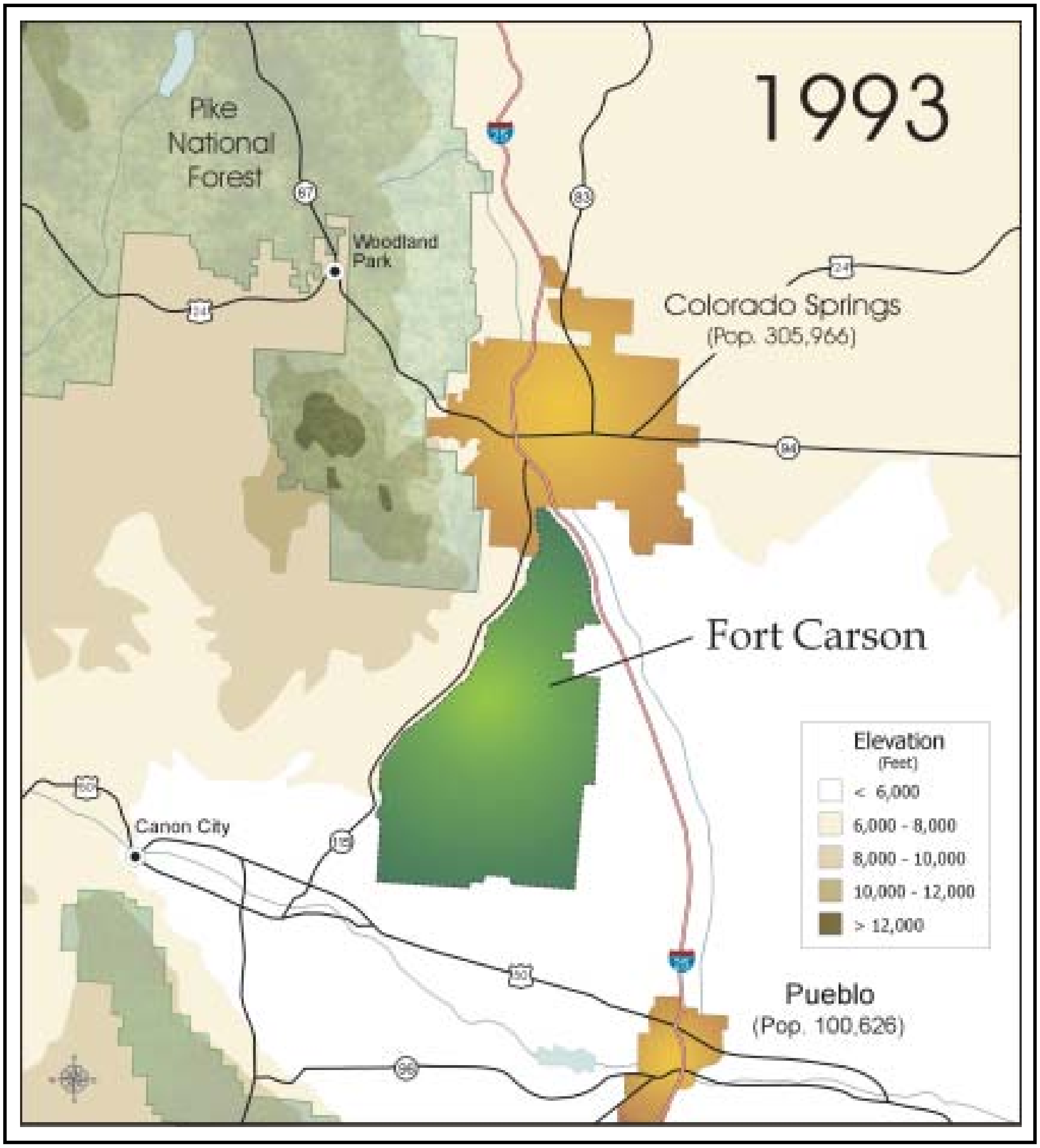

Figure A5. Fort Carson / Colorado Springs, frame 5 (1993).

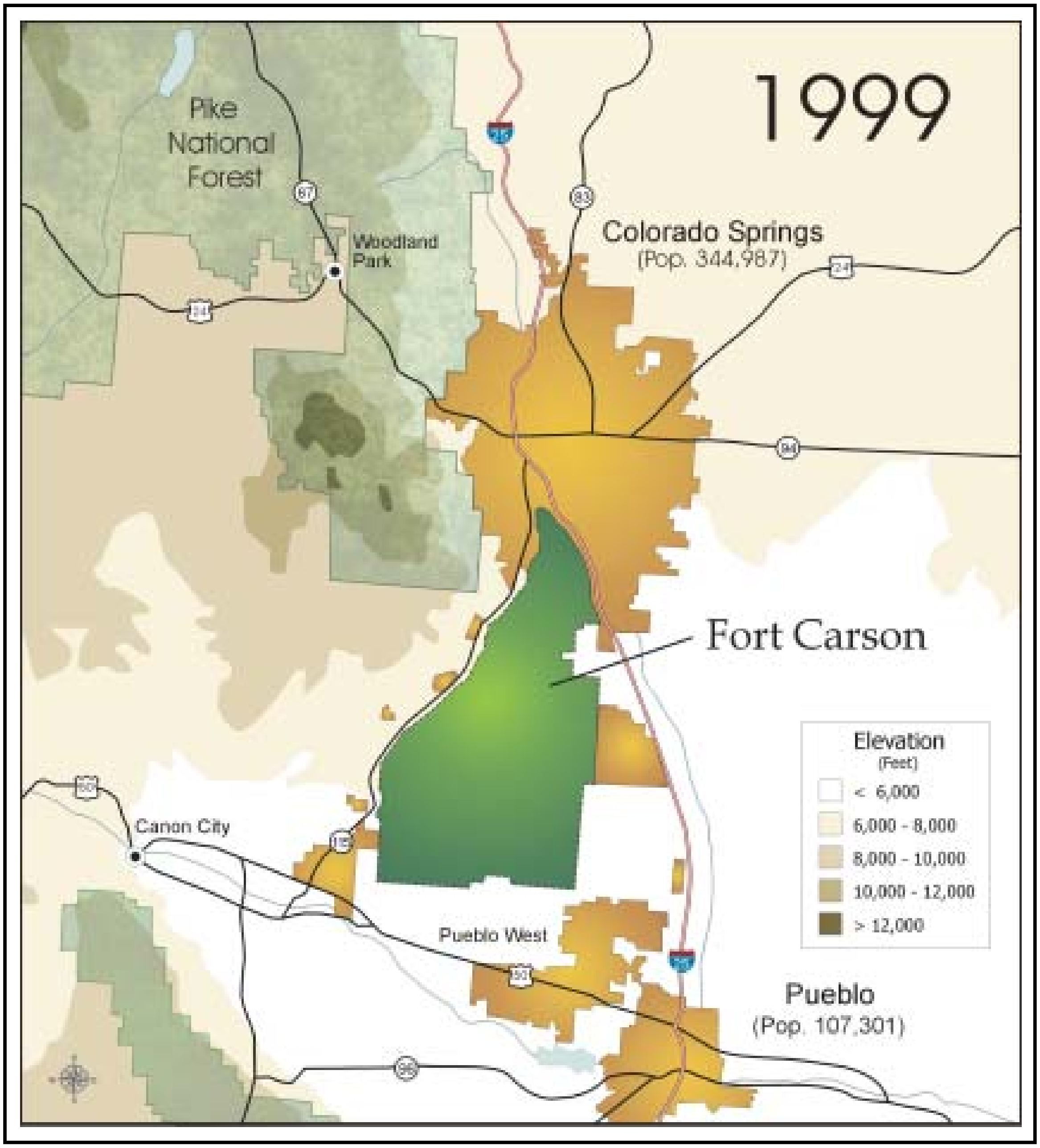

Figure A6. Fort Carson / Colorado Springs, frame 6 (1999).

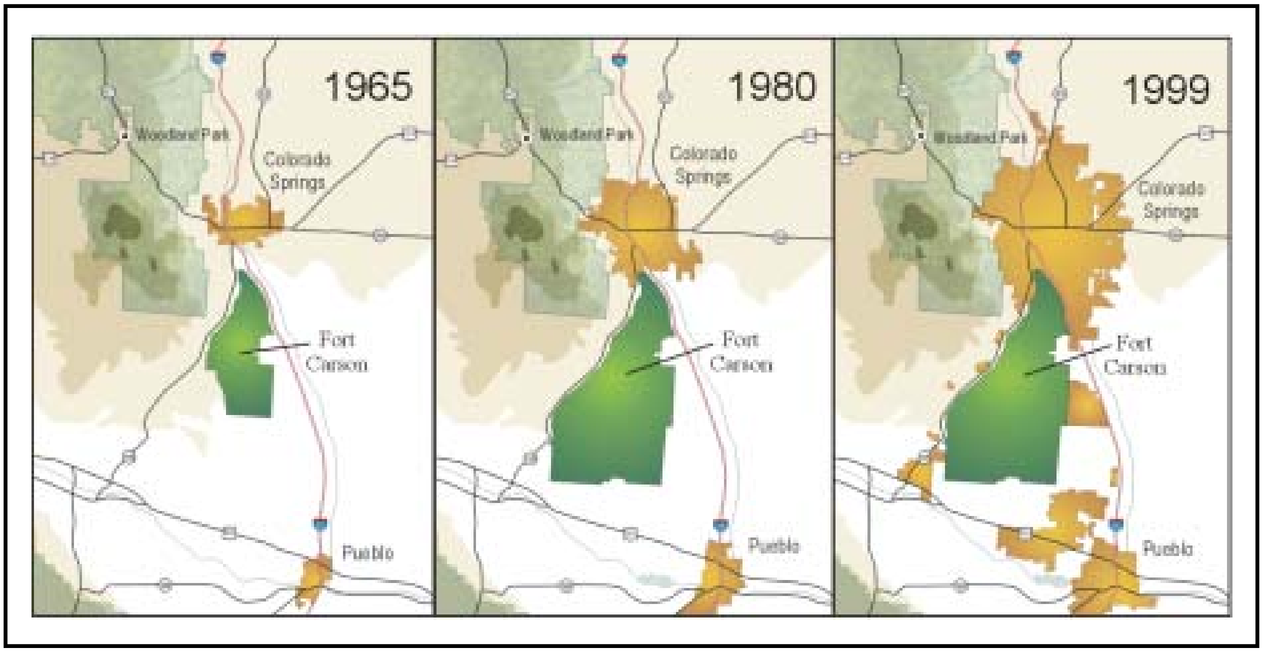

Figure A7. Print format example of historic urban growth series, Fort Carson / Colorado Springs (1965–1999).

Camp Pendleton Historic Urban Growth Series

Source Data References

All frames represent growth based on urbanized areas. This is a population aggregation and tracking approach used by the U.S. Census Bureau. An urbanized area is a contiguous area of dense housing, commercial, and industrial land uses encompassing more than 50,000 residents. Urbanized areas generally consist of multiple municipalities and neighboring and contained unincorporated areas.

Urbanized Area Data

- 1940 – 1980 frames interpreted from U.S. Census Bureau Decennial Census Urbanized Area Boundaries paper maps (obtained from University of Illinois Documents Library).
- 1990 frame compiled from U.S. Census Bureau Decennial Census Urbanized Area Boundaries GIS data (obtained from Census Bureau's Cartographic Boundary Files download site, www.census.gov/geo/www/cob/).

Context Data compiled from GIS digital data from multiple sources:

- GDT Major Roads and Major Water Bodies (obtained from ESRI Data & Maps 2000 product).

- Camp Pendleton Boundary and Other Federal Lands (obtained from National Atlas Federal and Indian Lands Map Layer, www.nationalatlas.gov, which is based on USGS 1:2,000,000 scale DLG composite).
- County and State Boundaries (obtained from Census Bureau's Cartographic Boundary Files download site, www.census.gov/geo/www/cob/).

All GIS data was reprojected to UTM Zone 11, NAD 27, meters. This projection was chosen as a "best match" to urbanized area paper maps.

Source Population Data

U.S. Bureau of Census Date	Oceanside Population	Los Angeles Urbanized Area	San Diego Urbanized Area
1940	4,651	2,904,596	256,368
1950	12,881	3,996,946	432,974
1960	24,971	6,488,791	836,175
1970	40,494	8,351,266	1,198,323
1980	76,698	9,479,436	1,704,352
1990	128,398	11,402,946	2,348,417

Figure A8. Camp Pendleton / Los Angeles, frame 1 (1940).

Figure A9. Camp Pendleton / Los Angeles, frame 2 (1950).

Figure A10. Camp Pendleton / Los Angeles, frame 3 (1960).

Figure A11. Camp Pendleton / Los Angeles, frame 4 (1970).

Figure A12. Camp Pendleton / Los Angeles, frame 5 (1980).

Figure A13. Camp Pendleton / Los Angeles, frame 6 (1990).

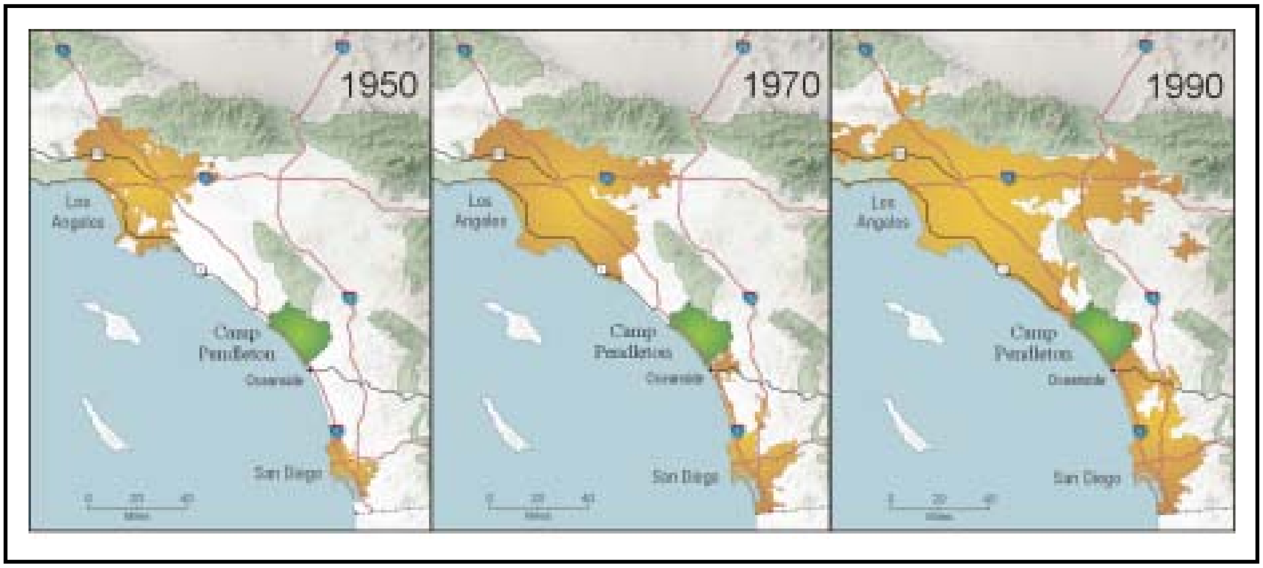

Figure A14. Print format example of historic urban growth series, Camp Pendleton / Los Angeles (1950–1990).

Fort Benning Historic Urban Growth Series

Source Data References

All frames represent growth based on USGS interpretation of built-up lands, i.e., areas characterized by buildings, asphalt, concrete, suburban gardens, and a systematic street pattern. Classes of urban development include residential, commercial, industrial, transportation, communications, utilities, and mixed urban. Political boundaries such as city limits are not used to define urban limits. The definition is available at URL:

http://mcmcweb.er.usgs.gov/phil/gis.html

Urbanized Area Data:

- 1955 – 1985 frames interpreted from USGS 7.5 min 1:24000 scale Topographic Maps (paper maps obtained from University of Illinois Map & Geography Library).
- 1955 and 1968 frame included maps data for 1955 and 1968 for quadrangles Columbus, Fort Benning, Fortson, and Phenix City.
- 1985 frame included 1985 maps for quadrangles Columbus, Fort Benning, Fortson, Midland, Ochillee, and 1984 maps for quadrangles Fort Mitchell and Phenix City.
- 1996 frame compiled from 1992 Bureau of the Census Urbanized Area Boundaries (obtained from ESRI Data & Maps 2000 product) and the USGS

National Land Cover Data for Georgia and Alabama (obtained from a secure USGS download site as part of a data-sharing agreement with USAC-ERDC/CERL).

Context Data Compiled From GIS Digital Data From Multiple Sources

- GDT Major Roads (obtained from ESRI Data & Maps 2000 product).
- Fort Benning Boundary and Other Federal Lands (obtained from National Atlas Federal and Indian Lands Map Layer, www.nationalatlas.gov, which is based on USGS 1:2,000,000 scale DLG composite).
- County and State Boundaries (obtained from Census Bureau's Cartographic Boundary Files download site, www.census.gov/geo/www/cob/).
- State of Georgia Department of Transportation 1994-1995 *Official Highway and Transportation Map* (obtained from University of Illinois Map & Geography Library).

All GIS data was reprojected to UTM Zone 16, NAD 27, meters. This projection was chosen to match USGS topographic maps.

Source Population Data

U.S. Bureau of Census Date	Columbus, GA-AL Urbanized Area
Construction Engineering Research Laboratory	118,485
1960	158,382
1970	208,616
1980	214,591
1990	220,698

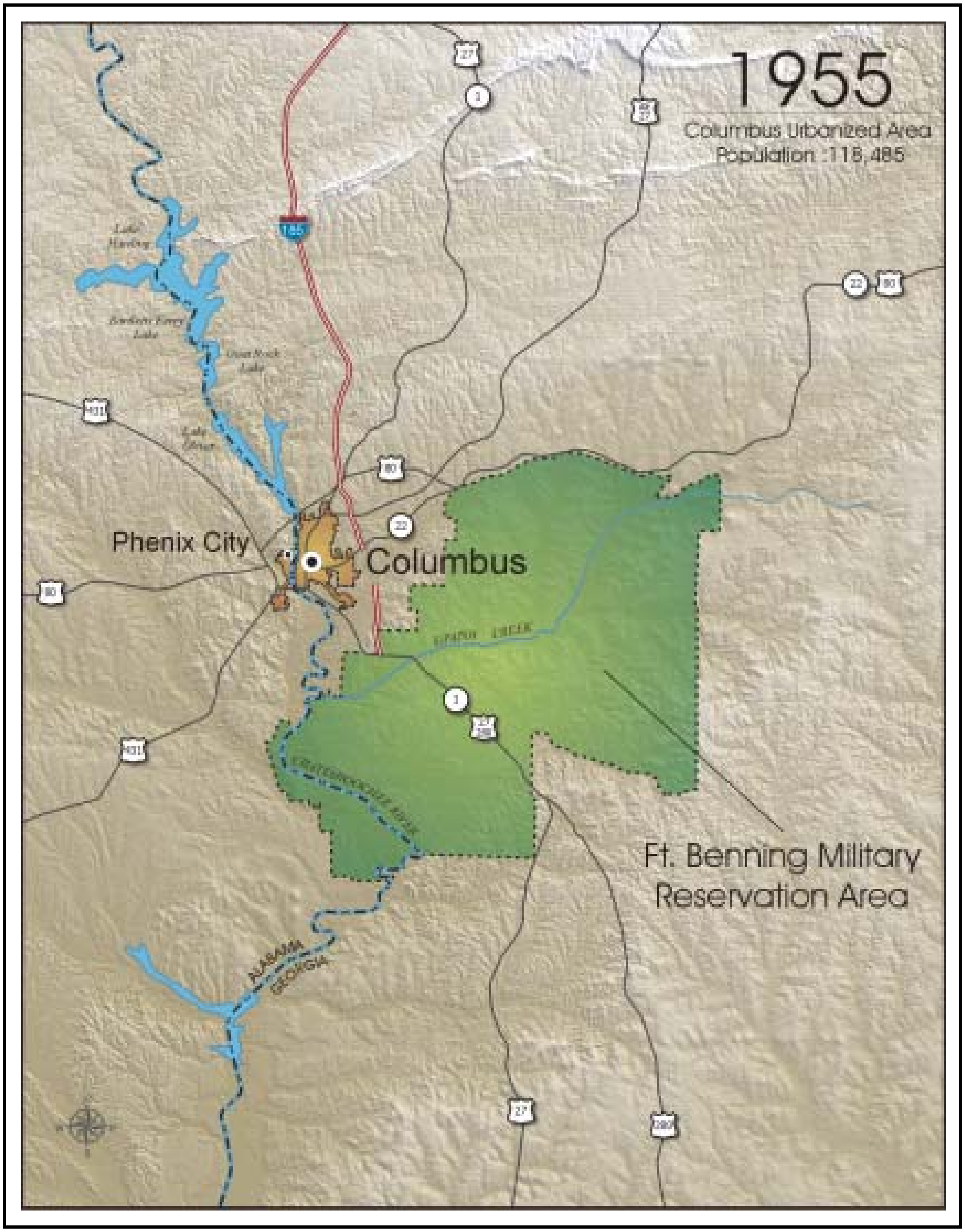

Figure A15. Fort Benning / Columbus, frame 1 (1955).

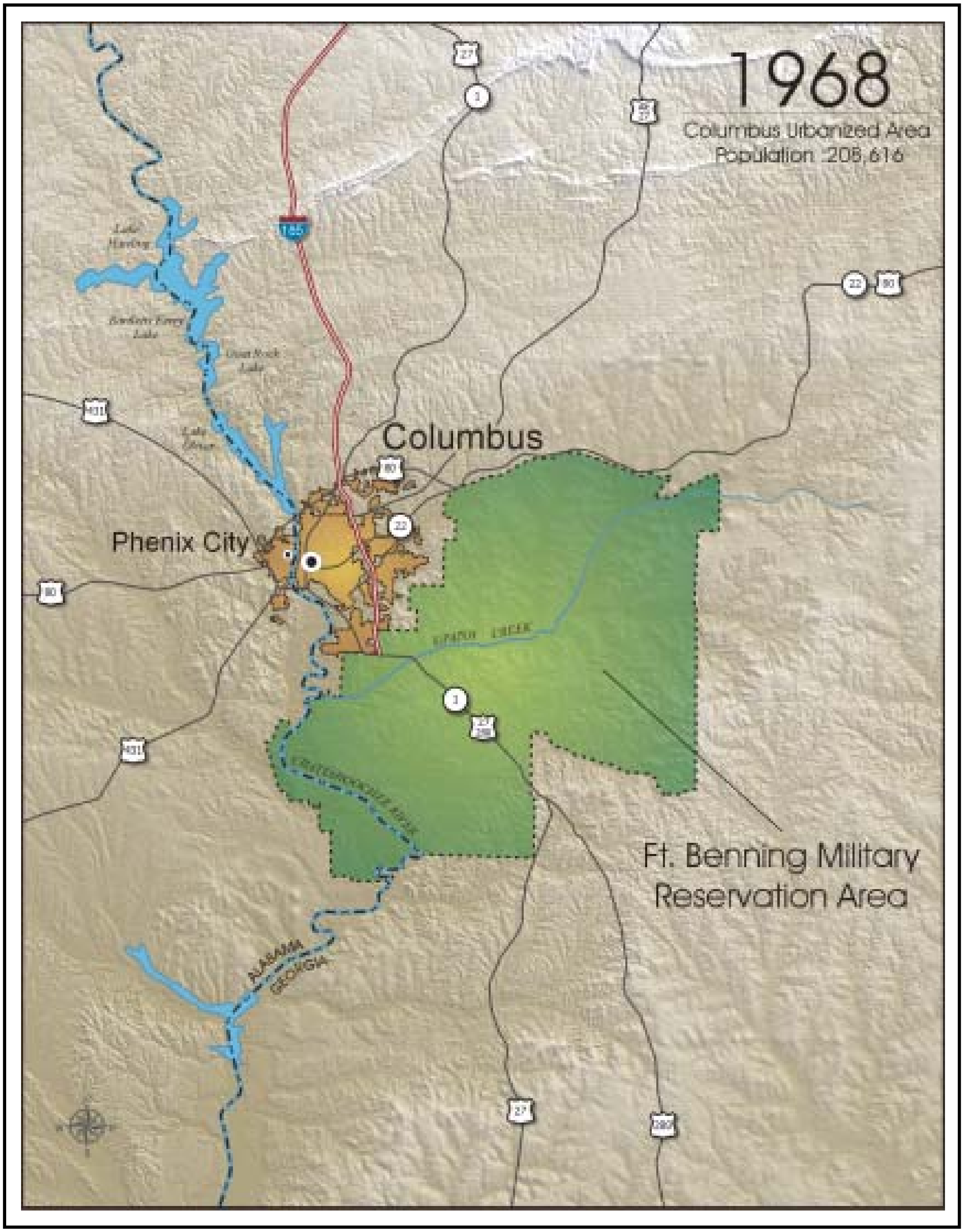

Figure A16. Fort Benning / Columbus, frame 2 (1968).

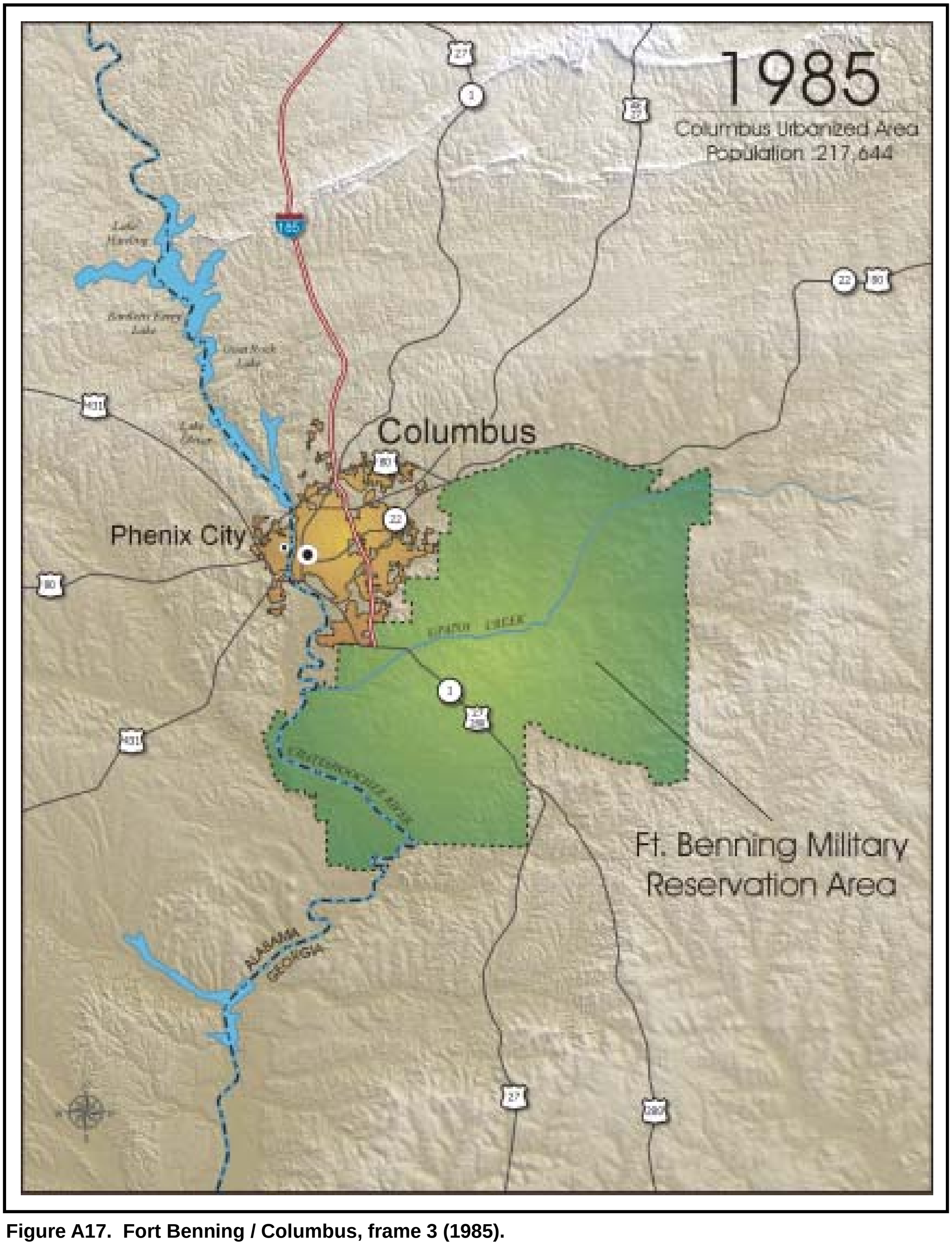

Figure A17. Fort Benning / Columbus, frame 3 (1985).

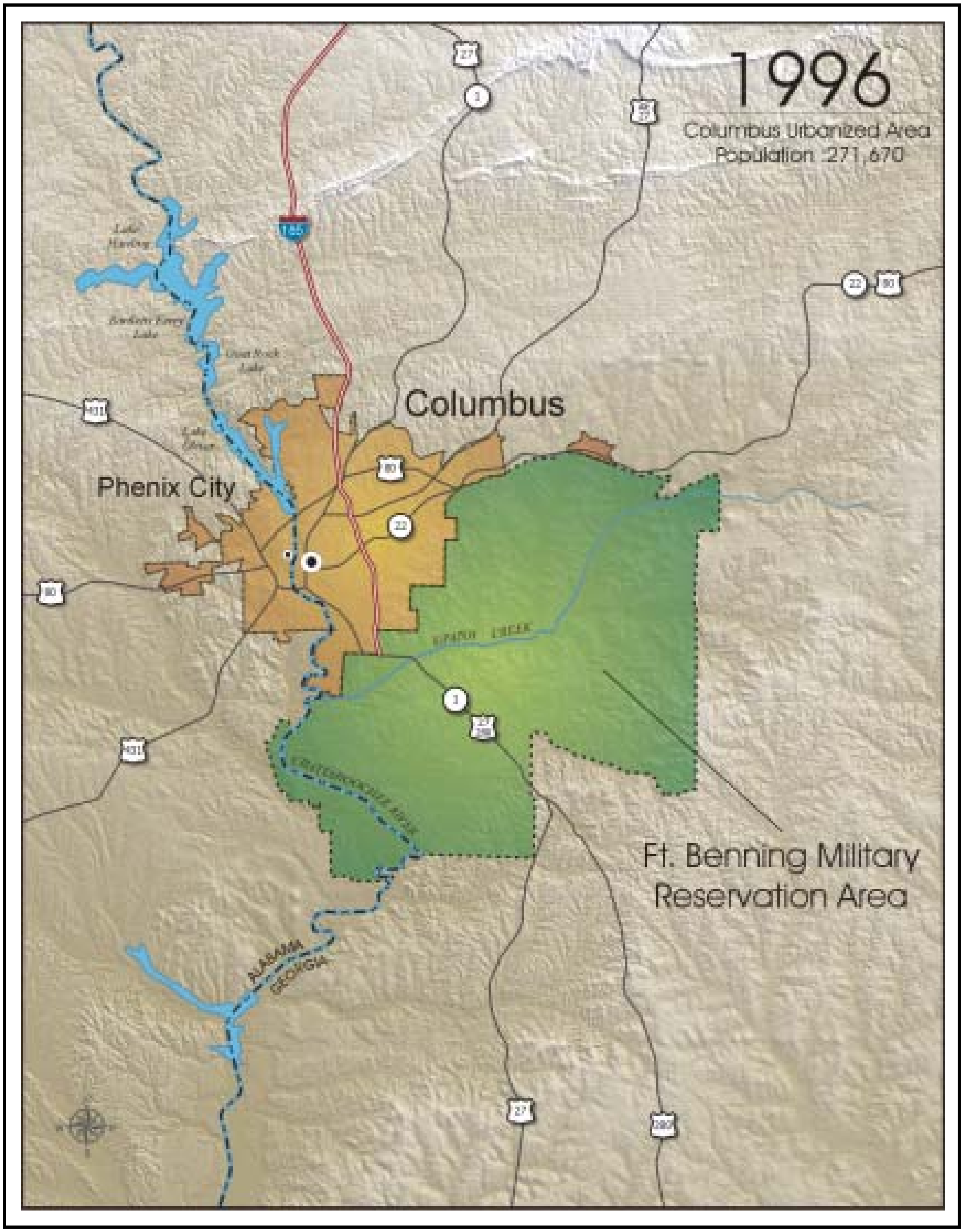

Figure A18. Fort Benning / Columbus, frame 4 (1996).

Fort Hood Historic Urban Growth Series

Source Data References

1960-1983 frames show growth based on USGS interpretation of built-up lands.

Urbanized Area Data:

- 1960 – 1983 frames interpreted from USGS 7.5 min 1:24000 scale Topographic Maps (1975 and 1983 digital raster graphics from Microsoft TerraServer; 1960 paper maps from UIUC Map & Geography Library).
- 1997 frame interpreted by the developer from 1997 USGS Digital Orthophoto Quadrangles (DOQs) (obtained from obtained from Microsoft TerraServer)
- Context Data compiled from GIS digital data from multiple sources:
  - GDT Major Roads (obtained from ESRI Data & Maps 2000 product).
  - Fort Hood Boundary and Other Federal Lands (obtained from National Atlas Federal and Indian Lands Map Layer, www.nationalatlas.gov, which is based on USGS 1:2,000,000 scale DLG composite).
  - County Boundaries (obtained from Census Bureau's Cartographic Boundary Files download site, www.census.gov/geo/www/cob/).

All GIS data was projected to UTM Zone 14, NAD 83, meters. This projection was chosen to match available DRGs.

Source Population Data

Due to time constraints in the development of this series, the population numbers used are not the best fit to the delineated urban extent. The Killeen-Temple MSA value, which represents the population for the entire Bell County area. The 1960 population number is from the decennial census. Population numbers for other years are mid-year population estimates calculated by the Census Bureau and available in the Regional Economic Information System distributed by the Bureau of Economic Statistics.

U.S. Bureau of Census Date	Killeen-Temple MSA
1960	118,058
1975	208,616
1983	229,601
1991	251,082
1997	299,444

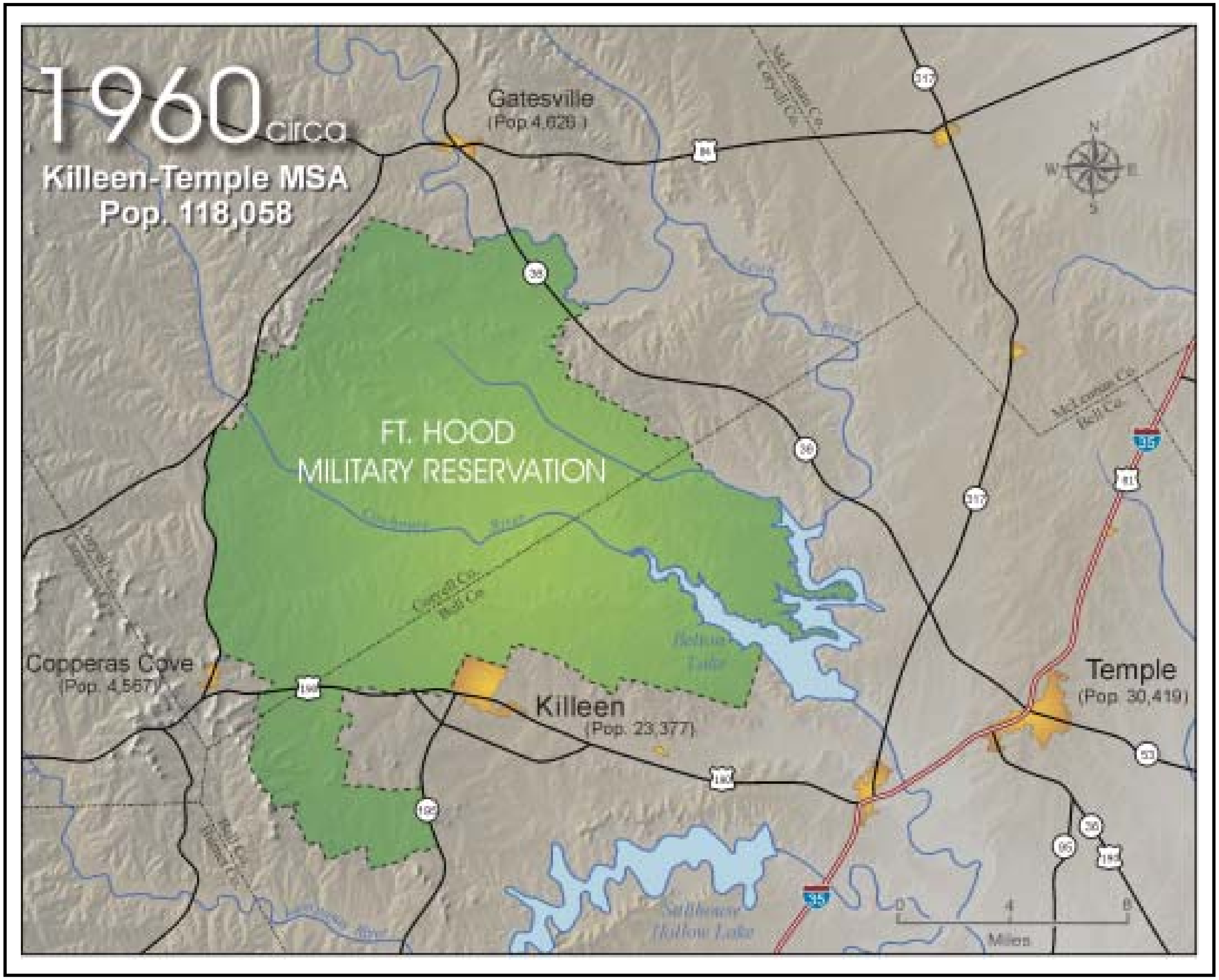

Figure A19. Fort Hood / Killeen, frame 1 (1960).

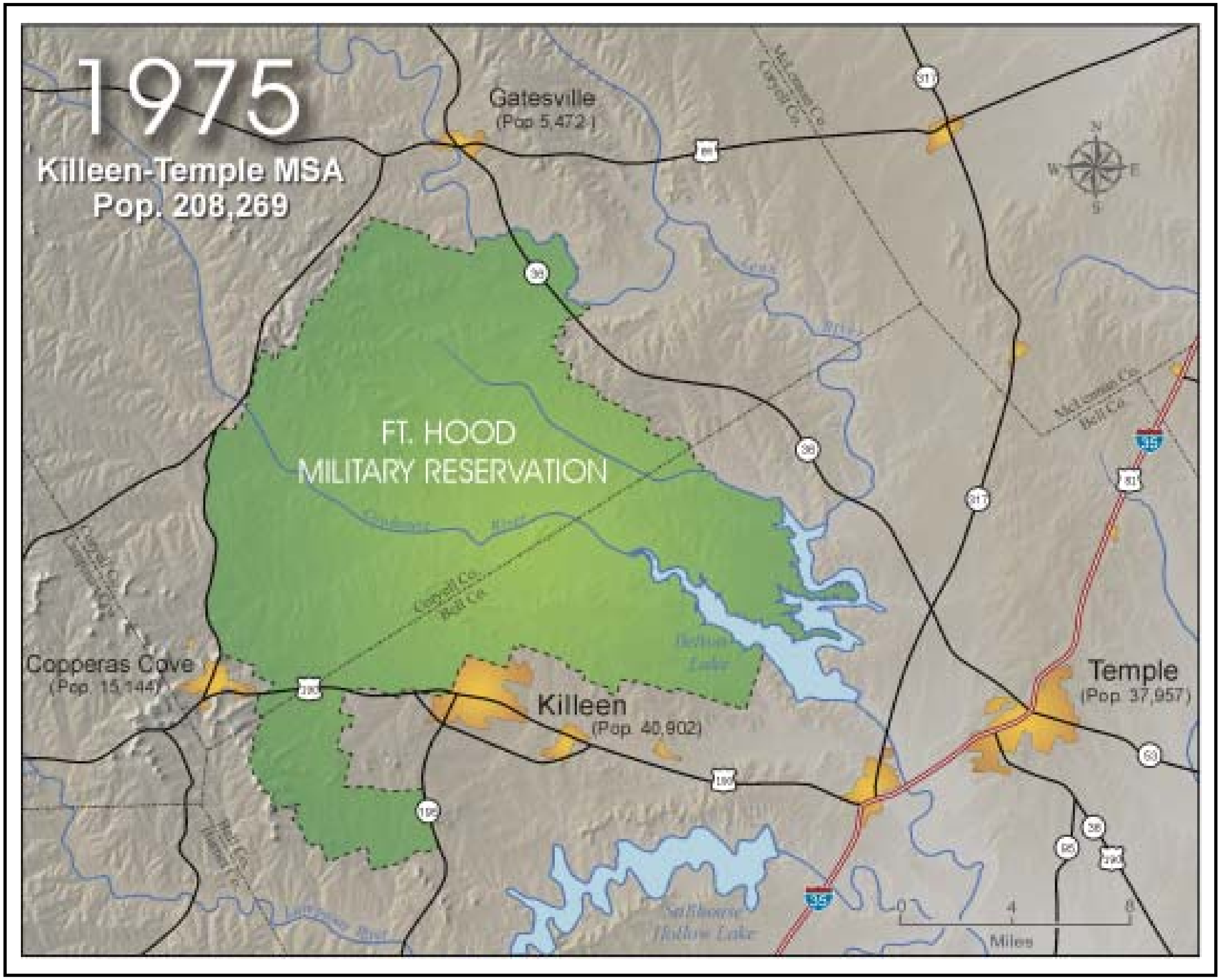

Figure A20. Fort Hood / Killeen, frame 2 (1975).

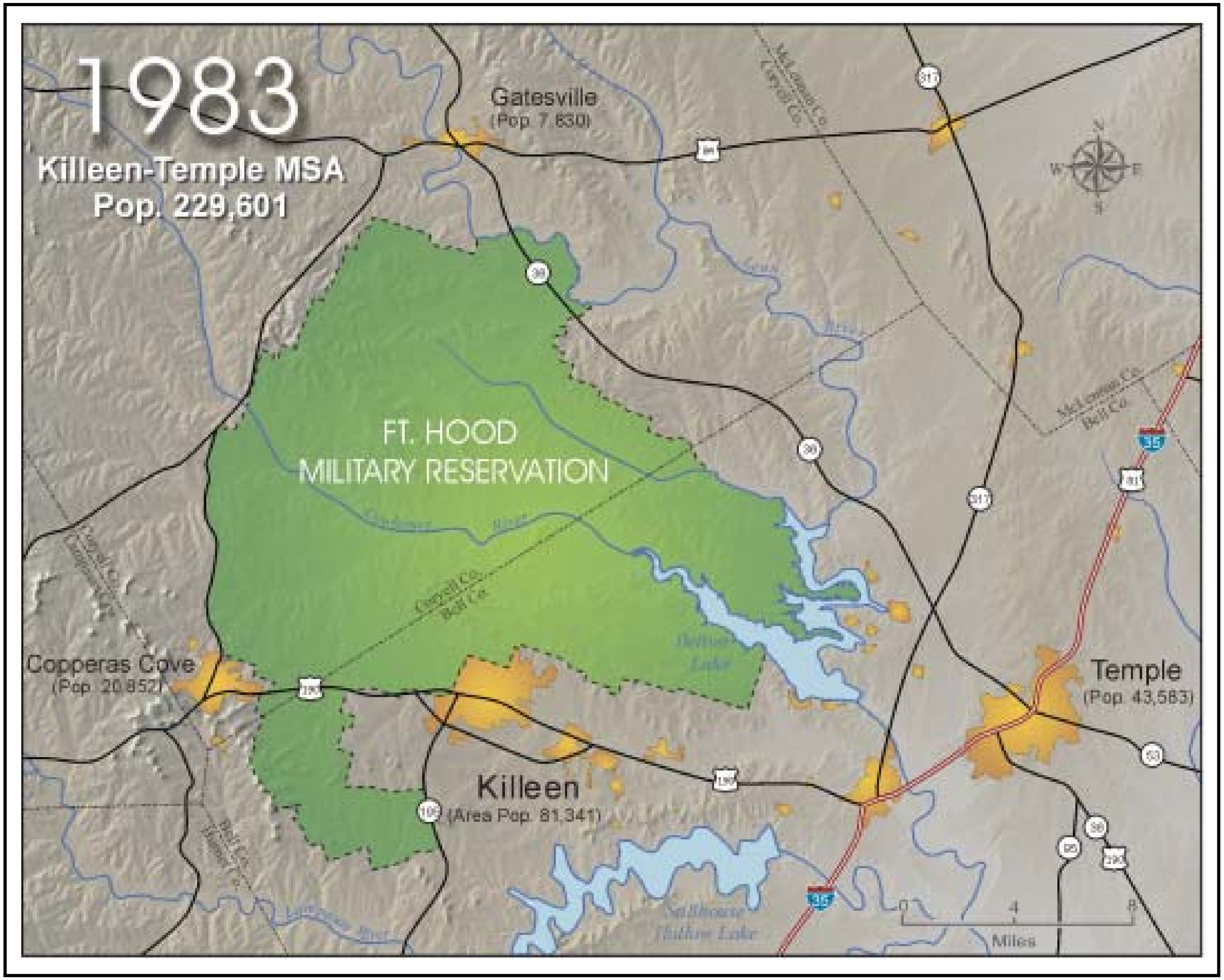

Figure A21. Fort Hood / Killeen, frame 3 (1983).

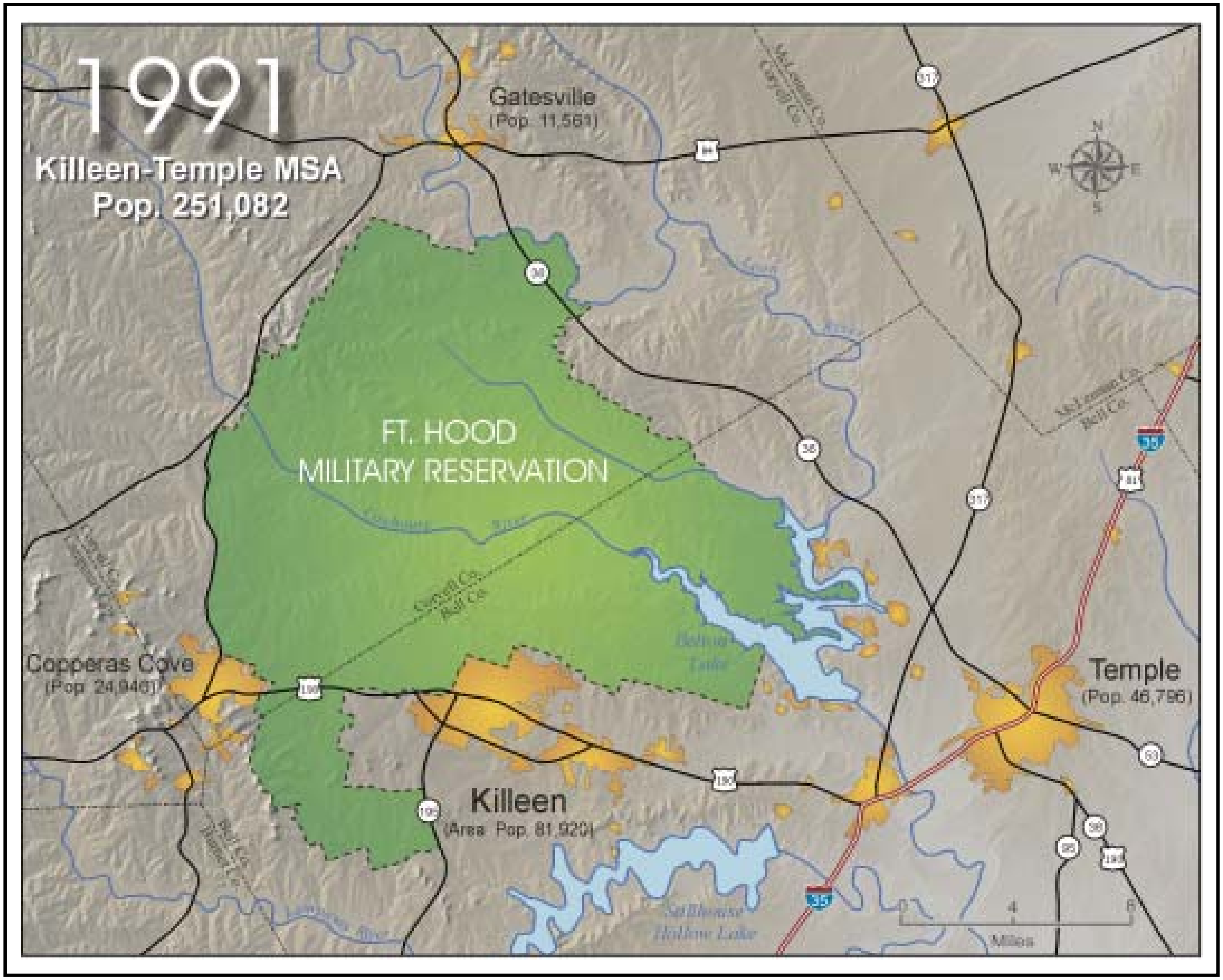

Figure A22. Fort Hood / Killeen, frame 4 (1991).

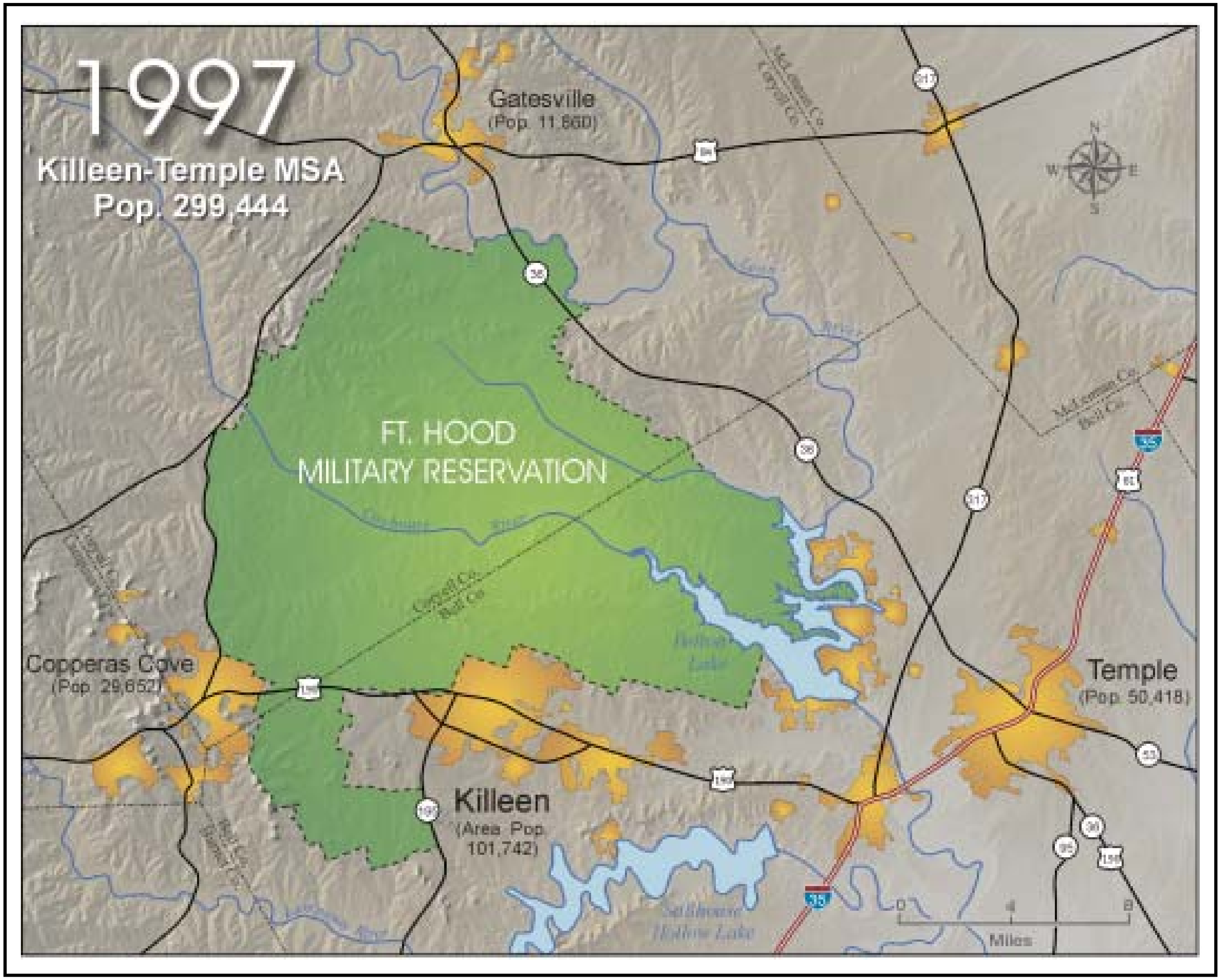

Figure A23. Fort Hood / Killeen, frame 5 (1997).

Appendix B: Background Digital Elevation Model

A digital elevation model (DEM) can be used as a supplemental layer within the series not only to present a more professional quality product, but to represent how topography can influence urban growth. The USGS is the best source for DEMs, as they provide virtually nationwide coverage and make their products available for a nominal delivery charge. (They can also be downloaded for free from www.gisdatadepot.com). While DEMS are available at many scales, the most commonly used scales are the 1:24,000 and 1:250,000. There are some regions for which USGS DEMs are not available at all scales.

There are a few options for incorporating terrain into a map output, depending on the available software resources and interests of the developer. Using ESRI's Spatial Analyst product, DEMs can easily be imported and a 2-D terrain rendered automatically. A methodology for doing this can be found in ESRI's documentation for Spatial Analyst.

Alternatively, National Park Service ranger Tom Patterson has developed a method to create terrain within a graphic imaging program such as Adobe Photoshop. This second method produces a more visually pleasing result that is easily incorporated into a graphic product. The following procedures, based on Patterson's method, describe the approach used to develop a terrain layer for the Camp Pendleton, Fort Benning, and Fort Hood growth series. Items required for this procedure are:

- DEM data (available free over the internet)
- Adobe Photoshop
- MicroDEM (a freeware tool for DEM manipulation, available from http://www.nadn.navy.mil/Users/oceano/pguth/website/microdem.htm)
- WinZip (an evaluation version available from http://www.winzip.com)

Download the individual DEM files from the web, and use MicroDEM to mosaic or stitch these together into one file. After the file is put together, remove the gridlines and change the compiled DEM to grayscale (Figure B1). Then output the DEM as a *.bmp file.

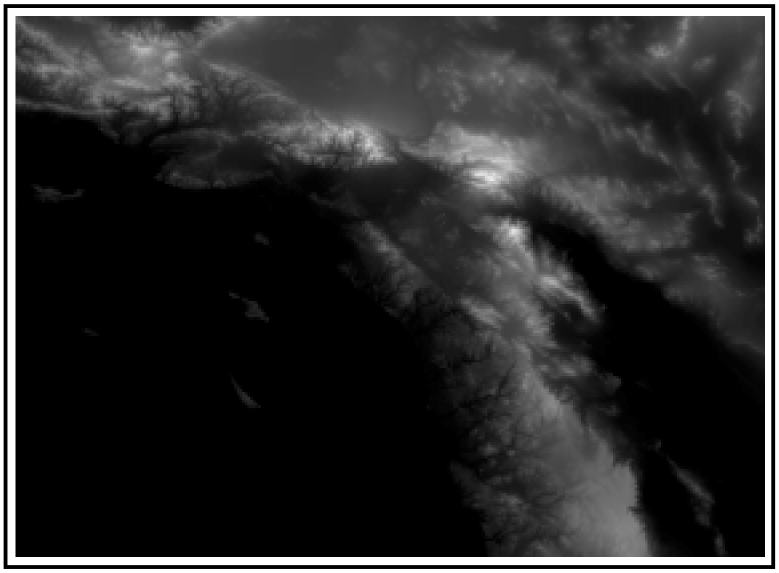

Figure B1. Mosaiced gray-scale DEM produced by MicroDem.

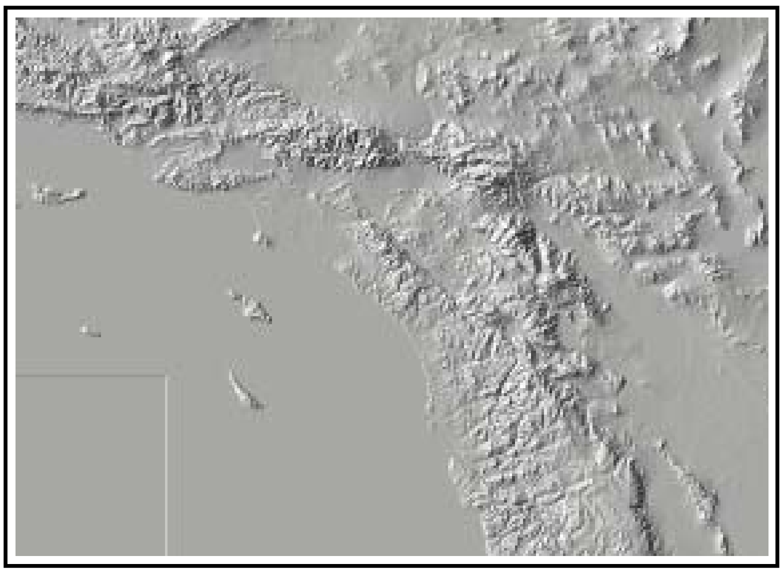

Figure B2. Shaded Relief produced by applying a lighting filter in Adobe Photoshop®.

The DEM can now be brought into Adobe Photoshop to begin hillshading. A lighting filter is applied to the DEM to create a texture that replicates the 2-D terrain (Figure B2). Patterson (1997) describes the process for creating the shaded relief in detail within his article. The DEM may need some clean-up previous to following the steps Patterson provides. Depending on the quality of the DEM (Level 1 = poor; Level 2 = average, Level 3 = excellent), the burn and dodge tools may be used sparingly (as Patterson suggests) to smooth out any inconsistencies or artifacts in the DEM that may cause problems such as edge matching or elevation spikes.

A variety of techniques can be used to alter the shaded relief from its gray-scale form. Resampling, hypsometric tinting, and readjustment of the light source are only a few modifications mentioned by Patterson. Different techniques will be used for different areas because of the various types of terrain in the United States. Below (Figures B3 and B4) show just a few examples from Camp Pendleton of how the DEM can be presented in the map series. The key is to experiment until the desired effect is reached.

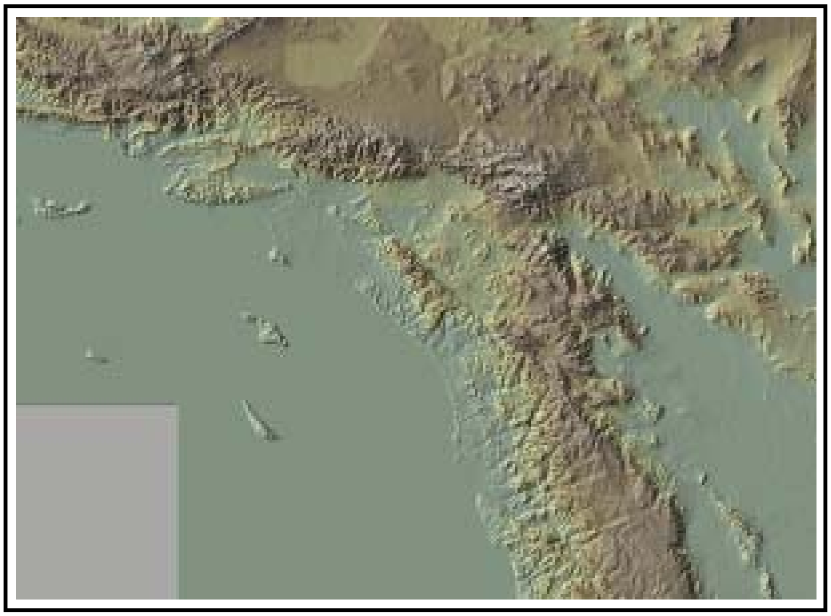

Figure B3. Shaded relief produced with hypsometric tinting.

Figure B4. Shaded relief produced with a serene shading technique.

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14. ABSTRACT

As communities that neighbor military installations expand and approach installation boundaries, the installations are increasingly asked to alter activities within their boundaries to alleviate conflicts. One approach to the problem is to track historical urban growth in areas surrounding military installations so that military and civilian planners can anticipate and devise appropriate strategies to deal with potential conflicts. One approach is the "installation-specific historic urban growth series," developed by the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL). This visual presentation quickly conveys the potential for conflicts as the separation between military lands and the neighboring community diminishes. This work investigated issues relevant to this documentation process, and developed and tested the process by designing case studies for four military installations.

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land use planning; military training; urbanization; military lands; risk assessment

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19a. NAME OF RESPONSIBLE PERSON
Brian M. Deal

19b. TELEPHONE NUMBER (include area code)
(217) 352-6511, X-7461