

GIS for Public Safety

An Annotated Guide to
ArcGIS Tools and Procedures

For Version 9.3

JOEL M. CAPLAN, PH.D.

RUTGERS



Center on
Public
Security



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ArcGIS Tools and Procedures

For Version 9.3

• *First Edition*

By
JOEL M. CAPLAN, PH.D.

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PREFACE

What is Public Safety?

Public safety means programs carried out or promoted for public purposes. This involves, directly or indirectly, the prevention of, protection from, and/or response to natural or man-made events that could endanger the safety or security of people or property in a given area¹. Public safety embraces an interdisciplinary framework to address these threats and respond to the needs of the general public.

Using GIS for Public Safety

Considering the spatial context of activities and events is important because everyone operates in space. This is a simple idea, but it is often overlooked. Think about it: your activities, legal and illegal, happen at some location on Earth. Therefore, public safety and individual risk can change with the geography—whether it's one side of a street or one side of town.

A Geographic Information System (GIS) is a tool that adds the dimension of geographic analysis to research and evaluation by providing an interface between data and a map. GIS has proven to be an ideal platform for the convergence of public safety-specific information in relation to historical events, natural or man-made disasters, vulnerable populations, and critical infrastructure key to a community's sustainability. Data and information in different formats from different locations can be integrated and displayed in GIS. The data can be quickly queried, analyzed, and displayed through a map. It can then be easily disseminated, understood and acted on.

About this Book

This book focuses on ESRI's ArcGIS functionality and presents many of the tools and procedures that are commonly used by public safety researchers and practitioners. It gives simple steps for descriptive, exploratory, and explanatory mapping tasks and includes concise but meaningful discussions to let you critically assess and accurately apply the software to your unique specialty. This provides a solid foundation for advanced spatial thinking and permits you to utilize GIS technology in your own innovative ways. This book is intended for an introductory audience, but GIS users at all skill levels will find value in it as a reference manual. "Introductory" does not mean limited content. Rather, it means that the focus of the book is on the technical (not theoretical) aspect of GIS mapping.

If you do not already own ArcGIS Desktop, you may download a free trial copy at www.esri.com. The download includes a full version of the software at the ArcEditor license level and all extensions discussed herein. If you are a student with a valid ID card, you might also consider purchasing the software at the discounted educational rate (as much as 80% off the regular price—good deal!).

PC or MAC?

PC is preferred. ArcGIS by ESRI is designed to run on a Microsoft Windows operating system. But with tools such as Parallels (www.parallels.com) or Boot Camp (part of MAC OS X Snow Leopard; www.apple.com), Intel-based Macintosh computer users can run ArcGIS products. (Just use an external mouse or learn how to right-click).

CHAPTER ONE

Introduction to Mapping and ArcGIS

What is GIS?

A geographic information system (GIS) is a computer software application for managing, editing, analyzing and displaying data which is spatially referenced to the Earth. GIS is a tool with which data can be layered with base maps that represent the landscape of the area where the data is associated. Base maps could represent the street network, buildings, census tracts, or local land-use patterns. These data can be represented as individual layers, displayed as separate entities, or be combined with other layers to be displayed together².



Imagine GIS as a high-tech overhead projector from the “old days” that used transparent plastic sheets and dry-erase markers as inputs that were then projected on a wall. If you think of each transparent sheet as a separate map layer, and you place all of the transparent sheets (map layers) on top of each other, you can see through all of them at-once. In this way, you can see relationships among the data that overlap in certain areas. Essentially, GIS does this in much more sophisticated ways.

Visualizing multiple map layers offers a means of exploring relationships among different data variables. For example, a map that only shows burglary points and absolutely no other data may not be particularly helpful. But, the burglary data can be layered with base map data that displays the street network to show where these burglaries were committed. A third layer could display all the properties across the area (e.g. owner occupied, rented, vacant buildings)³. These three layers might suggest that burglary incidents are highest on side streets—not major roadways—and in the areas where there is also a high percentage of vacant properties.

GIS Components⁴

A GIS has five components: hardware, software, people, data and storage. The bare minimum for **hardware** is a computer. GIS hardware requirements might also include peripherals such as a printer, plotter, or scanner. PDAs or GPS technology may also be used to synchronize data captured in the field to a central database⁵. Digital **storage** drives are also needed to keep large amounts of data.

Off-the-shelf GIS **software** products possess a wide range of functionality; though, software extensions can be added for advanced analysis and map production⁶. Some relevant software extensions include Spatial Analyst (for ArcGIS) and Spatial Predictive Analysis Crime Extension (SPACE). Specialist crime mapping software is also available such as GeoDa, School COP, and CrimeStat. Quantum GIS (QGIS; www.qgis.org) is a user friendly Open Source GIS that runs on Linux, Unix, Mac OSX, and Windows. It supports numerous vector, raster, and database formats and functionalities, and it is free to download and use.

Operating a GIS involves bringing together the computer files that contain the data to be used, and possibly editing them, querying against them, linking them, adding new data and generating a display for output. A GIS requires trained **people** to perform these technical skills, as well as to ask spatial questions and interpret and communicate findings⁷.

Data must have a geographic reference such as ZIP codes, street addresses, or x,y coordinates that can be used to link it to a map. Data collected via Excel, Access, Oracle, or any other type of spreadsheet or database management system has potential for use in a GIS⁸.

Choosing GIS Resources for Your Organization⁹

People

GIS users need to be technically skilled in specialized computer software and cartography, but should also be knowledgeable about your organization's mission and goals in order to conduct appropriate analyses and communicate findings effectively. You can train in-house staff to perform technical and conceptual GIS tasks; however, this could require a large investment of time and money—especially initially. Although this book can be a useful reference for the novice or advanced GIS user, learning to manage, map, and analyze data with ArcGIS is most effective if done initially with an experienced instructor in a tutorial or classroom setting. The person designated as the GIS specialist will likely need to take a college-level GIS course or attend specialized training workshops. ESRI and other GIS software developers also offer free online training videos, tutorials and workshops to help get you started. In addition to (or in place of) hiring GIS specialists or training existing staff, there are several other ways to find people to meet your organization's GIS needs. Internship opportunities, for example, can benefit both the students and your organization. Internships usually do not require extensive financial investments, especially if they are unpaid. Some universities require an internship as part of their curriculum, so the student's experience at your organization can be used towards college credit and serve as a critical component of their academic and professional development. Contests and scholarship opportunities are other ways to gain fresh perspectives on issues from the most competitive young minds. You may get a variety of innovative answers to your questions in exchange for a modest award to the winning applicant(s).

Software

Custom: Depending on the needs and resources of your organization, customized web-based or desktop GIS applications might be appropriate. Custom software can be designed with the most useful and relevant functionality to meet your organization's needs. This approach might require additional hardware (such as web servers) and can be expensive to design and maintain, but it is something to consider if you want a more streamlined GIS that can be used by one or many users with minimal training. The Cartographic Modeling Lab's Neighborhood Information System is one example of a publicly-available customized mapping application (www.cml.upenn.edu/nis). Many software developers specialize in custom GIS applications (be sure to check references and see examples of past work).

Off-the-shelf: There is a variety of off-the-shelf GIS software applications available for managing, editing, mapping, and analyzing spatial data. Free applications such as Quantum GIS and GRASS (Geographic Resources Analysis Support System) do not always come with user manuals and may not be useful for those who do not already have some basic GIS experience. ArcExplorer is a free GIS viewer by ESRI that includes supporting materials and is intended only to display, query and retrieve data. A list and brief description of other free GIS software applications is at www.freegis.org. PolicyMap (www.policymap.com) provides subscribers with web-based GIS applications to make maps, tables and charts using the company's database or uploaded user data. MapInfo Professional (www.pbinsight.com) is a Windows-based mapping and geographic analysis application by Pitney Bowes that has a long history of use in the public safety sector. ArcGIS by ESRI allows for mapping and advanced spatial analysis of geographic data, and is the focus of this book. Although this book is written for an ArcGIS user, be sure to consider all software options to meet the visual and analytical needs of your organization in the most sensible and meaningful way.

Is GIS Right for You? Guided Worksheet

Instructions: Before you invest time and money into purchasing the components of a GIS and training people to use it, be sure that it is right for you. Use this worksheet for guidance in answering if GIS might be a sound investment and a valuable tool for your organization.

What are the needs and goals of your organization?

How might GIS mapping help to achieve your organization's needs and goals?

Management decisions:

Needs assessment:

Resource allocation:

Research/evaluation:

Predictive modeling:

Strategic planning:

Other:

What spatial questions might you ask that a GIS can help answer?

- 1.

- 2.

- 3.

Is GIS Right for You? Guided Worksheet, page 2 of 3

Does the data that your agency and its partners maintain include geographic references such as street addresses or XY coordinates?

Yes No

If no, how can you begin to collect this information?

If you are considering GIS now or in the future, then you must ensure the integrity and consistency of your data. The accuracy and standardization of addresses and other variables will contribute to the overall ease or difficulty with which the data is integrated into a GIS.

Data are essential to mapping. Data collected via Microsoft Excel or Access, Quattro Pro, Oracle, or any other type of spreadsheet or database management system has potential for use in a GIS because they can export data in dBASE IV (.dbf) format. "Shapefiles" (.shp) are another compatible data format.

Do you have access to existing data in these formats? Yes No

What other data will you need in addition to the data that is available from your agency or its current partners? (Check all that apply)

- | | |
|---|---|
| <input type="checkbox"/> Census data | <input type="checkbox"/> Locations of courts |
| <input type="checkbox"/> Roads | <input type="checkbox"/> Jurisdictional boundaries of particular agencies |
| <input type="checkbox"/> Neighborhood boundaries | <input type="checkbox"/> Locations of public assistance agencies |
| <input type="checkbox"/> State/county boundaries | <input type="checkbox"/> Locations of public housing |
| <input type="checkbox"/> School/political districts | <input type="checkbox"/> Locations of hospitals and emergency rooms |
| <input type="checkbox"/> Transportation routes | <input type="checkbox"/> Locations of social/human services |
| <input type="checkbox"/> Park and recreation areas | <input type="checkbox"/> Locations of youth shelters |
| <input type="checkbox"/> Crime incidents | |
| <input type="checkbox"/> Locations of police stations/substations | |
| <input type="checkbox"/> Locations of prisons and jails | |

Other required data:

Are these additional data feasible to obtain? If yes, from where? If no, why not?

Is GIS Right for you? Guided Worksheet, page 3 of 3

In addition to people and data, GIS requires certain hardware and software components.

Do you have or can you obtain a computer with at least 1GB RAM and 1.6 GHz processor?

Yes No

Off-the-shelf desktop software products possess the majority of basic GIS functionality. ArcView by ESRI, for example, retails for approximately \$1,500; extensions for advanced analytical capability cost more. If you are a non-profit organization then you may qualify for a discount.

Is the software affordable to your agency? Yes No

People who operate GIS usually require some form of training to perform technical skills, as well as to ask spatial questions and interpret and communicate findings appropriately.

Are you willing and able to commit personnel and other resources towards training?

Yes No

If you believe that GIS would be valuable to your agency, but do not want to or cannot afford to commit time and resources to it now, then you can partner with other people or organizations.

With whom could you partner?

- Faculty or students at a college or university
- Student interns
- Other:

Representing Objects (Features) in a GIS¹⁰

Spatial objects, or features, can be represented in three ways on a map: points, lines or polygons.

- **Points** can either be represented as a dot or other symbol. Locations of hospitals, for example, may be represented with the **H** symbol rather than a dot.
- **Lines (also known as polylines)** are straight-line objects connecting two points. A polyline depicting a curved line (arc) is actually a series of straight segments. Lines can be displayed in a range of fonts (e.g. continuous or dashed) and in different colors and thicknesses¹¹. Bus routes, streets, and rivers are usually represented using lines.
- A **polygon** is a closed area represented around its perimeter with a polyline. It exists as a solid object for the region it covers¹². Police beats, counties, states, and ZIP Codes are examples of polygons.

Attribute Tables

Descriptive information about GIS features is stored in attribute tables. For example, an attribute table for point features representing crime incidents could include the crime type, the date of the crime, the time of the crime and the address of where the crime occurred. There is always one record in the attribute table that corresponds to each feature on the map. Attribute information can be used to view, select, analyze, and display features in a variety of ways on a map.

The attribute table and the features are linked together so that when a point, line or polygon is queried in a map view the attribute data for the object is also selected (as shown below).



Attribute tables in a GIS will always have at least three columns: FID, Shape, and ID. This information is used to define the feature and the corresponding record in the attribute table so that a one-to-one correspondence is maintained between the feature on the map and its attribute record. Basically, attribute tables act as a key table between map features and additional information about each feature.

Attribute Tables Support Many Fundamental GIS Operations¹³, such as:

- Tables organize and manage descriptive data about features.
- Tables are used for statistical summaries of descriptive data.
- Arithmetic and logic operations on rows and columns in tables are used to select features and to calculate new information for features.
- Tables are used to relate other information with features

DBF Files

Attribute tables are stored in the dBase file format (.dbf). dBase was the first widely used database management system (DBMS) for microcomputers. dBase gradually lost market share to competitors because it was slow to transition successfully to Microsoft Windows. Nevertheless, its underlying file format, the **.dbf file**, remains widely used in many contemporary applications that need a simple format to store structured data. The "shapefile" format for ArcGIS uses .dbf files to store feature attribute data.

Types of GIS Data

Tabular Data

Tabular data is where you store attribute information about map features. ArcMap can only work with Excel (.xls), comma-delineated text (.txt) and dBase (.dbf) files, so you will need to convert your tables to one of these formats before adding it to ArcMap.

Geographic Data

Shapefiles are the standard format for geographic data in ArcGIS. Shapefiles are made up of three or more separate files that all need to be located in the same directory in order for ArcMap to recognize them as parts of a shapefile. *NOTE: shapefiles are used for vector GIS data. Raster GIS data are stored in files that are more similar to images.*

Images

ArcGIS allows you to import and export many different types of images. The images you import may be scanned paper maps, aerial photos, or other pictures that you “hot link” to your map features. You can export finished maps in ArcMap in a number of formats: EMP, BMP, EPS, TIFF, PDF, JPEG, CGM, JPEG, PCX, and PNG.

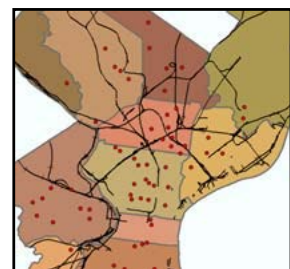
Shapefiles and Vector Data

Vector Data

Vector is the most common model for GIS data used in the social sciences. It uses points, lines, and polygons to represent map features. Vector data is excellent for representing discrete objects such as parcels, streets, and administrative boundaries. The vector format is not as good for representing things that vary continuously over space, such as temperature and elevation.

Shapefiles


Environmental Systems Research Institute (ESRI; the maker of ArcGIS) created the shapefile format in order to represent vector GIS data. Other GIS programs will use shapefiles, but geographic files from other GIS programs must be converted to shapefiles before ArcGIS applications can read them. As with other formats of geographic data, shapefiles link information about the location and shape of the map features to their attributes.



Shapefiles are made up of three or more files that need to be stored in the same directory in order for ArcGIS to recognize them. The most common files that make up shapefiles are:

.shp - the file that stores the feature geometry (point , line , polygon )

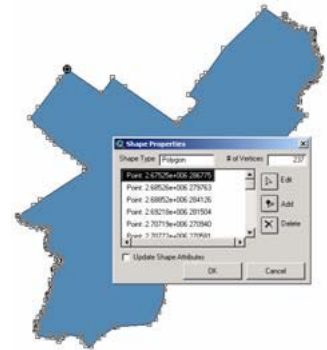
.shx - the file that stores the index of the feature geometry

.dbf - the dBASE file  stores the attribute information of features. When a shapefile is added as a theme to a map view, this file is displayed as a feature table.

.sbn and .sbx - the files that store the spatial index of the features. These two files may not exist until you perform theme-on-theme selection, spatial join, or create an index on a theme's shape field.

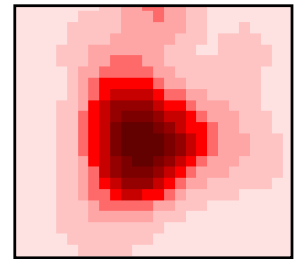
.prj – the file that stores information about the projection. This will only exist for shapefiles with defined projections.

The shapefile stores information about the shape of the map features, describing them in the “shape” field of the attribute table as point, line, or polygon. It also stores information about the real world location of each vertex that makes up the map features. Using this information, ArcGIS can perform spatial analyses.



Raster Data

Raster data use grids made up of regularly-sized cells to represent spatially continuous data. Each cell is assigned real world coordinates and one attribute value (such as precipitation level or elevation). The user defines the cell size, allowing for very fine or coarse raster surfaces. Even when the cell size is very small, you can see the individual square cells when you zoom in. Raster grids cells are like pixels on a TV or computer screen. Whereas shapefile-based map layers are oriented toward the depiction and analysis of discrete objects in space (represented as points, lines, or polygons), raster grids are oriented more toward the qualities of space itself.

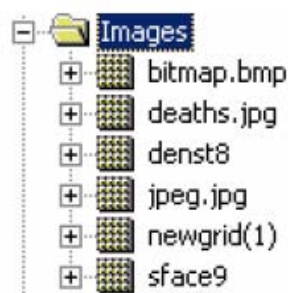


In order to work with raster data in ArcGIS, you need the Spatial Analyst extension. When raster layers have the same size cells, their values can be added, subtracted, multiplied, divided and queried using map algebra.

You can add raster data to ArcMap just as you do vector data, using the “Add Data” button. If the raster data have no spatial information (e.g. a scanned map that has not been georeferenced), ArcMap will not be able to display it with other map layers. In this case, you may need to “georeference” the raster data.

ArcGIS saves raster layers in its GRID format. ArcCatalog recognizes GRIDs and other image formats (including BMP, JPEG, TIFF) as raster layers. Images with no extension (such as “denst8” shown below) are GRIDs. If you view a GRID outside of ArcCatalog, it will consist of several files within a directory.

Raster Data in ArcCatalog



Raster Data in My Computer



Introduction to ArcGIS

ArcGIS is a scalable system of GIS software produced by Environmental Systems Research Institute (ESRI). This system contains three different products: ArcView, ArcEditor, and ArcInfo.

- **ArcView:** ArcView is the desktop version meant for a general (non-professional) audience. It is the most popular desktop GIS software program.
- **ArcEditor:** ArcEditor includes all the functionality of ArcView, adding the ability to edit features in a multi-user geodatabase so that multi-user editing and versioning are possible. ArcEditor also adds the ability to edit topologically integrated features in a geodatabase.
- **ArcInfo:** ArcInfo is ESRI's professional GIS software. It includes all of the functionality in ArcView and ArcEditor, and adds some advanced geoprocessing and data conversion capabilities.



Introduction to ArcView 9

ArcView 9 includes two separate applications: ArcCatalog and ArcMap. Although they are designed to work together, they run under separate executable files (.exe) so they each have their own icons.



arccatalog

ArcCatalog works sort of like Windows Explorer. It is a place to browse and manage your data. You can also create and edit metadata in ArcCatalog.



ArcMap

ArcMap is where you actually create maps and analyze spatial data.

ArcToolbox is integrated directly into ArcCatalog and ArcMap. It gives access to advanced geoprocessing tools, data conversion tools, and much of the ArcInfo functions.

Introduction to ArcCatalog

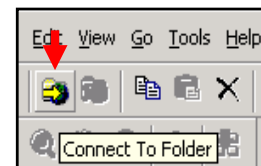
ArcCatalog is designed to help manage your spatial and non-spatial data. Using ArcCatalog may seem awkward at first, but doing so will develop good GIS habits, so it is worth the effort.



Connecting to Folder

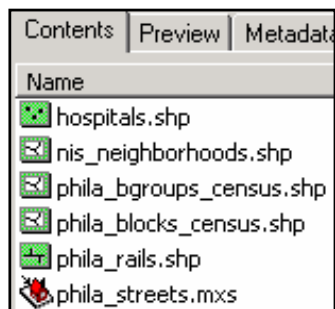
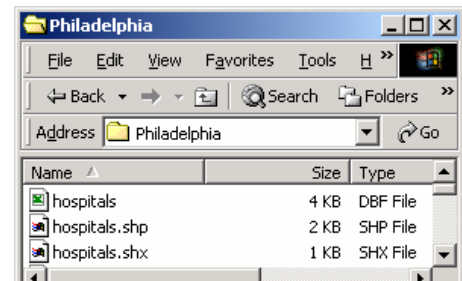
File > Connect Folder -or- Click the "Connect to Folder" Button

When you launch ArcCatalog (from the Start menu, go to ArcGIS, then ArcCatalog, or add a shortcut to your desktop), a list of all the folders and sub-folders on your computer will be displayed on the left in the catalog tree. "Connect to folder" allows you to make a direct connection to the place on your computer where your GIS data are stored. This is not necessary but will save time. You will use these same shortcuts in ArcMap (and you can connect to folder from ArcMap, as well). From the file menu, go to "Connect Folder..." or click on the "Connect To Folder" button (yellow arrow against a globe). Navigate until you find the folder with your data and click "OK." Your folder should now be listed under "Catalog" next to an icon.

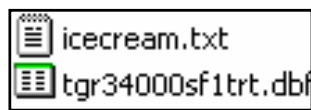


Seeing File Types

When the contents tab is active, ArcCatalog will indicate the type of file using icons. Shapefiles, the format for geographic files in ArcGIS, are made up of three or more separate files. If you viewed them outside of ArcCatalog (e.g. in Windows Explorer or through My Computer), you would see all of the files listed with extensions such as .dbf, .shp, .shx (see example at right).



In ArcCatalog these various files will appear as a single shapefile. ArcCatalog also indicates what kind of shapefile: point, line, polygon, or geocoding service. In the example on the left, the file “hospitals.shp” is made up of points, “nis_neighborhoods.shp” is made up of polygons, and “phila_rails.shp” is made up of lines. “phila_streets.mxs” is a geocoding service. This means that it has been indexed so that you can use it to geocode addresses. By copying and pasting shapefiles using ArcCatalog, you insure that you will keep all of the components of a shapefile together.



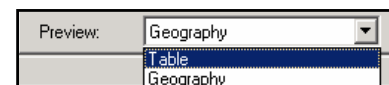
Tables that contain no spatial information can also be displayed in ArcCatalog. The icon changes depending upon the type of table. Images can also be displayed in ArcCatalog.

Basic Tasks in ArcCatalog

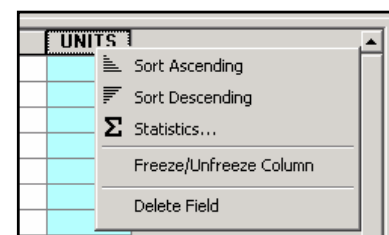
Previewing Files

By making the “preview” tab active, you can look more carefully at files. When the preview drop-down menu at the bottom of the window is set to “geography,” you can see what your geographic data looks like mapped. You need to view your data in ArcMap in order to make changes to the way it displays, but this preview in ArcCatalog allows you to look at it quickly. You can also view images in the preview mode (ArcCatalog may ask you if you want to build pyramids in order to display these more quickly, which is probably a good idea).

Switch the preview drop-down to “table” in order to view the attributes associated with your geographic features.



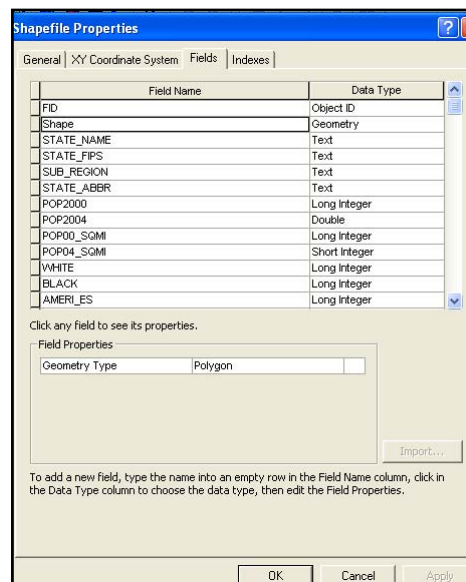
In the table preview mode, click on the “options” button to add a new field or export the table. Right clicking on a column heading allows you to access a number of other functions such as sort, freeze/unfreeze column, delete field, and statistics (the statistics option is only available for numeric fields). You can also access these functions in ArcMap.



Checking Properties

Right-click the file > Properties

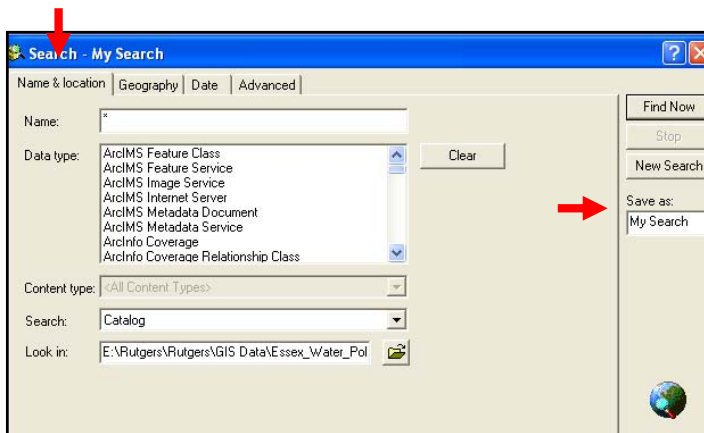
Double click on the file name to bring up the shapefile or table properties (or by right-clicking the file name and choosing “properties” from the menu). With the fields tab active, you can identify the data type for each of the columns in your table. When you click on a column name, the length of the field will appear below. When you click on the field name “shape,” several new field properties appear at the bottom. From the “spatial reference” field, you can see what datum and projection have been defined (if any). You can change or add to this information by clicking on the “...”. From the index tab, you can create attribute or spatial indexes in order to increase the speed of searching, querying, and drawing data.



Searching for Map Data

On the “Standard” toolbar, click the “Search” button

With ArcCatalog, you can search for geographic data on disk or across a network. You can search by name, file type, geographic location, creation date, or by other properties stored in the metadata. On the Standard toolbar, click the Search button.

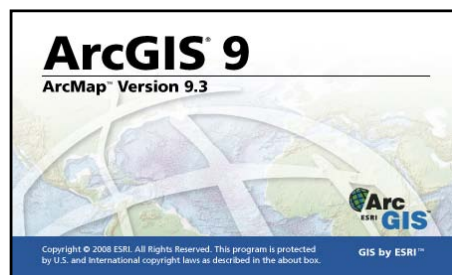


The “Search” dialog box opens with the “Name & location” tab active. The tabs on the Search dialog box give you different ways to search for data. On the Name & location tab, you search by file name or type. On the Geography tap, you search by geographic location. On the Date tab, you search by the date files were last accessed or by other dates in the metadata. On the Advanced tab, you search for keywords or other metadata text. ArcCatalog gives each search a name

and saves the results to a Search Results folder. It doesn't actually copy or move any data into this folder. Instead, it creates shortcuts, or pointers, to the data it finds.

Introduction to ArcMap

ArcMap is where you create maps and access most of the ArcGIS functionality. You can access some of the same functions through ArcCatalog and will need to decide for yourself which approach works best for you.



Starting ArcMap

From ArcCatalog, click the “Launch ArcMap” button

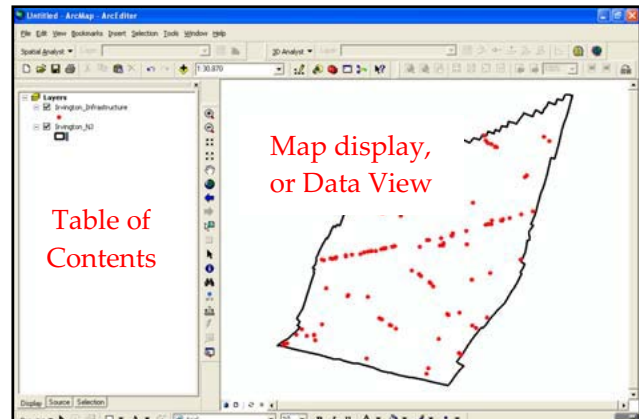


From Windows taskbar, Start > ArcGIS > ArcMap

When ArcMap opens, you will be asked if you want to open an empty map, use a template, or open an existing map. You can prevent this dialog from displaying again by putting a check mark in the “do not show this dialog again” box.

Customizing the Interface

ArcMap is made up of many different windows and (dock-able) toolbars that you can resize and move around, so don’t be surprised if ArcMap looks slightly different each time you open it.



The window that lists your map layers is the table of contents (TOC); the window that shows your map is the map display, or Data View. You can close the table of contents by clicking on the “x” and resize it by holding your cursor over the right edge until your cursor changes to a two-headed arrow. Left-click and drag the edge to resize this window. To move one of your toolbars, left click on the end (top or left), hold down, and drag to a new location.


Working with the Table of Contents

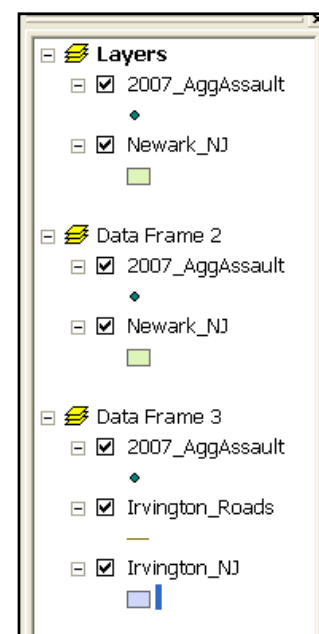
The table of contents has “display” and “source” tabs (at the bottom): When the display tab is active, the table of contents will only list data that can be drawn as a map layer. When the source tab is active, the table of contents will also show tables along with the path indicating where the data are stored. Turn on and off a layer by checking and un-checking the box next to it. Layers are drawn in the map display in the order in which they are shown in the table of contents. Map layers listed at the top will draw on top. To move a layer above or below other layers, left click and hold the mouse button down, then move the layer.

Data Frames

From ArcMap, Insert > Data Frame

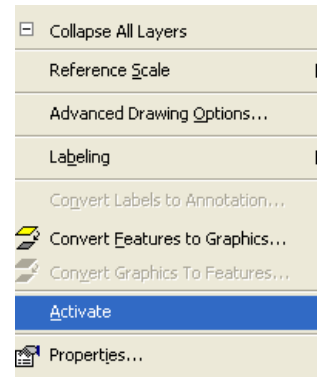
Data frames group map layers in ArcMap’s table of contents. Most of the time you will only need one data frame in a map document. But if you need to include more than one map in your layout (including the same map at a different extent), you will need two or more data frames (Also see “Creating Extent Rectangles” in Chapter Three).

When you open ArcMap, you will have just one data frame (called “Layers”) and every map layer you add to your map document becomes part of this frame. To add new data (e.g. shapefiles) to a particular data frame, right click on its name and go to “Add Data” or highlight its name and use the Add Data button  (or, Insert > Add Data).



If you want to move a layer to a different data frame once it is in ArcMap, right-click the layer > Copy. Then, right-click the data frame where you want to move the layer > Paste Layer. To remove the original copy of the layer, right-click it > Remove. *NOTE: Too many data frames can make your map document complicated and prone to crash.*

The layers in only one data frame can be displayed at a given time. It does not matter which data frame is listed first in the table of contents; it matters which one is “active”. To display and work with the layers in a data frame, right-click the data frame in the Table of Contents > Activate.



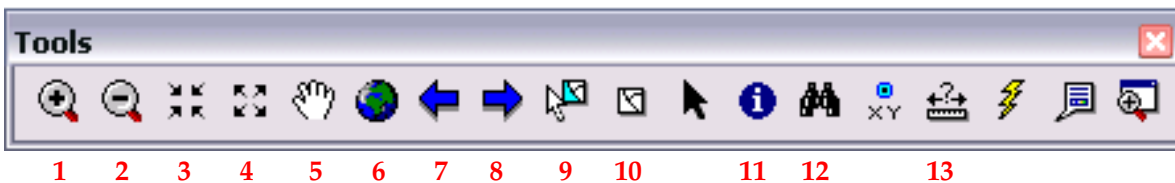
The Standard Toolbar

Most typically appears at the top of the ArcMap application window and is used for map printing, creating a new map, opening an existing map, saving your map, starting related ArcGIS applications, and more.



The Tools Toolbar

Used for map navigation and query within the active data frame.



1 and 2: The **Zoom In / Zoom Out** tools let you click on your map to zoom in or out at a fixed amount or to draw a box around the area that you want to see in more or less detail. The new map will be drawn so that the area you drew the box around is in the middle of the map display.

3 and 4: The **Fixed Zoom In / Fixed Zoom Out** tools work like the zoom tools when you click them rather than draw a box. Each time you click, you will zoom in or out a fixed amount.

5: Think of the **Pan** tool as a sticky hand. Left click on your map display, hold the mouse button down, and move your map. Your extent (amount zoomed in or out) stays the same while your map moves.

6: The **full extent button** will zoom in or out so that all of your active (checked) map layers can be viewed. You can also zoom in to a single layer by right clicking on the layer in the table of contents and choosing “zoom to layer.”

7 and 8: The **Go Back to Previous Extent** (7) button allows you to return to the extent you had before using one of the zoom tools. The **Go to Next Extent** button (8) allows you to jump forward an extent (after you have used the previous extent button).

9 and 10: The **Select Features** tool (9) allows you to select features on the map. The default in ArcMap is to select features on the top-most layer. The **Clear Selected Features** tool (10) clears any selected features on an active layer.

There are several ways you can select features with the **Select Features** tool: with your mouse pointer by clicking them one at a time or by dragging a box around them on the map. You can also select features in the map by selecting their records in the table or graph window with your mouse pointer. Features are simultaneously selected on the map, in a table, or in a graph. In order to view just the selected features in the attributes table, right click on the map layer that contains the selected feature(s) and go to “open attribute table.” This table includes all the attributes of all the features in that layer. In order to view just the selected feature(s), click on the “selected” button at the bottom of the table.

Applying a selection is also a way of specifying the features for which you want to calculate statistics, view attributes, move, and so on.

11: The points, lines, and polygons that make up map layers are all map features that have attributes stored in a table. You can access this information in several different ways. Using the **Identify** tool, click on a map feature in the map display. An “identify results” box will display all of the information known about that feature. Notice the layers dropdown menu. The default in ArcMap is to display information only about the top-most layer.

12: With the **Find** button, you can explore and query your data by finding particular geographic features, addresses, and places. Once the results of a query are displayed, you can navigate to the location. Click an entry in the results list to flash it on the map; double-click to pan to it (center the map on its location); or right-click to add a graphic marker or callout label at the place, create a spatial bookmark, add it to a list of your favorite places, and so on.

13: The **Measure** tool lets you to draw a line, or a series of connected lines, to roughly measure the Euclidean (straight-line, as the crow flies) distance between points. When you use the Measure tool in snapping mode, it will snap to the vertices of lines and polygons, or to point features, by default. This makes it easy to trace over features, such as to measure the distance between street intersections. If you want to snap to edges hold down Ctrl when measuring.

Using the Measure Tool

Click on your map at the starting point. Move your cursor to your end point, or next point, and click once, repeating until you are done. Double click to finish. ArcMap will display the cumulative distance in the bottom left part of the GUI (below the table of contents). Once you move your cursor outside of the map window, your results will disappear. *NOTE: The measure tool will use the display units you specified in the Data Frame Properties (right click on the name of the Data Frame > Properties > “General” tab).*

Adding Tools and Toolbars

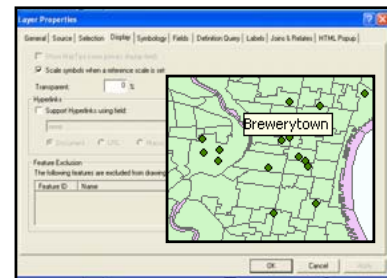
View > Toolbars

To add or remove a toolbar, left click anywhere outside of the table of contents, map display, or toolbar (somewhere gray) or, from the view menu, go to “toolbars.” Anything with a check mark next to it will be displayed. You can also add new buttons to your toolbars from the “customize” option. One especially helpful button allows you to zoom continuously. Choose the commands tab, scroll down to “pan/zoom,” then right click on the “Continuous Pan and Zoom” button on the right and drag it to your tools toolbar (the toolbar with the outline of a hand and an image of a globe in the middle) and release.

Showing Map Tips

From the Table of Contents, right-click on the layer > Properties > “Display” tab > check the “Show Map Tips” box

Map tips are small text boxes that appear when you hold the cursor over a map feature. You can determine which value in your attribute table is used in the map tips. To change the primary data field, make the “Fields” tab active in the “Layer Properties” dialog box and choose a field from the “primary display field” dropdown menu.



Getting Data into ArcMap

File > Add Data -or- Click the “Add Data” button

From ArcCatalog, you can click and drag shapefiles right into ArcMap (click on the file name in ArcCatalog and hold down, dragging to either the table of contents or map window and letting go).

Removing Data from ArcMap

From the Table of Contents, right-click the layer > Remove

This doesn't delete the original file. It just removes the layer from ArcMap.

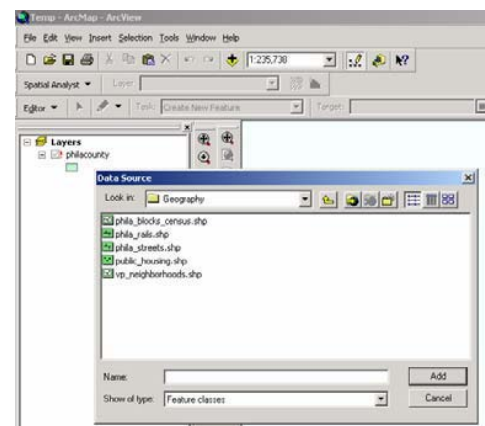
Saving Your Work

ArcGIS can integrate many different types of data into maps. The most common forms are tabular data and geographic data, but you may also use various images. Through ArcMap, you can create additional types of files, including map documents (.mxd) and map layers (.lyr). Naming and storing these files in a consistent manner will make your work with ArcGIS much easier.

Saving Map Documents

File > Save As

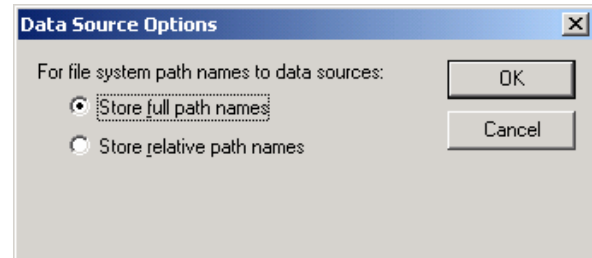
If you save all of your work in ArcMap (by going to the file menu, “save” or “save as”), you will create a map document (.mxd). This file will save all of the work you have done, including the data you have added and the changes you have made to layer properties, symbology, and the layout. This .mxd file does NOT save all of the data you included in your map. Instead, it includes information about the location of those files on your computer (or network, or Internet) and the formatting changes you made. This means that you



cannot move the data files you've included in a map document without running into problems. It also means that map documents are difficult to transfer from one computer to another. If you do move one of the files used in your map document, that layer will be shown with a ! next to it and will not draw when you open your map document. If you click on the grayed out check mark beside the layer name, ArcMap will bring up a dialog asking where you moved the file. Navigating to the file in its new location and clicking "add" will solve the problem, but this can be time-consuming (and frustrating) and is best avoided.

Using Relative Paths

File > Document Properties > click the "Data Source Options" button > select "Store relative path names to data sources" radial.



One way to minimize problems when you move files that are part of an ArcMap document is to use relative paths.

If you specify that you want to use relative paths, ArcGIS will be able to find the pieces of your ArcMap document if you move it or its components.

Map Layers

From the Table of Contents, right-click the layer > Save As Layer File

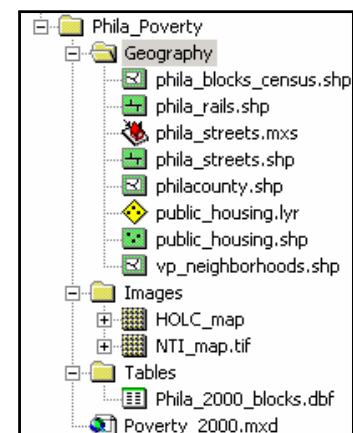
In addition to saving the entire workspace with a map document, you can save an individual map layer (.lyr). This file will store all the formatting changes you have made to the layer. This is particularly helpful if you want to use the same layer, with the same symbology, in another map document. As with the .mxd file, the .lyr file only includes information about the formatting and the path to the original data (generally a shapefile).

Naming Files

Giving your files clear and consistent names will make working with ArcGIS much easier. You need to develop your own naming convention that makes sense to you. ArcGIS can work with file names that are more than 8 characters, but really long names can be difficult to view. ArcGIS can also work with files that have spaces in their name, but this will create problems if you work with the Spatial Analyst extension. Your file names should help you distinguish the content and version of your data.

Storing Files

The most important thing in storing files for ArcMap is to think through a system BEFORE you start. Consider creating a new directory for each new mapping project. Keep all map documents in that directory. Create subdirectories for tabular data that are not associated with geographic files, geographic data, and images. Keep map layers in the subdirectory for geographic data.



Geodatabases

Geodatabases allow for topologically integrated features, similar to coverages used in ArcInfo, and define rules for the behavior of different types of objects. This provides a much more sophisticated approach to storing and managing data than using directories and subdirectories, and it works well for sharing data.

Introduction to ArcGIS Desktop Help

From Windows, click the Start button > Programs > ArcGIS > ArcGIS Desktop Help > ArcGIS Desktop Help

Sooner or later, you will need help with ArcGIS software. ArcGIS Desktop Help is the first place you should turn to get answers to basic technical, functional, and operational questions about ArcGIS applications.

You can access ArcGIS Desktop Help several ways:

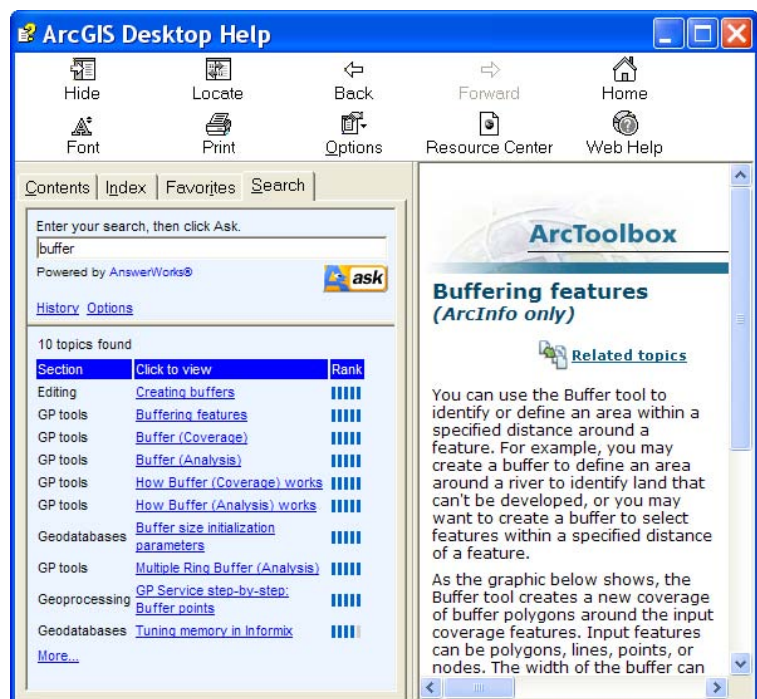
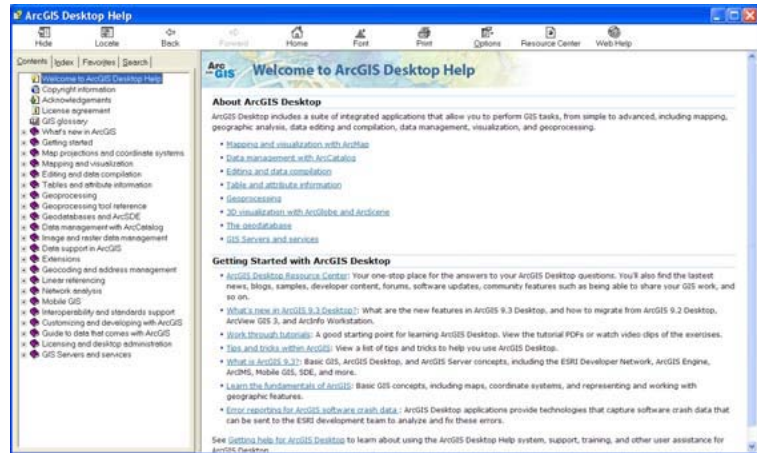
- From Windows, click the Start button > Programs > ArcGIS > ArcGIS Desktop Help > ArcGIS Desktop Help
- Press the F1 key from ArcMap or ArcCatalog
- From any ArcGIS application, click "Help" from the Main Menu, then click ArcGIS Desktop Help

The ArcGIS Desktop Help system contains a navigation pane—with Contents, Index, Search, and Favorites tabs—and a topic pane for viewing Help topics. Both panes are visible in the viewer at all times, allowing you to keep track of where you are in the Contents structure of the Help system.

Searching Help for Key Words

From ArcGIS Desktop Help, click "Search" tab



If you want to learn how to perform a specific task or if you need more information about a specific concept, it is best to search for Help topics that contain specific key words or phrases. After opening ArcGIS Desktop Help, click the Search tab. Type the key words you want to find. Click Ask.



All the topics in the Help system will be searched for the word or words entered. Click the related links that appear (in order of relevancy) to display the topic. View the topic in the topic pane on the right. *NOTE: Use double quotation marks to string together words in the search.*

Getting Help Directly Within the Applications

When you position the mouse pointer over a button or menu command, the name of the item appears. A brief description also appears in the status bar at the bottom of the application window.

- To get help on a command in a drop-down menu or button in a toolbar, click the What's This tool  on the ArcMap or ArcCatalog Standard toolbar, then click the item.
- To get help on a command in a context menu (menu launched by right-clicking), highlight the command and press Shift + F1.
- To get help on a control in a dialog box, click the "What's This?" button  at the top of the dialog box and click the control. On some dialog boxes there are also About or Help buttons, both of which provide additional Help information specific to the dialog box.
- To get help on a window, such as the Table of Contents or the Identify Results window, click inside the window, then press Shift + F1.

Direct access to the online Help for each tool and toolbox in ArcToolbox is available by using the "Show Help" button—in the tool's dialog box, which provides a general description of the tool and documentation for each parameter within a tool's dialog box.

CHAPTER TWO

Communicating with Maps

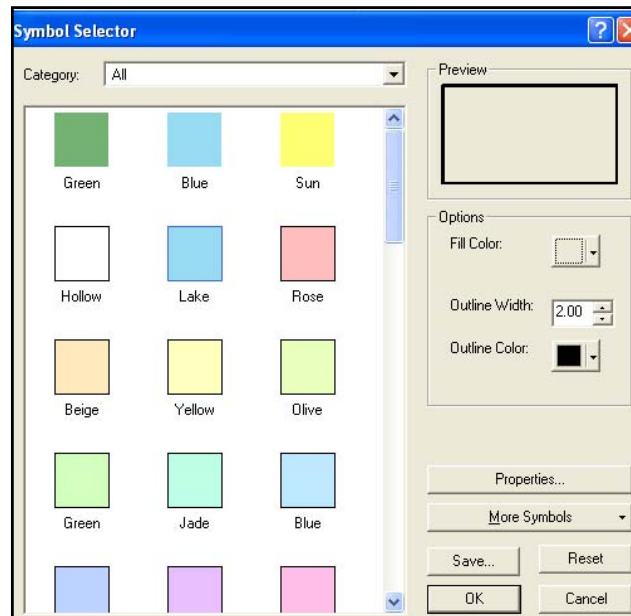
Map Symbology

From the Table of Contents, right-click the layer > Properties > “Symbology” tab

ArcMap has many options for changing the way your data are displayed. To make quick changes, click on the layer symbol in the Table of Contents. The “Symbol Selector” window that opens will look different depending upon the type of layer: point, line, or polygon. For points, you can choose a different marker from the default. When you choose a new marker, the default size jumps to 18 point (quite large). You can change the color, size, and angle using the options on the right of the window. For lines, the options are similar. For polygons, you have choices about the fill pattern, fill color, and

outline color. You can find many more symbols by clicking the “More Symbols” button. *NOTE: Remove the check mark next to one of the categories of symbols if you find that it is not helpful (to reduce the amount of scrolling necessary to find appropriate symbols).*

The “Reset” button will undo any changes you have made to the symbol since opening the symbol selector window. The “Properties” button gives you additional options (and often too many options) but may be helpful in fine-tuning the symbol’s appearance.

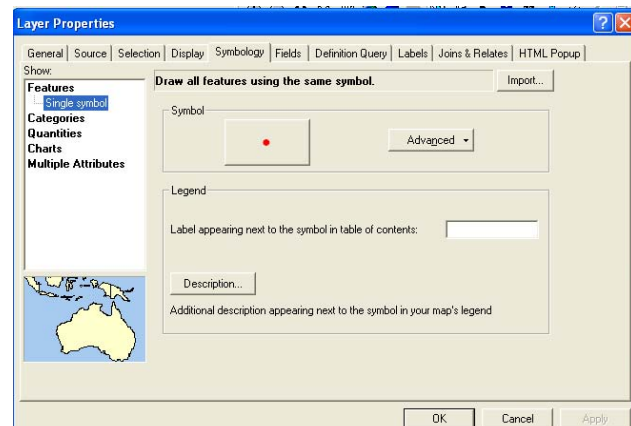


Symbolizing Point Features¹⁴

Symbolizing features means assigning them colors, markers, sizes, widths, angles, patterns, transparency and other properties by which they can be recognized on a map. Symbols may look like the objects they represent, as when the lake polygon is blue. Or on a street map, varying line thickness may show whether the street is a local road, an arterial, or a highway without implying that the widths on a map are proportional to the widths of the actual streets. By varying simple properties, you convey information about map features.

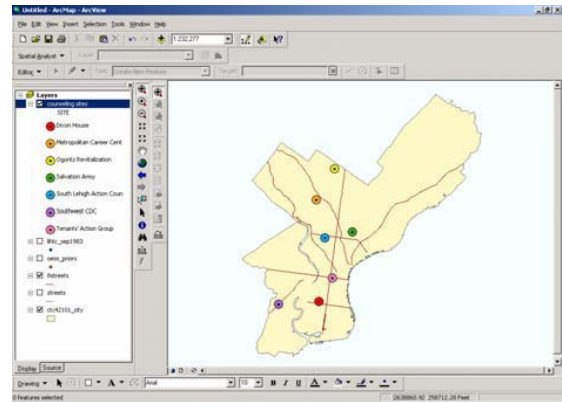
Single Symbol

The default in ArcMap is to represent all points with the same size, shape, and color symbol. This is how ArcMap will display your point shapefiles when they are first added to a map document or when you create them through geocoding or adding XY data. Open the layer properties (double-click on the shapefile name or right click and go to “Properties,”) and click on the “Symbology” tab. In the box on the left side, “single symbol” will be highlighted. You can change the size, shape, or color of the symbol by clicking on it, but as long as “Single symbol” is selected, all of your points will appear the same.



Unique Value

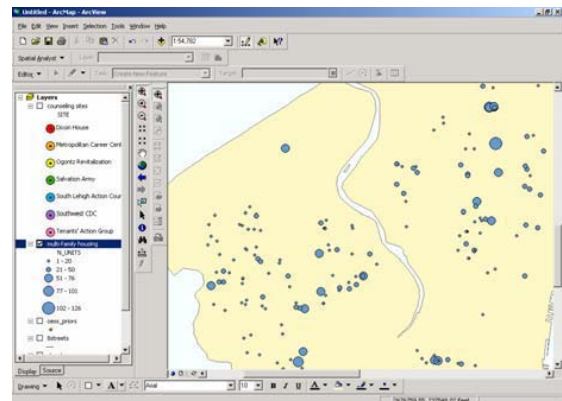
Unique value allows you to use a different symbol for each of the points in a shapefile. This can work well for small files (10 or fewer points) but can quickly be overwhelming for larger files. From the symbology tab, click on “categories” (under “Show:”), and “unique values.” Using the “Value:” dropdown menu, select the field with the values you wish to use to represent your points, and click the “Add All Values” button.



ArcMap will list a symbol for “<all other values>” that you can remove by taking away the check mark. You can change the individual symbols by clicking on them. You can make changes to all of the symbols, or selected symbols (hold down the shift key to select two or more) by right clicking. To remove a value, right click on it and choose “Remove Value(s).” Use the black arrows on the far right to move values up and down (the order here will be the order your values appear in the legend on your map).

Graduated Symbol

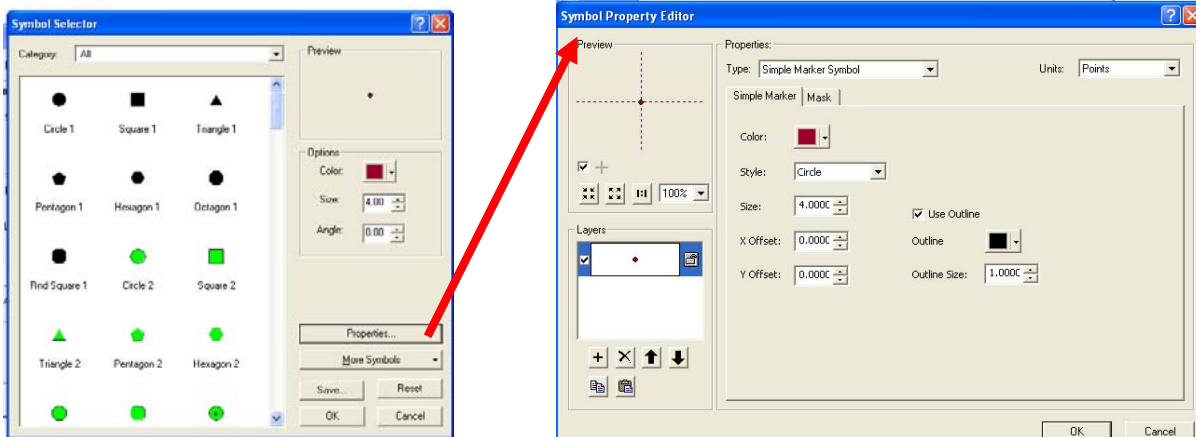
Graduated symbols allow you to have different size symbols to represent different attribute values. With the symbology tab active, click on “Quantities” and then “Graduated symbols.” From the “Values:” dropdown menu, select the field with the values you wish to use. The default is five categories, so five value ranges represented by different size dots should appear below. Use the “classes” dropdown menu to change the number of categories.



There are many ways to break up value ranges into categories. The default is “Natural Breaks,” which uses Jenks optimization to identify grouping of values that minimize within-group differences. To change this, click on the “Classify” button and use the Method dropdown menu to choose a different classification system. You can also adjust the cutoff points by moving the blue vertical lines in the histogram below that show the frequency of values. Alternatively, you can change values manually on the previous screen by clicking on them (you will only be able to change the ending value).

Create New Symbols from Bitmap Images¹⁵

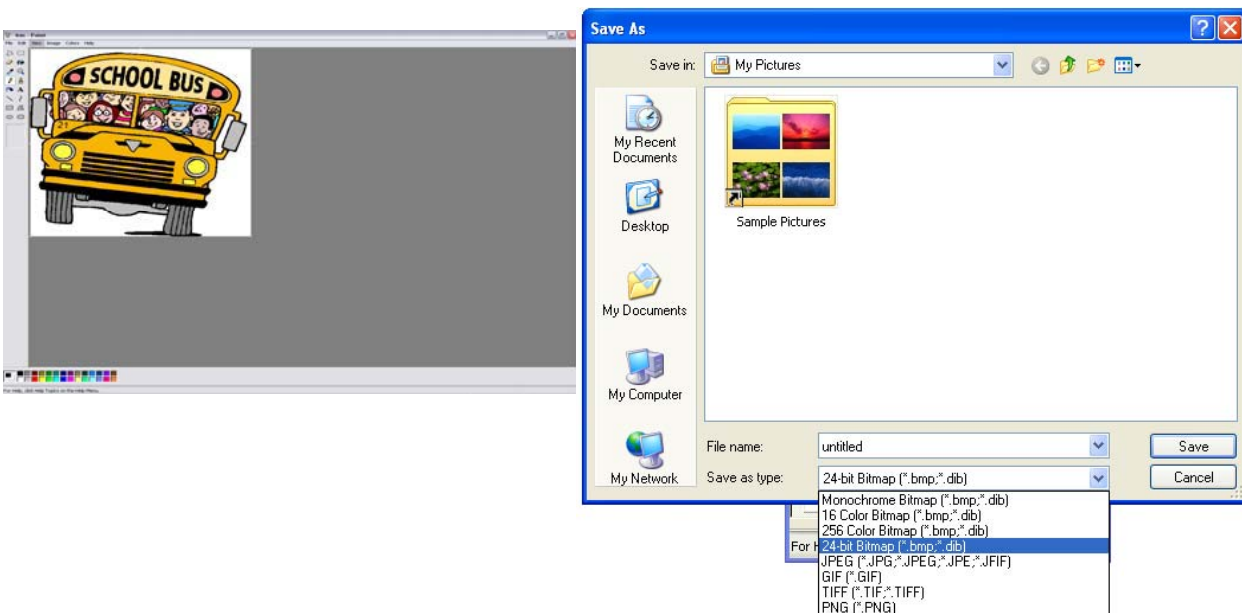
ArcGIS provides a basic set of fonts (symbols) to use for representing point features. The default appearance of these symbols can be edited by clicking on the “Properties” button in the “Symbol Selector” dialog box. This will open the “Symbol Property Editor” where certain minor edits can be made.



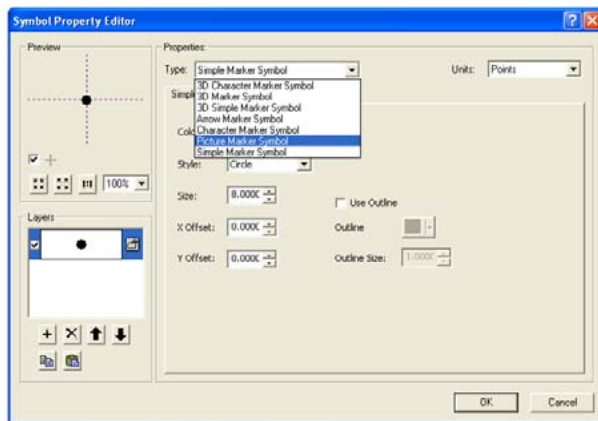
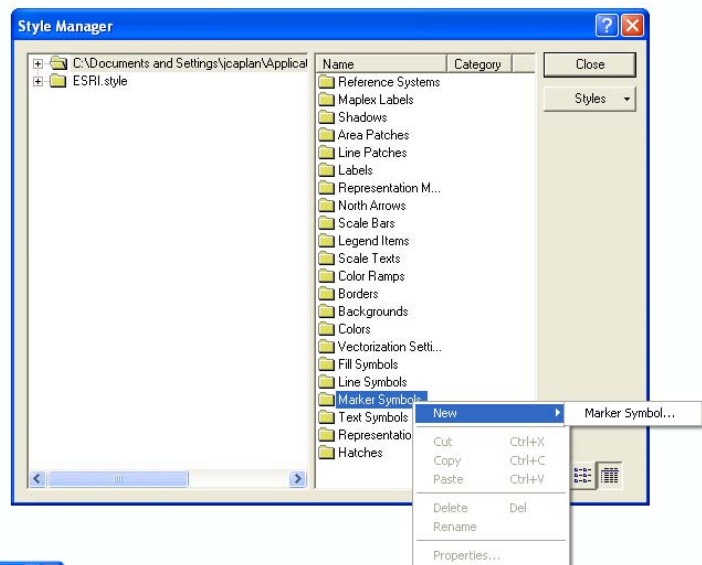
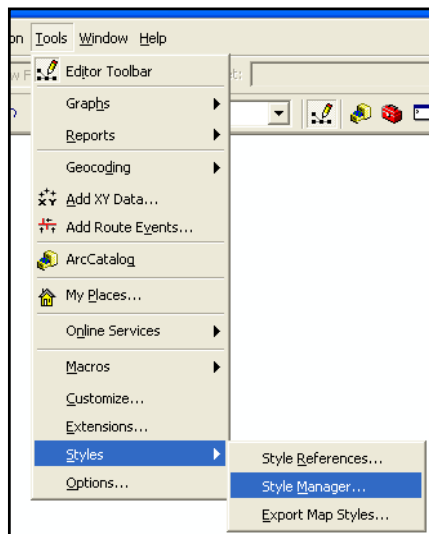
You can also create your own symbols by converting any bitmap (.bmp) image. All you need is a basic graphics program that can save images in a bitmap (BMP) file format. The Paint application, which comes standard with Windows Operating Systems software, will suffice.



You can draw your own bitmap image or use a pre-existing one (be careful about copyright issues). For example, you might use an image of a school bus to identify locations of school bus stops on a map. If this image is already a bitmap image file, then you can skip to the next step. If it is JPG, GIF, or some other file format, you must first convert it to BMP. To quickly convert a JPG or GIF image to BMP, open it in Windows Paint (usually located in the Start Menu > Accessories). Once opened, save it as a BMP by going to File > Save As. If necessary, you can change the file type in the “Save as type” drop down menu.



Start ArcMap and go to Tools > Styles > Style Manager. In the “Style Manager” window, click the appropriate folder on the left, so that you can see a list of folders on the right—one of which will be “Marker Symbols”. Right-click on the “Marker Symbols” folder and choose New > Marker Symbol.



The “Symbol Properties Editor” window will open. In the “Type” drop-down menu, choose “Picture Marker Symbol”. Browse to the location of your BMP image and import it by clicking the “Open” button.

Make any necessary edits to the image size, background color, or transparency. Click OK when finished. When you click OK, the “Style Manager” window will reappear; you can name your new symbol. Click the “Close” button. The new symbol will be accessible from ArcMap’s Symbology Selector. Repeat these steps for each new symbol.

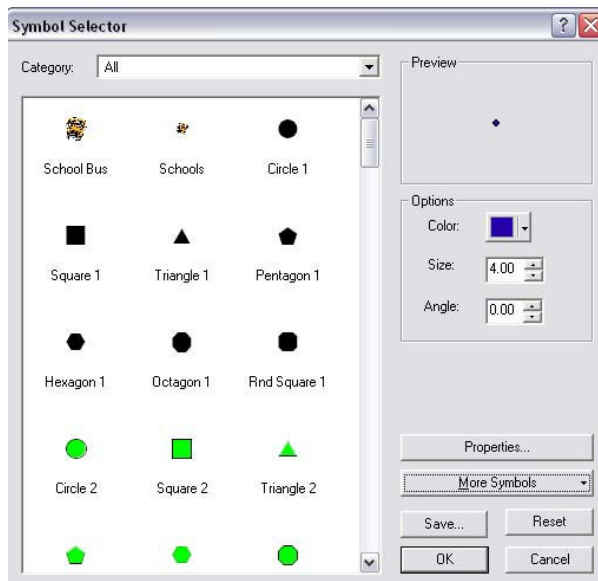
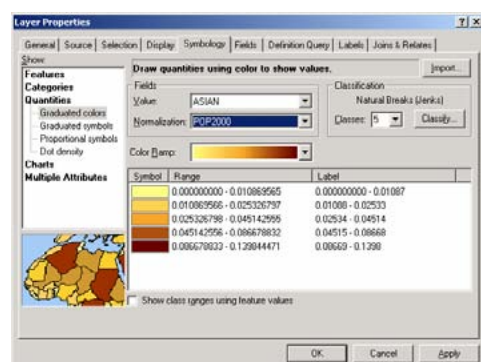


Image-derived symbols can take more time to refresh on a map than basic ArcMap symbology (depending on the size of the image). Therefore, if you have many points, displaying these symbols on a map can take considerable time and may frustrate your other preliminary GIS analysis tasks. To avoid this, use basic (e.g. default) symbols in preliminary steps and change to image-derived symbols for your final map layout. Another word of caution: use picture symbols sparingly. Remember that the purpose of your map is to communicate information. While clever

symbols might get the “oos-and-aaahs”, they are not always the best method to impart information. If the symbol is too small, unclear, or un-interpretable, it could create confusion and/or draw attention away from the main purpose of the map, thereby diminishing its value. People get distracted easily. Furthermore, a cartoony (and stereotypical) image of a burglar to represent burglaries may appear unprofessional. Conversely, a handgun to represent shootings or a car to represent auto thefts may reduce the need of the map reader to refer back-and-forth to the legend. Then again, guns could also represent “unlawful possession” or “registered gun permit holders”, and cars could represent “traffic accidents” or “carjacking”. Pictures do “speak a thousand words”, but you do not want them to speak more than your map’s legend.

Symbolizing Polygon Features

The symbols in ArcMap can be used for any type of data—points, lines, or polygons. The following symbology schemes work particularly well with area (polygon) data.



Graduated Color

You can use different colors—or different shades of the same color—to represent different values to create choropleth maps. From “Layer Properties,” click on the Symbology tab. On the left side of the screen, click on “Quantities” and “Graduated Color.” Choose the field with the values you wish to use. Use the “Classes” dropdown menu and the options in “Classify” to change the number of categories or method for breaking values into categories. You can normalize a value in order to transform it into a rate using

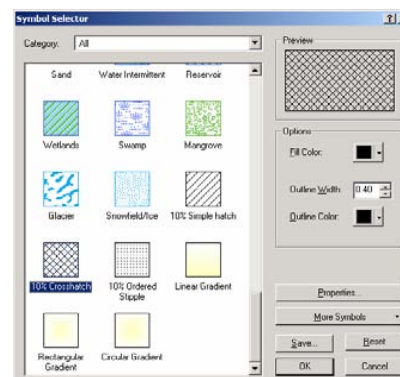
the “Normalization” dropdown menu. For example, in order to show the percent of households receiving public assistance, normalize the total number of households receiving public assistance by the total number of households. Choropleth maps are best used to represent rates rather than raw counts since raw counts can look deceptively large for large polygons (alternatively, you can create new fields in your attribute table corresponding to rates). Graduated color works best when you use the same shade of a single color, with lighter shades representing lower values and darker shades representing higher values. But keep in mind that it may be impossible to distinguish between more than four or five shades of the same color, depending upon the quality of your printer.

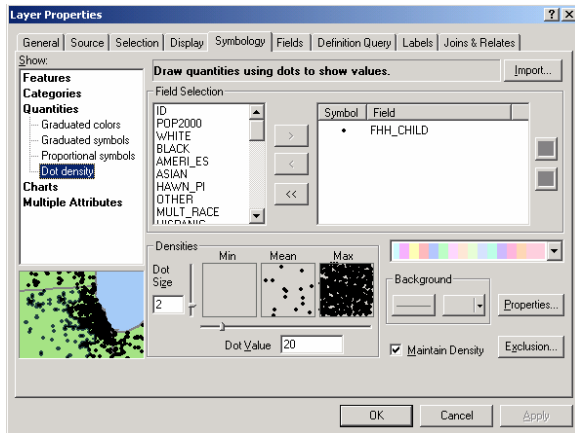
To fine-tune colors, go to “more colors” when choosing a color from the symbol selector. Here you can play with the hue(H), saturation(S), and value(V).



Fill Patterns

You can use different patterns in addition to, or instead of, using different colors to represent different values. Patterns are particularly helpful when you are restricted to printing maps in black and white. Choose “Graduated Colors” from the Symbology tab and select the field with the values you want to display. Set the number of classes and the method of classification, so that you are happy with the value ranges. Then click on the symbols and change the fill using the symbol selector. Click on the Properties button to fine-tune the fill pattern.





Dot Density

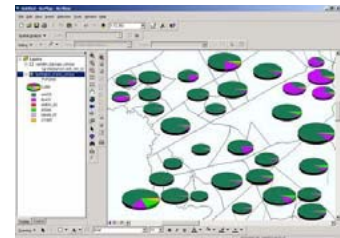
Dot density maps use randomly placed dots within polygons to represent different values. They provide an alternative to using choropleth maps to represent raw counts, although it is important to remember (and communicate to anyone reading your map) that the points do not represent precise locations.

To create a dot density map, open the Layer Properties and make the Symbology tab active. Click on “Quantities” and “dot density.” From “Field Selection,” choose the field you wish to use as the

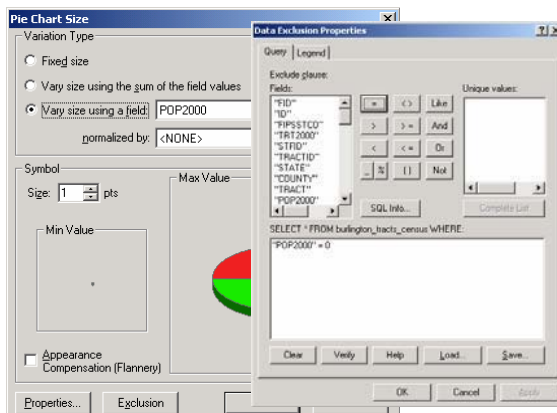
basis for the map. Counts (such as the total number of households on public assistance) are appropriate for dot density maps, but averages, medians, and rates are not. Choose your dot size, or keep the default (which is advisable, at least to start). The “Min,” “Mean,” and “Max” boxes will give you a preview of how your map will look. The “Dot Value” indicates how many units each dot represents. Change this as needed to create dot densities that have enough dots to show variation but not so many that they are all on top of each other. You can change the color of the dot by clicking on it under “Symbol” in the top right part of the screen. Checking “maintain density” will ensure that the dot density looks the same as you zoom in and out (by making the dots bigger and smaller).

Pie Charts

Charts are good for showing multiple values and the relationship between values on different variables. Pie charts are especially good for showing proportions. For example, individual pie pieces can be used to show the breakdown in race for the population in a census tract. Pies contain a lot of information, so it can be difficult to display them clearly.



To create pie charts, click on “Charts” and “Pie” from the Symbology tab. Holding down the Ctrl key, select the fields that you want to include. Make sure that together, they add up to 100 percent (you may need to create and calculate a new “other” field in your attribute table before using charts). Click on the “Background” button to change the color or fill (“Hollow” or white backgrounds might be best, so that you don’t have too many colors in your map). If you check “Prevent Chart Overlap,” ArcGIS will use “leader lines” to indicate where the pie charts belong if there is no room to display them within the map feature. Click on the Properties button to make adjustments to the look of the pie (3D, rotation, height).



Click on the Size button if you want to have different size pie charts depending upon the total (such as total population). If you choose to “Vary size using a field,” you may need to exclude records with a zero value. To do this, click on the Exclusion button and, using the appropriate field name, create an expression such as “POP2000=0”. You may need to play with the minimum size on the previous screen to make the maximum size pie chart a reasonable size.

Bar/Column Charts

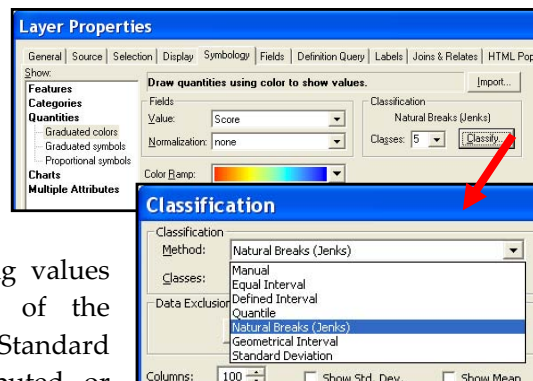
Bar charts can be used to compare values on two or more variables that do not represent proportions (they don't have to be subsets that add to 100 percent). To switch from column (vertical) to bar (horizontal) charts, go to Properties on the Symbology tab of Layer Properties and switch the radio button under "Orientation."

Stacked Charts

Stacked charts can be used to compare values on two or more variables (such as gender) that are subsets of a larger variable (such as total population) when you don't know, or don't want to display, all of the subsets. You have many of the same options for formatting (size, color) that you have with the other types of charts.

Classification Methods/Schemes¹⁶

ArcGIS provides several standard classification options. The most common are manual, natural breaks, quantile, equal interval, and standard deviation. **Manual** lets you set the class breaks manually if, for example, you want to emphasize certain features or patterns. Specify the class breaks by manipulating the histogram or entering values directly in the "Break Values" box to the right of the "Classification" dialog box. "Natural breaks" or "Standard deviation" methods work best with unevenly distributed or skewed data. "Quantile" or "Equal interval" methods work best with evenly and normally distributed data.



The default classification method in ArcGIS is **natural breaks**, whereby a statistical procedure identifies feature pairs, between which there is a relatively large difference in data value, so that class breaks are set to correspond with relatively large jumps in the distribution of values.

The **quantile** classification method arranges all observations from low to high and assigns equal numbers of observations to each class. If 20 census tracts and four classes exist, then each class will contain 5 census tracts, with the lowest 5 in the first group and the highest 5 in the last group. "Quantile" emphasizes the percentage of observations in each category and is best suited for linearly distributed data. Note that differences between classes can appear exaggerated with this approach because of the way in which values are grouped together.

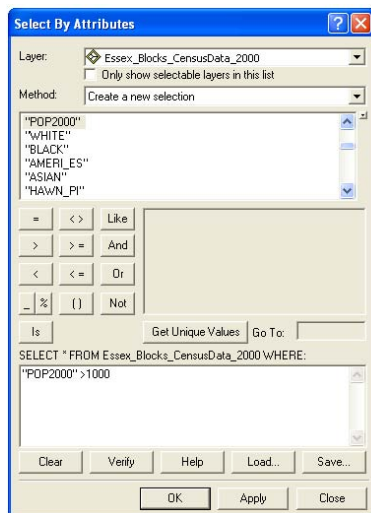
The **equal interval** approach divides the distribution of values so that the difference between the highest and lowest value is the same for each class grouping. "Equal interval" is best used with familiar data ranges such as percentages and temperature. With highly skewed data, most observations will be assigned to the lower or upper value categories and only a few observations will be assigned to the other categories. This could be useful to emphasize outliers in data (such as exceptionally high crime rates) but its limitations should be noted.

The **standard deviation** method emphasizes how much feature values vary from the mean. It shows how far each class category is from the mean, not the actual values in each class. With positively skewed distributions, outliers and clusters can easily be identified (remember the 68-95-99.7 rule?).

Adjusting Transparency

From ArcMap's Table of Contents, right-click the layer > Properties > "Display" tab.

Adjust the transparency value (%) in the "Transparency" text box.



Querying GIS Data

Query by Attribute

In GIS, you can identify a subset of map features based on their attributes or their location. You may use queries as an intermediary step, as part of getting to know your data, to create new values, or to answer your research questions.

Select by Attribute

From ArcMap, Selection > Select by Attributes

Your first step in the "Select by Attributes" dialog box is to select a layer that you wish to query (attribute queries are limited to a single layer). In the Method drop down menu, you need to decide whether you are building on a previous query or starting fresh. From here,

the query dialog is similar to "Calculate Fields." Build an expression using the field names and functions, connecting statements with "AND" or "OR" as necessary. The values associated with each field will be displayed in the text box at the far right. You can use these or type in your own. If you want help working through these steps, click on the Query Wizard button. Click "Verify" to make sure ArcMap likes your expression. You can import (Load) and save expressions using the buttons OR using Ctrl + C and Ctrl + V with a word processing file. *NOTE: if the values you input are text rather than numbers, then you need to put single quotes around them (for example, 'BROAD').*

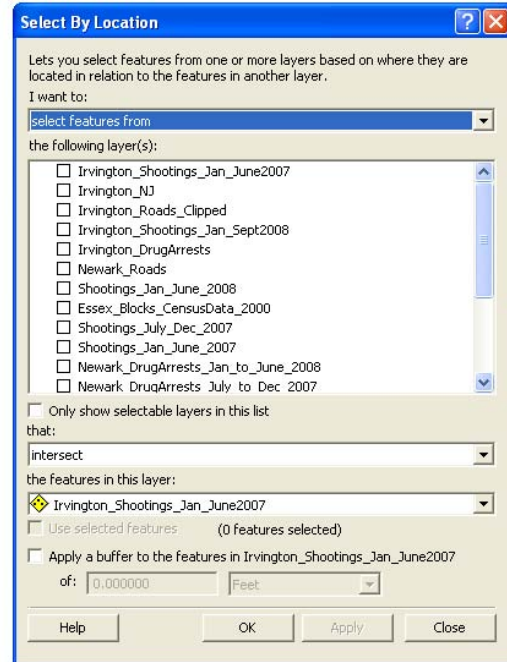
When you click "Apply," the map features that satisfy your query will be highlighted with a bright blue outline. You can perform an additional query (adding, removing, or selecting from this selected group) or close the query dialog. To review the selected records, right click on the map layer and go to "Open Attribute Table." Click on the Select button at the bottom to view only the selected records. You can calculate values on an existing or new field for only the selected records (for example, calculating the percent of multiracial people only in block groups with non-zero populations). You can also generate summary statistics for only the selected records by right clicking on a column name and going to "Statistics." To see all of the selected records at the closest extent, from the Selection menu, go to "Zoom to Selected Records." *NOTE: You can create a new shapefile that only includes your selected map features by right clicking on its name in the Table of Contents, going to "Data" and "Export Data." Choose the radio button regarding coordinate systems (you'll probably want the default). Make sure you have "Selected Records" chosen in the Export drop down menu.*

Select by Location

From ArcMap, Selection > Select by Location

The ability to query based on the location of map features is something unique to GIS, and combining attribute and location queries really takes advantage of GIS functionality.

Your first choice in the “Select by Location” dialog box involves the nature of the selection. Are you starting from scratch or querying a subset of map features already selected? In the next box, put a check mark next to the map layer(s) whose features you wish to select. The drop down menu then provides various relationships between the features in that layer and a subsequent layer (identified in the next drop down menu). For distance-based queries, you will be able to select your units as long as the map units have been specified in the Data Frame properties. The options/images at the bottom of the dialog box change as you choose a different type of relationship as the basis of your location query.



Combining Attribute and Location Queries

The “Select by Attribute” and “Select by Location” dialogs do not allow you to mix the type of query. But by performing one type of query first and then conducting a subsequent query on the selected records, you can perform attribute and location queries on the same map layer. For example, you may be interested in what census tracts are located along a river, but you are only interested in census tracts that have at least 100 people living in them. It doesn’t matter which query you do first. Just be sure that the selection method you choose for the second query allows you to add, remove, or select from the records selected from the first query.

Removing the Selection of Features or Attributes

Selection > Clear Selected Features

CHAPTER THREE

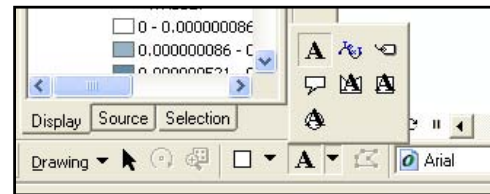
Map Design and Layout

Labeling Features

Labeling features in ArcMap can be tedious, but labeling features well is important to making your maps communicate effectively.


Using Text Boxes to Label Features

From ArcMap's "Data" view, click the "A" button on the "Drawing" toolbar > click the "A" > click on the map where you want the text to appear > type in the text box > hit the Enter key (or click the cursor outside the text box) to complete.




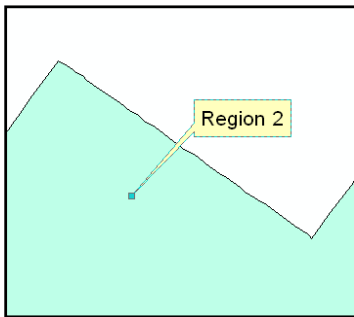
You can place text on a map in order to label map features. This works well if you only have a few map features to label. The "A" with the different shapes behind them allow you to add text within a polygon background.




The  lets you to draw a polygon shape. The rectangle lets you to draw rectangles, and the circle lets you draw circles.

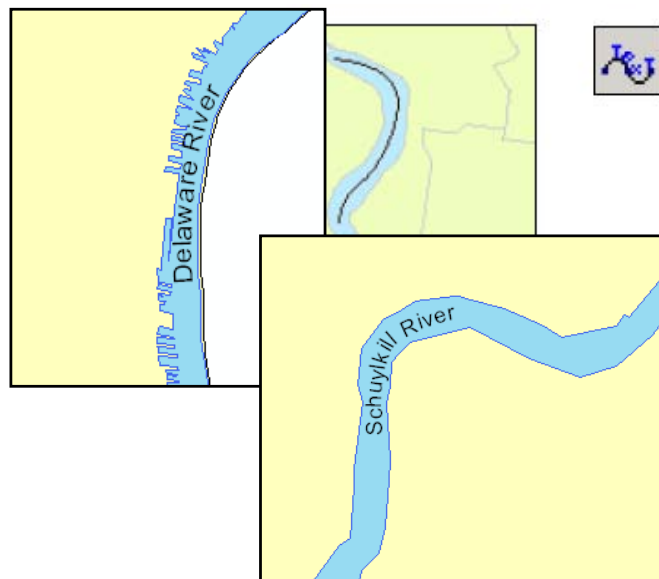


You can move the text around using the "Select Elements" tool . Double clicking on the text will bring up the Properties, where you can change the size and font (using the "Change Symbol" button).



The callout text tool  allows you to place your text away from the map feature while still indicating what is being labeled. Click on the tool and then click on your map feature. Before letting go, you can move the cursor to where you would like the label to be. Type your label. Using the "Select Elements" tool, you can move the text box so that it is closer or further from the map feature.

A third option is the spline text tool. This allows you to write text along a curved line. This works well for labeling rivers and curvy roads. Click on the spline tool, then click on the starting point for your label. Continue to click along the curve (you don't need to make many clicks) and double click to finish. Then type your label in the text box. You will probably need to try this several times to get a label with which you are happy (just click on the label with the "Select Elements" tool and hit the "delete" key to delete a label).

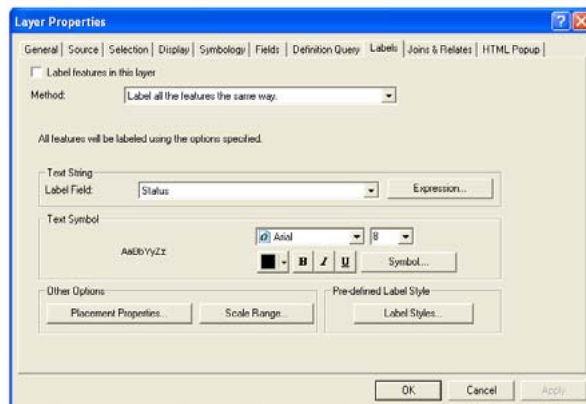


Manually Placing Labels

Click the “A” button on the “Drawing” toolbar > click the “Label” tool




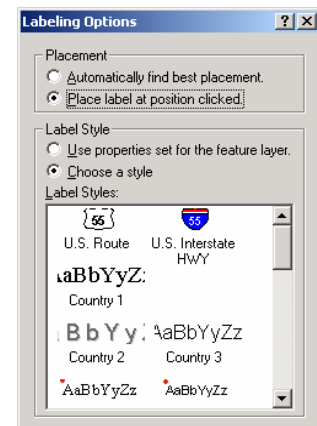
Using the label tools in ArcMap, rather than the text tools, allows you to use the values in a layer’s attribute table for your labels (in other words, you don’t have to type the label out as you do with the text tools). By manually placing labels, you also avoid having your labels act as a group, which means it is easier to move or edit a single label. Before you can use the label tools in ArcMap, you need to indicate which field in the attribute table of your map layer you want to use as the basis for labels. From Layer Properties, click on the “Labels” tab. Leave the “label features in this layer” box empty. Choose the appropriate field from the Label Field dropdown menu. Click on symbol to change the size, style, or font for your labels. (Guessing what size to make your labels is difficult and you will probably need to make small adjustments after seeing what works). Using the “Placement



Properties” button, you can instruct ArcGIS what to do about duplicate labels.

The “Scale Range” allows you to instruct ArcGIS when to draw or not draw labels, depending on the extent. In order to do this, you need to know the exact scales you will be using (so you probably just want to leave this alone). The “Label Styles” button gives you access to some fancier label options. The highway labels are particularly helpful.

Now you can use the label tool to manually label your map features. Click on the button marked “A” on the drawing toolbar and choose the “Label” tool . The “Labeling Options” window will open. Select if you want ArcMap to decide the best label position or if you want to determine that yourself. The “Choose a style” radio button gives you access to those fancier labels again. You can move these labels (using the “Select Elements” tool) and change their size and style (double click to bring up Properties). You can delete a label by clicking on it and pressing the delete key.



Auto Labeling

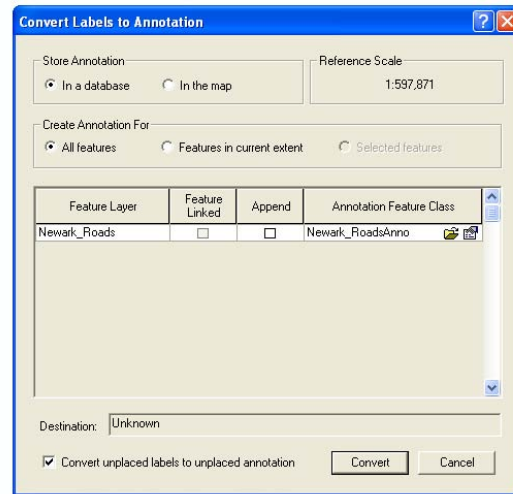
From the Table of Contents, right-click the layer > Properties > “Label” tab > check the “Label Features in this Layer” box

You may find it easier to automatically label all of your features. This saves time if you are happy with the way the labels look, but it offers you much less control over the label placement. When you automatically label features, the labels are “dynamic” so changes you make to one (e.g. changing the style) are made to all. To delete your labels, you will need to remove the check mark from “Label Features in this layer” box. *NOTE: you can also label automatically by right-clicking a map layer and going to “Label Features.”*

Converting Labels to Annotation

From the Table of Contents, right-click layer after labeling it > Convert Labels to Annotation

Labels are one option for placing text on an ArcGIS map. Labels are positioned on the map by the software based on a set of labeling properties defined in the "Labels" tab of the "Layer Properties" dialog box. If you want full control over where labels are placed, you must convert them to annotation.



Using Annotation Layers

After labels have been converted to geodatabase annotation, the annotation class is automatically added to the map. Annotation groups are listed in the Data Frame Properties dialog box on the Annotation Groups tab. In the Table of Contents, right-click the Layers data frame and click Properties. Click the Annotation Groups tab. Annotation labels can be toggled on or off, and their properties can be changed in this dialog box. Click the group that you want to use and then click the Properties button. Click the Associated Layer drop-down list and click <None>. This allows you to turn the annotation layer on and off independently from the map layer. Click OK, then click OK again.

Designing Map Layouts

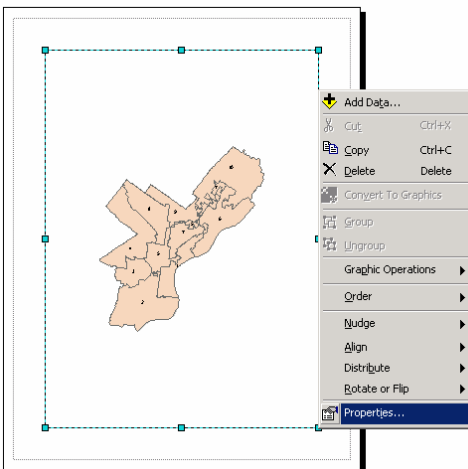
Displaying data so that you can analyze spatial patterns on a computer screen is one thing; printing out a map for other people to look at is another. ArcMap thinks of these as distinct functions and makes available a series of tools for designing map layouts that you don't need until you are ready to print.

Layout View


View > Layout View -or- Click the "Layout View" button at the bottom of the map display

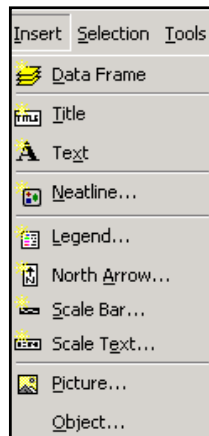


When you open ArcMap, you are in "Data View" and use the "Tools" toolbar to navigate your map. When you switch to the "Layout View", you have access to a different range of tools and use the "Layout" toolbar to navigate. In Layout View, you get a much better idea of how your map will look when it is printed.



ArcMap will automatically place a border ("neat line") around your map. You can change this by right clicking on it and going to "Properties." Click on the "Frame" tab. From here you can choose a different style or color frame (to get rid of it altogether, choose "no color" from the color selector). You can also change the background color and add a shadow (to add a shadow, you'll need to change the X and Y offset to something other than 0).

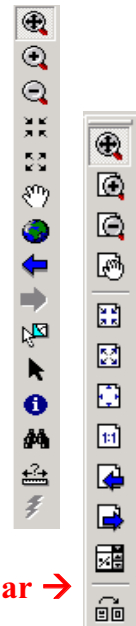
To make your map larger or smaller on the page, you can use the zoom tools on the Tools toolbar or on the Layout toolbar. The Layout toolbar also includes a pan tool that you can use to move your whole layout. To move just your map (and not the whole page), use the pan tool in the Tools toolbar. The fixed zoom tools in the Layout toolbar work like the ones on the Tools toolbar. The “Zoom to whole page” button  is especially useful.



One of the biggest differences in Layout View is that many more options in the “Insert” menu become active. These options allow you to add elements—including a title, legend, north arrow, scale bar, and image—to your layout. Each of these will be separate objects in your layout that can be moved and resized through their Properties. You won’t see any of them if you switch back to Data View since they are meant to clarify printed maps, not help you interpret your map on the screen. You can add text in the Layout View, but you are better off trying to label features from the Data View, using the label or text tools.

Tools Toolbar →

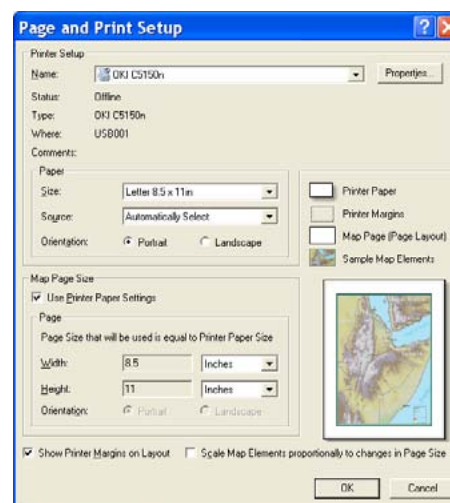
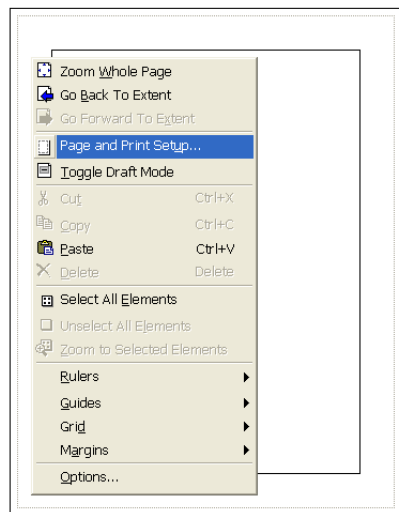
Layout Toolbar →



Page and Print Setup

From ArcMap’s Layout View, right-click the page > Page and Print Setup

By default, the paper size in Layout View is 8.5” x 11”, portrait orientation. Make adjustments to the paper size, orientation, and margins, or add page guides from the “Page and Print Setup” dialog box. The paper size, not the data frame’s size, dictates the size of the image (i.e. JPG) that will be exported. Guides are very helpful for aligning map elements, which can be forced to “snap to guides” to ensure proper and consistent alignment.



Adding a Title

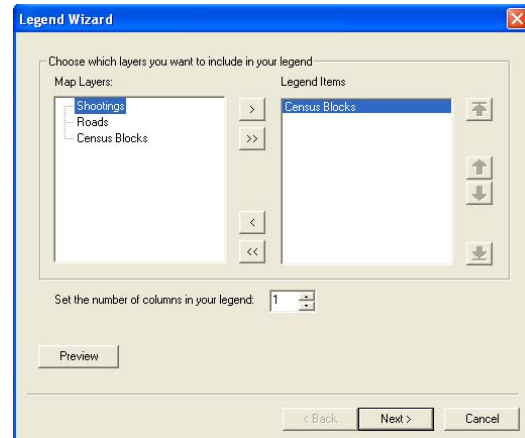
From ArcMap’s Layout View, Insert > Title

Type your title in the text box and hit the enter key or click the cursor outside the text box. Double-click on the title to bring up the Properties where you can make formatting changes.

Adding a Legend

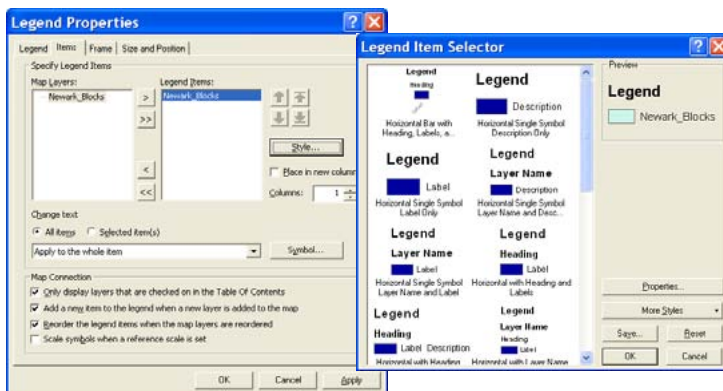
From ArcMap's Layout View, Insert > Legend

Unless your labels are able to fully explain your map features, you will need a legend on your layout. ArcMap gives you flexibility in formatting your legend, and all the choices can be overwhelming. Your first choice in the "Legend Wizard" is what map layers you want included. ArcGIS will guess that you want to include all active layers. This may not be the case if you have layers such as a county boundary, rivers, or other obvious features that do not need to be included in the legend. To remove a layer from the legend, click on its name on



the right side of the Legend Wizard dialog box and click on the "<" button. The order your layers are listed under "Legend Items" will correspond to the order in which they appear in your legend. To change the order, click on the name and hit the up or down arrows (don't worry; this won't affect the order in which they are drawn). If you want more than one column in your legend, make the adjustment here. To see what your legend will look like (before working your way through the rest of the screens), click the "Preview" button. If you are satisfied with it, you can click the Finish button and skip the other steps. Otherwise, click the "Preview" button again and click "Next."

On the second screen of the Legend Wizard, you can give your legend a title or leave the word "Legend" as the title (or just leave it blank). The third screen allows you to create a frame and shadow around your legend (not necessary, but depending upon your layout it may be helpful, particularly if you gave your layout a background color). On the fourth screen, you can change the symbols and symbol size used to represent lines and polygons in your layout. On the final screen, you can make adjustments to the spacing between items in your legend. Click "Finish."

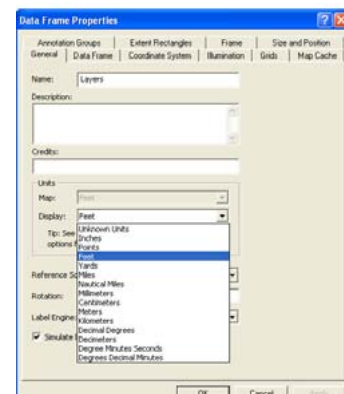


To make changes after you have created your legend, double click on it to bring up the "Legend Properties" dialog box. You can change the legend's appearance by clicking the "Style" button in the "Items" tab of the Legend Properties window. The "Legend Item Selector" dialog box will appear with a variety of legend styles to choose from.

Adding a Scale Bar

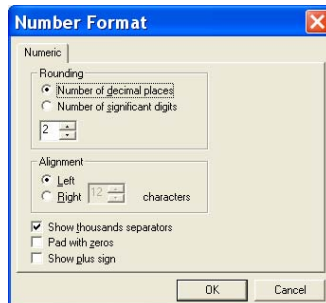
From ArcMap's Layout View, Insert > Scale Bar

To add a scale bar, you must identify the appropriate units for your map. You can set these from the Data View or Layout View. From Layout View, right click in the layout (anywhere inside the neat lines), go to Properties, and make the General tab active. From the map units dropdown menu, choose the units used for the original map projection. Once this is set, you can choose any display units you want.

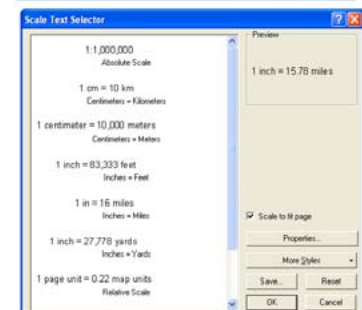
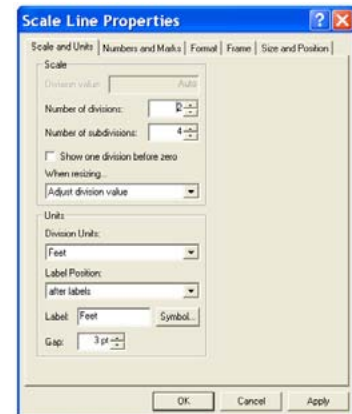


From the “Scale Bar Selector” dialog box (Insert > Scale Bar), select a style and hit “OK.” Your scale bar should appear on your map. You can move or resize it by clicking on it. Double click to bring up the Properties, where you can change the number of divisions as well as the font size (by clicking the Symbol button or from the format tab).

The number of divisions, subdivisions, and frequency of numbers and marks can be adjusted manually by right clicking on the scale bar and selecting “Properties”. The Scale Line Properties dialog box will appear. Adjustments can be made under the “Scale and Units” or “Numbers and Marks” tabs.



To change the number format, click the “Number Format...” button in the “Numbers and Marks” tab. In the “Number Format” dialog box you can set the number of decimal places, add or remove thousands separators, and more.



Adding Scale Text

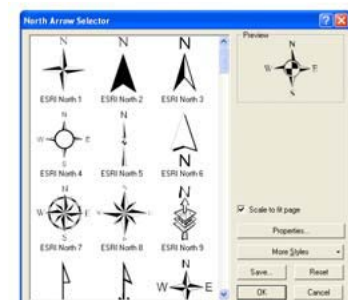
From ArcMap’s Layout View, Insert > Scale Text

You may wish to include a text description of the map scale, particularly if this is important to your audience and you deliberately chose a scale. To make changes to or format the units of the scale text, double-click it in the Layout to bring up the Properties.

Adding a North Arrow

From ArcMap’s Layout View, Insert > North Arrow

Choose a style from the “North Arrow Selector” (preferably something simple and small). You can move it around on your layout by clicking on it. Double-click to change the size or style.



Rotating a Map

From the “Data Frame Tools” toolbar > click the “Rotate Data Frame” button



You can rotate a map to better fit the page or to make it easier to read (just because you can do this doesn’t mean it’s a good idea). If you do this, make sure that you have a north arrow on your map. As you rotate your map, your north arrow will adjust to indicate which direction is north. Using the “Rotate Data Frame” tool, click and hold, moving your map to change the rotation. To restore the original orientation, click on the “Clear Rotation” button.

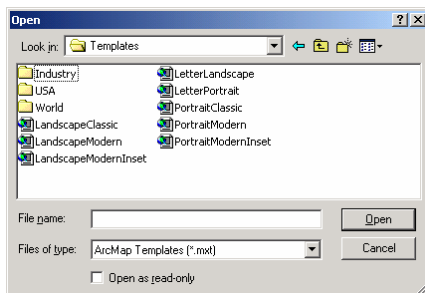
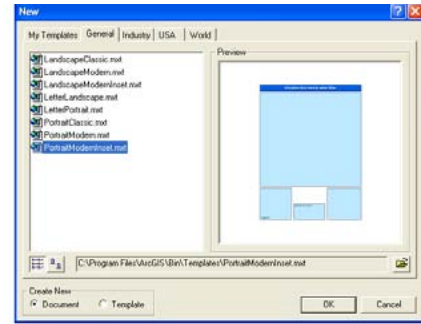
Map Templates

Using map templates can save you time and lead to greater consistency in your printed maps. You can use ArcMap’s custom templates or design your own. When you open a template, you get a new, untitled ArcMap document plus any layout or data that was saved in the template. This means that some templates provided by ESRI include (projected) base layer shapefiles.

Opening Map Templates

File > New



Decide if you are going to use a map template before you start adding data to your map document. When you open ArcMap, choose to start using ArcMap by clicking on the template radio button in the dialog box. The templates listed in the General and Industry tabs provide empty layouts while those in USA and World tabs include base map layers. Choose a template by double clicking on its name or clicking once and hitting "OK." Don't worry if the template includes colors or elements that you do not want. It only provides a starting place and you will have the opportunity to customize it.



If you have turned off the opening dialog box (by putting a check in the "Do not show this dialog again" box when you opened ArcMap previously), go to the File menu and "Open." From the "File or type" dropdown menu, choose ArcMap Templates (*.mxt). Navigate to ArcGIS's template folder (probably C:\Program Files\ArcGIS\Bin\Templates) and choose a template. You can't preview the templates if you access them this way.

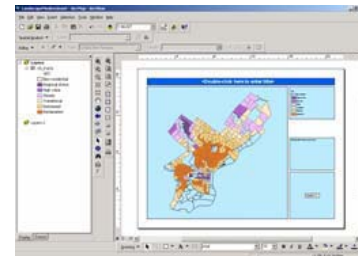
Using Map Templates

If you selected a map template that contains no data, you must add one or more data layers to your map document. Once you do, the legend and other elements of your layout will be automatically created based on the template design. Make changes to the data frame (which contains your map), legend, scale bar, and north arrow from the Properties dialog boxes (right click on any of these and go to Properties). You can also move the elements around (click and hold down) as needed. Notice that when you use map templates, ArcMap opens in Layout View. You can still switch back and forth

to Data View using the   buttons.

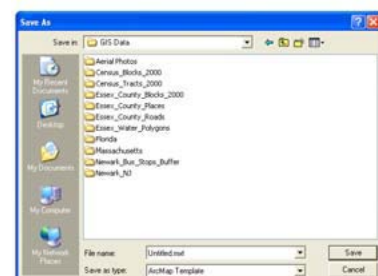
Using Inset Map Templates

For the map templates that include insets, you will need to add at least two layers. When you open one of these templates, you will see Layers 1 and Layers 2 listed in your table of contents. By having two separate groups (i.e. Data Frames) of layers, you can have two maps in your layout. This might be two different maps or the same map at different extents. Right click on "Layers" and go to "Add Data" to select the map layer for the main map in your layout. Then right click on "Layer 2" and, from "Add Data," find the map layer for the inset map.



Creating Your Own Template

File > Save As > from the "Save as type" drop-down menu, select "ArcMap Template" -or- File > New > "My Templates" tab > at the bottom left, select the Create New "Template" radio.



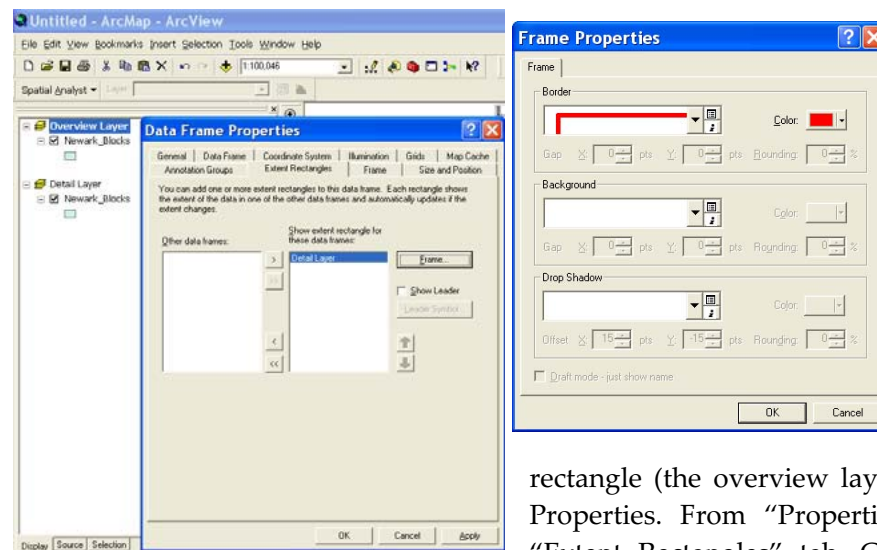
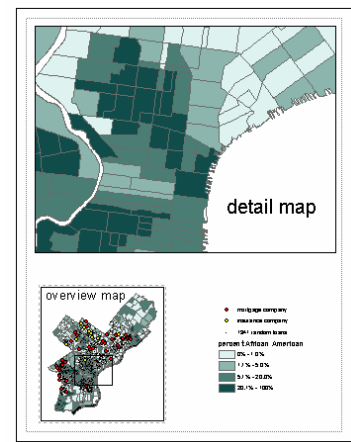
You can create your own map template by modifying an existing custom template or starting from scratch. Once you have created a layout that you would like to reuse, go to the File menu and “Save As.” From the “Save as type” dropdown, choose “ArcMap Template (*.mxt).” If you are not in the ArcGIS Template folder, navigate to it (c:\ArcGIS\arcexe82\Bin\Templates). Give your template a name and hit “Save.” Your new template will appear under the General” tab when you choose to start using ArcMap with a template (You must save your template in the Templates folder in your profiles location in order for it to appear under the “My Templates” tab. If you create a new subdirectory in the Bin/Templates folder, your templates will appear under a new tab with the name of your subdirectory).

Creating Extent Rectangles (Inset Maps)

From the Table of Contents, right-click the (receiving) data frame > Properties > “Extent Rectangles” tab

You may need to create a map layout that includes more than one map, either because you cannot fit everything (such as Alaska and Hawaii) on your main map or because you want to zoom into a small area for your main map and indicate on a smaller map what area that covers.

Extent rectangles show the extent of one data frame within another data frame. They are dynamic: if you change the extent of either data frame the extent rectangle will update automatically. Extent rectangles also update when the data is rotated or when the projection is changed.



To create an extent rectangle, start with at least two Data Frames: a detail layer and an overview layer (See “Data Frames” section in Chapter One). At least one data frame must be showing an extent that is completely within the extent of the other. Right click on the data frame that will be receiving the extent rectangle (the overview layer) in the Table of Contents > Properties. From “Properties” dialog box, click on the “Extent Rectangles” tab. Click the data frame with the smaller extent (the detail layer) to select it. Click the > button to move the selected data frame from the left to the right side—to the “Show extent rectangle for these data frames” list. Click on the “Frame” button to make changes to the outline of your box. Click the “OK” button to all dialog boxes. *NOTE: When you have several data frames in a map, name them clearly and descriptively so it is easier to know which to choose when creating an extent rectangle.*

Exporting Maps

File > Export Map

If you just need paper copies of your maps, you will probably have the best results printing them from ArcGIS. But if you need to insert maps into PowerPoint or word processing files, will need to export your maps. You can export a map from ArcMap when you are in Data View or Layout View. However, if you want your exported map to include titles, legends, scale bars, north arrows, and anything else you added to the layout, you need to export from Layout View. There are many options for export formats in the “Save as type” drop down menu.

.PDF — The .pdf format allows you to open the map directly (without inserting it into PowerPoint or MS Word) as long as you have Acrobat Reader. This is probably the best option if you need to send someone a map or post a map on the Internet.

.JPG — The .jpg format will compromise the quality of your image, so be sure to click on the “options” button when you export and increase the resolution to at least 200 dpi. The .jpg format is good because it stores your map in a fairly small file and, unlike some other file types, your map will not be compromised if you open it on a computer that does not have ArcGIS installed.

.TIF and .EPS — The .tif and .eps formats work well if you are going to open your maps in a graphics software package, but they result in larger files.

Screen Capture — If all else fails, you can take a screen capture (print screen, or alt + print screen) and crop the image, but this will not result in a presentation-quality map.

Guidelines for Professional Map Production¹⁷

Map Communicability

The intended purpose of the map should be clear and the map should clearly and prominently display the information that is intended to be imparted to the map reader.

Map Layout & Design

Maps should be refined and aesthetically pleasing. Use a consistent layout and cartographic element styles across multiple but related maps. This lets the reader focus on changes to the maps' key features and to make comparisons more easily across multiple maps. Layers should be arranged with key features on top. Be sure that the map and its features are of adequate size, but not too large. You don't want maps to appear too crowded or confusing.

Map Titles and Text

A title and/or subtitle should always be present and should communicate the main purpose of the map. Make sure they suggest what your symbology and category labels actually show. Text should be of adequate size and a very legible font. Text is symbology too. Different text sizes could imply differential importance (i.e. not simply that you are trying to fit the text within a polygon). Space on the map layout is precious, so there is no need to repeat the same text or phrases over again. Text should be clear and concise. Strictly limit your use of abbreviations in order to prevent confusion; some abbreviations mean different things to different people. Proofread your maps for "floating", or unassigned, labels and spelling/grammatical errors.

Map Colors

Use as much color contrast as possible between categories, especially with grayscale. For example, with 3 categories, use white, gray and black—not light gray, medium gray, and dark gray. Darker colors commonly represent higher values (or greater significance), and lighter colors represent lower values (or lesser significance). When you reverse this, you risk misinterpretation by your map reader. Consider the photocopyability of your map. Color contrasts are greatly diminished when printed or copied in black and white or grayscale. Be sure that all map features are easily distinguishable. Check out ColorBrewer, a web tool for selecting color schemes for thematic maps: www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html

Symbology

Never use "selection" as symbology. Be sure that map features are identified and map symbology is explained (e.g. polygons represent blockgroups; shading of polygons shows % of population below poverty). Use meaningful class breaks.

Cartographic Elements

Maps should include all necessary (audience appropriate) cartographic elements, including a North arrow and scale bar. Values on a scale bar should be easily additive, divisible, etc.; units should be stated; numbers should not be cluttered. Most visible features on the map should be included in a legend, with few exceptions. However, all items included on a legend should always be visible on the map. Be sure to change the layer/label names from their defaults. Clearly and meaningfully label class breaks and do not include unnecessary decimal places.

Checklist for Professional Map Production and Dissemination

Scholarship

- Good critical thinking
- Well written
- Showed creativity and innovation
- Thoughtful interpretation of maps
- Appropriately referenced maps in the body of text when discussing them

Map Communicability

- The intended purpose of the map was clearly communicated
- The map seems to serve its purpose
- The map makes sense

Map Layout & Design

Maps should be refined, aesthetically pleasing, and appear professional.

- Not too crowded/confusing
- Adequate map/feature size
- Layers ordered appropriately
- Consistent layout and cartographic element styles across multiple, but related, maps.

Map Titles and Text

These are necessary to convey the meaning/purpose of a map.

- Title/Subtitle (present)
- Title/subtitle suggest what symbology and category labels actually show.
- Adequate text size and legible font/style
- Text and phrases are not unnecessarily repeated
- No “floating” or unassigned labels
- No spelling errors

Map Colors

- Good contrast
- Easily distinguishable features
- Used as much color contrast as possible between categories, especially with grayscale.

Symbology

- Appropriate class breaks
- “Selection” not used as symbology
- Features identified and symbology explained

Cartographic Elements

Maps should include all necessary (audience appropriate) cartographic elements.

- North arrow (present)
- Scale bar/text (present)
 - Values on scale bar are easily additive, divisible, etc.
 - Appropriate number of breaks, text is not cluttered
 - Units defined
- Legend (present)
 - Layer/label names changed from filenames
 - All necessary features/layers are included in legend
 - All items included on legend are visible on map
 - Values of class breaks are appropriate (i.e. no unnecessary decimal places, etc.)

General Items

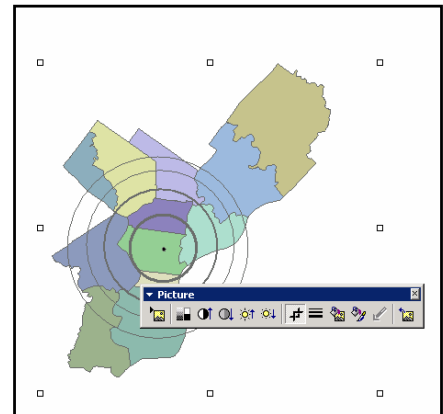
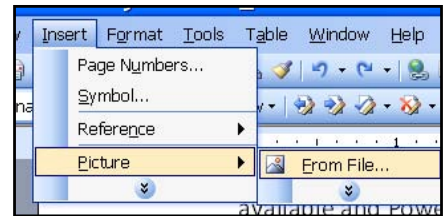
- Be careful: Text is symbology too. Different text sizes could imply differential importance—e.g., not simply that you are trying to fit the text within a polygon.
- Be clear: Abbreviations don’t always mean the same thing to everyone. For example, “N” and “Y” don’t always mean “No” and “Yes”.
- Darker colors commonly represent higher values (or greater significance), and lighter colors commonly represent lower values (or lesser significance). When you reverse this, you risk misinterpretation of your map.
- Given the color contrast, map(s) may not be photocopy-able. This is something important to think about.

Inserting Maps into Microsoft Word and PowerPoint

From the application, Insert > Picture > From File > navigate to the image file > click the "Insert" button

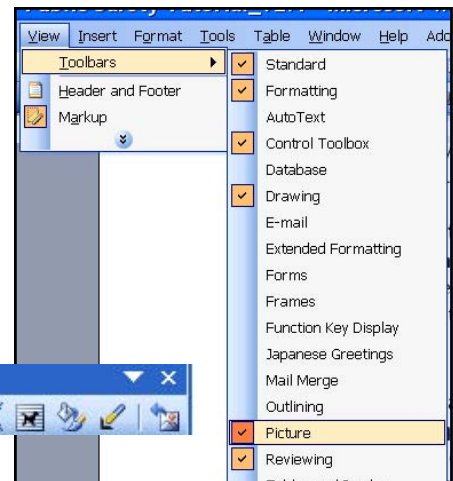
Save your map as a .jpg. You are probably better off creating map titles in PowerPoint rather than ArcMap. Also, if you are making a map specifically for PowerPoint, consider making the legend larger than usual (14 points or more) so that your audience can read it.

You may encounter problems displaying maps in PowerPoint or Word if you try to show the exported map images on another computer and it doesn't have ArcGIS loaded. Your symbols (i.e. the dots or other images used to represent points on your map) may come up looking like # and other strange symbols. This is because your exported maps are relying on the ESRI fonts to draw these symbols correctly. If ArcGIS isn't loaded, those fonts are not available and Microsoft comes up with the closest approximation from other fonts. If you use .pdf files or screen captures, you can avoid the problem but will sacrifice image quality and flexibility. Whenever possible, embed fonts or convert them to curves as you export them from ArcGIS.




Picture Toolbar

The "Picture" toolbar provides several tools that let you edit and format images in Microsoft Office applications such as Word or PowerPoint. To activate the "Picture" toolbar (if it is not already available) go to View > Toolbars > Picture. *NOTE: the Picture toolbar is only visible when a picture is selected. So if you don't see it, be sure a picture in your document is selected (i.e. click on it with your mouse).*

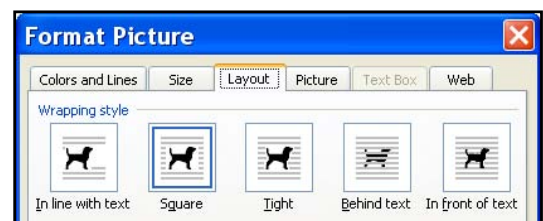


Cropping Map Images

You may notice that there is a lot of white space around your map. Eliminate this in MS Word or PowerPoint by using the "Crop" tool  on the "Picture" toolbar.

Picture Format and Layout

Formatting the picture by "Wrapping" text around maps, for example, is useful when writing policy briefs or research reports. Click the "Text Wrapping" tool on the "Picture" toolbar, or Right-click image > Format Picture > "Layout" tab. You can also add/edit the image border, size, and alignment from the "Format Picture" dialog box.

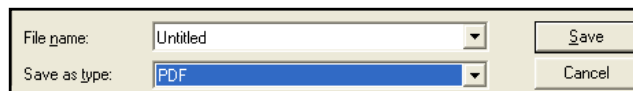


Portable Document Format (PDF) Files

Portable Document Format, or PDF, is a digital file format created by Adobe Systems for document exchange in a manner that is independent of the original software application. PDF files are an excellent way to distribute documents via email or online because they are generally small in file size and can be universally viewed; no matter what computer operating system you open them on, they will look exactly the same. PDF files can be thought of as static images of the original document's content.

Viewing PDF Documents

Adobe Reader is necessary to view PDF files. Many computers already come with this software installed. However, if your computer does not have Adobe Reader installed, you can download it for free at www.adobe.com. It is compatible with most operating systems including PC and MAC. To open a PDF file, click (or double click) it and Adobe Reader will open automatically to display the document.



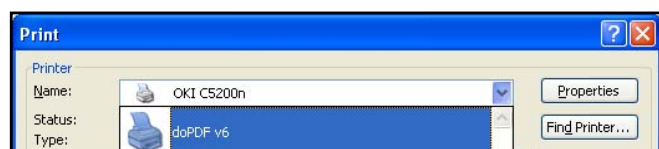
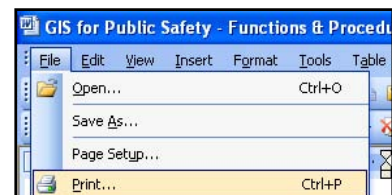
Saving Maps and Documents as PDF

ArcMap has built-in capability to save map layouts as PDF. From the Layout View, go to File > Export Map. In the "Export Map" dialog box, select "PDF" from the "Save as type" drop down menu. This method is useful if you intend your map layout to be the final product or deliverable. However, it is more likely that you will produce maps in ArcMap, export them as a PDF, JPG, or other image file, and then import them into a Word Document, PowerPoint Presentation, or other software application where you will produce the final document.

The most common (and easiest) way to turn a document into the PDF format is from within the software application where you created the document. For example, convert a Microsoft Word document to a PDF file from within the Microsoft Word application. A "PDF creator" is required to do this. Adobe's software suite for creating and editing PDF files is not freely available and can be expensive. If you do not have Adobe, you will need another PDF creator.

There are several free PDF creators that serve as alternatives to Adobe. "doPDF", for example, is free for both personal and commercial use and permits users to create high-quality searchable PDF files by simply selecting the "Print" command from any application. Because the availability of PDF creators changes constantly, it would be inappropriate to list all of the current options here. Rather, search for "PDF Creator" on www.download.com or another reputable software website for freeware, try-ware, or paid software that creates PDF files and that meets your specific needs.

With PDF creator software installed on your computer, it is likely that you will be able to convert a document to PDF by going to File > Print, and then selecting the PDF Creator from the printer "name" pull-down menu in the "Print" dialog box. Click the "OK" button; you will likely be instructed to choose a file name and directory to store the PDF file. Rather than printing to printer hardware, your document will be "printed", or "imaged," to a new digital PDF file stored on your disk drive.



PowerPoint Design & Presentation Tips¹⁸

1. Dark background with light text

PowerPoint presentations look best with a dark background and light text as these are the easiest to read and most gentle on the eye. Dark blue backgrounds are popular and are effective because the wavelength of blue means that it tends to fade into the background emphasizing the text on top. Try experimenting with other dark shades (but stay clear of red as a background).

2. Simple titles & points

Keep titles and bullet points short and relevant; do not overcomplicate your slides. Use the slides as a prompt and do not read directly from them. Use about 5 key bullet points per slide. Break longer lists into multiple slides whenever possible. A presentation should be a summary of your work, not the whole thing. Listening to a presenter read a list verbatim from the screen is boring.

3. Font size and type

Absolute minimum font size should be 16pt. But keep in mind that with some fonts 16pt is much smaller than in another font. If you cannot fit your text onto the screen using a font size of at least 16pt, do not reduce the size. Reduce the number of words or use multiple slides. Simple San Serif-type fonts such as Arial are simplest to read. If you are taking your presentation somewhere else and using another computer, do not use a unique font that only you might have. The host presentation computer is unlikely to have the font and your presentation will not look as expected. Stick with basic fonts.

4. Builds & dimming

“Builds” is the term given to those fancy ways to introduce text or other items to the screen (e.g. text flies in from the left, one letter is added at a time from the right, etc.). Strictly limit the use of builds or do not use them at all. If used, stick to the simple ones. Regular conference attendees have seen them all and are not impressed. They also distract from your message. “Dimming” is the term given to the dulling (or the disappearance of text or objects once the next item has been introduced). Many conference attendees have a short attention span, take notes, or look elsewhere momentarily. You do not want them to return to viewing the screen and realize that they missed information. If it is important enough to be included on your slide in the first place, do not dim it.

5. Do not rely on the spell checker

Pubic safety is not the same as public safety. Form instead of from, or policy instead of police, are other common mistakes. Also check your grammar and punctuation. Be consistent with punctuation. Periods, for example, should be present or absent from text on all slides or none of them.

6. Number your slides

This allows people to take notes or ask questions that reference specific slides. If necessary, you can then return to the slide easily for discussion.

7. Exclude technical detail

The presentation should be a short, impressive summary of your work. If you must include technical detail, give a handout afterwards or point the audience to your most recent book/article/publication. If you anticipate technical questions, consider adding this information in slides at the end of the PPT that you can show only in support of your (short) answer to specific questions. The audience expects you to talk about the content of your slides. Skipping through slides because you are running out of time appears very unprofessional.

8. Continuity across slides

Good presentations maintain a style throughout. Decide on a color scheme and one or two fonts, formats and text sizes (Title vs. heading text, for example) and stick to them. Maintain consistent margins. Be consistent with punctuation.

9. Finish on your title slide or black screen

When you finish talking let the audience see your title slide with your contact details or end on a black screen so that they can concentrate on your message and how good you are. Do not end the presentation by returning to the software application and let them see the slide layout view.

10. Arrive early to set up

Before the audience is in the room, get your PowerPoint presentation ready and cued. Do not let the audience see that you don't know how to run Windows or which folder has the presentation. Decide on which side of the room/projector you are going to stand and try to stay there. Do not wander in front of the projector. Finally, have a backup plan for when things go wrong. At the very least, take a copy of your presentation on a CD or flash drive, bring a hard-copy print out, and email it to yourself as an attachment. Be prepared for technical difficulties and for systems to fail.

11. Eye contact

Share your eye contact around and do not stay too long on any individual. Make sure you do not single out any group or individual (that can be freaky!). If you take a question, respond to the person who asked, but after a few seconds open your answer (i.e. eye contact) out to the whole room. When using a laser pointer, avoid pointing and talking to the screen for protracted lengths of time.

12. Be prepared and appear confident

First impressions count. The first few seconds of your presentation are vital to captivate your audience. Stand tall and start with a smile, but then move to a more serious expression when you begin to talk. Even if you do not have confidence in yourself, act like you do! Remember, you know your own material better than anyone else. Dress well but not too flashy. Never say that you just finished the presentation a few minutes ago. It suggests that the presentation—and the audience—is not important enough to devote more time to.

CHAPTER FOUR

*Spatial Data Sources, Projections
and GIS Data Management*

Base Maps

Data are essential to GIS and base maps are the foundation. Essentially, base maps are your reference layers for orienting and analyzing your primary study data. Typically, they comprise a street centerline and a geographic backdrop such as a census tract, ZIP Code, and/or county boundary. Street centerlines of almost every city, state, or region can be downloaded free from the Internet (see “FREE GIS Data Sources” section).

City planning departments also have GIS data (such as updated street files) that they may be willing to share. You can also integrate data from other sources, such as criminal justice data or health and social services data. Remember, you want to obtain “shapefiles” if possible, which are the most compatible forms of data for use in a GIS. If shapefiles are not already available that’s OK, you can create them. But, the data—whether it is your own or from another agency—must have a geographic reference such as street addresses or XY coordinates that can be used to link it to a map.

Examples of criminal justice data include:

- Number of crime incidents
- Types of crime incidents
- Locations of police stations, substations, and patrols
- Computer-aided dispatch calls
- Firearms purchases
- Locations of prisons and jails
- Locations of criminal and juvenile courts
- Open-air drug markets
- Gang locations
- Jurisdictional lines for state police, county sheriffs, tribal police, and municipal police
- Number of protective/restraining orders

Examples of health, social & environmental data include:

- Locations of public assistance agencies
- Locations of public housing
- Locations of hospitals & emergency rooms
- Locations of mental health programs
- Locations of youth shelters
- Census data
- Neighborhood boundaries
- State and county boundaries
- Business locations
- Transportation routes
- Park and recreation areas

FREE GIS Data Sources

- Criminal Justice Web Sites | <http://www.icpsr.umich.edu/NACJD/links.html#crime>.
- National Archive of Criminal Justice Data | <http://www.icpsr.umich.edu/NACJD/gis>
- New Jersey Department of Environmental Protection | www.nj.gov/dep/gis/lists.html
- State of Florida Shapefiles | <http://www.fgdl.org>
- State of Massachusetts Shapefiles | <http://www.mass.gov/mgis/laylist.htm>
- Geography Network | <http://geographynetwork.com/data/downloadable.html>
- Census TIGER/Line® Data | http://arcdata.esri.com/data/tiger2000/tiger_download.cfm
- Geospatial One Stop | <http://www.geodata.gov>

Also contact local government agencies and NGOs, and Google keywords such as “GIS data”

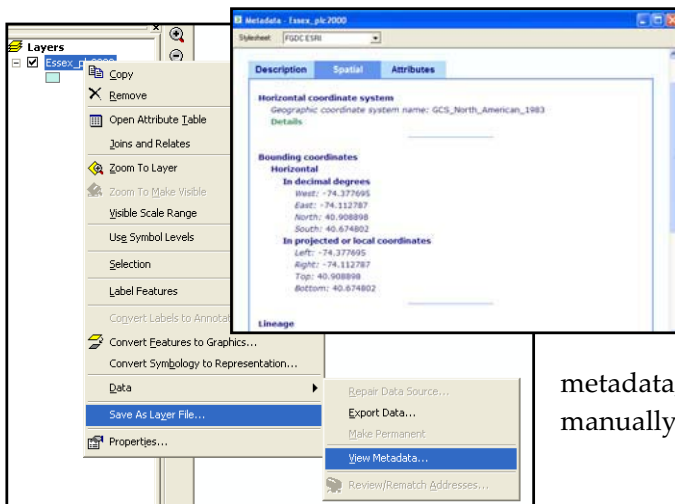
Aerial Photographs and Orthophotography

Aerial photography refers to photographs of the ground taken from an elevated position. Some of the first aerial imagery of the Earth was drawings done from hot air balloons. Today, there are much more sophisticated means of acquiring images of environments, such as with aircraft-mounted gyro-stabilized digital cameras. If you ever used Google® Earth, or clicked the “Aerial” button when viewing Bing™ Maps, then you have seen aerial photographs. Digital orthophotography combines the image characteristics of a photograph with the geometric qualities of a map. This is done through a process which converts a digitized perspective aerial photograph to a digital product that has been rectified for camera lens distortion, vertical displacement caused by terrain relief and variations in aircraft altitude and orientation. Digital images such as aerial photographs or orthophotos can be added to ArcMap as a layer—in the same manner as you would add a shapefile. These layers can serve a variety of purposes such as a reference tool for revision of street networks or as a backdrop that provides additional environmental context to shapefile features layered on top. Some state agencies (such as NJ DEP) provide aerial photographs to the public via free internet download. You can also add Google® Earth satellite (or other digital) imagery into ArcMap. *NOTE: Georectifying the images in ArcMap may be necessary.*



Examining Metadata

From ArcMap’s Table of Contents, right-click layer > Data > View Metadata



Metadata is data about data. In ArcGIS, it is information about shapefiles and other spatial data. It is a separate document (usually in XML format) that communicates the basic characteristics of a data or information resource. It represents the who, what, when, where, why and how of the resource¹⁹. In ArcGIS Desktop, ArcCatalog is used to create metadata. When creating metadata, much of the information must be entered manually.

ZOOM IN: Police Officers' Perceptions of Maps and Aerial Photos

Adapted or excerpted directly from: Canter, P. & Harries, K. (2004). Police officers' perceptions of maps and aerial photographs. Journal of Police Science and Management, 6(1), 37-50.

With the increasing adoption of geographic information systems (GIS) by police departments and other law enforcement agencies around the world, the issue of how effectively maps and related media communicate information has become germane. Canter and Harries surveyed a small sample of police officers in order to test the utility of alternative visualizations of crime data presented at varying geographic scales. Their ultimate objective was to enhance understanding of the effectiveness of maps and aerial photographs commonly used in the context of various investigative, community, managerial, and other applications of GIS tools.

With due caution for the unrepresentative and small sample size that was used, their findings should at least be considered when designing maps for police personnel. The study highlights the importance of understanding your audience(s) and, thus, making finished maps that will effectively communicate findings. Even when presenting results from the same GIS analysis to different groups of people (i.e. policy-makers, police officers, academics), remember that you should (re)design and present your maps to each unique group as appropriate. The following are generalized findings:

1. The interpretation and use of large-scale crime maps can be improved when aerial photography and building footprints are introduced to the display. As a group, officers favored a combination map to view crime at the neighborhood scale.
2. Officers were able to relate the location of a crime incident to other map features such as buildings, wooded areas, and parking lots. Several officers commented on the utility of aerial photographs and building footprints to identify possible ingress/egress points or offender travel paths. Officers noted the location of auto theft locations within parking lots, which they were unable to do using centerline maps.
3. Officers generally believed that aerial photographs and building footprints improved their ability to read and interpret a crime map.
4. Centerline maps tended to be more useful when displayed at an intermediate or community scale. Unlike the neighborhood scale crime map, officers tended to dislike the introduction of building footprints to a community-scaled centerline map.
5. Aerial photographs improved the visualization of mapped crime data, particularly when displayed at a large scale. The utility of neighborhood centerline maps for showing the location of crime improved when building footprints and aerial photographs were added to the view.

Downloading Census Shapefiles

1. Download a census geography (i.e. tract or block group) shapefile for one county at a time from any part of the country. You can do this from the ESRI TIGER site http://www.esri.com/data/download/census2000_tigerline or from the census website http://www.census.gov/geo/www/cob/bdy_files.html

The left screenshot shows the ESRI website's 'Download Census 2000 TIGER/Line Data' page. It features a map of the United States with state boundaries highlighted in different colors. Below the map is a 'Select a State:' dropdown menu with a list of states including Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. The right screenshot shows the U.S. Census Bureau's 'Cartographic Boundary Files' page. It has a navigation menu on the left with links for 'Download Boundary Files', 'Descriptions and Metadata', 'Technical Information', and 'Boundary Files Site News'. The main content area lists various boundary file types and their corresponding years, such as 'Alaska Native Regional Corporations: 2000', 'American Indian Areas/Alaska Native Areas/Hawaiian Home Lands: 2000 | 1990', 'American Indian Tribal Subdivisions: 2000', 'Census Block Groups: 2000 | 1990', 'Census Divisions: 2000', 'Census Regions: 2000', 'Census Tracts: 2000 | 1990', 'Congressional Districts: 1990b | 1980b | 1970b | 1960b | 1950b | 1940b | 1930b', 'Consolidated Cities: 2000', 'County and County Equivalent Areas: 2000 | 1990', 'County Subdivisions: 2000 | 1990', and 'Incorporated Places/Census Designated Places: 2000 | 1990 | 1990'.

2. Define that shapefile as geographic, NAD 1983 (because it is unprojected).
3. Project that shapefile into the appropriate state plane (or your best guess).
4. You can download SF1 (short-form) data from the ESRI site for tracts, block groups, or blocks, but this only includes basic age, sex, race, household composition and own/rent data, so you will likely need to download SF3 (long-form) census data from the US Census Bureau site.

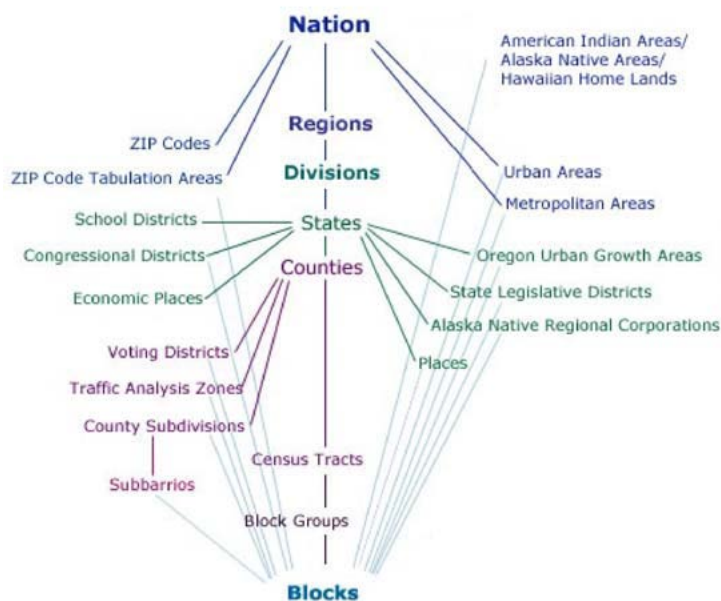


Diagram illustrating the legal and statistical entities for which the Census Bureau tabulates data during the decennial census.

(Source: U.S. Census Bureau, Geography Division. Created: January 17, 2002.)

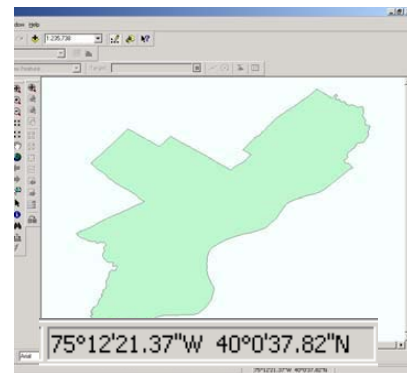
Map Projections

Projections manage the distortion that is inevitable when a (mostly) spherical earth is viewed as a flat map. All projection systems distort geography in some way— either by distorting area, shape, distance, direction, or scale. There are dozens of different projection systems in use since different systems work best in different parts of the Earth and, even within the same parts of the Earth, GIS users have different priorities and needs. The tools for working with projections in ArcGIS are relatively advanced particularly in their ability to re-project layers with different projection systems “on the fly.”

Recognizing the Coordinate System

From ArcMap, right-click the layer > Properties > “Source” tab -or- From ArcCatalog, right-click the shapefile > Properties > XY Coordinate System” tab.

Map layers can be drawn according to a geographic coordinate system or projected coordinate system. Geographic coordinate systems indicate location using longitude and latitude based on a sphere (or spheroid) while projected coordinate systems use X and Y based on a plane. As long as computer screens and printed maps are flat, projected coordinate systems will be more appropriate for working with GIS data. Often you will not know the coordinate system used, particularly if you inherit data or download it from the Internet. If you are lucky, the shapefile will include a .proj file which contains information about the coordinate system. If there is no projection information, you can map the data to determine its coordinate system. If the map units displayed in the gray bar below your map are in degrees, seconds, and minutes, then you know the data are in a geographic coordinate system. You may also recognize this because your maps look distorted. For example, when Philadelphia map layers are in a geographic coordinate system, the image appears to be sagging to the east. Map layers in geographic coordinate systems are sometimes described as “unprojected.” Map layers downloaded from the US Census Bureau are generally in this format.




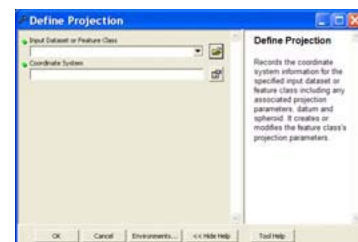
Projecting Unprojected Shapefiles

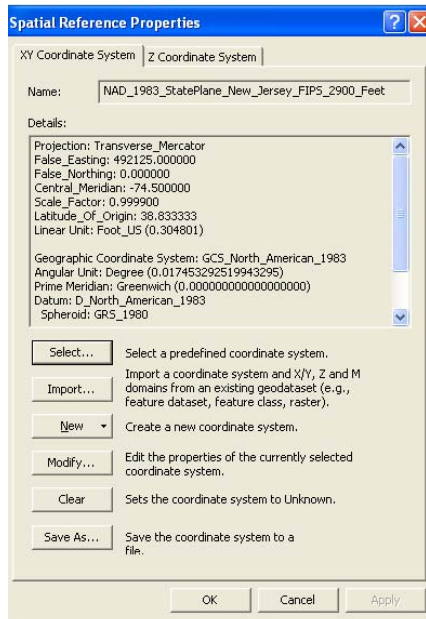
From ArcCatalog, right-click the shapefile > Properties > XY Coordinate System” tab > “Select” button -or- From ArcToolbox > Data Management Tools > Projections and Transformations > “Define Projection” tool

In most cases you will want to convert unprojected map layers—those with a geographic coordinate system—to projected map layers. There are two steps involved in this process. First, you must create a .proj file “defining” the map layer as unprojected; then you can “project” the map layer using the projection of your choice. *NOTE: If you are projecting a raster image, use the “Project Raster” tool under “Raster” (also within the “Projections and Transformations” toolbox).*

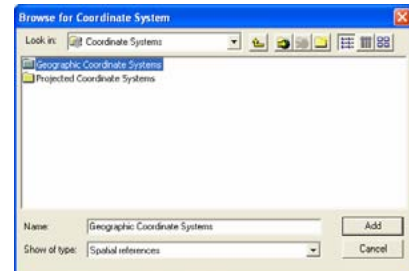
In the “Define Projection” tool’s dialog box, choose a dataset (i.e. shapefile) as the input. If you added the relevant map layer to ArcMap, you will be able to find it in the dropdown menu. Otherwise you will need to click on the “folder icon” button to locate your map layer.

Then you can choose the coordinate system using the  button.






From the “Spatial Reference Properties” dialog box, click the “Select” button on the Spatial Reference Properties, then choose “Geographic Coordinate Systems,” “North America,” and “NAD 1983 Datum.” Click the “Add” button, then click “OK” on the Spatial Reference Properties dialog, then “OK” on the “Define Projection” tool.



You should not notice a difference in how the map layer is drawn as a result of defining the coordinate system. As a result of defining it, there is now a .proj file associated with your map layer and you can look at the detailed spatial reference information. Before you define a layer as unprojected, ArcGIS will refer to it as “assumed geographic.”

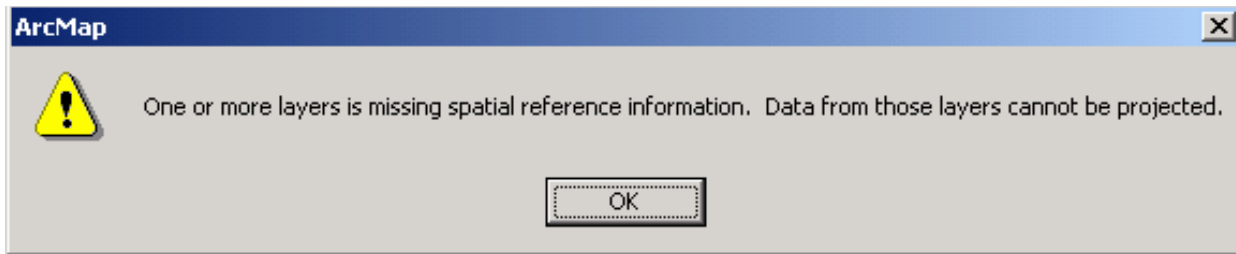
In order to project the map layer, open the “Define Projection”

tool again. Click on the  button to the right of “Output Coordinate System” to choose your projection. Click on the “Select” button on the “Spatial Reference Properties” dialog box, then choose “Projected Coordinate Systems.” Now you need to choose your projection. For relatively small areas like Philadelphia, the differences in projection systems (the distortion in shape, area, distance, direction, and scale) are minimal. You are best choosing whatever projection system is most commonly used. In Philadelphia, that is State Plane 1983 (feet) Pennsylvania South. After making your selection, click “OK.” ArcGIS may indicate that there is a “Datum conflict between map and output.” In order to map your newly projected layer, create a new ArcMap document.

Working with Projected Map Layers

Sometimes the map layers you receive will already be projected but won’t carry a .proj file so you don’t know the projection. If you download the data, be sure to read any metadata files that may contain information about the project. If someone has sent you the map layers, ask them about the projection. If these approaches fail, try mapping the data. You may recognize that the data are projected by the units showing in the gray bar below the map. If they are not in longitude and latitude, they are probably projected. As you work with a particular projection system, you will come to recognize the map units and range of coordinate values. For example, State Plane coordinates for Philadelphia are generally in feet and look like 2691607.78, 246268.98. UTM coordinates will be in meters and look like 486850.72, 4430095.19.

When you add a shapefile to ArcMap that the software recognizes as being projected but has no .proj file, ArcMap will usually warn you that spatial reference information is missing. Data that are projected but missing spatial reference information will look fine when they are drawn, but you may not be able to use ArcMap’s “on the fly” projection capabilities, measurement tools, spatial join, or geoprocessing functions.



If you know the proper projection, you can use the “Define Projection” tool in ArcToolbox. You will need to select the projection from the “Projected Coordinate Systems.” If a map layer is already projected AND defined, you can change the projection using the same tool. *NOTE: You must add the re-projected shapefile to a new ArcMap document to see the results.*

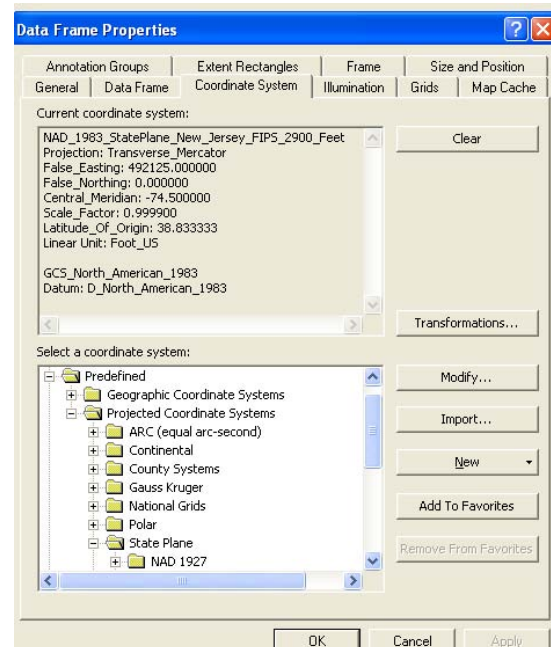
Troubleshooting with Projections

If you are unable to draw your map layers together or if your distance units do not make sense, you are likely experiencing a problem with projections. If you are not able to figure out the problem, you may want to show your shapefiles to someone with more GIS experience. It is easy to get confused while using the “Define Projection” and “Project” wizards, and frequently the more you try to fix the problem, the more mixed up your projections get. Stay calm and don’t be ashamed to ask for help. You may also have luck returning to your original files (be sure to keep a copy of the originals before messing with the projection).

Defining Projection for a Data Frame

From ArcMap’s Table of Contents, right-click on the Data Frame > Properties > “Coordinate System” tab

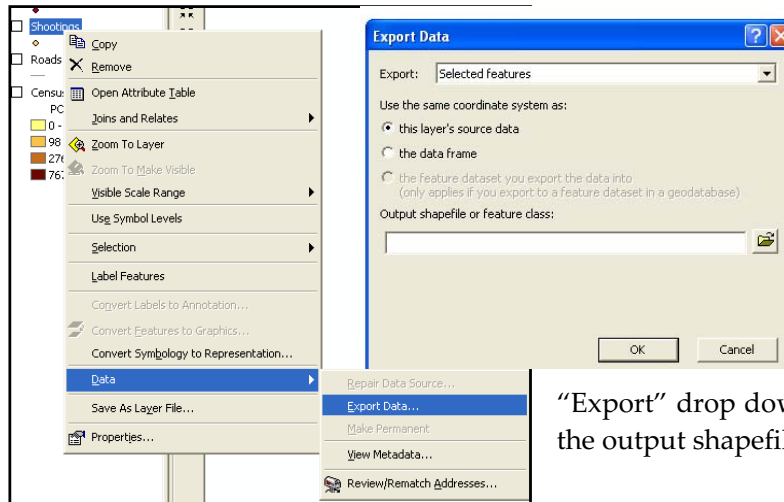
Ideally, you will know and will specify the projection of each of your map layers. Alternatively, you can set the projection for your Data Frame for your map document. All of the map layers listed under the Layers icon in your table of contents are in the same data frame (you can have multiple data frames in the same map document, although in most cases you will probably have just one). *NOTE: The Data Frame will automatically assume the Geographic or Projected Coordinate System of the first shapefile that is added to ArcMap. If subsequent shapefiles are unprojected, or in a different coordinate system than the data frame, ArcMap may notify you to this effect prior to (temporarily) re-projecting the shapefile on-the-fly.*



Creating New Shapefiles from Existing Shapefiles

From ArcMap's Table of Contents, right-click layer > Data > Export Data

This makes a separate duplicate shapefile. It works like a "save as". In the "Export Data" dialog box, give your new file a name and location. The resulting shapefile will have the exact same features and variables in the attribute table as the original shapefile.



You can create a new shapefile that only includes your selected map features by right-clicking on its layer name in the Table of Contents > Data > Export Data. Choose the appropriate radio button regarding coordinate systems (you'll probably want the default). Make sure you have "Selected features" chosen in the "Export" drop down box. Select a location and name for the output shapefile and then click the "OK" button.

Data Frame projections are temporary, shapefile projections are (or should be) permanent. However, if you want to quickly and permanently project an unprojected shapefile that is within a Data Frame of the desired Projected Coordinate System, then the "Export Data" function is a good method. In the "Export Data" dialog box, under "Use the same coordinate system as:", select the radio button next to "the data frame." This will automatically create a new shapefile that will be permanently projected with the same coordinate system as the Data Frame.

Using Excel Spreadsheet Files

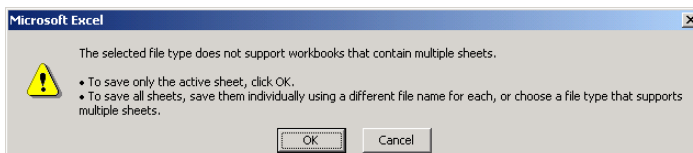
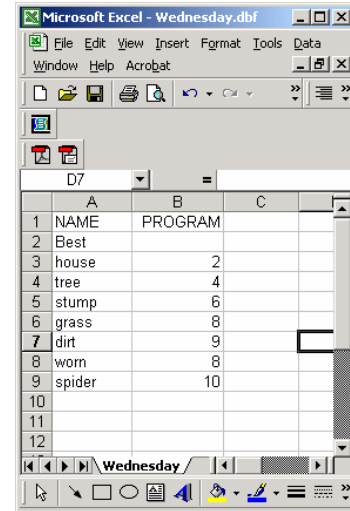
ArcGIS 9.3 is the first version that does not require Excel spreadsheets to be converted to DBF format prior to importation. Though, some preparatory work is still recommended. The name of the Excel file that will appear in the Table of Contents in ArcMap is the name of the Worksheet (i.e. those 3 tabs at the bottom of the screen that read "Sheet1", "Sheet2", "Sheet3", and appear by default when you open a new spreadsheet). Therefore, you should change the name of the Excel "Worksheet Tab" that you will import to something meaningful (When you add the Excel Spreadsheet file to ArcMap, it will prompt you to choose to one of the Worksheets). Since ArcGIS only permits 10 characters or less as attribute table column headings, you should change the column names in the Excel Worksheet to be 10 or fewer characters, with no spaces, to prevent undesired truncation.

Converting Files to .DBF

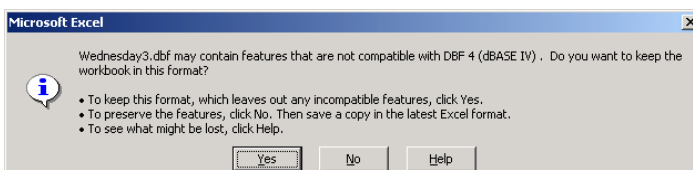
Although ArcGIS imports Excel files directly from .XLS format, it still creates and exports attribute tables as DBF files. That is, DBF is still the primary and preferred format. So it is good to know how to convert files to DBF should the need ever arise. You can use Excel, SPSS, ACCESS, or other statistical and database packages. In many cases, Excel will be the only software available for the job.

Excel can open a wide variety of formats, including delimited or fixed width text, Lotus, Quattro Pro, and web pages. If you are working with one of these other formats and need to make changes to your data in Excel, it is probably best to save the document as an Excel worksheet. When you save an Excel document, you can choose another format using the “save as” options. But even if you choose .dbf at this stage, you may encounter problems. For example, your new .dbf file may not include all of the cells in your original file, or the columns may be formatted as strings rather than numbers. Here are some things you can do to increase the odds of preserving your data during the conversion.

1. Limit your column headings to 10 characters. Excel will let you have infinitely long column names, but ArcGIS will shrink them. It’s better to come up with your own abbreviated names than to risk losing important information when ArcGIS truncates the names.
2. Check your columns to be sure that they are formatted correctly as strings (left justified) or numbers (right justified). Also, look for rows at the very top that may be blank or contain data that are different from the following cells. For example, you may have a column named “programs” with values ranging from 2-10 for all of your cells, but the first cell is blank or has an “NR” for “not reported.” This column will be formatted as a string when you convert to .dbf and open it in ArcMap—because .dbf takes its cue from the first data cell in the column. To avoid this problem, you can resort the data so that the blank cell is not on top, or you can put in an appropriate numeric value (such as 0 or 999 for missing data). You can convert a string field to numeric in ArcMap, but it’s easier if you start with the right format.
3. When you are ready to save your data, highlight all of the cells that contain values (including the column names). From the Insert menu, go to “Name” and “Define.” Type in a name (type anything; it doesn’t matter), click “Add” and “OK.” This increases the likelihood that all of your cells will be included in the new table. Now you can save your document. First, save all changes in your Excel document. Then, from the File menu, choose “Save As” and select “DBF4” from the dropdown menu. First Excel will give you a warning that the .dbf format doesn’t support multiple worksheets and that only the data in the top (active) worksheet will be saved. Click “OK.”



Excel will then give you a second warning message because .dbf is very different from .xls and some formatting may be lost. Just click “OK.”




If you don’t get BOTH of these warnings, then the conversion to DBF was not successful. Try it again by copying everything into a new workbook.

When you close Excel, Excel will prompt you again with these messages, as though it is still incredulous that you would choose any format other than Microsoft's. Humor the software and go through these two steps again. As soon as you add your table to ArcMap, look it over to make sure that all of the data came through and are in the right format.

Before converting an Excel spreadsheet to DBF...

Your table must have a row with column headings/names	Your table must have a column with Unique ID numbers for each row	All data must be fully visible. If necessary, ← Expand column widths →	Crime_Type	Crime_Date	Conviction
	ID	Address			
	1	123 Main St	Robbery	1/25/99	Y
	2	30th St & Walnut St	Theft	1/26/99	Y
	3	1776 University Ave	Burglary	1/01/99	N

	1000	900 Cooper Pl	Car Jacking	1/15/99	Y



• Highlight all of the data in your table before "Saving As" visible in each field will be converted.

• There's **NO** NEED to use **bold** or *italic* formats—these formats will not transfer to the DBF file. **B** *I* **U** **B** *I* **U** **B** *I* **U**

• When Saving As a DBF, you will receive multiple warnings from Excel that the DBF version may mess up the formatting. Just say "yes" and "OK." Close Excel before adding the new DBF file to ArcMap.

• It is recommended to save your table as both an Excel (.xls) file and a dBASE (.dbf) file. That way, you can always go back to the original Excel file to make changes if necessary.

GIS Data Format and Data Cleaning

GIS mapping follows the time tested theorem “garbage in, garbage out”. If your addresses are not clean, then you are significantly increasing the probability that they will not be geocoded correctly. Address information should comprise 4 fields: Street Address, City, State, and ZIP code (last 4 digits of a ZIP should be in a separate field).

“Correct”

Record	Address	City	State	ZIP
1	677 Huntington Ave	Boston	MA	02115

“Incorrect”

Record	Address
1	677 Huntington Ave, Boston, MA 02115

Cleaning addresses means:

- Retaining only the key address elements in one field: house/building number; street name; street type (e.g., 100 Main St)
- Getting rid of all extraneous characters (e.g., “BSMT” “REAR” “APT 1” “UNIT 3”, etc.)
- Standardizing spelling (e.g., converting all incidences of “Mass Ave” to “Massachusetts Ave”)
- Removing all irrelevant punctuation including commas, quotation marks, apostrophes, parentheses, dashes, etc. that may interfere with the application’s coding and can cause an error. (Periods are not needed after abbreviations, such as street types).
- Changing street address ranges (e.g. “110-114 Main St”) to only one number (e.g. “110 Main St”)
- Finding appropriate street addresses for building or location names (e.g. “Wynnwood Apartments”, “Homeless Shelter”)
- Standardizing cross streets (e.g. use ampersand [&])

Some examples:

Record #	Original Address	“Cleaned”
1	677 Huntington, #304	677 Huntington
2	46 Burr REAR	46 Burr St
3	Unit B, 1200 Comm Ave.	1200 Commonwealth Ave
4	423 Allston St., 4th Floor, Suite 100	423 Allston St
5	The Landmark Building, 401 Park Drive	401 Park Drive
6	99 ½ Chauncey St	99 Chauncey St
7	111-113 Walnut Street	111 Walnut Street
8	Main St and Chestnut Ave	Main St & Chestnut Ave

X-Y coordinates should comprise two separate fields. Do not round the numbers.

For example:

Record	X	Y	Provider
1	2672973.889167	222351.750051	Safe Meadows Healthcare Center

Record	X	Y	Provider
1	-75.238221	39.916205	Safe Meadows Healthcare Center

GIS-Friendly Datasets

- Must have spatial location
 - i.e. Street address, ZIP code, State, Tract, XY
- Must have a unique ID number
- Can include any other variables about each observation. Different variables should be in separate columns.
- Column/heading names must be 10 or fewer characters; No spaces.

ID	Location	Variable1	Variable2	Variable3
0001	123 Main St	Medical	Male	Refusal
0002	33rd St & Park Pl	Trauma	Female	Transport
0003	227 Penn Ave	Trauma	Male	Transport

Philadelphia
philadelphia
PHILADELPHIA
philly
Phila
City of Brotherly Love

Data is taken literally in a GIS, so differences in spacing, case, or coding can cause problems. Each field in the example to the left is different as far as ArcGIS is concerned, even though they all refer to the City of Philadelphia.

ArcGIS differentiates data by the type of information entered into each field of a table. Data can be numerical (i.e., 19104) or string (i.e. Pennsylvania). The ZIP code 19104 entered as *numerical* is not the same as 19104 entered as a *string*. Think ahead about the format your data should take. Your decision might be dependant on the type of analyzes or outputs you want to produce. Numbers, for example, can be added or subtracted while text strings cannot.

CHAPTER FIVE

*Geocoding Addresses and
Working with XY Data*

Geocoding²⁰

Geocoding refers to the process of transforming street addresses into map features. In order to geocode, you need to have a table with addresses and a shapefile for streets that matches the geographic extent of your addresses. Through the geocoding process, ArcGIS will create a new point shapefile by matching each street name and number in your table to a place along a line segment in your street shapefile that represents a certain range of house numbers. *NOTE: For a more detailed discussion of geocoding, see the COPS Publication entitled “Geocoding in Law Enforcement [Final Report]” (2000). Available at www.cops.usdoj.gov/files/RIC/Publications/geocodinginlawenforcementfinalreport.pdf*

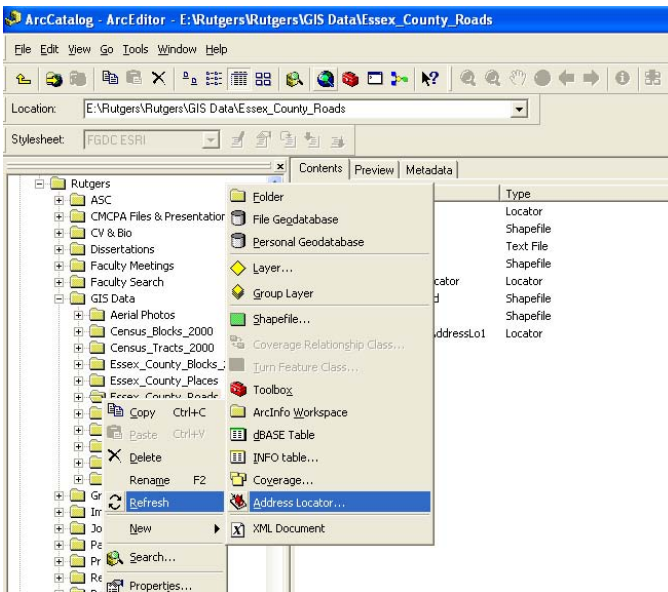
CATEGORY	NAME	STREET	CITY
Liquor Stores	Maple Liquor	876 Springfield Ave	Irvinton
Liquor Stores	Bravo Liquor and Grocery	1117 Grove St	Irvinton
Liquor Stores	Brozeo Liquor	1117 Grove St	Irvinton
Liquor Stores	Marmol Liquor	1158 Stuyvesant Ave	Irvinton
Liquor Stores	Roseway Liquor	701 Lyons Ave	Irvinton
Liquor Stores	Irvington Liquor	1394 Springfield Ave	Irvinton
Liquor Stores	Jason Liquor	764 Chancellor Ave	Irvinton
Liquor Stores	Old Brothers Liquor II	859 18th Ave	Irvinton
Liquor Stores	Vanity Fair Liquor	468 Chancellor Ave	Irvinton
Fast Food Restaurant	Wendy's	462 Chancellor Ave	Irvinton
Fast Food Restaurant	Burger King	500 Lyons Ave	Irvinton
Fast Food Restaurant	Number One Chinese	1064 Springfield Ave	Irvinton
Fast Food Restaurant	Lucky Chinese	1306 Clinton Ave	Irvinton
Fast Food Restaurant	Chengs Garden	1183 Springfield Ave	Irvinton
Fast Food Restaurant	Lily Chinese	350 18th Ave	Irvinton
Fast Food Restaurant	Chan Chung	700 Chancellor Ave	Irvinton
Fast Food Restaurant	Zheng	1316 Springfield Ave	Irvinton
Fast Food Restaurant	Orient Express	1073 Springfield Ave	Irvinton

1. Preparing Tabular Data

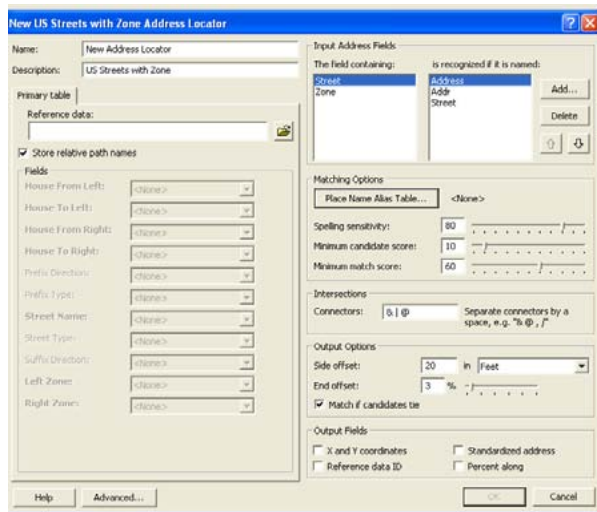
In order to geocode you need a table (.xls, .dbf or comma-delimited .txt) that has a field with street addresses. If the parts of the address—house number, street direction, street name, and designation/type—are in separate fields, you will need to collapse these into a single field. Having a separate field with the ZIP code can also be helpful.

2. Creating an Address Locator

From ArcCatalog, right-click folder where you want to store the Address Locator > New > Address Locator



From the “Create New Address Loca...” dialog box, scroll down the list of Address Locators, then locate and click the “US Streets”. Click OK.



The US Streets address locator style is used for the majority of common United States street addresses. Several things should be considered when choosing an address locator style, including the type of geometry in your reference data and the format of address data you wish to search.

“US Streets with Zone” is another common alternative. First, it zeros in on a specific ZIP code area, and then finds an address on a specific side of a street within that ZIP. This is useful when your study area encompasses multiple jurisdictions that have the same street names. For example, if my study area is Essex County, NJ,

“Main Street” might be the same name of different roads in the neighboring cities of Newark and Irvington. “US Streets with Zone” would ensure that the geocoded point is placed at the address in the correct city (i.e. the address in the correct ZIP code area).

From the “New US Streets (or US Streets with Zone) Address Locator” dialog box, you need to define the properties associated with the US Streets Address Locator. Reference Data is a shapefile that includes information about all of the streets in your area. A street centerline shapefile is made up of line segments that represent certain ranges of house numbers. The line segments also contain information in their attribute table about which side has even and odd house numbers. Where it says “Reference Data”, click the button with the “folder icon” to browse to your streets shapefile and click “Add” button. In the “Fields” section below, ArcGIS may be able to identify the appropriate fields on its own. If no field names appear in the drop down menus, or if they do not look right to you, you’ll need to identify them yourself.

FEDIR	FENAME	FEType	FECC	FRADL	TOADDL	FRADDR	TOADDR
A	Ridgewood St	A41	5400	5400	5401	5499	5499
A	Pontbridge St	A41	5300	5388	5301	5388	5388
S	53rd St	A41	1021	1049	1018	1096	1096
	Florence Ave	A41	5400	5488	5401	5499	5499
S	54th St	A41	1201	1219	1200	1224	1224
	Florence Ave	A41	5344	5388	5365	5398	5398
S	Ruby St	A41	1101	1189	1100	1198	1198
S	53rd St	A41	1051	1089	1058	1098	1098
	Florence Ave	A41	5328	5342	5333	5367	5367
S	Peach St	A41	1101	1199	1100	1198	1198
	Florence Ave	A41	5300	5326	5301	5331	5331

The “Input Address Fields” section allows you to identify the names for the field(s) in your tabular data that contain the street address information. The “Matching Options” section allow you to indicate the level of sensitivity for the matching process. Essentially, ArcGIS needs to match the house numbers and street names in your tabular data with information in the street shapefile’s attribute table (reference data). If the spelling of the street name is slightly different or an appropriate range of house numbers cannot be located, ArcGIS will assign the match a less than perfect score (100 is a perfect match). ArcGIS can geocode based on street intersections in addition to specific house numbers. In the “Intersections” section you can identify symbols (or “AND”) used in your tabular data to indicate intersections. The “Side Offset” option allows you to place points slightly away from the middle of the street centerline file. While ArcGIS will know what side of the street your address falls on, your points will appear to fall directly on the centerline unless you specify an offset (e.g. 15-20 feet is usually adequate).

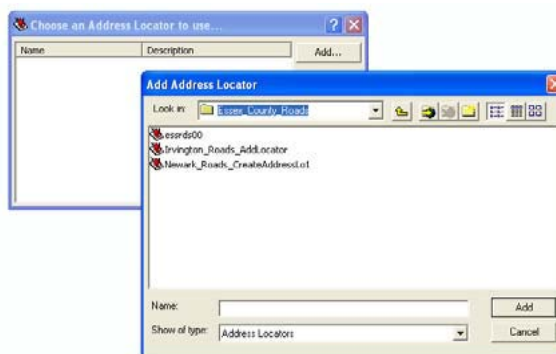
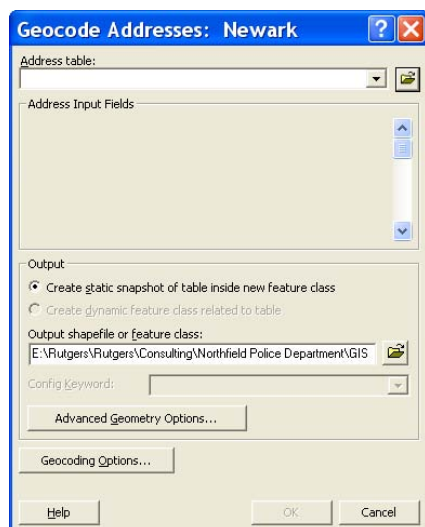
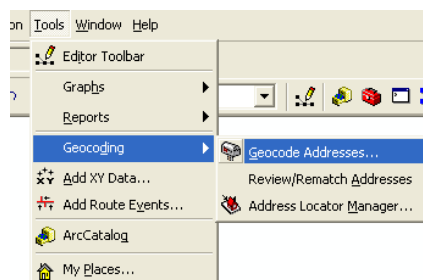
If you check “X and Y coordinates” under the “Output Fields” section, ArcGIS will add X and Y fields to the new (geocoded) point shapefile’s attribute table. Once you click “OK,” a new address locator will be created. Once you create an address locator, you do not need to do it again (unless you go to a new computer).

3. Geocoding Addresses

From ArcMap, Tools > Geocoding > Geocode Addresses

NOTE: You do not need to have your street shapefile (reference data) added to your map document.

In the “Choose an Address Locator” dialog box, select the appropriate Address Locator or, if necessary, click the “Add” button and navigate to the folder where the “Address Locator” is located. After finding your address locator, click “Add,” then click “OK.”



On the next screen (“Geocode Addresses:” dialog box), you need to select the tabular file with the addresses you want to geocode. Then select the field in the table that contains the street address; choose a name and location for the new point shapefile that will be created (output). The “Geocoding Options” button gives you access to many of the same options available when you create an address locator. When you click “OK,” ArcMap begins the geocoding process. The next screen indicates how well ArcGIS was able to match the addresses. When you click the “Close” button, a new point shapefile should appear in the Table of Contents.

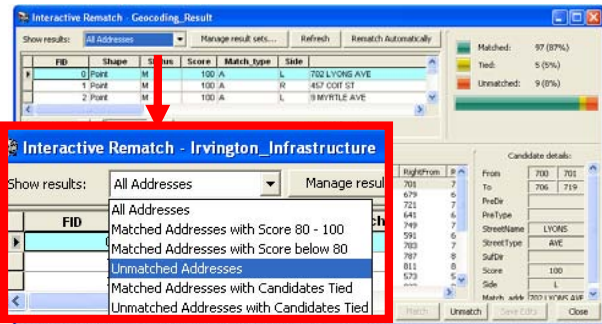


If you open the attribute table associated with the shapefile, you will see that the geocoding process added several fields to your original address table. The “Status” field indicates whether the record was matched (M) or left unmatched (U). The “Score” field indicates how closely the record matched the street centerline file. The “Side” field indicates on which side of the street the address was matched. The “Arc_Street” field is the address used in the match. This will be the same as the original address unless you edit it during the “Interactive Review.”

4. Interactive Review and Rematching Addresses

Click the “Rematch” button from the “Geocoding Addresses” Results dialog box -or- From ArcMap > Tools > Geocoding > Review/Rematch Addresses > choose the layer name of the Geocoding Result -or- Right-click on the geocoded layer in the Table of Contents > Data > Review/Rematch Addresses

You will need to start an edit session in order to proceed with the Interactive Rematch process. The interactive review process can be used to correct and then match the unmatched or poorly matched records. If you have thousands of addresses in your address table, you may not be able to review all of the unmatched records. But for smaller data sets it is very important to review the unmatched records.



From the “Interactive Rematch” dialog box, you can edit the addresses in order to get a match/better match (don’t worry, this only changes the address that ArcGIS uses for geocoding; it does not change the data in your original table of addresses). Before you begin reviewing addresses, click the “Show results” drop-down menu to display only the addresses you are interested in reviewing. For instance,

rather than scrolling through all the Matched or Tied addresses, you might only be interested in reviewing the “Unmatched” addresses.

To edit an address, simply click in the “Street or Intersection” text box and make the changes, then hit the “Search” button. ArcGIS will list possible matches. Highlight the best candidate and click the “Match” button. Street intersections are the most likely to create ties in the matching process. For example, ArcGIS might not know whether to place the “10th and Market” point on 10th Street or just north or just south of Market Street. Most likely, it will not matter for your work. If it does, you are better off using a house number and street, rather than an intersection. Choosing the “match if candidates tie” box in the geocoding options will help you avoid having to match these individually.

Determining an Acceptable Match Rate

A minimum reliable geocoding match rate is 85 percent²¹. Be sure to write down the match rate so that you can report it later. Often you will receive a list of addresses that contains some PO Box numbers or missing data that will prevent you from matching all your records. Other times your addresses will look fine but simply won’t match the street centerline file. The most important thing to determine is if the error (the unmatched records) is random or systematic. If you have done all that you can to gather complete and accurate addresses, random error is acceptable and probably unavoidable. Systematic error is not. Be sure to check for patterns in your unmatched records (either by interactively reviewing unmatched records or, after finishing geocoding, open the attribute table and sort by “status” to review all the “U” (unmatched) records. There is no guarantee that the matched records will be mapped in the right place. Check with the “Identify” tool to make sure that records were mapped somewhere that makes sense to you.

Locating an Individual Address

Edit > Find > “Addresses” tab

If you have only an address or two to map, you can take a shortcut. From the “Addresses” tab of the “Find” dialog box, choose an address locator in the drop down menu. If you have not already created an address locator, you will need to do so. Next, type the address in the “Street or Intersection” text box and click the “Find” button. ArcGIS will display the possible matches below, with their score. Right click on one of the addresses for mapping options. You might choose to “Flash” candidate locations to make sure ArcGIS is mapping in the right area or “Add Point” if you want a marker at the location. Keep in mind that this is only a graphic; it can easily be deleted or moved. You can change the size and color of the graphic, but you cannot turn it on and off like a map layer. It has no attributes associated with it.



Creating XY Coordinates from Addresses

When creating an Address Locator, or from the “Geocoding Options” button, check the “add x-y coordinates” box

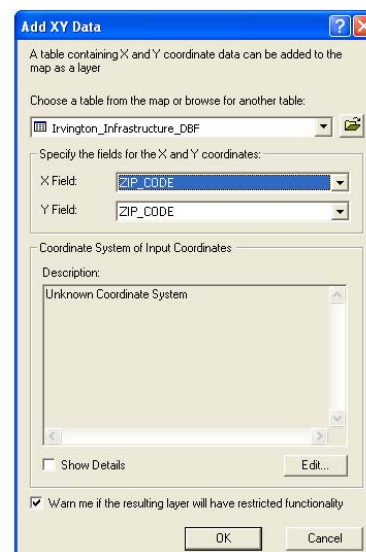
Displaying XY Data

From ArcMap, Tools > Add XY Data

Sometimes you will need to map a table that just has X and Y coordinates identifying specific locations but no shapefile associated with it. This might occur because a GPS (global positioning system) unit was used to collect the data or because that is the way a private vendor has chosen to distribute the data. A table with X and Y coordinates is much easier to distribute than a shapefile, because it is smaller, does not involve multiple files, and is not ArcGIS-specific. In order to map the data in ArcGIS, the X and Y values will need to be included as separate columns in an Excel, dBASE or delimited text file. You can add the table to ArcMap just as you would a shapefile (with the “Add Data” button), but you do not need to add it to ArcMap in order to map it.

From the “Add XY Data” dialog box, browse to the table with the XY data. ArcMap will probably find the appropriate fields in your table; otherwise, use the dropdown menus to indicate the fields containing the X and Y values and click “ok.” As with shapefiles, tables with XY data that you acquire may be projected. If the Spatial Reference “Description:” box reads “Unknown Coordinate System, then they are unprojected.

ORGANIZATI	X_COORD	Y_COORD
Azomingo Development Corporation	-75.10261	39.98045
Yorktown Community Development Corporation	-75.15637	39.97995
People's United Community Organization, Inc.	-75.17861	39.98678
Raphael Heights Homes, Inc.	-75.13848	40.00007
Carroll Park Community Council, Inc.	-75.22659	39.97414
Campfor Council for Community Development, Inc.	-75.22309	39.96868
Intercommunity Action, Inc.	-75.21344	40.03184
Perspective Homes Insight Inc.	-75.22348	39.92436
Campus Boulevard Corporation	0	0
Philadelphia Chinatown Development Corporation	-75.15604	39.9554
Fresh Start Community Development Corporation	-75.15803	39.9420
Tolerance Community Center and CDC	-75.16209	39.92597
Faith Community Development Corporation	-75.17432	40.03703
Fern Rock-Oponts-Bellfield CDC	-75.14107	40.03020

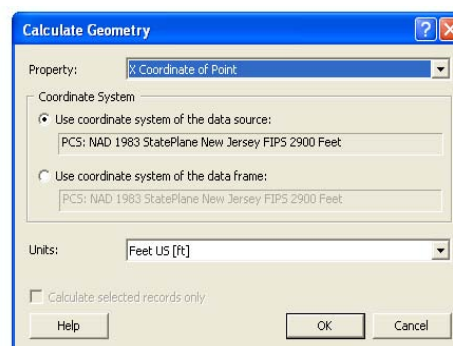


Adding XY Coordinates to Points, Lines or Polygons (Centroids)

From the shapefile's attribute table, right-click the column name > Calculate Geometry

Just as you may need to convert a table with XY data into a map layer, you may need to add XY coordinates to an existing layer containing points, lines or polygons. With your attribute table open, go to options, add new field called “X,” type “Double.” Right click at the top of your new column and go to “Calculate Geometry.” A message might appear warning that you are about to calculate outside of an edit session. Acknowledge this by clicking the “OK” button.

In the “Calculate Geometry” dialog box, select “X Coordinate of Point (or Centroid, if it's a polygon shapefile)” from the Property drop-down box. Click OK. ArcMap will calculate the x-coordinate for each point in the shapefile. Repeat the above steps to calculate the y-coordinate in a new field named “Y”. You can check the new XY coordinates by mapping them. With your table open, click on “Options,” and go to “Export.” Choose “yes” and add the new table to your existing map; then close the table. From the tools menu, go to “Add XY Data” and select your table from the drop down menu (ArcMap will probably have done this for you already). Click “OK.” Your table of contents should now show two identical point layers.



CHAPTER SIX

Spatial and Tabular Joins

Joining Tables

From ArcMap's Table of Contents, right-click the layer > Joins and Relates > Join

Often you will have attributes stored in a separate table that you will need to join to a shapefile in order to display that data. This is especially common with census data, when you will often obtain census attribute data (SF1 or SF3) in files separate from the shapefiles for census tracts, blockgroups or other unit of analysis. Tables to be joined with shapefiles must be in either the DBF or Excel file format.

1. Identifying a Key

In order to join an attribute table to a shapefile, you must identify a field that is common to your attribute table and the attribute table associated with your shapefile. This field is known as a key, or unique identifier, because it uniquely identifies each record in your table and shapefile on which ArcGIS can join, or match, your data. The values must be formatted in an identical way (i.e. numerical, string). If they are not, you must edit one of the fields or create a new field and recalculate the values so that their formats match perfectly.

FID	Shape*	ID	FIPSSTCO	TRACT	GROUP	STFID	STATE
0	Polygon	1	42101	000100	1	421010001001	42
1	Polygon	2	42101	000100	2	421010001002	42
2	Polygon	3	42101	000100	3	421010001003	42
3	Polygon	4	42101	000100	4	421010001004	42
4	Polygon	5	42101	000100	5	421010001005	42
5	Polygon	6	42101	000200	1	421010002001	42
6	Polygon	7	42101	000200	2	421010002002	42
7	Polygon	8	42101	000200	3	421010002003	42
8	Polygon	9	42101	000200	4	421010002004	42

At left, the attribute table of a census tract shapefile contains multiple fields that uniquely identify each record (e.g. STFID)

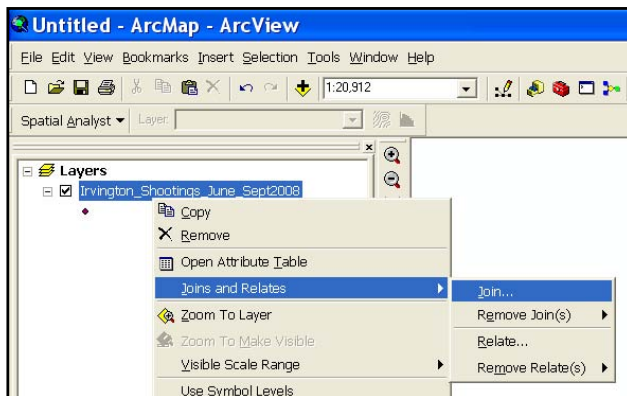
The table to the right includes several attributes of census tracts but cannot be mapped until it is joined to a shapefile. There is one field that uniquely identifies records AND can be used to match fields in the census tract shapefile: STFID.

FID	Shape	ID	FIPSSTCO	TRACT	STFID	POPN	FAMILIES	HSEHOLDS
0	Polygon	1	42101	000100	421010001001	174	36	101
1	Polygon	2	42101	000100	421010001002	466	66	328
2	Polygon	3	42101	000100	421010001003	728	75	528
3	Polygon	4	42101	000100	421010001004	52	2	8
4	Polygon	5	42101	000100	421010001005	1230	128	783
5	Polygon	6	42101	000200	421010002001	250	23	66
6	Polygon	7	42101	000200	421010002002	959	233	350
7	Polygon	8	42101	000200	421010002003	125	21	31
8	Polygon	9	42101	000200	421010002004	28	4	12
9	Polygon	10	42101	000300	421010003001	758	27	154
10	Polygon	11	42101	000300	421010003002	132	5	54
11	Polygon	12	42101	000300	421010003003	1680	295	1031
12	Polygon	13	42101	000400	421010004001	431	1	1
13	Polygon	14	42101	000400	421010004002	3057	478	2331

The field name doesn't have to be the same in the attribute table and the shapefile in order to join them; they just have to be formatted in the same way. While you may perform joins on census data most frequently, you can join attributes to shapefiles for other data: zipcodes, councilmanic districts, counties. You can join on a name (such as neighborhood name, or the name of an institution), although keep in mind that differences in spelling and spacing will prevent records from joining.

2. Joining a Table

To join attribute data to a shapefile, you must add the shapefile to ArcMap. Right-click the shapefile layer in the Table of Contents > Joins and Relates > Join. From the “Join Data” dialog box, select “Join attributes from a table” from the first drop down menu, under where it reads “What do you want to join to this layer?”. In the drop down menu under item 1, select the key field in your shapefile. In the drop down menu under item 2, select the table you wish to join to the shapefile (the table does not need to be added to ArcMap first). In the drop down menu under item 3, select the key field in your table (from item 2) that you wish to join.



Keep in mind that ArcMap does not check to make sure that the key fields or their formats match, so you should double-check them (by opening both tables) before performing the join.

Under the “Join Options” section, indicate what you want ArcMap to do if all of the map features in the shapefile do not have a match in the attribute table, or vice versa. The default is to “Keep all records”, meaning that some map features might have no values for some fields. (Individual records might not match because of problems with the key or because there are different numbers of records in each of your files). When you open your shapefile’s attribute table after a successful join, there should be new fields that contain the data from your table. The new field names will include the name of the attribute table from which it came.

When you perform an attribute join the data is dynamically joined together. This means that nothing is written to disk and the join holding the data together is not permanent. To make the join permanent, right-click on the shapefile layer in the Table of Contents > Data > Export Data”. This works like a “save as,” so it creates a new shapefile. The resulting shapefile will have variable names that are much shorter than those in the table created during the temporary join, and it will include attributes from both (or all) joined tables. *NOTE: Several tables or layers can be joined to a single table or layer and relationship class joins can be mixed with attribute joins.*

Removing Joins

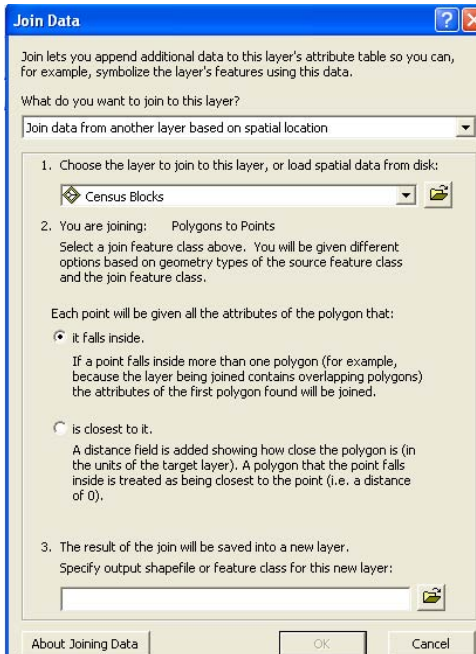
From ArcMap’s Table of Contents, right-click the layer > Joins and Relates > Remove Join(s)

When a join is removed, all data from tables that were joined after it are also removed, but data from previously joined tables remain. Symbology or labeling that is based on an appended column is returned to a default state when the join is removed.

Spatial Joins

From ArcMap's Table of Contents, right-click the layer > Joins and Relates > Join

Tabular joins use a common unique identifier to attach an attribute table to a shapefile. Spatial joins use common geography to append fields from one layer, or information about a layer, to another layer. This allows you to assign the characteristics of an area—such as a census tract or city council district—to individual houses, individuals, or events as well as to aggregate points by areas.



Assigning Area Characteristics to Points

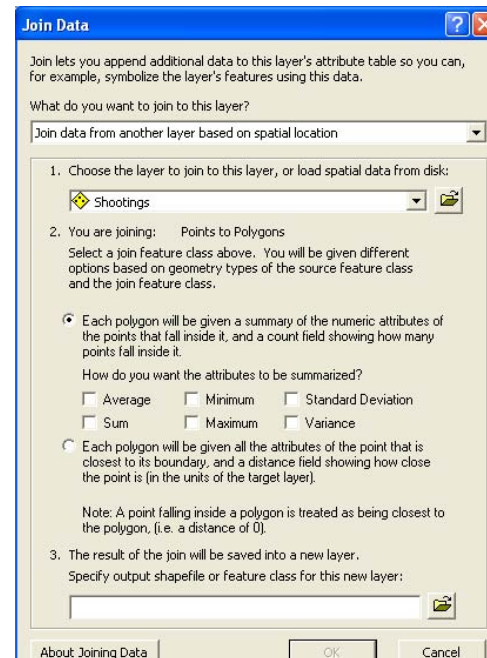
Using a spatial join, you can identify into what area a point falls. For example, you might need to determine in what census tract each of your study participants lives. You must have a point theme and a polygon theme in ArcMap in order to do this. In the first dropdown menu of the “Join Data” dialog box, indicate that you want to join data to that layer based on spatial location. In the next dropdown menu, choose your polygon layer. Next, choose the first radio button so that each point is given all the attributes of the polygon it falls inside. If you have points outside your polygon (for example, if you have a census tract map of Philadelphia with points representing addresses in the city and just outside it), choose the second radio button. Specify the name and location of the new point shapefile that will be created and click “OK.” The resulting point shapefile will have as many new columns as your polygon shapefile. This

may include only the polygon identifier (such as the census tract number) or the identifier and attributes.

Aggregating Points to Lines or Polygons

Using a spatial join, you can also determine how many points fall in each polygon. For example, you might need to determine how many mortgages were made in each city council district. You must have a point layer and a polygon layer in ArcMap in order to do this.

In the first dropdown menu of the “Join Data” dialog box, indicate that you want to join data to that layer based on spatial location. In the next dropdown menu, choose your point layer. Next, the radio button should be set for “Each polygon will be given a summary of the numeric attributes of the points that fall inside it, and a count field showing how many points fall inside it.” If your points do not all fall within your polygons (for example, you have a map of city council districts and points representing addresses in the city and just outside it), choose the second radio button, instead. You can then decide if you want to summarize the attributes of your points by their areas in the boxes below. Finally, specify the name and location of the new area shapefile that will be created. Click “OK.”



Finally, specify the name and location of the new area shapefile that will be created. Click “OK.”

If you did not check any of the boxes to summarize the attributes of the points, your new shapefile will have only one new field named "Count_". This will indicate how many points fall into each polygon. You will probably want to change the name to something that you will remember (by creating a new field called "TheftCount," for example, and calculating it as equal to "Count_"). Now you can use this count value as the basis of a thematic map.

Attributes of NewPolygonShapefile									
FID	Shape	FID_1	AREA	PERIMETER	COUNCIL_	COUNCIL_ID	DISTRICT	Count_	
0	Polygon	0	682378958.20999	215638.1514	2	1	10	12	
1	Polygon	1	311968600.96382	210527.15661	3	2	7	123	
2	Polygon	2	404595288.01292	161336.01977	4	6	6	98	
3	Polygon	3	240417188.56527	111021.59261	5	5	9	109	
4	Polygon	4	367541458.84149	123988.20549	6	3	8	128	
5	Polygon	5	565854280.23639	160508.2786	7	4	4	119	
6	Polygon	6	189397616.15819	85694.36971	8	7	5	210	
7	Polygon	7	239301335.56468	174618.58418	9	8	1	200	
8	Polygon	8	201698823.2118	75535.79585	10	9	3	151	
9	Polygon	9	612056055.27539	171832.225	11	10	2	165	

Record: 1 Show: All Selected Records (0 out of 10 Selected.) Options

Downloading & Joining Census Attribute Data

- Go to the US Census Bureau website www.census.gov. Follow the link for American Factfinder and then data sets (buttons on left).
- Select your data set. SF3 is the census long form and contains the most data.
- Select either “detailed tables” or “custom tables” (if you want to pick individual variables from within census tables... this is more involved but gives you greater flexibility).
- Choose your geography. If you want census tracts, select that from the first dropdown menu, then choose your state and county. Be sure to choose “all census tracts.” If you want block groups, first choose the “geo within geo” tab at the top of the page, then choose block groups from the first drop-down menu. If you want all the block groups within the county (most likely), choose “county,” then your state and county. Be sure to choose “all block groups” at the end. Click “add” then “next.” Be sure to let the website refresh fully after each step before you make your next selection.
- Choose your variables. You may find it easiest to use the “by subject” or “by keyword” tabs so you can see the variables listed by topics of interest to you. If you used the “custom table” option, put a check mark next to the box for each variable you want (see below); only these will be downloaded. Be sure to include an appropriate denominator (it will usually be listed first, as “total” as in total people who answered this question). If you used the “detailed tables” option, you will download all of the variables within a particular table which will include a denominator.
- Go the “print/download” option from the blue header to download your data. Save as an Excel table. This will automatically transpose the records, so each row will represent a geographic unit (such as a census tract) and each column will represent a different variable. (IF YOU HAVE TROUBLE DOWNLOADING DATA and are using Microsoft Explorer, you may need to change the settings: Select Tools > Internet Options > Security > Custom Level > Downloads > Enable automatic prompting for file downloads)
- Unzip your files. You will only need the Excel file that ends with the word “data.”
- Open the Excel table. Change the column names to be 10 or fewer characters, with no spaces in the names, so you can bring this into ArcGIS. Create a data dictionary, if necessary, to remember what each variable means. Be sure to have only one row with column names (when you open the table, there will be two). Confirm that one of the geographic identifiers matches the geographic identifiers in your corresponding shapefile. Save your file with these changes.
- Add your table to ArcMap. Look at it and make sure the columns imported correctly.
- Join the table to an appropriate shapefile. Check to make sure your join worked. Make a permanent copy of the joined table and shapefile. Right click on the shapefile, go to data and export, then save a new copy. Yes, do add it to the map when you are done.

The image shows two screenshots of the U.S. Census Bureau American Factfinder website. The top screenshot shows the 'Select Geography' page where 'Block Group' is selected, and 'New Castle County, Delaware' is chosen for both state and county. The bottom screenshot shows the 'Select a table and click "Go"' page where 'P7 HISPANIC OR LATINO BY RACE [17]' is selected, and the 'Total' and 'Not Hispanic or Latino' options are checked under 'Select one or more data elements and click "Add"'. The 'Current data element selections:' section shows 'Total' and 'Not Hispanic or Latino' selected.

NOTE: You may need to calculate new values in your table in order to get the variable you want. If you use poverty, for example, you'll need to add three columns (income 50% or less than poverty line, 50-74%, and 75-99%) together to get the total number of people living below the poverty line. If the data doesn't download correctly, turn off your pop-up blocker

CHAPTER SEVEN

Working with Attribute Tables

Attribute Tables for Shapefiles

From ArcMap's Table of Contents, right-click layer > Open Attribute Table

Every shapefile has an attribute table associated with it. The table will have as many rows, or records, as it does map features. The total number of records will be shown at the bottom of your table. There can be any number of columns, or fields. Two are standard: FID (the feature ID) and Shape (which can be point, polyline, or polygon). The rest of the fields will vary. There should be a field that identifies each map feature with a unique name or number, such as a census tract number or neighborhood name. There may be additional fields identifying attributes of the map feature (type of crime at a particular address, number of people living in a census tract).

FID	Shape*	NUMBER	NAME
0	Polygon	1	Olde City
1	Polygon	2	Logan Square
2	Polygon	3	Market West
3	Polygon	4	Center City East
4	Polygon	5	Society Hill

Other Attribute Tables

Often you will have attribute data in a table separate from your shapefile. For example, you may have a census tract shapefile with no attribute information and a table with all of the 2000 census tract data. ArcGIS can read Excel (.xls), dBase (.dbf) and comma-delimited text tables (.txt), but will allow editing for only .dbf or .xls tables (you can convert .txt tables to .dbf in EXCEL, SPSS, ACCESS, or in ArcMap). You can add attribute tables to ArcMap just as you do shapefiles, using the "add data" button or, from the file menu, "Add Data." When you add a table, ArcMap will switch the table of contents from the "display" to "source" tab. You can only see tables listed when the "source" tab is active. Open the table by right clicking on its name in the table of contents and going to "open." *NOTE: Your table should have at least one column that contains geographic information. This might be a street address, X and Y coordinates, census tract number, zip code, or other identifier that will allow you to match the information in your attribute table to map features in a shapefile.*

You can work with tables—sort values, freeze columns, generate summary statistics, select records, and export tables—without worrying about corrupting your data. You cannot change any of the data in your table unless you go to "start editing" from the editor toolbar... except to add new fields or delete existing fields.

Sorting Records

From the shapefile's attribute table, right-click column name > Sort Ascending/Descending

COUNTY TRACT	STFID	POP2000
001	000	
001	000	
001	000	
001	000	
001	000	
001	001	
001	001	

Freezing Columns

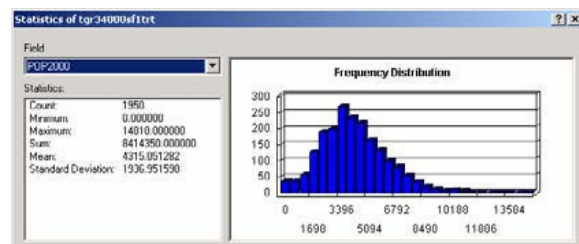
From the shapefile's attribute table, right-click column name > Freeze/Unfreeze Column

Freezing a column means that it will remain in view even as you scroll.


Summary Statistics

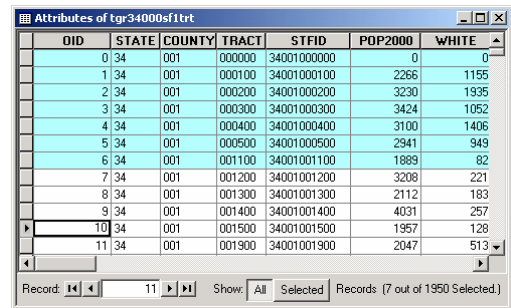
From the shapefile's attribute table, right-click column name > Statistics

You can bring up summary statistics for any numeric field (numeric fields will be justified right). You can obtain summary statistics on additional fields from the "Field" drop down menu of the "Statistics" dialog box.



Selecting Records

You can select a subset of your records to look at more closely in a number of different ways. You can highlight an individual record (row) by clicking in the gray area at the far left side of the table. To highlight multiple records, hold the control key down. At the bottom of the table, ArcMap will indicate how many of the total records are highlighted. Click on the “Selected” button to view only the selected records. You can switch the selection, so that all of the highlighted records become un-highlighted and all un-highlighted records become highlighted. From the options menu, choose “Switch Selection.”  You can also select all records or clear selection from the options menu.



OID	STATE	COUNTY	TRACT	STFID	POP2000	WHITE
0	34	001	000000	34001000000	0	0
1	34	001	000100	34001000100	2266	1155
2	34	001	000200	34001000200	3230	1935
3	34	001	000300	34001000300	3424	1052
4	34	001	000400	34001000400	3100	1406
5	34	001	000500	34001000500	2941	949
6	34	001	001100	34001001100	1889	82
7	34	001	001200	34001001200	3208	221
8	34	001	001300	34001001300	2112	183
9	34	001	001400	34001001400	4031	257
10	34	001	001500	34001001500	1957	128
11	34	001	001900	34001001900	2047	513

Exporting Tables

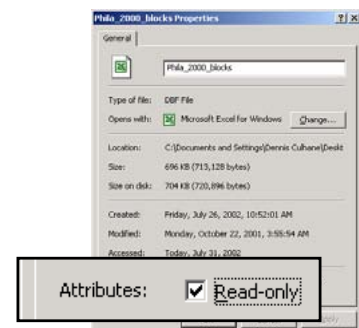
From the shapefile's attribute table, click the “Options” button > Export

You may need to export your table from ArcMap, because you have made changes, need to convert a .txt table to .dbf, or for any other reason.

Add New Column/Field

From the shapefile's attribute table, click the “Options” button > Add Field -or- From ArcToolbox > Data Management Tools > Add Field

To create a new field, open your table in ArcMap (you can also add fields from ArcCatalog). This can be a free-standing table or one that is associated with a map layer, but only .dbf tables can be edited. Click on the “Options” button (if you do not see the options button, make your table bigger; it's in the lower right corner). Go to “Add Field.” If this option is grayed out, you do not have permission to edit the table. Most likely, this is because the “read only” box is checked in the table properties. This happens automatically when you copy data from a CD. To change this, find your table on your hard drive (through Windows Explorer or My Computer, not through ArcCatalog), right click, and go to “properties.” Remove the check mark next to “read only.”



From the “Add Field” dialog box, give your new field a name. Do not use ?,&,\$,#,@,!,~ or spaces and keep your field name to 10 or fewer characters. From the dropdown menu, choose the type of field. Short Integer: numeric, no decimal place, up to 19 characters Long Integer: numeric, no decimal place, up to 19 characters Float: numeric, with decimal place, (default is one place before decimal and 11 after) Double: numeric, with decimal place (default is 7 places before the decimal and 11 after) Text: numbers or letters, specify length (default = 50 characters) Date: can include time and date Blob: up to four characters. Finally, determine the scale (number of places) and precision (number of places to the right of the decimal point), or accept the defaults by leaving them 0.



Delete Column/Field

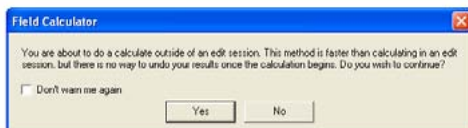
From the shapefile's attribute table, right-click column name > Delete Field

ArcGIS will give you a warning that the deletion is permanent and not reversible. Do this with caution. Changes will be permanent not just within your map document, but in your original file on your hard drive, as well.

Calculating Values Outside an Edit Session

From the shapefile's attribute table, right-click column name > Field Calculator

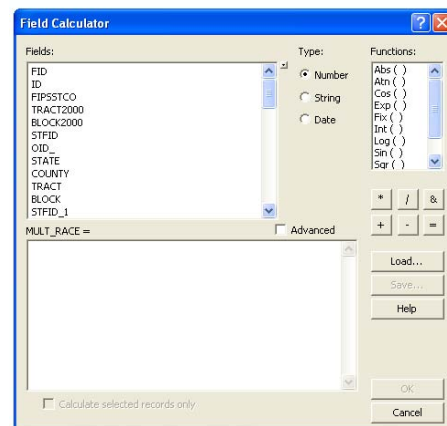
You may find it easier to edit your attribute tables outside of ArcGIS, but ArcGIS has fairly sophisticated tools for calculating values. In ArcMap, you can edit values in an existing field or create a new field and calculate new values. Keep in mind that you cannot change the format (text, integer, long integer) of an existing column, so if you need to transform the format of a column, you will need to create a new field. ArcMap will ask you if you are sure that you want to calculate values outside an edit session, warning that you will not be able to undo your results. Choose "Yes."



ArcMap will bring up the "Field Calculator" dialog box. If your value is

a constant, you can simply type the value in the box at the bottom. More likely, your new value will be based on values in other fields, so you will need to use the calculator. You can create an expression by double clicking on the field names. For example, to calculate the percent of the population 65 and up, click on the field name with the total 65 and up, click on the "/" button, and click on the field name with the total population. If you edit a table outside an edit session, it's best

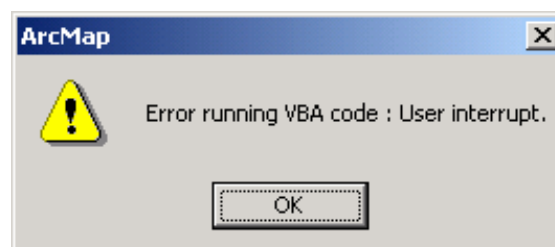
to create new fields rather than to edit values in an existing field—since you cannot undo your work. With new fields, you can just delete a field and start over if you mess up. *NOTE: If any of the records in your table are highlighted, ArcMap will only perform calculations on the highlighted records.*



Common Error when Calculating Values

ArcGIS will not allow you to divide by zero, so if the denominator (i.e. total population in the example above) is zero for any of your records, ArcGIS will not calculate any of the values and will display an error message. To get around this, you need to select only the records where the denominator is something other than zero.

Start by selecting the records with a zero in the denominator (because there are fewer of these). Do this by right-clicking the field with your denominator and sort ascending. While holding down the "Ctrl" key, highlight all the records that have a value of zero. From the "Options" button menu, choose "Switch Selection" so that all of the records with non-zero values are highlighted. Now you should be able to proceed with calculating values.



Location Quotients

The location quotient is most frequently used in economic geography and locational analysis, but it has much wider applicability. The location quotient (LQ) is an index for comparing an area's share of a particular activity with the area's share of some basic or aggregate phenomenon. In other words, the LQ is a measure of the relative significance of a phenomenon (e.g. burglaries) in a region (Newark) compared with its significance in a larger ("benchmark") region (New Jersey). Or, put another way, LQ is a measure used to identify concentration within an area and is expressed as a ratio of the proportional share of the subjects at the local level (census tract) to the ratio of the total area covered (Philadelphia). Location quotients are calculated within the Attribute Table of a polygon feature class. Location quotient is expressed as:

$$LQ = (x_i/t_i) / (X/T)$$

where x_i represents the number of persons in group x (e.g., study group) in census tract i ; t_i represents the total population of persons (e.g., general or poverty) in the particular census tract i ; and X and T represent the city-wide number of persons in group x and population t , respectively. The numerator of Equation (3-1) is the percentage of the activity in area i , and the denominator is the percentage of the base. A location quotient is thus the ratio of two percentages and is therefore dimensionless. (NOTE: A common error occurs in ArcGIS when a calculation requires dividing by zero (0) for at least one record in the attribute table. Check your data and calculate again using only the "selected" records whose denominator will not be an attribute with the value of zero.)

If $LQ > 1$ this indicates a relative concentration of the activity in area I , compared to the region as a whole.

If $LQ = 1$ the area has a share of the activity in accordance with its share of the base.

If $LQ < 1$ the area has less of a share of the activity than is more generally, or regionally, found.

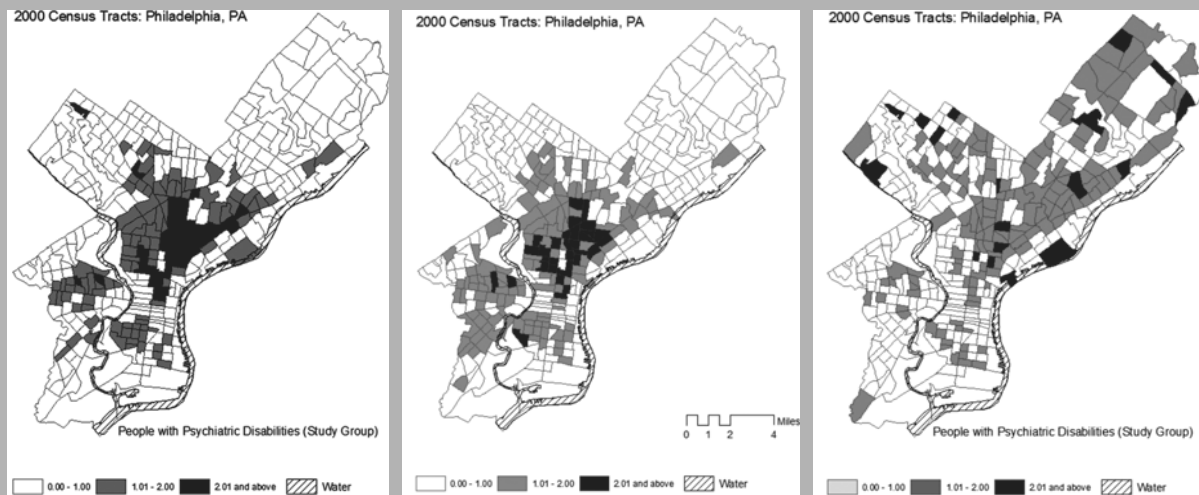
The formula for Location Quotients requires that something of interest (e.g., Index Crimes per County) be divided by some other meaningful variable, such as "square miles", "population", "number of sworn police officers", etc.

Location Quotients are interpreted as "the likelihood of finding 'something' of interest in an area, given the other attribute about that area." In effect, the Location Quotient formula controls for the denominator variable. So, a question might be: "What is the likelihood of index crimes occurring in each county, given the number of people (i.e. population) who could commit a crime in that county?" Results less than 1 are not very likely, and the likelihood increases as values increase above 1.

Location quotient values, once calculated, can be displayed as a choropleth map.

ZOOM IN: Location Quotient Choropleth Maps²²

Metraux, Caplan, Klugman and Hadley (2007) used location quotients (LQ) to assess the extent of residential segregation among 15,246 people diagnosed with severe mental illness (SMI) and receiving Medicaid in Philadelphia. Once location quotients were calculated in the Attributes Table of the Census Tract Shapefile, corresponding choropleth maps were constructed using ArcGIS. The figure below (left) shows areas of Philadelphia with elevated LQs for the study group based on using the general population of adults as the denominator for both local and overall proportions.



Location quotient values for adults (ages 18–64) living in households with incomes below the poverty threshold, based on their proportional representation among the overall adult population are presented in the figure above (middle). Census tracts with the highest LQs for the study group contained disproportionate shares of poor adults, which suggested that poverty should be controlled for. The figure above (right) shows LQs for the study group using “adults in poverty” as the denominator (rather than the general population of adults)—in effect controlling for poverty. By controlling for poverty, the number of tracts with substantial concentration (LQ > 2) was reduced and the tracts with elevated LQs (i.e., high concentrations of SMI persons) were more scattered across Philadelphia. They also included areas that did not have an elevated poverty LQ. This more accurately depicted the concentrations and distribution of SMI persons throughout the city.

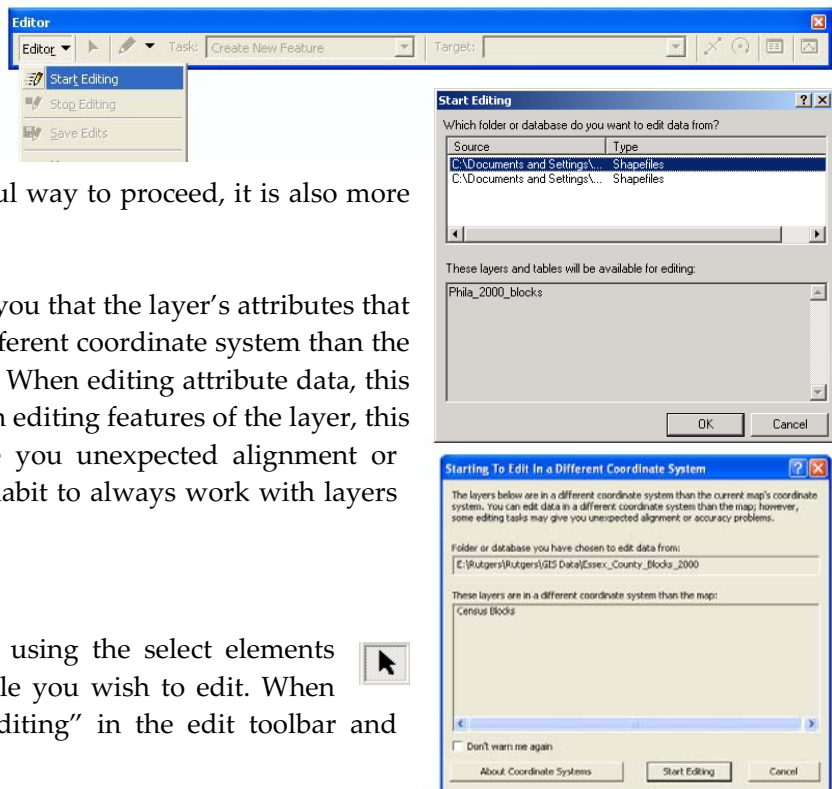
Results indicated that overall levels of residential segregation among persons with SMI were modest at their most extreme, were not markedly different from a control group of Medicaid recipients without any record of treatment for SMI, and were substantially reduced after taking poverty into account. There were, however, localized areas in Philadelphia that showed distinct concentrations of persons with psychiatric disability, suggesting there may be a subgroup that is more at-risk for living in areas with elevated concentrations of persons with serious psychiatric disability.

Editing Individual Values

Starting an Edit Session

From the “Editor” toolbar, click “Editor” button > Start Editing

You can only edit the contents of one directory at a time in an edit session, so you need to identify the directory that contains the table you wish to edit. While this is the more careful way to proceed, it is also more tedious.



You may get a message warning you that the layer’s attributes that are about to be edited are in a different coordinate system than the current map’s coordinate system. When editing attribute data, this is less of an issue. However, when editing features of the layer, this can—and most likely will—give you unexpected alignment or accuracy problems. It is a good habit to always work with layers that are properly projected.

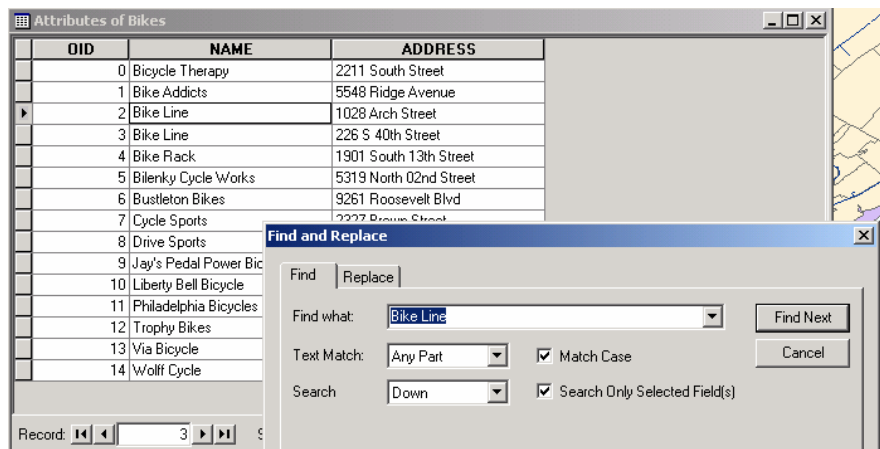
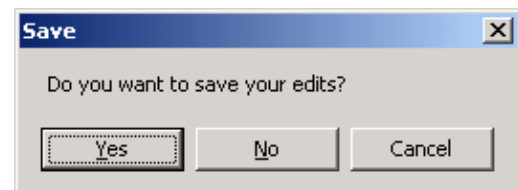
Editing Attribute Data

Open your attributes table and, using the select elements tool click on the cell in your table you wish to edit. When you are finished, go to “stop editing” in the edit toolbar and choose “Yes” to save your edits.

Finding & Replacing Values

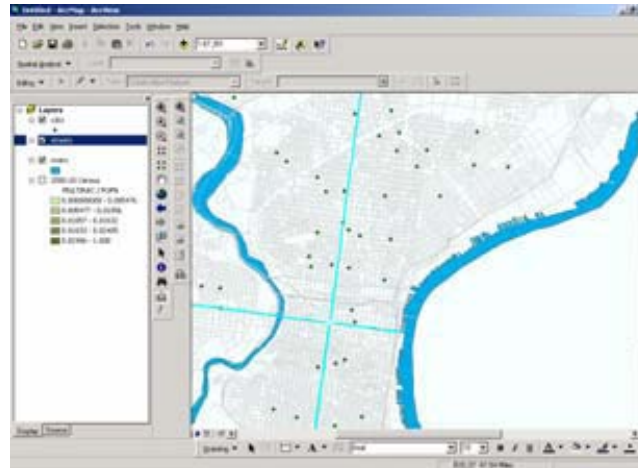
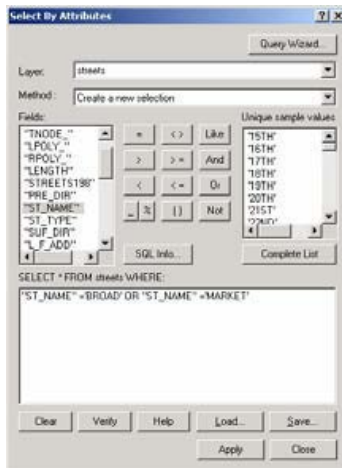
From the shapefile’s attribute table, click the “Options” button > Find & Replace

Use the “Find & Replace” function to systematically find and replace values in a table. In order to replace values, you must have started an edit session (from the “Edit” toolbar > Editor > Start Editing).

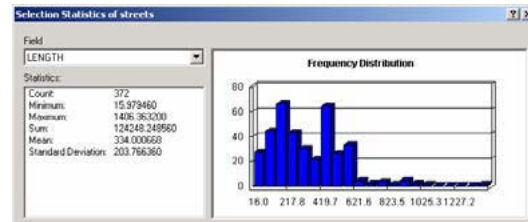


Measuring with Attribute Data

If you need more accurate measures of distance than you can get using the measure tool, you can use the values in perimeter (polygons) and length (line) fields of the shapefile attribute tables. Select the features of interest, then right click on the perimeter or length field and go to "Summary." The "sum" field will indicate the total distance. For example, if you need to know the total length of Broad and Market Streets, go to "Select by Attributes" and select all line segments in the street centerline file called "BROAD" or "MARKET." Then open the attribute table associated with the street centerline file, right click on the "length" column heading, and go to "Summary." The "sum" should indicate how long Broad and Market Streets are. *NOTE: You may need to first calculate perimeter or length values. See the section (below) "Calculating Area, Perimeter and Length".*



FID	Shape	FNODE	TNODE	LPOLY	RPOLY	LENGTH	STREETS198	PRE_DIR
344	Polyline	239	236	0	0	303.24769	345	N
345	Polyline	240	239	0	0	238.52625	346	N
346	Polyline	238	237	0	0	471.72204	347	N
350	Polyline	241	240	0	0	466.65272	351	N
353	Polyline	244	243	0	0	195.82967	354	N
354	Polyline	245	244	0	0	106.24301	355	N
356	Polyline	246	245	0	0	304.45318	357	N
358	Polyline	248	247	0	0	193.40236	358	N
361	Polyline	249	246	0	0	145.67578	362	N
363	Polyline	247	245	0	0	138.7579	364	N



Measuring Distance with Networks

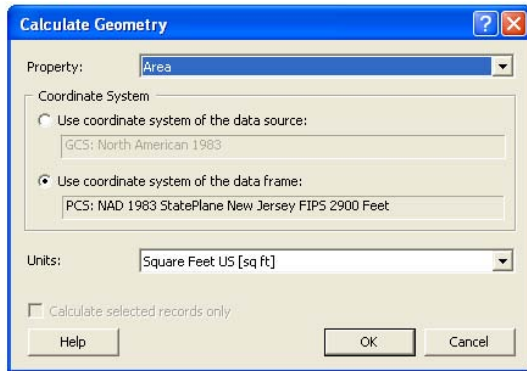
Euclidean is just one method of measuring distance, and a rather crude one at that. Using ESRI's Network Analyst Extension is another method. It lets you factor in travel times and traffic patterns, among other considerations.

Calculating Area, Perimeter, and Length

From the shapefile's attribute table, right-click on column name where you want to calculate values > Calculate Geometry

Usually there will be fields called "area", "perimeter", and "length" in a shapefile when you receive it that indicates the measures of each map feature. If your shapefile is missing these fields or if you have edited the shape and size of the map features, you will need to calculate them yourself. Area, for example, can be especially helpful when you are trying to normalize values and create densities (i.e. calculating persons per square mile).

For this example, we will calculate “Area,” though the process is very similar for the other calculations, as you’ll see. You must open the attribute table associated with your shapefile (right click on the name in the table of contents and go to “Open Attribute Table”). From the options menu, go to “Add Field.” Call your field “area,” choose “double” as the style, and click “OK.” Right click on your new field and go to “Calculate Geometry.”



Select the geometric property you want to calculate from the “Property” drop-down menu. Different properties are available depending on the type of layer you’re using. To calculate Area, select “Area” from the drop-down menu. To calculate Perimeter, select “Perimeter” from the drop-down menu, etc. Click to use either the coordinate system of the data source or the coordinate system of the data frame. Select the units of the output calculations.

Optionally, if you have selected records in the table, choose whether to apply the calculations to all records or just the selected ones. Finally, click OK.

Tips *(adapted or excerpted from ArcGIS Help files)*

- You can only calculate the area, length, or perimeter of features if the coordinate system being used is projected.
- Keep in mind that different projections have different spatial properties and distortions. If the coordinate system of the data source and data frame are not the same, you may get a different result if you calculate geometry using the data frame’s coordinate system than when you calculate using the data source’s coordinate system.
- If you are calculating into a text field, you can choose to add a units abbreviation to the calculation. For instance, 47.5673 sq m is an example of the output of area calculated into a text field with the units abbreviation.
- To avoid seeing the warning message when you attempt to calculate values outside an edit session, you can check the Don’t warn me again box on the message. You can turn on the warning message again from the Tables tab of the Tools > Options menu.

The Calculate Geometry dialog box respects the number of decimal places (three, by default) specified on the General tab of the Editing Options dialog box. To change this setting, click the Editor menu on the Editor toolbar and click Options. This setting is saved in the map document.

CHAPTER EIGHT

Georectifying and Digitizing

Georectifying Images

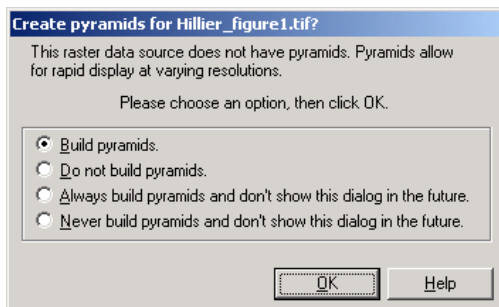
Georeferencing allows you to convert a picture or scanned map image into a GIS map layer. Essentially, the process assigns X and Y coordinates to points on your digital map image, shifting, rotating, and scaling your map so that you can view it as a map layer along with your shapefiles.

Create a Raster Image: Scan your paper map, take a photograph, or use a computer graphic. The higher the resolution, the better. ArcMap can handle pretty big files, and it can work with lots of file types (.jpg, .tif, .bmp). If you have a choice, go with .tif.

Add a Map Image: Add your image to ArcMap just as you would a shapefile or table, using the



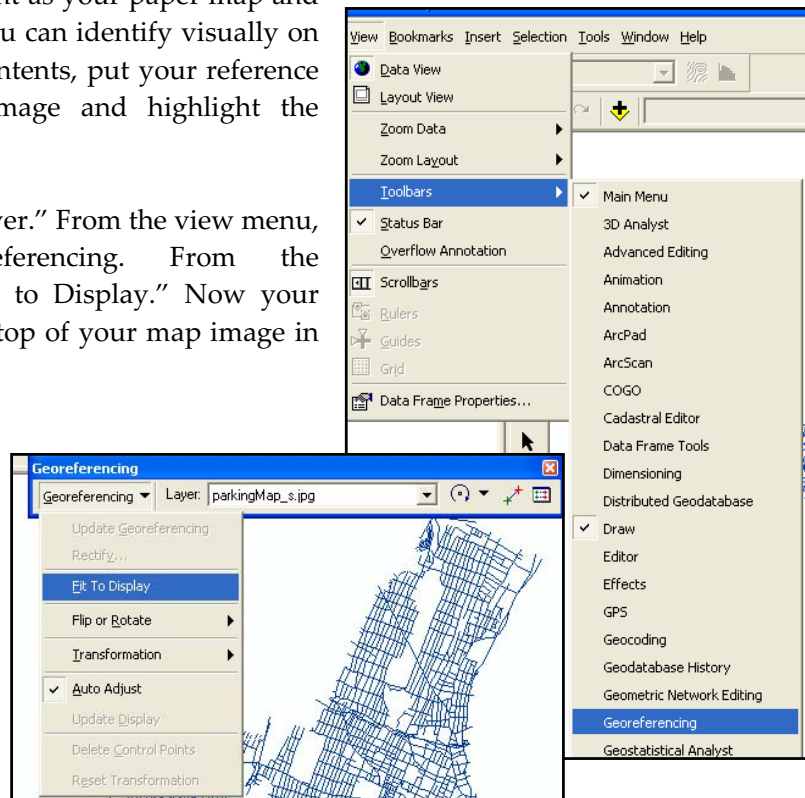
button or from the file menu, choose “add layer.” Depending upon the size of your image, a dialogue box will ask you if you’d like to add pyramids. Click “OK.”



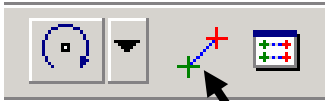
Don’t worry if you get a warning message that your image lacks projection information. The name of your image should now appear in the table of contents and be drawn in the map view window. At this point, your image is in “pixel space” since there is no coordinate information.

Add Reference Layers (shapefiles): Choose an existing shapefile that contains spatial information that will help you georeference your paper map (choose more than one, if necessary). You need a shapefile that covers the same extent as your paper map and that contains several points that you can identify visually on your paper map. In the table of contents, put your reference layer(s) on top of your map image and highlight the reference shapefile.

Right click and choose “zoom to layer.” From the view menu, choose toolbars then georeferencing. From the georeferencing menu, choose “Fit to Display.” Now your reference layer(s) should draw on top of your map image in the view map window.



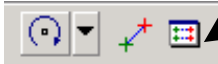
Add Control Points




Click the “add control points” button. Create your first control point on your image by clicking once on a point that you can also identify on your shapefile. Then click on the shapefile in the corresponding spot. Double click to create a control point. You may find it easier to use the magnifier window (from the window menu, choose “magnifier”). Create additional control points. After doing this two or three times, your paper map should shift significantly to line up with the shapefile. Continue to add control points as long as doing so improves the alignment.

View Links

Click on the “view links” button to view the coordinates of each of the control points you’ve created.



The “residuals” column indicates the amount of error. You may improve the alignment of your image by deleting the point(s) with the greatest error. Click on the  button to delete control points. If you have six or more control points, you can perform a second order transformation; if you have twelve or more control points, you can perform a third order transformation.

Link	X Source	Y Source	X Map	Y Map	Residual
1	0.341123	3.338748	2650877.861106	243359.021156	1601.77508
2	3.816111	3.146702	2701835.725657	236569.214733	1226.96780
3	4.058123	6.165402	2707749.428025	270518.246948	2380.51037
4	3.204793	3.087143	2684500.635057	237130.841223	465.56129
5	2.826576	3.633241	2630481.065440	243853.838193	664.81135
6	6.044573	3.203443	2725327.525021	251320.714221	2393.61534

Auto Adjust: Transformation: 1st Order Polynomial (Affine) Total RMS Error: 1793.50033

Rectify Image

In order to permanently save the transformation, choose “rectify” from the georeferencing menu. ArcMap will create a new image (rather than changing your original data). Check the ArcMap Desktop Help if you want information about choosing a resampling type. You don’t have to rectify your image. If you want to revert to your original (ungeoreferenced) image, from the georeferencing menu, choose “reset transformation.”

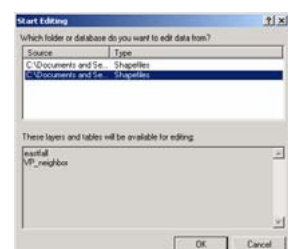
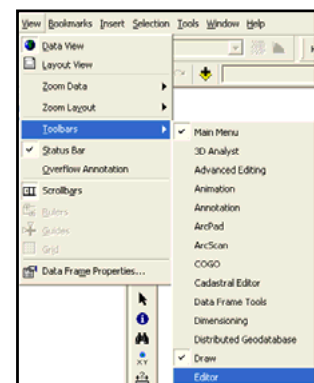
Editing Existing Shapefiles

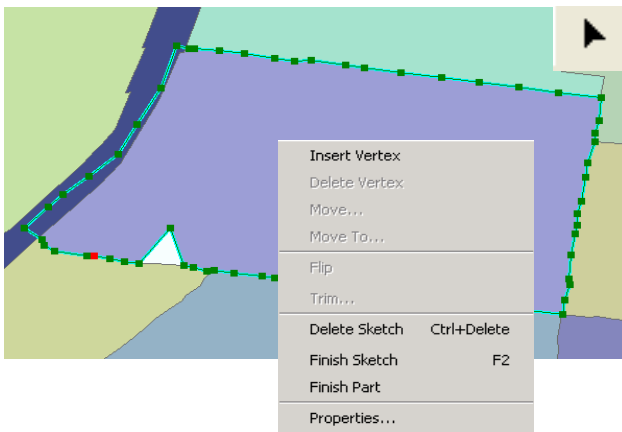
Editing shapefiles is tricky—and a bit dangerous—territory. If possible, use the geoprocessing tools to make changes to your shapefiles rather than using the editing tools described below. Also keep in mind that editing shapefiles can change attribute values (such as area and perimeter) that you may need to update.

Deleting and Modifying Features

From the “Editor” toolbar, click the “Edit” tool

In order to make changes to a shapefile, you must start an edit session. From the Editor toolbar, choose “start editing.” If you have multiple shapefiles in your map document that are from different subdirectories on your computer, you will need to specify which directory will be part of the edit session (you can only edit the files in a single folder at one time). From the Target drop down menu in the Editor toolbar, indicate which map layer you wish to edit.





Use the “Edit” tool to click on the feature (point, line, polygon) you wish to edit (it should become highlighted). By clicking and holding down the mouse button, you can move your map feature to a new location. To modify a line or polygon feature, double click on it. Notice that the vertices become visible and the Task menu automatically brings up “Modify a Feature.” You can reshape your feature by putting your cursor over a vertex, clicking, and dragging it. Click outside of the map feature to complete. (ArcGIS will show the last created

vertex in red). You can **add a vertex** to a feature by right clicking on a green line and going to “insert vertex” (a new vertex will be created where you right click). Click anywhere on the map to confirm the edits. You can **delete a vertex** by placing your cursor over the vertex, right-clicking, and choosing “Delete Vertex.”

To save edits, from the Editor menu on the Editor toolbar, choose “Stop Editing” and choose “yes” to saving edits. Notice that you do not have a “save as” option. You may want to make a backup of your original data before editing.

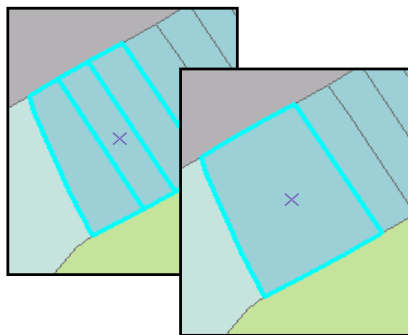
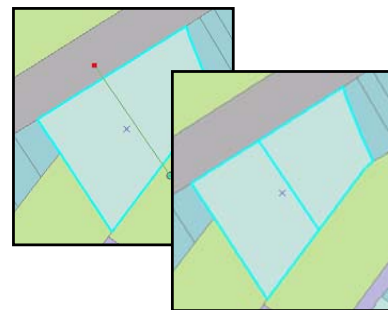
Advanced Edit Tools

There are several advanced editing tools. To access them, go to View > Toolbars > Advanced Editing.

Edit Tasks

The Task drop-down list on the Editor toolbar contains a set of editing tasks that affects how the Sketch tool functions. The editing tasks are organized into four groups: Create Tasks, Modify Tasks, Topology Tasks, and Other Tasks.

For example, to **split features**—to cut a polygon into two new polygons—select the polygon you want to cut, choose that Cut Polygon Features task, then use the Sketch tool to define the line along which you want to cut the selected polygon.

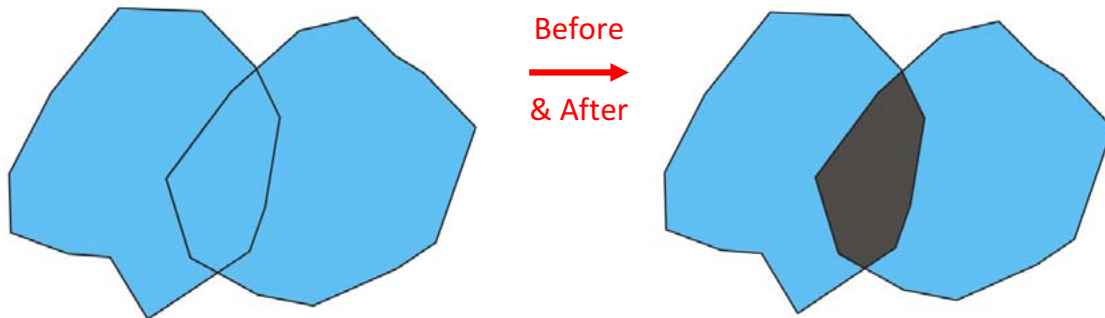


Merging Features

In order to dissolve the boundaries between two or more polygon features, you must start an edit session. Using the edit tool and the shift key, click on the features you wish to merge (they should become highlighted), then from the Editor menu on the Editor toolbar select “Merge.” You can also select map features based on their attributes by opening the attribute table and selecting the corresponding records.

Intersecting Features

The Intersect command creates a new feature from the common areas or edges of any two selected features of the same geometry type. For instance, you can create a new patrol area out of overlapping patrol areas. The original features are maintained, and the new feature is created in the target layer without attribute values (they can be entered manually).



The Intersect command is in the “Editor” drop down menu on the Editor Toolbar. You can create a new feature from the intersection of features of different layers, but the layers must be of the same geometry type (either line or polygon). Line features that you are trying to intersect must share a common edge. Two lines that cross each other, such as in a X pattern, do not share a common edge. To break this type of line intersection you must use the “Split” command on the Editor toolbar. The Intersect command only works on two selected features. The Intersect Geoprocessing Tool creates new features from the overlaps of all input layers or feature classes. You can also choose what attributes from the input features will be transferred to the features of the output shapefile.

To intersect features, click the Edit tool on the Editor Toolbar. Click the features from whose intersection you want to create a new feature. Click the Target layer drop-down arrow and click the layer with the type of features you want the new feature to belong. Click the Editor menu and select Intersect.

Digitizing Using the Merge Tool

From the “Editor” toolbar, click the “Editor” button > Merge

The tools in ArcMap for dissolving boundaries between features provide another approach to digitizing. This may give you less control over the shape of new map features, but it provides an easier way of creating new shapefiles that line up with existing shapefiles. In order to create shapefiles using the dissolve tools, you need to have a shapefile that can serve as building blocks for your new file. For example, you may want to create a map of health districts. If the districts are based on census tracts, you can use a shapefile of census tracts to build your new district file. A census block file may prove the most helpful. Census blocks are bounded by streets, so any new polygon



feature with streets as borders can be created by dissolving the boundaries between census blocks. To start, add a street centerline layer and census block



layer to ArcMap. To avoid making permanent changes to your census block file, create a new copy of it (right click on it, go to “Data” and “Export Data”) and add it to your map. With the streets and (new) block layers drawn, zoom into the area where you wish to create new features. Use the label tool to identify street names (that’s why you need the street file; census block files don’t contain street names). Using the Select Features tool, highlight the blocks that cover the area of your new feature. You can select multiple features by holding down the shift key. You can also draw a box around the area containing the individual features (this is faster).

To dissolve the boundaries between the blocks, start an edit session, then from the Editor menu choose “merge.” Stop editing and save edits to finish. If your new shapefile only needs to include this single map feature, you can right click on the block shapefile (with the new feature still selected), go to Data and Export Data. Be sure that the Export drop down menu indicates that only selected features will be included. Alternatively, you may need to repeat the process of dissolving boundaries so that all census blocks become part of a new map feature.

Adding Other Graphics

ArcMap also has a set of tools on the Drawing toolbar used to draw graphics. Objects drawn with the drawing tools are stored in the map document as graphics, not as features in a feature class (and they have no attributes attached to them). To access the Drawing toolbar, click “View”, “Toolbars,” and select “Draw.” From the Drawing toolbar, click any of the drawing tools (as shown to the right) and draw graphics.

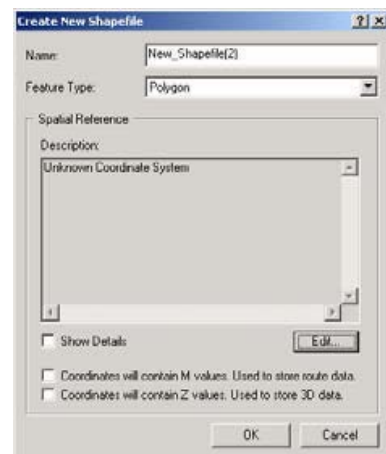


Creating New Shapefiles²³

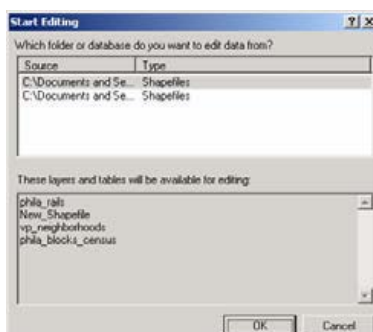
From ArcCatalog, right-click the folder where the shapefile will be stored > New > Shapefile

Most of the time you will use shapefiles that someone else created. Using existing shapefiles saves time and generally results in more accurate map layers. But if you need a line or polygon file that does not exist—such as a boundary for your study area—you will need to create it yourself. Digitizing is the process of drawing or tracing map features to create a new geographic file. ArcGIS has some on-screen digitizing tools that allow you to create new shapefiles without additional hardware or software.

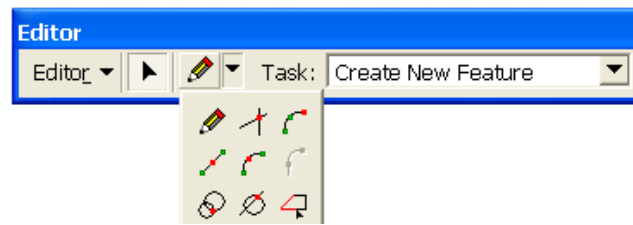
From the “Create New Shapefile” dialog box, give your new shapefile a name and indicate what type of features the shapefile will have: point, line, or polygon. Use the Edit button to set the projection. This shapefile is essentially just a shell since it contains no information. But you need this before you can start to create new map features.



Next, open ArcMap and add your new shapefile, along with other map layers that may serve as references to help you draw your new features. Start an edit session: from the Editor menu in the Editor toolbar, choose “Start Edit Session,” and indicate which directory contains the shapefile (shell) you just created.



Be sure that your new shapefile is listed as the “Target” in the “Editor” toolbar and that “Create New Features” is selected from the “Task” menu. Choose a drawing tool. You have nine choices:



Use the **Sketch tool** to create point features and digitize the vertices of line or polygon features. After you finish the sketch, ArcMap adds the final segment, and the sketch turns into a feature.

The **Arc tool** helps you create a segment that is a parametric (true) curve. Instead of being made of numerous vertices, a parametric curve has only two vertices as endpoints. You might use the Arc tool to digitize a cul-de-sac, using an aerial photo image as a backdrop.

The **Direction–Distance tool** allows you to create a vertex using a distance from a known point plus a direction from a known point to define a bearing line. For example, a pole might be located at a specified distance from the corner of one building and at a defined angle from the corner of another building.

The **Distance–Distance tool** lets you create a point or vertex at the intersection of two distances from two other points.

The **Endpoint Arc tool** allows you to specify the start and endpoints of the curve, then define a radius for the curve. This is particularly useful in sketching cul-de-sacs, where the beginning and ending points of the arc, as well as the radius of the cul-de-sac, are known.

The **Intersection tool** creates a point or vertex at the place where two segments would intersect if extended far enough.

The **Midpoint tool** lets you define the location of the next vertex by clicking two points; the new vertex is placed at the midpoint of the line between these points. If you were creating a road feature class from parcel data, you might use the Midpoint tool to create the vertices directly between the parcels on opposing sides of the road.

The **Tangent tool** adds a segment that is tangential to the previously sketched segment. This tool is practical when sketching rail lines in which the curves are nearly always tangential to the previous segment. Note that the Tangent tool can only be used if you have already sketched a segment using one of the other sketch construction tools.

The **Trace tool** helps you create segments that follow along existing segments. Suppose you want to add a new road casing feature that is offset 15 feet from the front of a parcel subdivision. You could use the Trace tool to trace along the existing line features instead of typing the angle and length of each segment. You'll need to select the parcel features before you can start tracing the road casing feature. The Trace tool only follows selected features. Click to create a new vertex, click again to create another vertex, etc. Right-click and click “Finish Sketch” to finish. In the example here, a new polygon feature was drawn

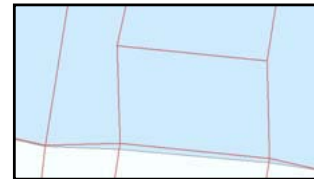


that follows streets. To delete the newly-created feature, click on it using the Edit Tool to select it and then hit the delete key on your keyboard. Hit Ctrl+Z to undo the last vertex. To save your new feature, from the Editor menu choose “Stop Editing” and save edits.

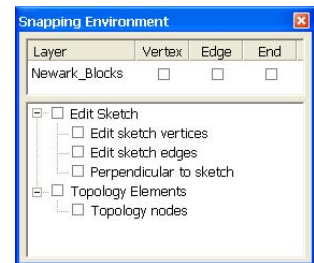
Snapping to an Existing Feature

From the “Editor” toolbar, click the “Editor” button > Snapping (you must “Start Editing” first)

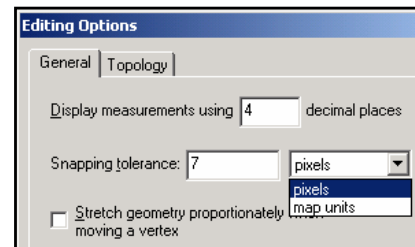
It is nearly impossible to draw features that match an existing layer just by looking at it. Zooming in to the polygon shapefile created above shows that there are gaps between the new shapefile and the street centerline that was used as a guide. This looks sloppy and can impact the result of your analyses.



You can avoid this problem by “snapping” your new lines to an existing shapefile. From the Editor menu of the Editor toolbar, go to Start Editing and indicate which directory contains the shapefile (shell) to which you want to add map features. At the top of the “Snapping Environment” options box, you can identify the layer(s) to which you want to snap your new features. Try drawing your new features using different combinations of layers and vertices and/or edges. If you use a street centerline file as your guide, vertices will work well.



To create the most accurate line, move your cursor slowly over the existing shapefile, clicking at each vertex to create a new vertex in your shapefile. You can change the snapping “tolerance”—the distance from the existing shapefile you can be and still snap to it—from the Editor menu choose “Options,” and go to the “General” tab. The map units reflect the units you identified in the Data Frame properties (General tab).



Using the snapping tool, you should be able to create new features that line up with existing shapefiles, even when you zoom in close. If you are not happy with your results, click on the map feature with the Edit tool and hit Delete (you can do this even after saving edits to the shapefile, as long as you start an Edit Session).

Adding Attribute Data to New Features

From ArcMap’s Table of Contents, right-click layer > Properties > Open Attribute Table

After creating new features in a new shapefile (or after editing/adding features in an existing shapefile), you can assign information to them in the Attributes table. Attribute tables of new shapefiles with new features will have only three columns named FID, Shape, and ID. These are automatically created by ArcMap. To add new fields so that you can enter additional information, click the “Options” button in the Attributes table, then click “Add Field.” If you are unable to select this option, go back to the Editor toolbar, click Stop Editing, and then try again to add a field (You cannot add new fields during an edit session). Once the new field has (or many fields have) been added, click Editor on the Editor toolbar, and then Start Editing. Be sure to save your edits! *NOTE: In order to enter data into the fields of an Attribute table, you must be in an edit session.*

CHAPTER NINE

ArcToolbox and Geoprocessing

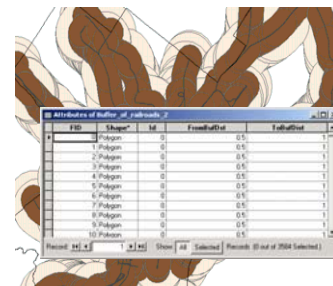
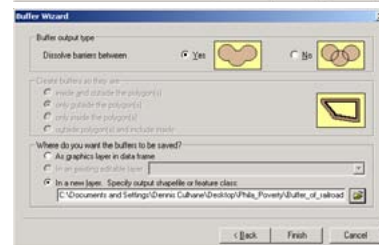
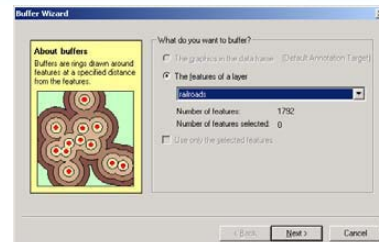
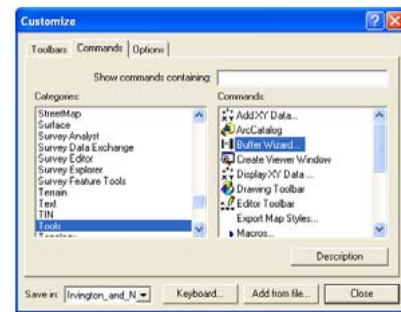
Buffers

Buffers allow you to create temporary graphics or permanent shapefiles around existing map features. You can create buffers around any type of vector data (points, line, or polygons) and around selected or all features in a map layer. The Buffer Wizard is a custom tool that must be added to the ArcMap interface. From the tools menu, go to “customize” and click on the “commands” tab. From the “categories” list, click on “tools.” You can then drag the Buffer Wizard to one of your active toolbars. From the drop down menu in the Buffer Wizard, choose the map layer you wish to buffer. If some of the features in your layers are selected, you can choose to buffer only the highlighted features.

On the next screen, you choose how you want to create buffers. You can make buffers based on a certain distance or based on an attribute in your map layer (this would allow you to have larger and smaller buffers around different features). If necessary, change the distance units at the bottom of the screen. You can make multiple rings of a certain distance.

On the final screen, you must decide what to do if the buffers overlap: dissolve the intersecting lines or leave them? If the map layer you are buffering contains polygons, you can specify whether buffers should be drawn inside, outside, or both. Finally, specify how ArcMap should save the layer. If you save it as a graphic, it will be temporary. This is helpful if you are just playing to get the right buffer since it can easily be deleted. Saving the buffers as a separate shapefile is more permanent and deleting a shapefile involves more work. To save the buffer as part of an existing layer, you must start an edit session and make that layer edit-able.

Buffering can take ArcGIS a long time, especially if you choose to dissolve the barriers within the buffers. However, if you do not dissolve the barriers, your buffers may involve lots of separate polygons. If you saved the buffers as a shapefile, there will be an attribute table with records corresponding to the separate polygons making up the buffer. If you choose to dissolve the barriers, there will be just one record (and just one polygon). *NOTE: A “Buffer” tool is also available: ArcToolbox > “Proximity” toolset > “Buffer” tool*



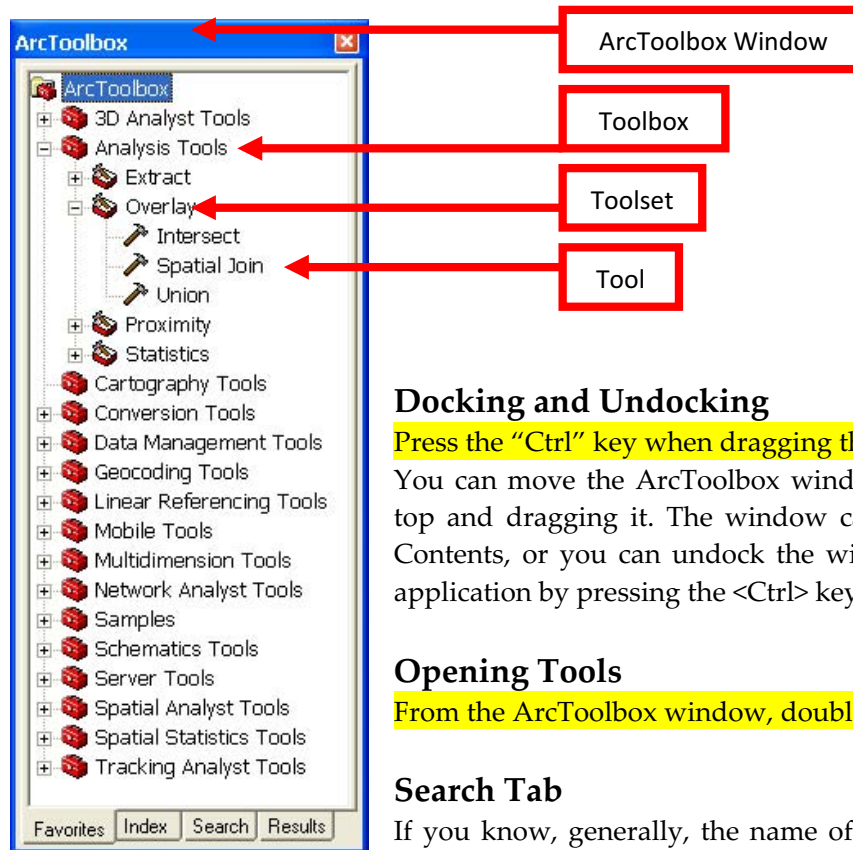
ArcToolbox Window²⁴

From ArcMap or ArcCatalog, click the “ArcToolbox” button



The ArcToolbox window is where you find, manage, and execute geoprocessing tools. Tools are (and must be) stored in Toolboxes, which are sorted alphabetically. The exact number of tools and toolboxes available depends on what extensions you have installed. You can also create your own tools (with Python or ModelBuilder), organize them into new toolsets and toolboxes, and share them with any ArcGIS user.

The toolboxes you see in ArcToolbox are analogous to shortcuts in Windows Explorer or layers within ArcMap. If you remove a toolbox from ArcToolbox, you are simply removing it from the list and not actually deleting it on disk. BUT, if you delete a tool in a toolbox, the tool will be permanently deleted from the disk.



Docking and Undocking

Press the “Ctrl” key when dragging the ArcToolbox window

You can move the ArcToolbox window by clicking on the bar at the top and dragging it. The window can be docked—like the Table of Contents, or you can undock the window to have it float above the application by pressing the <Ctrl> key when dragging.

Opening Tools

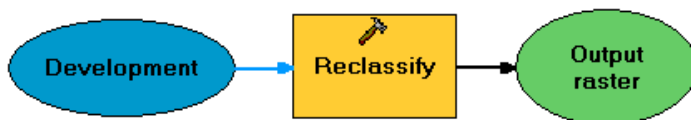
From the ArcToolbox window, double-click the tool

Search Tab

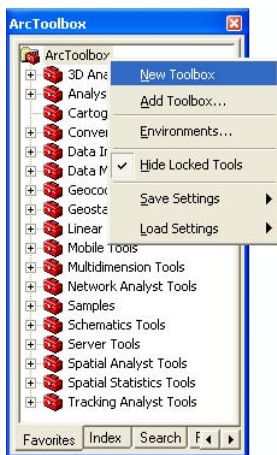
If you know, generally, the name of the tool you want to use or the function you want to perform, but cannot remember where the tool is located, use the “Search” tab. Type in the keyword(s) and click the “Search” button. Results will appear in the box below. After finding the tool you want to use, click the “Locate” button to show where it is in the tree view or double-click the tool to open its dialog box.

Model Builder

ModelBuilder is a tool that helps you build, manage and automate spatial models. A spatial model is a set of one or more processes. A process includes input data, a spatial function (tool) that operates on the input data, and output data. Processes can be connected so that the output of one process becomes the input to another process.

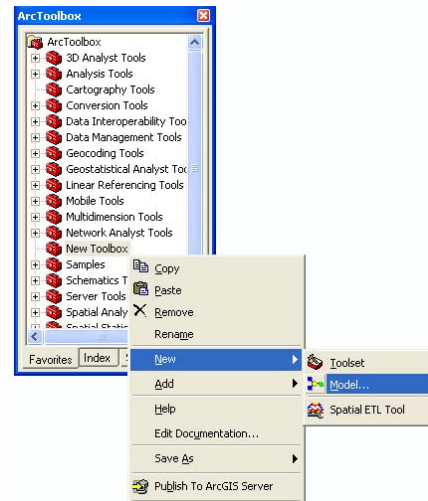
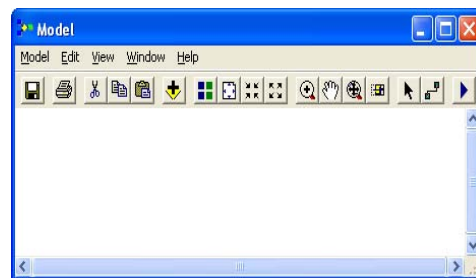


A spatial model is represented in ModelBuilder as a diagram that looks like a flowchart. The spatial model does not actually contain spatial data; it has placeholders, called nodes, which represent the data that is processed and created when the model is run. The nodes are connected by arrows that show the sequence of processing in the model. The actual data is managed and displayed in ArcMap; ModelBuilder just gives processing instructions to ArcMap when the model is run.



To build a new model, start by opening ArcMap and add one or more existing data layers that will be used as input to the model you are about to build. Open the ArcToolbox window by clicking the “Show/Hide ArcToolbox Window” button.

Right-click inside the ArcToolbox window > New Toolbox. Give the new toolbox a meaningful name. Right-click the new toolbox > New > Model. The ModelBuilder window will open. You can create your model there.



Detailed steps for using ModelBuilder to build a model are not discussed here. For more information refer to the ArcGIS Desktop Help.

ModelBuilder Tips

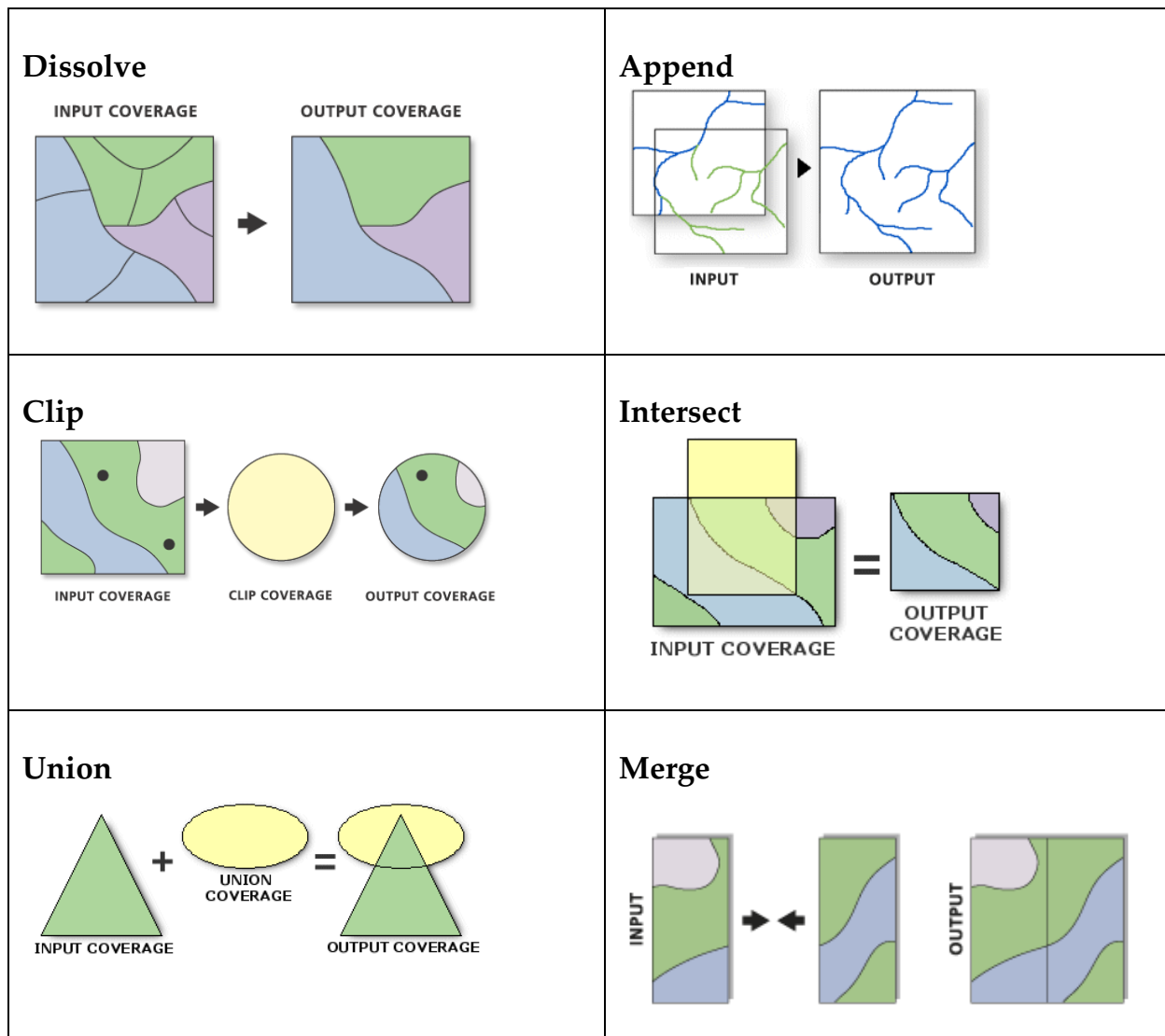
- Do not use Model > Run to execute a model. Instead, use Model > Run Entire Model
- To save a model, use Model > Save
- To close a model, use Model > Close or just close the ModelBuilder window.
- To rename a model, right-click on its name in the ArcToolbox > Rename
- To open a saved model for editing, right-click on its name in ArcToolbox > Edit

Spatial Data Processing Tools

Transforming Shapefiles

There are a number of different functions you can perform on map layers, either based on location or attribute values that result in new map layers. In ArcGIS 9, they have been incorporated into an expanded suite of ArcToolbox tools. You must define the projection for map layers before using any of these functions. If you have selected a subset of features within a map layer, the functions will only be performed on the selected features.

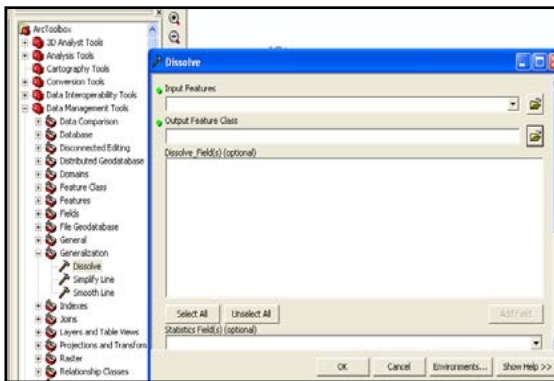
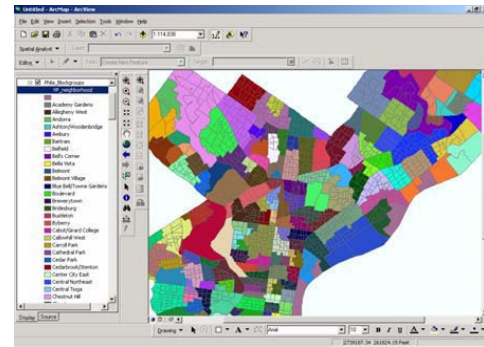
Examples of the tools described in this section are below:



Dissolve

ArcToolbox > Data Management Tools > Generalization > “Dissolve” tool

The dissolve operation allows you to collapse the boundaries between polygons if they share the same value on a particular attribute. For example, you could create a neighborhood map layer by assigning each blockgroup to a neighborhood and then dissolving the boundaries.



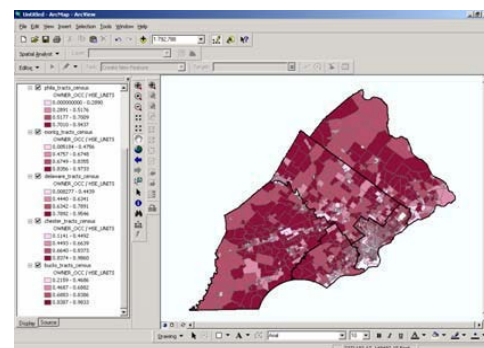
In the “Dissolve” dialog box, you need to identify the map layer whose features you wish to dissolve under “Input Features.” If the layer is already added to ArcMap, you can use the dropdown menu. Otherwise you need to click on the folder icon to locate the shapefile. ArcMap will create a new shapefile with a default name by adding “_Dissolve” to the original name. If you want to rename this or change the location, click on the folder to the right of “Output Feature Class.”

Next, choose the column the shapefile’s attribute table that contains the information you wish to use for the dissolve. This must be an attribute for which multiple map features (polygons) have the exact same value. The values can be numbers or text, although keep in mind that nominal and categorical variables will work better than ratio variables. If polygons have the same value but are not contiguous, they will still be dissolved into a “multipart feature.”

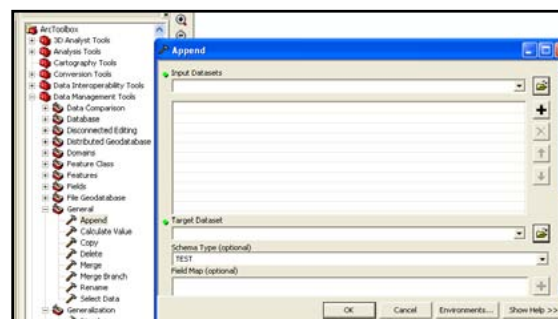
Append

From ArcToolbox > Data Management Tools > General > “Append” tool

Appending allows you to incorporate two or more non-overlapping layers into a single map layer without changing their map features. You can append point, line, and polygon layers. Appending can save you time when it comes to symbolizing features and can lead to more consistent symbology. For example, you can append (i.e. merge) census tract files from several counties so that when you display the percent of homeowners, you do not have to repeat the process of classifying your data for each county.



In the “Append” dialog box, under “Input Datasets,” list all the map layers you wish to merge. You can use the dropdown menu if you have already added the map layers to ArcMap, but you will need to add them one at a time.



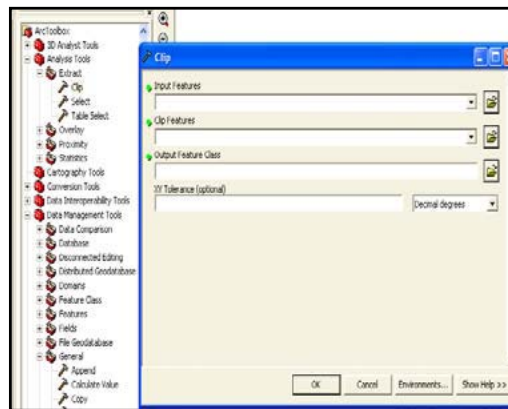
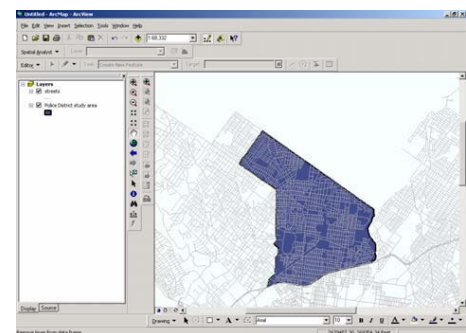
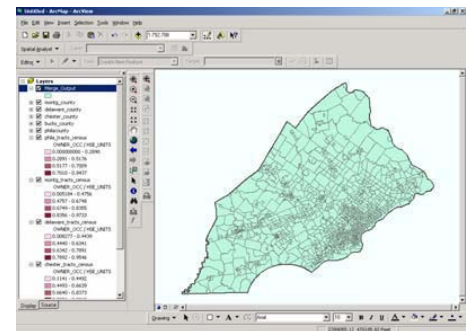
A new layer will not automatically be created, so you will need to specify an EXISTING layer in the “Target Dataset” field. This will overwrite the existing layer, so be sure to make a backup copy if necessary. If the columns in the attribute tables of all the input features are identical, you can select “TEST” under “Scheme Type.” Otherwise, you must choose “NO_TEST.”

The resulting shapefile will contain all of the map features in the appended layers. If the column names were the same for all of the layers (as they could be for census tract files from different counties), there will be values for each record in each column. Keep in mind that these merged shapefiles can grow very large, particularly if you merge street centerline files.

Clip

From ArcToolbox > Analysis Tools > Extract > “Clip” tool

Clipping allows you to turn one shapefile into a cookie-cutter in order to cut out part of a larger shapefile. For example, you might need to create a map layer of streets for the area within a single police district but your street centerline file covers the entire city. Using a street file that is clipped by the police district boundaries will allow you to work with a smaller and more manageable file that looks neater.



The “Clip” tool allows you to clip *vector* shapefiles. In “Clip” dialog box, you need to identify an input feature (the layer to be clipped) and the clip features (cookie cutter). Specify the name and location of the new file in the “Output Feature Class” field. You can leave “XY Tolerance” blank, or at 0. Changing it will allow slightly mismatched map layers to be considered “coincident.”



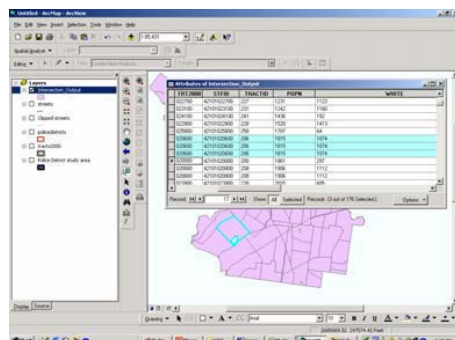
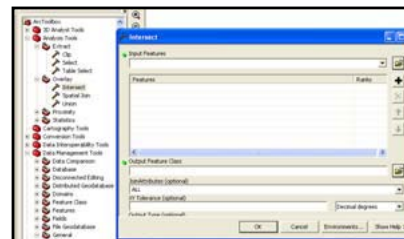
To clip raster grids you need to use a raster clipping tool. This can be found in ArcToolbox under Data Management Tools > Raster > Raster Processing. You can also find vector and raster clipping tools by searching for keyword “clip” in the Search tab of ArcToolbox. Double-clicking on the tool in the results area opens it directly.

Intersect

From ArcToolbox > Analysis Tools > Overlay > “Intersect” tool

Intersect allows you to fuse two overlapping layers together to create a new shapefile that includes the attributes of both layers for the area in which the layers overlap. In effect, this combines the union (described below) and clip operations. You can intersect two polygon layers or a line and polygon layer.

In the “Intersect” dialog box, select the Input Features. The default name for the new shapefile will be the first input feature name plus “_Intersect.” If you want to change this or the location of the new file, click on the folder to the right of the “Output Feature Class” field.

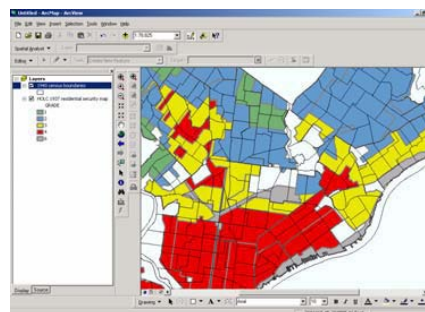


If you intersect a line and polygon layers, the resulting shapefile will contain “polylines” that act like lines. If you intersect polygon layers, the resulting shapefile will contain polygons. Length, perimeter, and area values will be inaccurate after you perform an intersection, so if you need these be sure to recalculate them. Other attribute values maybe deceptive, as well. In the example at the left, census tracts were intersected with police districts. The result was many sliver polygons resulting from slight differences in their digital boundaries, not real differences in their actual boundaries. Note that three polygons have been given the same total population based on the census tract data, two of which are sliver polygons. Adjusting the cluster tolerance can help you avoid sliver polygons.

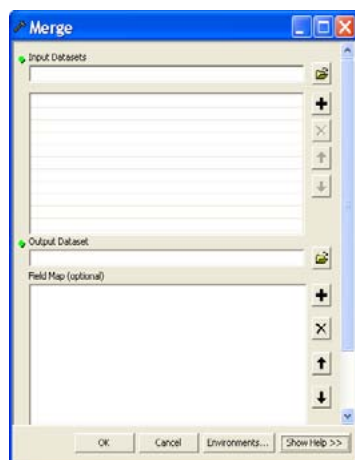
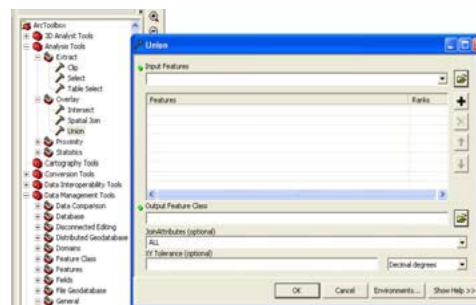
Union

From ArcToolbox > Analysis Tools > Overlay > “Union” tool

Union is similar to intersection in that it fuses the boundaries of two layers together, but rather than clipping the resulting shapefile to include only the area covered by both, it creates a new shapefile that covers the combined extent of the layers.



From the “Union” dialog box, select the Input Features. The default name for the new shapefile will be the first input feature name plus “_Union.” If you want to change this or the location of the new file, click on the folder to the right of the “Output Feature Class” field. As with shapefiles created through intersections, the shapefiles created by a union will most likely have some attribute values that no longer make sense. Be sure to recalculate length, perimeter, and area if you need these variables.



Merge

From ArcToolbox > Data Management Tools > General > “Merge” tool

Merge is similar to “Dissolve”. However, while the Dissolve tool combines features within the same shapefile based on a common attribute, the Merge tool combines features from multiple sources/shapefiles into a single, new, output shapefile. The features must all be the same type (i.e. point, line, polygon). The “Merge” tool keeps all of the input features as separate entities. The input features do not have to be adjacent, overlap or distance between features is allowed.

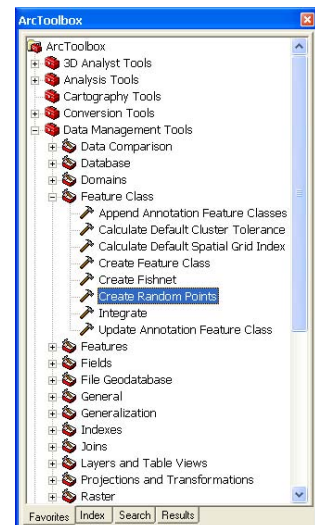
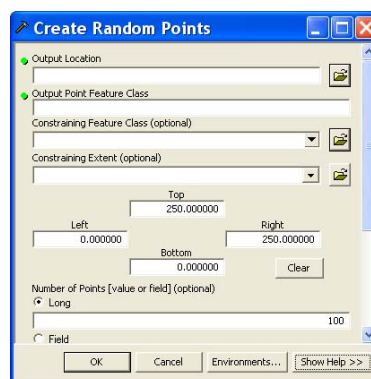
From the “Merge” dialog box, select all of the input datasets that you want to combine together. These can be point, line, or polygon feature classes; tables can also be merged. In the “Output Dataset” text box, specify a name and location the new shapefile that will be created.

Create Random Points

From ArcToolbox > Data Management Tools > Feature Class > “Create Random Points” tool

This tool does just what it says—it creates a specified number of random points within a given area, within polygons, or along line features of a shapefile. The placement of points is done according to specialized algorithms that consider the geography of the extent where the points can lay. Remember, “random” does not mean “mutually exclusive.” So, at least conceivably, two or more points can be placed at the same location; this is rare, but the probability does exist. It is always a good habit to review the placement of points after they are created to ensure that they will satisfy your needs. *NOTE: This tool is only available if the Spatial Analyst or 3D Analyst extension is installed.*

The “Output Location” text box requires you to select an existing folder (i.e. directory) where the new shapefile with random points will be created. The “Constraining Feature Class” or “Constraining Extent” options are useful if you want to limit the possible locations of points to a specific study area (i.e. extent) or within/along features of an existing shapefile. For example, researchers at Rutgers University sought to measure the impact of surveillance cameras on crime within the cameras’ immediate areas. Their quasi-experimental design called for a comparison between areas surrounding the surveillance cameras (i.e. cases) and areas elsewhere in the city (i.e. control areas). The selection of control areas was done randomly using the “Create Random Points” tool. Since surveillance cameras were only placed along streets, the permissible locations for control cameras to be placed had to mimic this limitation. Therefore, a streets shapefile was used as the “Constraining Feature Class” to ensure that random points could only be set along streets in the city. *NOTE: When you “constrain” points to features, ArcMap places the specified number points to every unique feature. With a shapefile of streets, for example, which tends to have many line segments, 10 points will be randomly placed on every line segment if you specify “10” as the value in the “Number of Points” text box.*



CHAPTER TEN

*Spatial Analyst Extension,
Density Mapping and 3D Modeling*

Spatial Analyst Extension

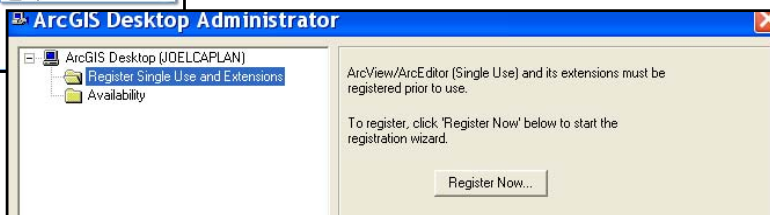
The Spatial Analyst Extension is specifically intended for the processing of grids (raster data). You will need the Spatial Analyst Extension and requisite toolbar to make density maps and work with raster data. Accessing the extension requires up to 3 steps.

1. Install and Register the Spatial Analyst Extension

Whether you have a trial version or a full license of ArcGIS, you will need to install and register the Spatial Analyst Extension before creating density raster maps. To do this, go to Start > Programs > ArcGIS > Desktop Administrator. Select the "Register...Extensions" folder and then click the "Register Now" button. When the Registration Wizard appears, select the radio button next to "I

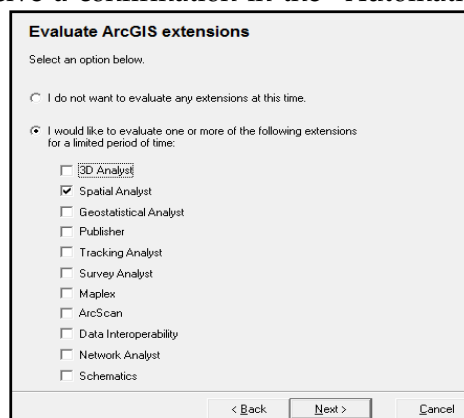


have already registered the software and need to register additional ArcGIS extensions". Continue through the following registration screens, entering your user information as requested.



For trial version users (screens and options may differ slightly for fully licensed users): When you get to the

"Evaluate ArcGIS Extensions" screen, click the radio button next to "I would like to evaluate one or more of the following extensions for a limited period of time." Then select the Spatial Analyst Extension by checking the box. Click the "Next" Button to continue with the registration. If you registered using the internet (recommended) you should receive a confirmation in the "Automatic Registration" screen as to what programs and extensions have been "Successfully registered and authorized". Click the "Finish" button and then exit out of ArcGIS Desktop Administrator.



2. Activate the Spatial Analyst Extension

Once extensions are installed and registered, you need to activate them. Open ArcMap and click Tools > Extensions. Check "Spatial Analyst" and then click the "Close" button.

3. Display the Spatial Analyst Toolbar

The Spatial Analyst Toolbar looks like this:

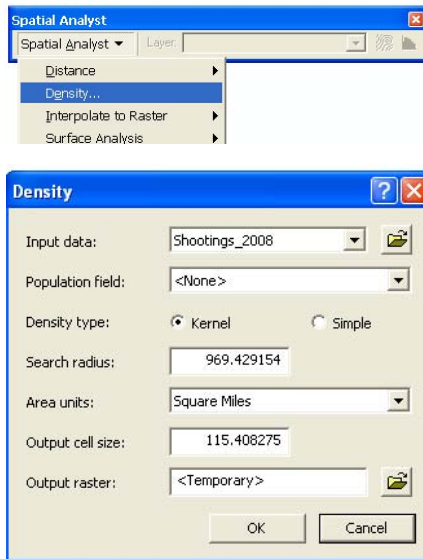
 A screenshot of the Spatial Analyst toolbar in ArcMap. It shows a dropdown menu with 'Spatial Analyst' selected, followed by a 'Layer:' dropdown, and several icons representing different spatial analysis tools.

If the toolbar is not already visible, go to View > Toolbars, then select "Spatial Analyst".

Density Raster Mapping

From "Spatial Analyst" toolbar, click "Spatial Analyst" button > Density

You will need the Spatial Analyst Extension installed, registered and activated, and the toolbar visible, to make a density map (see above). In the "Density" dialog box, select the input shapefile to calculate density from. The input can be a point or polyline feature class. Point density calculates the density of point features around each output raster cell. Conceptually, a neighborhood is defined around each raster cell center, and the number of points that fall within the neighborhood is totaled and divided by the area of the neighborhood. Line density calculates the density of linear features in the neighborhood of each output raster cell, and is calculated in units of length per unit of the area.

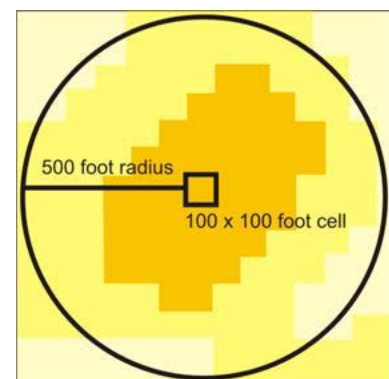


The Population field is the quantity that is to be used in the calculation of, or that is spread across the landscape to create, a continuous surface. Use "None" if no item or special value will be used and each feature will be counted once.

Simple vs. Kernel Density Calculations: If the selected density type is "Simple", and if the input is points, Density calculates the density of point features around each output raster cell. If the input is lines, Density calculates the length of the portion of each line that falls within the circle and then multiplies it by the Population field value. If the selected density type is "Kernel", conceptually, a smooth curved surface is fitted over each point feature. The surface value is highest at the location of the point, and diminishes with increasing distance from the point, reaching zero at search radius distance from the point.

The "Search Radius" determines the distance to search for points in order to catch for a density value for each cell in the output raster. If the option is set to save the output in the same coordinate system is the first input (on General tab of the Options dialog), the units for the search radius will be the same as the map units of the first input. If the option is set to save the output in the same coordinate system is the active data frame, the units for the search radius will be the same as the map units of the data frame.

"Area units" determines the units in which the density values will be calculated. The output density values are calculated as magnitude per Area Unit. If the map units are known (i.e., projected), then Area Units can be Square Miles, Square Kilometers, Acres, Hectares, Square Yards, Square Inches, Square Meters, Square Centimeters, or Square Millimeters. The "Output cell size" refers to the size of individual cells in the output raster. Cell size determines how coarse or smooth the patterns will appear. The smaller the cell size, the smoother the density surface will be. However, very small cells also require considerably more processing time and computer storage space. The size of the search radius will determine how generalized the density patterns will appear. A smaller search radius will show more local variation, while a larger search radius will show broader patterns in the data.



Name the new density map in the "Output raster" box. If you leave the default, <temporary>, the output raster will be temporarily written to your working directory. If you do not specify a path for the output raster, but type a name, it will be permanently written to your working directory. You can also type the path to a location on disk, or use the browse button to navigate to a location to place the output raster. To make a temporary result permanent, right-click on the output in the Table of Contents and click "Make Permanent." If you do not make temporary rasters permanent, they will not be available the next time you open your project (even if you save your project).

Possible Error Calculating Density of Geocoded Points

You might receive an error message when attempting to calculate the density of points that were geocoded with a match rate below 100%. The cause of the error is likely that there are "unmatched" addresses that appear in the shapefile's attribute table. Because the addresses are unmatched, there are no respective points on the map. This presents a problem to ArcGIS when it cannot find these points to include in the density calculation. To resolve this quickly, you must create a new shapefile with only the "matched" or "tied" records, thereby removing the "unmatched" records from the shapefile and its attribute table. Or, if you want a more inclusive density map with all of the original records, you must clean the data and geocode it properly.



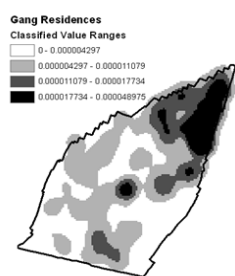
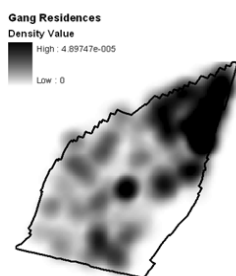
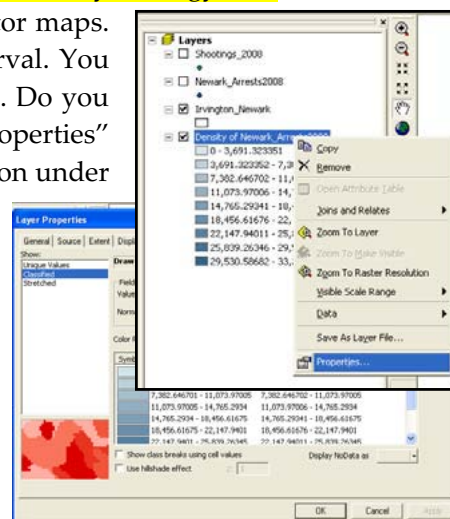
To remove unmatched records from an existing shapefile: In the Attributes table, there is a column called "Status" that notes whether each record was Matched (M), Tied (T), or Unmatched (U) during the geocoding process. Select all of the "M" and "T" records and then export these selected data to create a new shapefile (i.e. without unmatched records). Perform a density calculation using this new shapefile as the "Input data".

FID	Shape	Status	Score	Match_type	Side
102	Point	M	100	A	R
103	Point	T	100	A	R
104	Point	M	82	A	R
105	Point	U	0	A	R
106	Point	M	100	A	R
107	Point	M	100	A	R
108	Point	M	100	A	R

Density Map Symbolology

From ArcMap's Table of Contents, right-click the layer > Properties > "Symbology" tab

Symbolizing raster (i.e. density) maps differs slightly from vector maps. By default, density map symbology is displayed as Equal Interval. You may get a message that says "Unique histogram does not exist. Do you want to compute unique values?" Click "Yes". In the "Layer Properties" dialog box, under the "Symbology" tab, click the "Classify" button under the "Classified" scheme (on the left). Standard Deviation (SD) is a good option for showing variation in raster values. The map on the left in the example below shows a "Stretched" classification scheme, whereby each cell is shaded from white to black according to its density value. In this map, darker



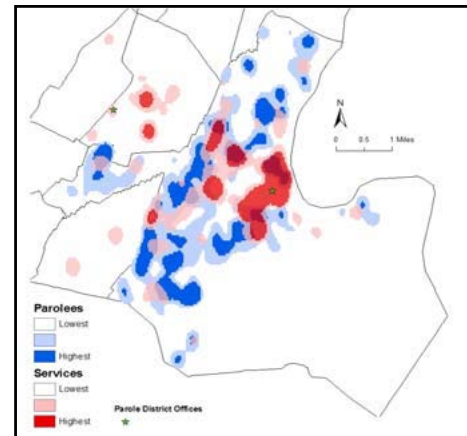
colored cells represent a higher density of gang member residences.

The map on the right shows the same cells classified into four groups—according to SD breaks. White colored cells have values below the mean cell value; cells colored light

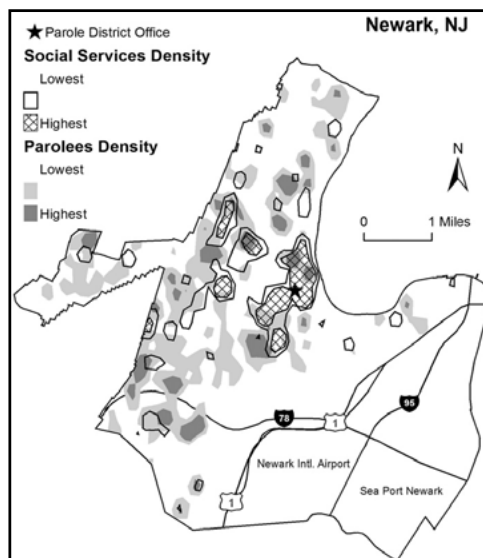
grey have values between the mean and +1 standard deviation (SD); cells colored dark grey have values between +1 SD and +2 SD; cells colored black have values greater than +2 SD. In other words, the black colored cells have values in the top five percent of the distribution (remember the 68-95-99.7 rule from statistics?).

Symbolizing Raster Density Maps with Multiple Layers

It can be difficult to symbolize a density raster map in a way that makes another map layer below it easily visible. For example, you could make the top raster map partially transparent to see through it to the layer below, as shown in the figure to the right. However, this can be confusing to the map reader and it tends to print to paper much worse than it appears on a computer screen.



Transparency works best with color raster maps, but should be used cautiously and sparingly, and only after careful consideration has been given to the map's intended purpose and the medium by which the final map will be delivered (i.e. computer screen or printed document). Colors and transparency are not appropriate for black-and-white publishing (e.g. journal articles) or for documents that will likely be copied and distributed widely (e.g. policy briefs).



Converting raster maps to vector features (such as polygons) provides additional symbology options, particularly in grayscale. For example, the figure to the left communicates the same information as the color map (above), but does so in grayscale and with the “Social Services Density” layer converted from raster to polygonal features. This allows for the crosshatching that symbolizes the “Highest” density areas. Layering these raster and vector maps permits a clearer visual analysis of the spatial overlap of parolee residences and social services: While parolees may live on any piece of land in Newark (with the exclusion of Newark International Airport or the seaport), a higher concentration of parolees live in the shaded grey areas on the map; a higher concentration of social services are located within the black outlines and crosshatched areas on the map.

Before converting a raster map to polygonal features, you should symbolize it using the “Classified” schema. The “Classified” schema groups raster cells based on their respective values, and then symbolizes them accordingly. For example, the raster map to the right is classified into four categories: All raster cells whose numerical values are above +2 Standard Deviations (SD) are symbolized with the color Black. All raster cells whose numerical values are between +1 SD and +2 SD are symbolized with the Medium Grey color; between the Mean and +1 SD is

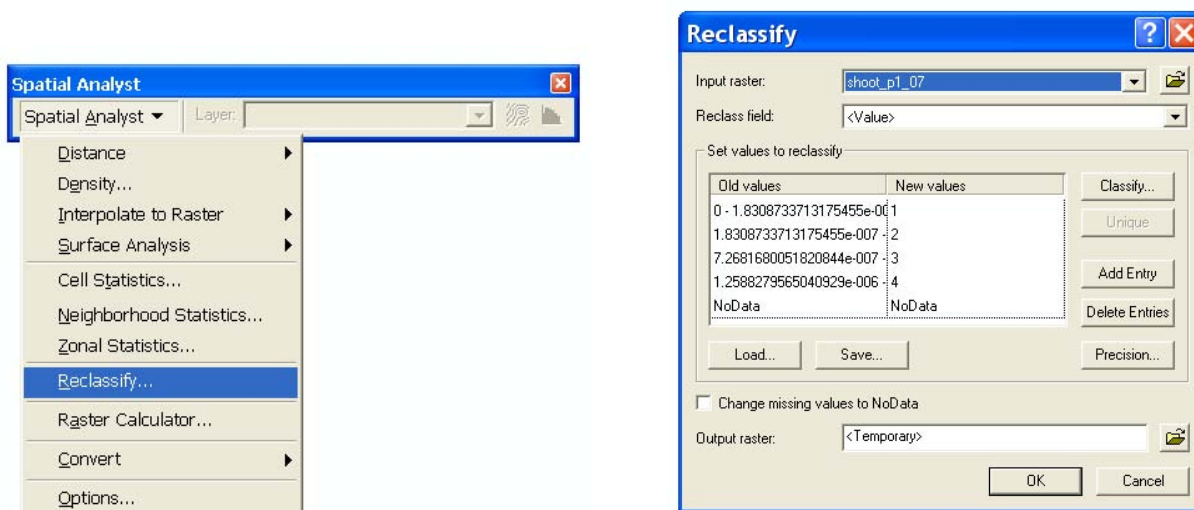


Light Grey; less than the Mean is White. Each raster cell retains its original value; it is merely (temporarily) symbolized according to a four category classification schema. You can then convert the similarly grouped contiguous cells into polygonal features. First, however, you must permanently change the values of the cells to specify to which group they belong. For example, all cells whose original values are above +2 SD (symbolized by the color Black) will get a new value of "4"; all cells whose original values are between +1 SD and +2 SD will get a new value of "3"; and so on. This task is done using the "Reclassify" operation in the Spatial Analyst Extension.

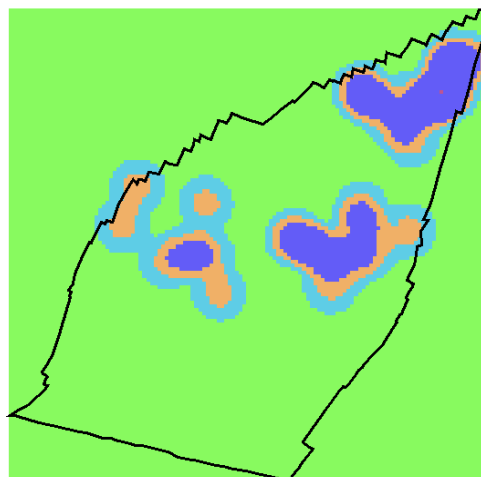
Reclassify Raster Values

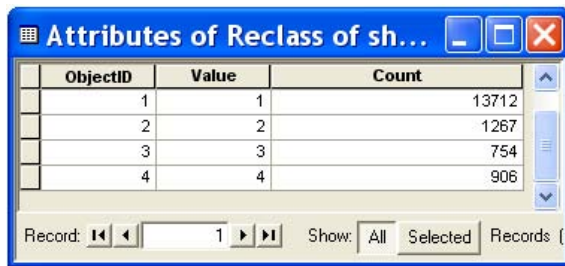
On the "Spatial Analyst" toolbar, click Spatial Analyst > Reclassify

A raster map is a grid of equally-sized cells covering the entire study area. Each cell has only one value associated with it. The Reclassify operation changes the values. This can be used to generalize or create new categories of data, or to create discrete categories from continuous data (such as density values).



In the "Input Raster" field of the "Reclassify" dialog box, select the raster map whose values you want to permanently change. ("Reclassify" actually creates a new raster layer, so the original raster map and data will not be altered). Notice how the "Old values" are grouped into the same classification schema that the map is symbolized in. By default, the "New values" are ordered numerically (e.g. from 1 to 4). In the example above, all cells with old values between zero (0) and 1.8308733713175455e-007 will get a new value of 1, and so on. Manually enter new values for each category or keep the defaults. New values can be of the numerical or string type. Choose a name and location to save the "Output raster" and then click the "OK" button. A new raster map will be created: In this example, each cell will have a value of either 1, 2, 3 or 4.



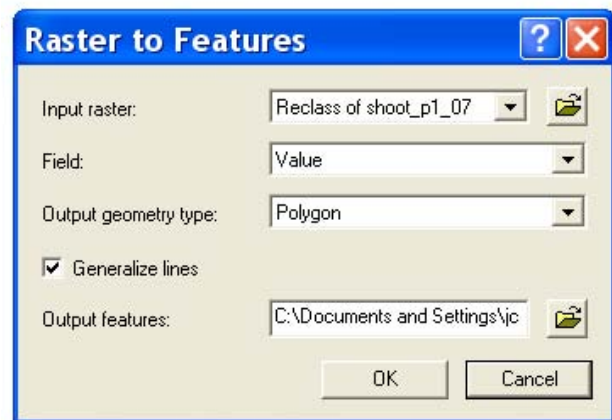
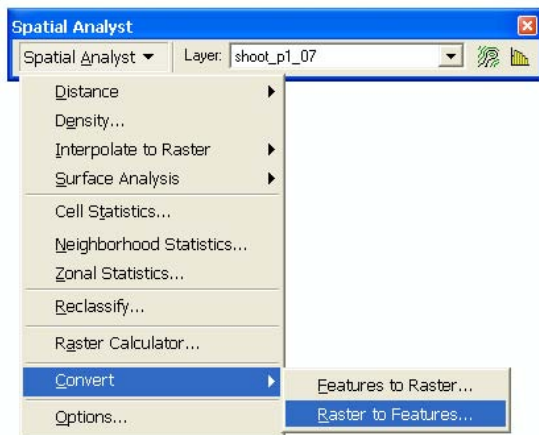


ObjectID	Value	Count
1	1	13712
2	2	1267
3	3	754
4	4	906

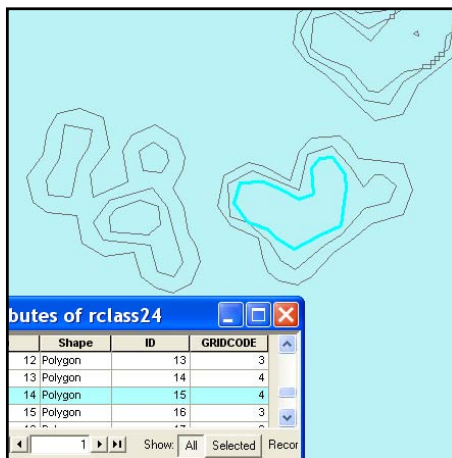
The Attribute table of the new (Reclassified) raster map shows that 13,712 cells now have the value of “1”, 1,267 cells have the value “2”, and so on. Groups of contiguous cells with the same values can now be converted into polygonal features using the “Convert” tool.

Raster/Vector Conversions (Convert Tool)

In the “Spatial Analyst” toolbar, click Spatial Analyst > Convert > Raster to Features.

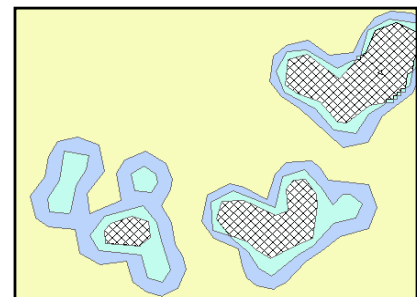


In the “Raster to Features” window, select your reclassified raster map as the “Input raster”. You will only have one option in the “Field” drop down menu—“Value”: the value of each cell will be saved in the Attribute table of the new vector shapefile. The “Output geometry type” should be “Polygon.” Generalizing lines is helpful for getting rid of the stair-stepped look that features can have when converted from square raster cells. In the “Output features” text box, give a name and location for the polygon shapefile that will be created.



The newly created polygon shapefile will have a unique feature for each group of contiguous cells that was in the input raster map. Each polygonal feature will also have a respective record in the shapefile’s Attribute table. The attribute of each polygon will be the value of the cells that once comprised the area within it. As shown in the figure to the left, the selected polygon was once a contiguous group of cells with the value “4”.

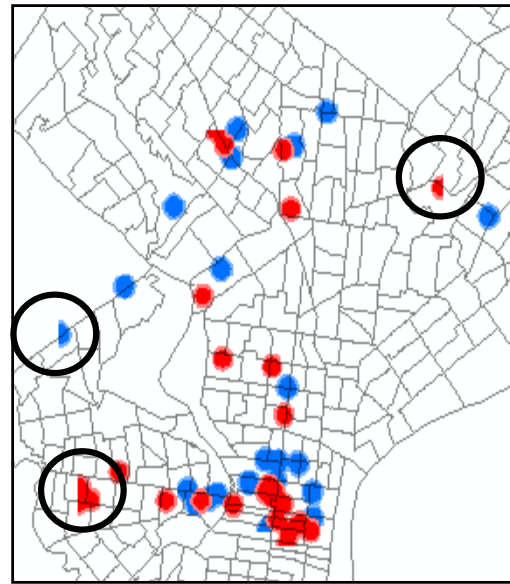
These polygonal features can be symbolized like any other vector shapefile by right-clicking on the layer in the TOC > click “Properties” > select the “Symbology” tab. You can also calculate area/perimeter, perform spatial joins, etc.



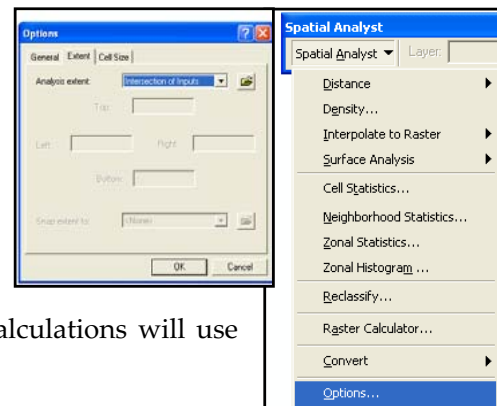
Raster Analysis/Output Extent

From the "Spatial Analyst" toolbar, click "Spatial Analyst" button > Options > "Extent" tab

At the outset of a raster data analysis, you might want to define a particular study area, referred to in ArcGIS as the analysis "extent". Or, you might notice that some of the areas on the density raster map that you created seem to have the hotspots cut off, as exemplified in the black circles to the right. This occurs when the extent of the density calculation is limited to only the perimeter (i.e. extent) of the points that you are calculating the density of. Imagine this phenomenon as ArcGIS framing the output density raster map to only the smallest square box that includes all of the input points. Instead, you want the extent to be the same as the data frame or the other shapefile layers that you are working with (such as a city outline).



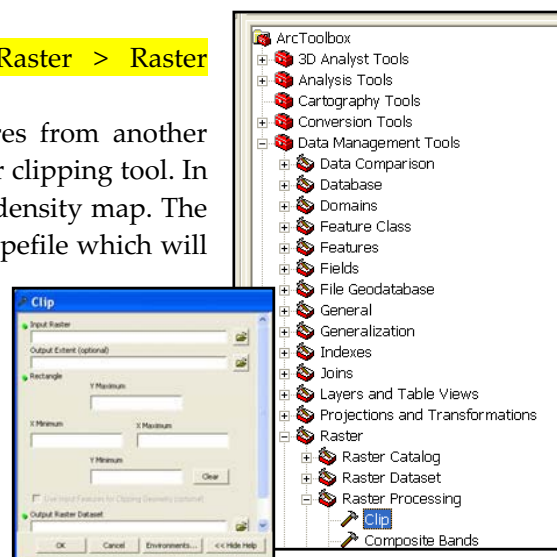
In the "Extent" tab of the "Options" dialog box, the default setting is likely to be "Intersection of Inputs." In the "Analysis extent" drop down menu, select an appropriate extent to meet your needs. If you want to use the same extent as another shapefile, add that shapefile layer to the Table of Contents in ArcMap first, then adjust the Analysis Extent: The drop down menu will provide an option for "Same as layer...". Click OK. Future density calculations will use this newly set extent.



Clipping Raster Maps

From ArcToolbox > Data Management Tools > Raster > Raster Processing > "Clip" tool

To clip density maps exactly to the outline of features from another shapefile, such as a city outline, you need to use a raster clipping tool. In the "Clip" dialog box, the "Input Raster" will be your density map. The "Output Extent" will be an existing raster or vector shapefile which will be used as the clip extent (like a cookie cutter). If you want to clip the raster based on the polygon features within the shapefile, check the box next to "Use Input Features for Clipping Geometry (optional)". *NOTE: Raster Dataset file names cannot be more than 13 characters.*

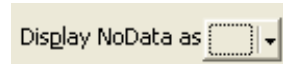


"NoData" Raster Cell Values

Every raster cell has a value assigned to it. Values can be either positive or negative, integer, or floating point. Cells can also have a "NoData" value to represent the absence of data. NoData means

that not enough information is known about a cell to assign it a value; or, that the cells are in areas that a user intentionally does not want to display (or wants to exclude from raster calculations). NoData and 0 are not the same; 0 is a valid value. If NoData exists in any of the input raster datasets the computation of output values can be affected in one of three ways: NoData is returned for the cell location no matter what; NoData is ignored and a value is computed using any available values; or a value is estimated for the cell location and NoData cannot be returned.

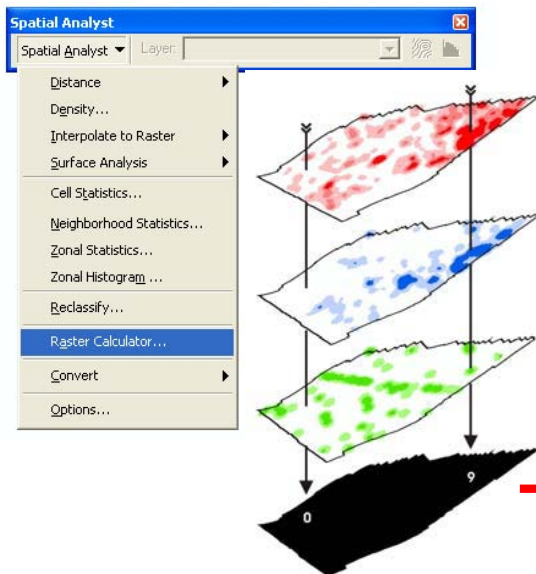
By default, NoData values are displayed transparent in a raster map. To change the symbology from ArcMap, right-click on the raster layer > Properties > "Symbology" tab > click the "Display NoData as" drop-down arrow > select a color > click "OK" button.



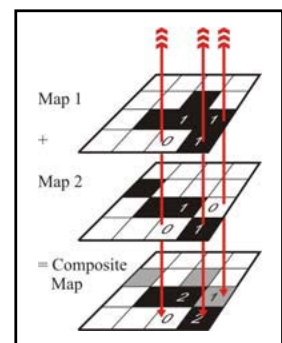
Raster Calculator

From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Raster Calculator

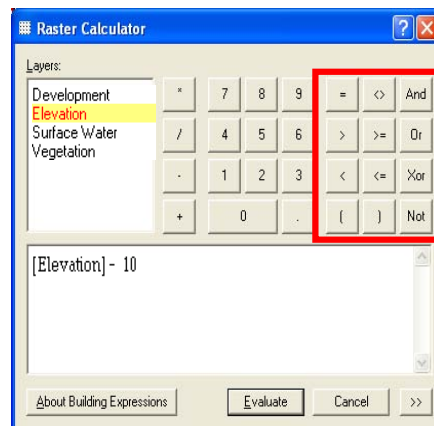
The "Raster Calculator" operation in the Spatial Analyst Extension creates a new grid on which the value of each cell is computed by applying map algebra and/or logical functions to the value of the cell on one or more existing grids. Essentially, it produces a new composite map. Consider, for example, the three raster (grid) layers shown to the left. In each layer, cell values range from 0 to 3. If



Raster Calculator were to be used to add each cell's values on these three grids, the result would be a composite raster map with cell values (potentially) ranging from 0 to 9.



The "Raster Calculator" dialog box provides for building algebra-like expressions that will produce new maps. Variables (in the form of grid layers and/or numbers) and functions are inserted into the expression box either by typing, by double-clicking on the layer names in the "Layers" section, or by using the buttons. Once an expression has been fully specified, click the "Evaluate" button to generate a new grid. Logical expressions prove to be either true or false for any given cell. These results are stored in the form of a new grid on which every cell is either set to 1 (for true) or 0 (for false).

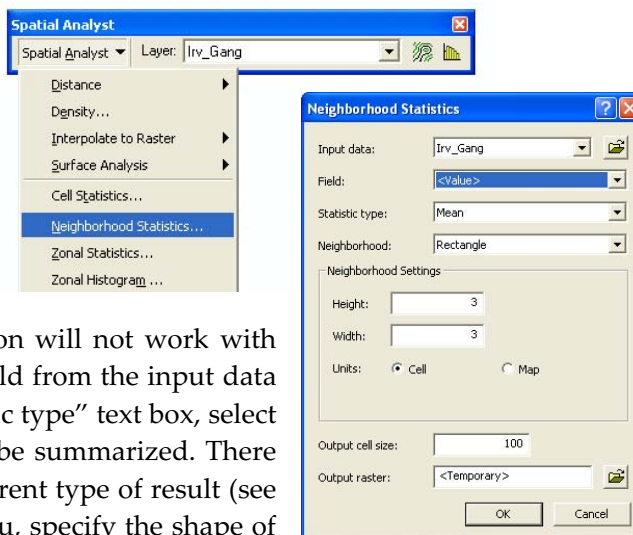


Logical Expressions Operators

Neighborhood Statistics²³

From the “Spatial Analyst” toolbar, click “Spatial Analyst” > Neighborhood Statistics

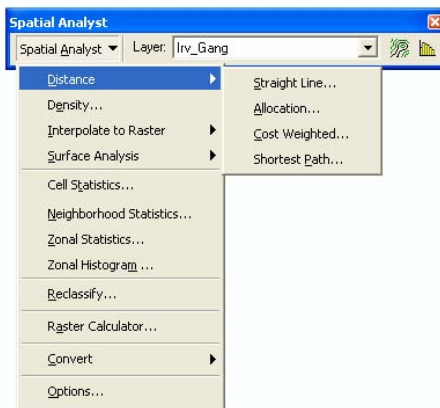
This creates a new grid in which each cell's value is computed by applying a specified statistical function to the values of an existing grid that are associated with a neighborhood of surrounding cells. This neighborhood may be in any of a variety of shapes and/or sizes.



From the “Neighborhood Statistics” dialog box, specify your input raster data. This function will not work with vector data. In the “Field” text box, select the field from the input data you wish to use in the calculation. In the “Statistic type” text box, select the statistic with which the input values are to be summarized. There are 10 statistics available, each producing a different type of result (see below). In the “Neighborhood” drop-down menu, specify the shape of the neighborhoods. Then in the “Neighborhood Settings” section, specify the size (the number of cells or map units) of the neighborhoods. The neighborhood dictates the shape of the area used to obtain a value for the cell being processed. There are four available shapes: rectangle, circle, annulus, wedge.

Neighborhood Statistics Operations

- The **sum** statistic computes a new value for each cell by adding the existing value of that cell to those of its adjacent neighbors.
- The **mean** statistic computes a new value for each cell by averaging the existing value of that cell with those of its adjacent neighbors.
- The **median** statistic selects whichever of the values in the immediate vicinity of that cell comes closest to being equal to or just greater than those of half the others.
- The **maximum** statistic computes a new value for each cell by selecting the greatest value to occur within its immediate vicinity.
- The **minimum** statistic computes a new value for each cell by selecting the lowest value to occur within its immediate vicinity.
- The **majority** statistic computes a new value for each cell by selecting whichever value occurs most frequently within its immediate vicinity. If two or more values tie for that distinction, a value of NoData is assigned.
- The **minority** statistic computes a new value for each cell by selecting whichever value occurs least frequently within its immediate vicinity. If two or more values tie for that distinction, a value of NoData (black) is assigned.
- The **range** statistic computes a new value for each cell by subtracting the lowest value from the greatest value to occur within its immediate vicinity.
- The **standard deviation** statistic computes a new value for each cell by calculating the mean of the squared differences between the average of all values in its immediate vicinity and each original value.
- The **variety** statistic computes a new value for each cell by determining how many different conditions occur within its immediate vicinity.



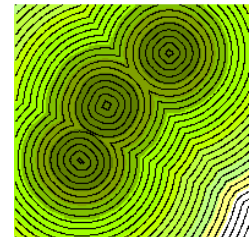
Spatial Analyst's Distance Operations²⁶

You can perform distance analysis of raster data using two main methods: Euclidean distance and cost distance. Euclidean Distance measures straight-line distance (from cell center to cell center) from each cell to the closest source; the source identifies the objects of interest, such as roads or a school. Cost Weighted Distance tool equates distance as a cost factor—the cost to travel through any given cell. For example, it may be shorter to (illegally) travel through a private property to get to a destination, but it is less risky to walk around it.

Straight Line Distance

From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Distance > Straight Line

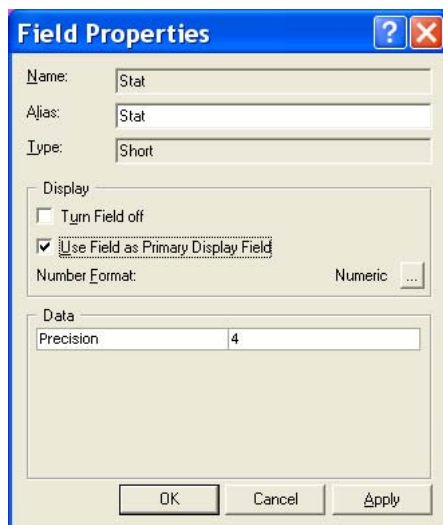
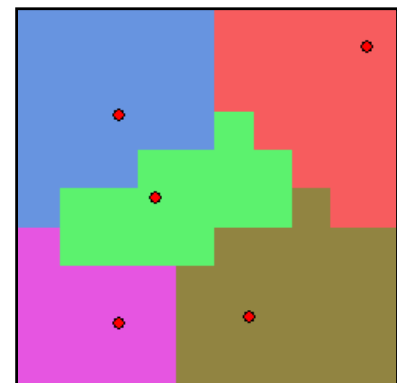
The straight line distance option creates a new grid in which each cell's value indicates its horizontal distance between the center of that cell and the center of the nearest of a designated set of cells on an existing grid. The units of distance are map units associated with the coordinate system of the source layer.



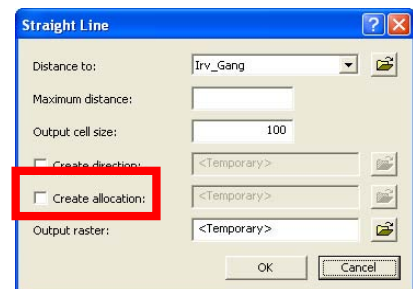
Allocation

From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Distance > Allocation

The allocation option creates a new grid in which each cell is set to the value of the nearest of a designated set of source cells on an existing grid (or source features of points, lines, or polygons). Here, every cell has been set to the value of the nearest Drug-Free School Zone. This "zoning" of the landscape that is generated by this operation is variously referred to as "proximal zones", "Voronoi regions", "Wigner-Seitz cells", "post office areas", and "Thiessen Polygons". The "Create allocation" checkbox on the "Straight Line" distance dialog box does the same thing.



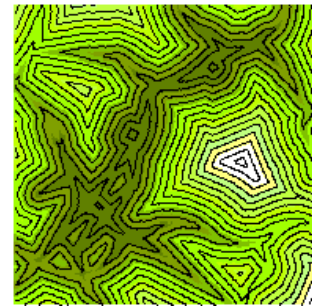
Allocation works with raster or vector data. Every cell or feature about which each allocated zone will be created must have a unique value. ArcGIS produces one zone per unique value per cell/feature. Raster cells always have only one attribute (though not always unique). The field (i.e. column) used by ArcGIS to create zones around point, line, or polygon features must be specified manually: In the layer's attribute table, right click the column heading > Properties > check the box next to "Use Field as Primary Display Field".



Cost Weighted

From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Distance > Cost Weighted

The cost weighted distance operation is similar to the "straight line" option in that nearness is defined in terms of distances that are measured horizontally from the center of each cell to the center of the nearest source cell. However, with the Cost Weighted option, those distances are not measured in units such as feet or meters. Instead, they are measured in units such as minutes, gallons of fuel, or risk of apprehension. These are not merely units of physical separation but units of cost that accumulate as a consequence of motion across a physical environment.



Shortest Path

From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Distance > Shortest Path

The Shortest Path operation generates a shapefile of one or more lines that trace the path(s) of minimum cost between designated "source" and "destination" areas. The operation is closely related to the cost weighted distance operation and, in fact, relies on that operation to calculate the costs to be minimized. The destination layer can either be a shapefile of point, line, or polygon features (in which case the destination feature(s) should be selected), or a raster grid (in which case a destination zone should either be selected or just set to any value other than NoData).



[Best Single]

[For Each Zone]

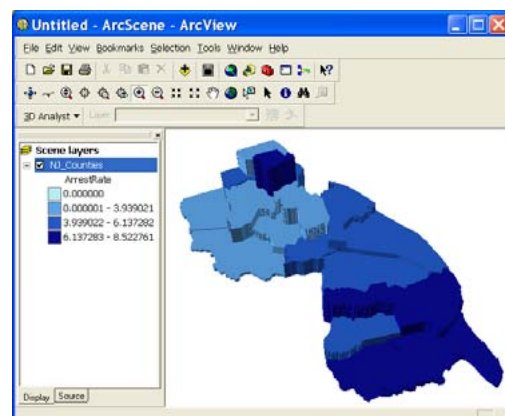
[For Each Cell]

One final item to be specified in the "Shortest Path" dialog box is the "Path Type" that can be set to any of three choices: Best Single, For Each Zone, or For Each Cell. The "Best Single" option traces the shortest path from the source to whichever

destination cell is closest. The "For Each Zone" option traces the shortest path from the source to whichever cell is closest within each of the zones of cells that comprise a destination. The "For Each Cell" option traces the shortest path from the source to every cell that is part of the destination.

ArcScene 3D Modeling

What most distinguishes ArcScene from the other ArcGIS applications is its ability to place layers in a three-dimensional setting. ArcScene may be used to explore the relationship of two variables in one map by adding a third-dimension. For example, you might extrude polygons of New Jersey counties to heights that represent the number of full-time municipal police officers, while symbolizing the same polygons with a gradient of colors that represent arrest rates. You might hypothesize that counties with the most police officers will also have the highest arrest rates. The third dimension allows you to explore the relationship between two separate attributes of a single polygon shapefile. Although this 3D map can be exported as a 2D image, this technique is recommended here more for exploration of GIS data layers and variables, not as a final map.



Adding Shapefile Layers

File > Add Data -or- Click the “Add Data” button

You can also click and drag shapefiles right into ArcScene: From ArcMap, click on the layer in the Table of Contents and hold down > drag to the Table of Contents on ArcScene and let go.

Removing Layers from ArcScene

From the Table of Contents, right-click the layer > Remove

Layer Properties

From the Table of Contents, right-click the layer > Properties

The “Layer Properties” dialog box offers more options—compared to the number offered in ArcCatalog or ArcMap. Most tabs/options should already be familiar to you from working in ArcMap (if not, see earlier chapters of this document).

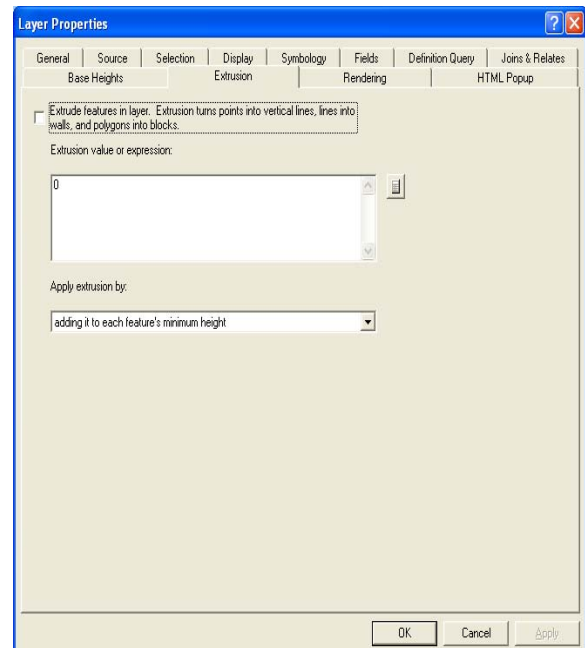
Under the “Extrusion” tab you can turn point features into vertical lines, lines into walls, and polygons into blocks.

Under the “Base Heights” tab, you can set the height of continuous surfaces based on a constant value or by referencing one or more attributes so the height can vary from feature to feature. For example, the figure to the right is a raster map whose cells are elevated based on the density of Social Services the city. Darker shades of blue represent areas with higher concentrations of people living at or below poverty. This map is one way to communicate that the poverty population in the city does not tend to live near where the highest concentrations of social services are located.



The “Navigate” tool on the “Tools” toolbar lets you rotate the display about two axes: one running left to right through the cartographic plane, and the other running perpendicular to it.

NOTE: Refer to ArcGIS Desktop Help for more information about using ArcScene.



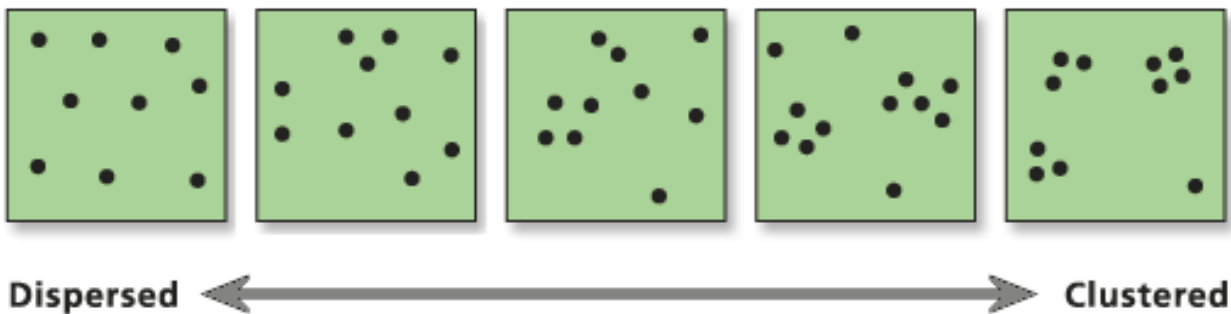
CHAPTER ELEVEN

*Identifying Significant Patterns
and Hot Spots*

Nearest Neighbor Analysis

From ArcToolbox > Spatial Statistics Tools > Analyzing Patterns > "Average Nearest Neighbor" tool

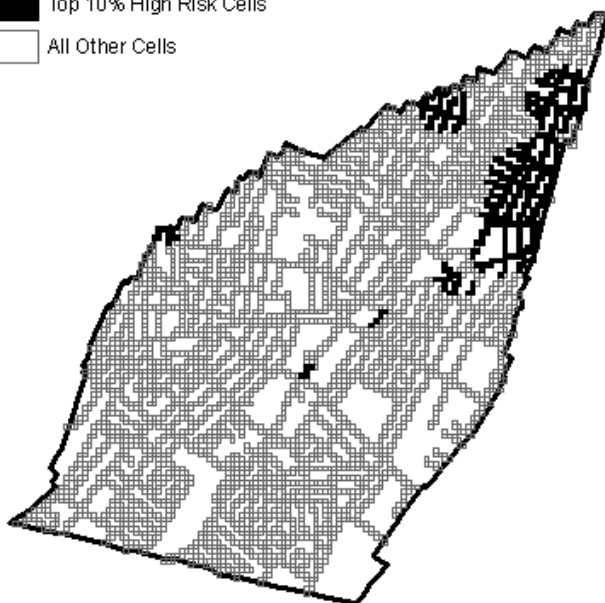
The Average Nearest Neighbor tool in ArcGIS is used to perform a Nearest Neighbor (NN) analysis. The NN analysis is a test of spatial randomness and works by calculating the distance from each point in a collection to its nearest neighboring point. For polygon or line features, the NN analysis measures the distance between each feature's centroid and its nearest neighbor's centroid location. These distances are then compared to the expected mean NN distance for a random distribution of points. If the average distance is less than the average for a hypothetical random distribution, then the features being analyzed are considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. The equation in ArcGIS used to calculate the average NN value, Z score, and p-value are based on the assumption that the points being measured are free to locate anywhere within the study area (i.e. all points are located independently of one another).



Graphic obtained from ArcGIS Desktop Help

Period 1 Risk Terrain: Highest Risk Locations

- Top 10% High Risk Cells
- All Other Cells



0 2,000 Feet



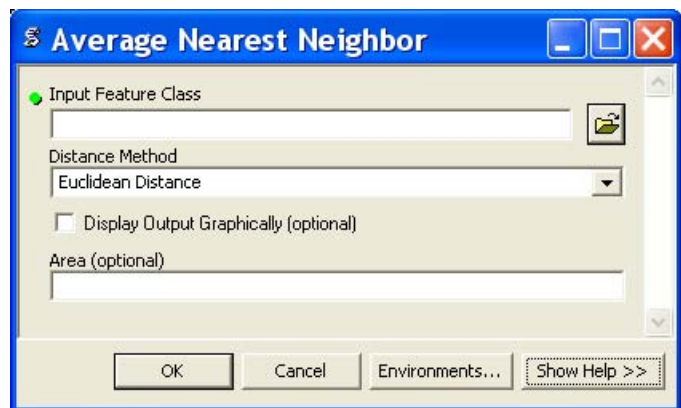
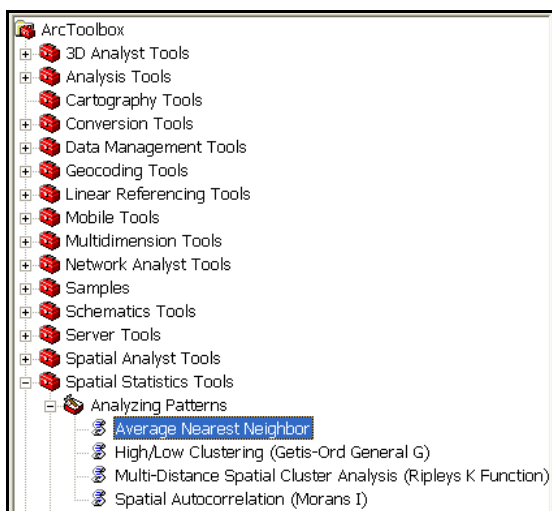
The Average Nearest Neighbor tool was used to determine whether the high-risk (polygon/vector) cells in the Period 1 Risk Terrain (left) were statistically significantly clustered. Results suggest that there is less than one percent likelihood that the clustered pattern of high risk cells could be the result of random chance (Observed/Expected Mean Distance = 0.63; Z Score = -14.33 standard deviations; Critical Value = -2.58; $p < 0.01$). Although this is quite evident upon visual inspection, the pattern is *statistically significant*. Other patterns may not be so obvious.

DWI Arrest Locations
2008 (n=59)



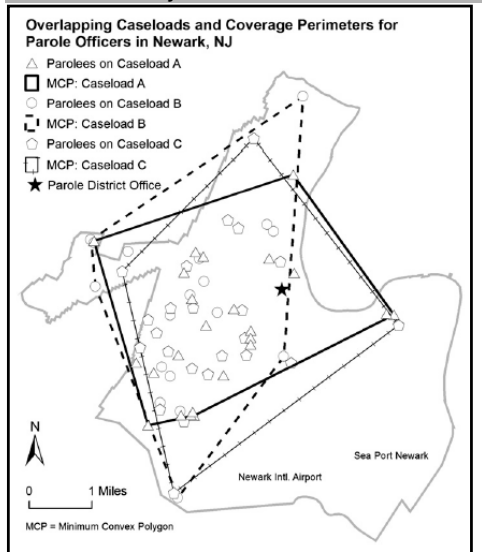
The pin map to the left is another example of how Nearest Neighbor analysis can be used. It shows incident locations of DWI arrests during 2008. If motor vehicle stops that result in DWI arrests cluster in certain areas of the city, then police patrols and interventions such as sobriety checkpoints are warranted, and can be more easily and efficiently targeted to the high-risk locations. Results of a NN analysis suggest that the distribution of DWI arrest locations is significantly clustered (z score= -10.31; $R=0.33$; $p<0.05$; Mean NN Dist.=348.07; Expected Mean NN Dist.=1065.90). A density map or standard deviation ellipse might be used to show how and where DWI arrests are concentrated in particular areas.

From the “Average Nearest Neighbor” dialog box, select your input shapefile for which the average NN index will be calculated. This is typically a point shapefile, but can be line or polygon shapefile as well. You will need to specify how distances between features should be calculated. “Euclidean Distance” is the default and most commonly used. It measures straight-line distances (as the crow flies).



ZOOM IN: Parole Officer Caseloads²⁷

Mellow, Schlager, and Caplan (2008) randomly selected parole officers' caseloads from the Newark, NJ region to investigate their distribution and overlap. Minimum convex polygons (MCP) were used to show the smallest perimeter within which each of these caseloads was distributed (see below, left). Further analysis revealed that caseloads were inefficiently distributed and had a high degree of overlap:



Parole officer (PO) A's case load of 24 parolees represented just 4% of the total study sample, but was distributed to a perimeter of 13.49 miles and covered an area of 11 square miles, or 45% of the total Newark study area; PO B's case load of 24 parolees represented just 4% of the total study sample, but was distributed to a perimeter of 14.85 miles and covered an area of 13 square miles, or 53% of the total study area; PO C's case load of 18 parolees represented just 3% of the total study sample, but was distributed to a perimeter of 15.41 miles and covered an area of 13 square miles, or 49% of the total study area.

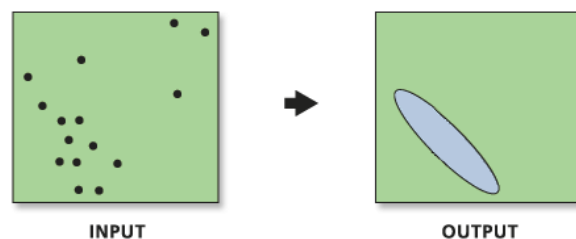
Related to overlap, clustering of PO caseloads should be a logistical concern for parole agencies because the geographic distribution of parolees within a caseload is an enabling factor for parole officers to serve as efficient and effective case managers and supervisors. Therefore, it was hypothesized by Mellow et al. that the residential locations of parolees within the same caseload would be spatially clustered together in certain parts of Newark. This was not the case. Nearest Neighbor analyses validated the researchers' conclusion that regardless of caseload size, parolees within a given caseload were randomly dispersed throughout Newark without any regard to geographic clustering. A random distribution suggested no forethought on the part of the parole agency to assign caseloads based on the geographic location of parolee residences. On average, parolees on the same case load resided ten times farther apart from each other than the "natural" geographic distribution of all parolee residences within Newark.

Through a hypothetic-deductive process that utilized GIS, Mellow et al. concluded that a revised system of caseload allocation based on the natural distribution of parolee residences could save time, money and resources for parole officers and their agencies. The study also provided empirical evidence that GIS is an instrumental tool for use in the parole system.

Standard Deviation Ellipses²⁸

From ArcToolbox > Spatial Statistics Tools > Measuring Geographic Distributions > "Directional Distribution" tool

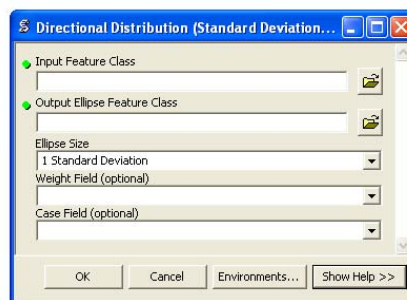
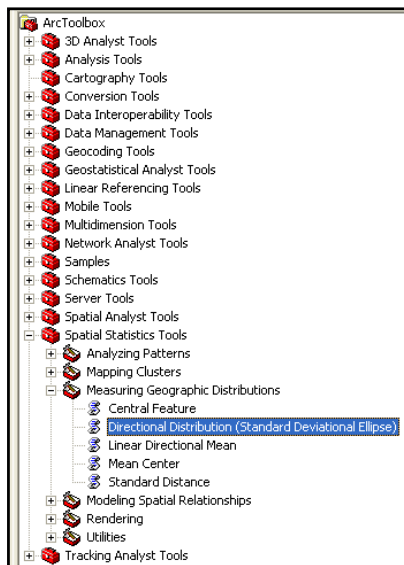
A Standard Deviation Ellipse (SDE) can be used to measure central tendency of a set of points, lines or polygons. A SDE identifies dispersion as the standard deviation of the distance of each feature location from the mean center, as well as the direction of that dispersion. The mean center, or



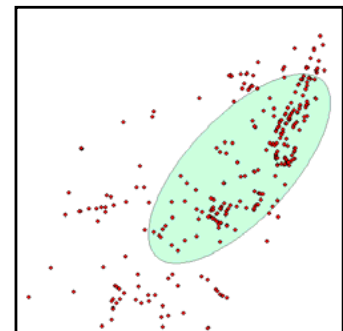
central location, refers to the arithmetic mean of all feature locations (centroids are used in the case of line or polygon features). The ellipse is referred to as the standard deviation ellipse because the method calculates the standard deviation of the x coordinates and y coordinates of each feature from the mean center to define the outer bounds of a smoothed ellipse polygon, which is displayed as a map feature. The attribute values for a SDE include two standard distances (long and short axes), the orientation of the ellipse, and the case field, if specified.

The “Directional Distribution” tool in ArcGIS creates SDEs. In the “Directional Distribution” dialog box, select a shapefile to be the “Input Feature Class.” This should contain the set of points, lines, or polygons for which the SDE will be calculated. In the “Output Ellipse Feature Class” field, choose a name and location for the new polygon shapefile that will contain the output ellipse feature. Choose the size of the output ellipse in the “Ellipse Size” drop down menu. The default is 1 standard deviation (SD); available options are 1, 2, or 3. With features normally distributed around the mean center, one SD will cover approximately 68 percent of all

input feature centroids. Two SDs will cover approximately 95 percent of all feature centroids. Three SDs will cover approximately 99 percent of all feature centroids.



The optional “Weight Field” permits the weighting of locations according to their relative importance; it is based on a value in the input shapefile’s attribute table. The resulting ellipse is termed a weighted SDE. The optional “Case Field” can be used to group features for separate directional distribution calculations. The Case Field can be of numeric, date, or string type. Once all parameters have been set, click the OK button.

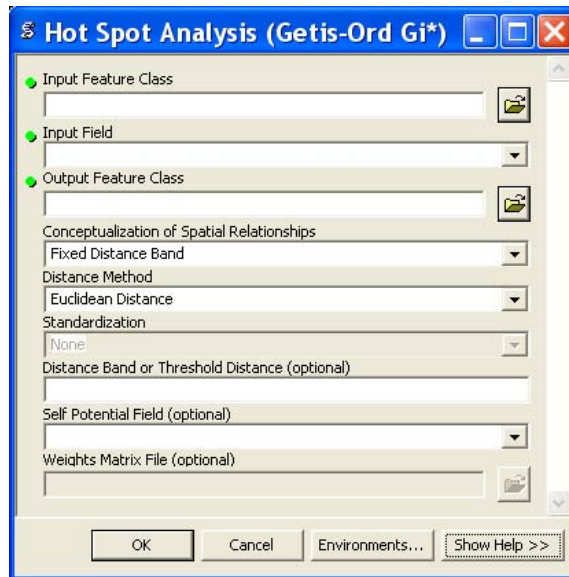
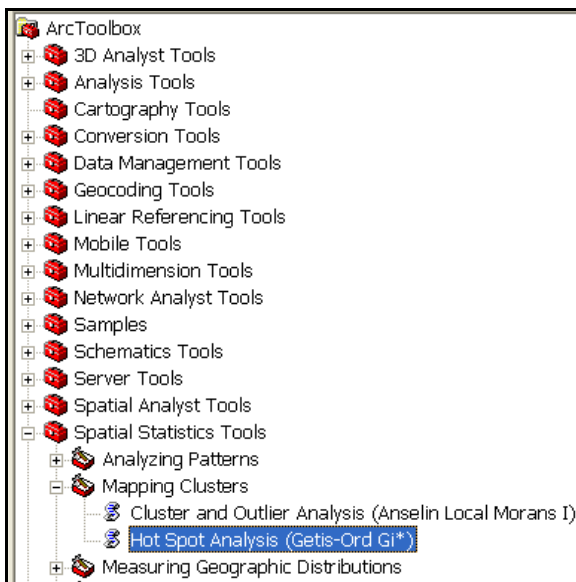


Hot Spot Analysis (Getis-Ord G_i^*)²⁹

From ArcToolbox > Spatial Statistics Tools > Mapping Clusters > “Hot Spot Analysis” tool

Your choice of symbolgy and classification schemes might imply areas that some people would call “hot spots” upon visual inspection alone. However, this terminology should be used cautiously. The (often) arbitrary choice of colors and classification ranges, or the classification method (e.g. Equal Interval, Natural Breaks, Standard Deviation) could substantially change a map’s appearance. For this reason, a “hot spot” defined upon visual inspection is much different than a “statistically significant hot spot”. To be statistically significant, a feature must have a high value and be surrounded by other features with high values. Similarly, cold spots consist of features with low values surrounded by other features with low values. This pattern must occur beyond random chance.

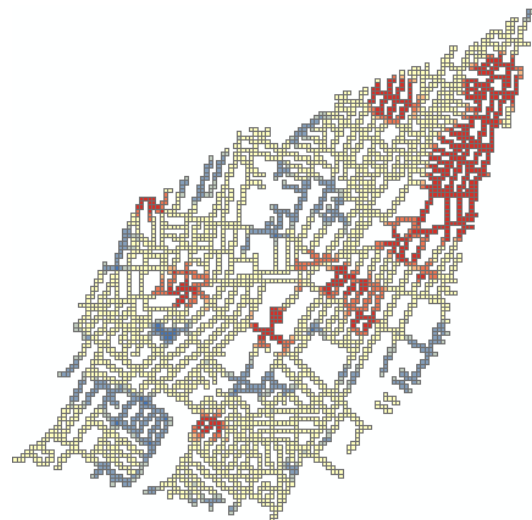
The “Hot Spot Analysis” tool in ArcGIS calculates the Getis-Ord G_i^* statistic (Z score) for each feature in a dataset. The larger the statistically significant positive Z score is, the more intense the clustering of high values (hot spot). The smaller the statistically significant negative Z score is, the more intense the clustering of low values (cold spot).



The default selections in the “Hot Spot Analysis” dialog box are recommended. The Input Feature Class (shapefile) must have an analysis field (Input Field). The tool assesses whether high or low values (e.g. the number of crimes per polygon; number of victims for each point) cluster spatially. The field containing those values is your analysis field. Prepare this field in the shapefile’s attribute table before using the “Hot Spot Analysis” tool. Output from this tool may look similar to the example map below—where red colored cells represent statistically significant hot spots of “high risk” locations, and blue colored cells represent statistically significant cold spots of “low risk” locations.

How you construct the analysis field determines the types of questions that can be asked. For example, if you divide the number of burglaries by the number of houses in a city, and then run the Hot Spot Analysis tool on this ratio, you are no longer asking “Where are there a lot of burglaries?”. Instead, you are asking “Where are there unexpectedly high numbers of burglaries, given the number of houses?” By creating a rate or ratio prior to analysis, you can control for certain relationships and possibly identify unexpected hot or cold spots.

NOTE: ArcGIS Desktop Help presents “3 things to consider when undertaking any hot spot analysis”. You should review this help section by searching for keywords “How hot spot analysis works” > click to view the first topic found.



Additional Spatial Analysis Software

CrimeStat

FREE | Available at: <http://www.icpsr.umich.edu/CRIMESTAT>

CrimeStat is a Windows-based spatial statistics program for the analysis of crime incident locations (point patterns). The program inputs incident locations in .dbf, .shp, ASCII or ODBC-compliant formats using either spherical or projected coordinates. It can then calculate various spatial statistics and write graphical objects in shapefile format. *CrimeStat* is a popular tool for researchers, police departments and other public safety practitioners.

GeoDa

FREE | Available at: <http://geodacenter.asu.edu/>

GeoDa is a freestanding software application that does not require a specific GIS system. It consists of an interactive environment that combines maps with statistical graphics, using the technology of dynamically linked windows. GeoDa is often used to analyze aggregated crime data (area patterns); but it also has a spatial regression package included that allows for the modeling of correlates or determinants of crime. According to the GeoDa website, general features include:

Data Input and Output

- read and write shape files; copy graphs and maps to clipboard; save maps and graphs to bitmap file

Spatial Data Manipulation

- create point shape files from text files; centroids for polygons; Thiessen polygons from points; contiguity based spatial weights for polygons; distance based spatial weights for points and polygons

Visualization and Queries

- graphs, maps and table; linking and brushing of all maps and graphs, multiway linking of table; spatial selection on maps; query selection in table

Mapping

- quantile and standard deviational maps; outlier maps: box map and percentile map; rate mapping and smoothing: excess risk map, Empirical Bayes smoothing, spatial smoothing; map movie

EDA

- histogram; box plot; scatter plot; full dynamic linking and brushing

Spatial Statistics

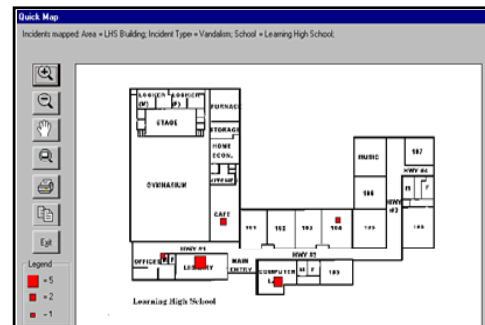
- Moran's I; Moran scatterplot: univariate, bivariate, EB corrected; LISA local Moran: univariate, bivariate, EB corrected

For a detailed, but introductory, discussion of the functionality of CrimeStat and GeoDa, see pages 43-63 of Eck, J. E., Chainey, S. Cameron, J. G., Leitner, M., & Wilson, R. E. (2005). Mapping crime: Understanding hot spots. Washington, D.C.: National Institute of Justice. Available at <http://www.ncjrs.gov/pdffiles1/nij/209393.pdf>

SchoolCOP

FREE | Available at: <http://www.schoolcopsoftware.com>

The School Crime Operations Package (*School COP*) is a FREE software application for entering, analyzing, and mapping incidents that occur in and around schools. *School COP* can include incident data from a single school or several schools (for example, schools in a district). Target users include school security staff, school police departments, school resource officers, and school administrative staff.



Schools can enter their own codes for describing attributes of incidents (e.g. incident type, severity, status, special circumstances codes) and attributes of persons involved in incidents (e.g. actions taken and special characteristics codes). These codes are used when new incidents are entered in the system. *School COP* also includes a flexible search capability. Searches can be made for incidents containing any specific value (e.g. all incidents that occurred in the cafeteria) or combination of values (e.g. all incidents that occurred in a specific month that involves a suspension of a student).

School COP can produce maps showing the location of incidents within school buildings or on school grounds and it can produce an assortment of graphs, including bar graphs and pie charts. It also includes a variety of pre-formatted tabular reports, including reports that summarize a specific incident or set of incidents and that aggregate incidents by month or school.

SPACE (Spatial Predictive Analysis of Crime Extension) by Bair Software

FREE | Available at: <http://www.bairsoftware.com/space/>

SPACE is an extension for ESRI's ArcGIS application that provides tools optimized for crime analysis and for analyzing and predicting spatial information. Its functionality is similar to what used to be known as CASE, but it works with newer versions of ArcGIS.

- *Link points*
- *Directional distribution*
- *Spider diagram*
- *Minimum convex polygon*
- *Nearest neighbor*
- *Sequencing*
- *Study area*
- *Buffer*

Geospatial Modeling Environment (GME)

FREE | Available at: <http://www.spatalecolology.com/gme>

GME incorporates most of the functionality of its predecessor, HawthTools, and has many improvements to facilitate analyses and modeling of spatial data. Whether you need to quickly place random points on a map or test statistical models, the tools in GME are very useful.

More Options

The International Association of Crime Analysts (IACA) maintains a comprehensive list of analysis software that can be useful to a variety of public safety practitioners: www.iaca.net/Software.asp

ENDNOTES

- ¹ Adapted from: <http://law.justia.com/us/cfr/title41/41-3.1.1.2.13.8.175.6.8.html>
- ² Stoe, D. A. (2003). Using Geographic Information Systems To Map Crime Victim Services: A Guide for State Victims of Crime Act Administrators and Victim Service Providers. U.S. Department of Justice: Washington, DC.
- ³ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁴ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁵ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁶ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁷ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁸ Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ⁹ Ideas and lists presented in this section are not exhaustive. Products were listed in no particular order and inclusion or exclusion of a particular GIS software or company does not suggest an endorsement (or lack thereof) of that software or product.
- ¹⁰ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ¹¹ Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ¹² Adapted from: Chainey, S. & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Wiley: West Sussex, England
- ¹³ From:
http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=1430&pid=1427&topicname=How_and_when_to_use_attribute_tables
- ¹⁴ Adapted from: Ormsby, E., Napoleon, E., Burke, R., Groess, C., & Feaster, L. (2001). Getting to know ArcGIS Desktop (2nd ed.). Redlands, CA: ESRI.
- ¹⁵ This section was adapted from content provided by: Ahmet Rahmi Kirkpinar, Graduate Student (2009), Rutgers University, School of Criminal Justice.
- ¹⁶ Parts of this section were excerpted or adapted from *Mapping Crime: Understanding Hot Spots* (2005) by Eck, Chainey, Cameron, Leitner, & Wilson. Available at <http://www.ncjrs.gov/pdffiles1/nij/209393.pdf>
- ¹⁷ This section was inspired by work produced by Jerry Ratcliffe and some of its content was adapted or excerpted from <http://www.jratcliffe.net/>
- ¹⁸ This section was inspired by work produced by Jerry Ratcliffe and some of its content was adapted or excerpted from <http://www.jratcliffe.net/>
- ¹⁹ Adapted from: <http://www.fgdc.gov/metadata>
- ²⁰ This section was adapted from and inspired in part by the COPS Publication entitled *Geocoding in Law Enforcement [Final Report]* (2000). Available at www.cops.usdoj.gov/html/cd_rom/tech_docs/pubs/GeocodinginLawEnforcementFinalReport.pdf
- ²¹ Ratcliffe, J. H. (2004). Geocoding crime and a first estimate of a minimum acceptable hit rate. *International Journal of Geographical Information Science*, 18, 61-72.
- ²² Metraux, S., Caplan, J. M., Klugman, D., & Hadley, T. R. (2007). Assessing Residential Segregation Among Medicaid Recipients with Psychiatric Disability in Philadelphia. *Journal of Community Psychology*, 35(2), p. 239-255.
- ²³ This section were adapted or excerpted from ArcGIS Desktop Help files.
- ²⁴ This section were adapted or excerpted from ArcGIS Desktop Help files.
- ²⁵ Some of the content of this section was adapted or excerpted from work produced by Dana Tomlin.
- ²⁶ Some of the content of this section was adapted or excerpted from work produced by Dana Tomlin.
- ²⁷ Mellow, J., Schlager, M. D., & Caplan, J. M. (2008). Using GIS to evaluate post-release prisoner services in Newark, New Jersey. *Journal of Criminal Justice*, 36(5).
- ²⁸ This section was adapted or excerpted directly from ArcGIS Desktop Help files.
- ²⁹ This section was adapted or excerpted directly from ArcGIS Desktop Help files.

JOEL M. CAPLAN is an Assistant Professor at Rutgers University School of Criminal Justice and Associate Director of the Rutgers Center on Public Security. As an expert of spatial analysis and a pioneer of Risk Terrain Modeling, he advises many public safety agencies on strategic decision-making and evidence-based practices. Joel has professional experience as a 911 dispatcher, EMT and police officer.

GIS

GIS for Public Safety focuses on ESRI's ArcGIS functionality (the most popular GIS software, worldwide) and presents many of the tools and procedures that are commonly used by public safety researchers, analysts and practitioners. It gives simple steps for descriptive, exploratory and explanatory mapping tasks and includes concise but meaningful discussions to let you critically assess and accurately apply the software to your own unique specialty. This provides a solid foundation for advanced spatial thinking and permits you to utilize GIS technology in your own innovative ways. Its comprehensive content makes it the perfect coursebook or reference manual for students, researchers, crime analysts and other GIS users at all skill levels.

To use a construction metaphor, this book is intended to teach a carpenter what tools are in his toolbox and how to use them. This instills confidence in his ability to apply these tools to any job when needed. Other books teach the carpenter specifically how to build a house. However, skills needed to build a house might fail the carpenter when he needs to build furniture instead. GIS for Public Safety focuses on a complete working knowledge of the toolbox to let the carpenter accurately apply the tools to his or her own unique specialty.

“Ready? Fire! . . . now Aim. In trying to teach a set of new techniques, this can actually be good advice. Take a shot, check the target, learn what you will, and take another shot. It works and, ironically enough, it works especially well as the strategy employed in GIS for Public Safety. By presenting most of his material in the form of immediately-executable steps, Caplan is able to guide his reader in a manner that is remarkably efficient, demonstrably effective, and ultimately quite enjoyable.”

– C. Dana Tomlin, Professor and originator of map algebra

“The information is presented in a very clear, uncomplicated manner that benefits users of varying experience levels. Everyone who reads this book should immediately be able to apply the discussed techniques to myriad of public safety issues.”

– Eric Piza, GIS specialist, Newark Police Department

“Dr. Caplan’s GIS for Public Safety embodies his unique blend of skills and experience in teaching, GIS, and public safety. He demystifies what can be a frustrating process of learning to make GIS software do what students of GIS want it to do and offers a series of practical tips for making sure that maps communicate effectively.”

– Amy Hillier, Professor and author

“The author’s use of illustration and screen capture allows for complex and oftentimes cumbersome mapping procedures to be conducted and understood by the reader with little difficulty. This book will allow for fellow map-makers and practitioners alike to either build new spatially-oriented skills or to increase and fine tune their existing abilities.”

– Michael Ostermann, Research Scientist, NJ State Parole Board

“I’m very impressed with this manual – the steps in GIS analysis are very clearly laid out and explained.”

– Ronald V. G. Clarke, Distinguished criminologist