

Michael Kennedy

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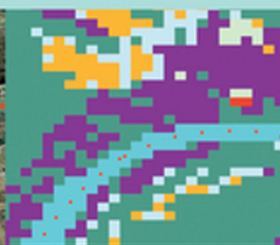
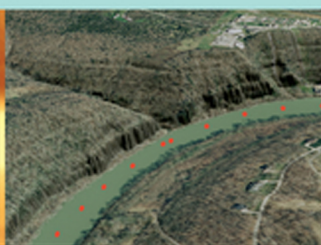
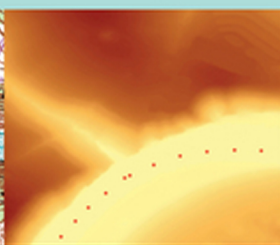
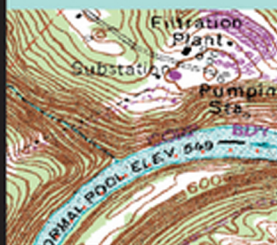


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# Introducing Geographic Information Systems with ArcGIS®

Third  
Edition

A WORKBOOK APPROACH TO LEARNING GIS





Introducing Geographic  
Information Systems  
with ArcGIS®

## About the Cover

The cover shows six images of the same geographic area, demonstrating various GIS data formats, depicting both natural and human-made features. The scene is a river flowing through a canyon. North of the river is a water filtration plant. The top scene is a TIN (Triangulated Irregular Network) indicating the elevation of the surface. Across the bottom of the cover, left to right, the first two images are portions of (a) a DRG (Digital Raster Graphics) file digitized from a US Geological Survey 7.5 minute quadrangle and (b) a DEM (Digital Elevation Model). The last two images, left to right are (d) a raster-based (cell-based, grid-based) depiction of different types of land cover and (e) a DOQ (Digital Ortho Quadrangle), which is an aerial photograph that has been rectified so it can be used as a map. In the center at the bottom is (c) a three-dimensional view in which ArcGIS software was used to “drape” a DOQ over an elevation model. The red dots along the river depict points collected by a GPS (Global Positioning System) receiver on a boat moving along the river.

# Introducing Geographic Information Systems with ArcGIS® Third Edition

A Workbook Approach  
to Learning GIS

**Michael Kennedy**

*University of Kentucky*

**WILEY**

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***To the memory of Evan Kennedy,  
who had every gift but that of years***





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# Foreword

*by Jack Dangermond*

*Introducing Geographic Information Systems with ArcGIS* offers a unique approach to GIS instruction. In it, Michael Kennedy re-creates his time-tested methods of teaching GIS in the classroom in a step-by-step guidebook to GIS. Students on a journey to learn GIS with Professor Kennedy may feel like he is taking the journey with them, offering them his sage advice each step of the way. Professor Kennedy cares deeply for his students, and the detail of this care and years of teaching GIS come through in this book. In it, he walks students through the multitude of questions that come up daily in the classroom. His goal is to help students understand GIS concepts and learn GIS skills. It takes a master teacher to map GIS knowledge, making it clear to students and enabling them to gain confidence in their growing skills.

Once GIS students have learned the basics, the next step is to learn how to analyze spatial data and identify problems and create solutions. Learning to analyze spatial data moves students beyond exploration, beyond locating places on maps, and helps them create maps that guide better decisions.

All of us learn GIS skills in different ways. Some people are visual learners, some are auditory learners, and some need a hands-on approach. As the learning styles of students in general vary, so do the learning needs of students of GIS. Some students will need classroom study, with conversations and time to process information about GIS concepts, spatial data, geodatabases, map projections, attribute tables, feature classes, datasets, and building maps, while others need only a guidebook with clear graphic illustrations. So, a variety of approaches to teaching GIS will help ensure that the increasing number of students worldwide have opportunities to gain GIS skills in ways that best suit their needs.

GIS is becoming part and parcel of the daily work lives of most people in many fields, from architects to zoologists, from academia to the business world, from city planning to national and international spatial data portals. Teachers are now taking on the essential task of opening the door for students to learn GIS. In *Introducing Geographic Information Systems with ArcGIS*, Professor Kennedy opens such a doorway for students to learn the skills basic to understanding GIS and to prepare students to make our communities better places.



# Preface<sup>1</sup>

It turns out to be hard, for me anyway, to write the preface for a third edition. As I tried to compose this I put a lot of electrons in the recycle bin. Most of what I have to say was said in the prefaces to previous editions. And who wants to want to wade through eleven pages of those in addition to this one!

So what I will do is just to tell you about the new material in the text and then just abstract and reference earlier information and ideas. I'm eliminating the Preface to the Second Edition. If you haven't used the book before, you probably should read the Preface to the First edition, included after this one.

First, of course, is that the material is oriented to ArcGIS Desktop versions 10.0 and 10.1. Where there are differences between these two, and there are several, I have usually pointed them out. However, those using 10.0 will occasionally have to adapt the Step-by-Step instructions, which favor version 10.1. I recommend using 10.1 if it is available and you are familiar with it. (To indicate the extent of the changes, we can start with the fact that the functionality level names have changed from those in version 10.0 and before. In 10.1 ArcView is Basic, ArcEditor is Standard, and ArcInfo is Advanced.)

The CD-ROM used in earlier editions has been replaced by a DVD, because the data sets are more extensive and all the figures in the book are available.

Since the first edition, sections and exercises have been added on the topics of:

- ❑ Publishing maps on the Internet, using ArcGIS.com.
- ❑ Using the Esri online data service to add basemaps to the student's map.
- ❑ The terrain data structure, made possible by the emergence of LIDAR as a remarkable method of very dense data collection, is covered both in theory and by exercise.
- ❑ Layer packages – a welcome invention which facilitates the transfer of feature classes of all formats from one computer to another, without worries like relative path names and separate data transfers.
- ❑ Since this book is primarily aimed at preparing professionals for using GIS to do analysis and synthesis (topics separate from display and mapmaking, which, for completeness, is covered in considerable detail in Chapter 3), topology plays an important role. A number of exercises, therefore,

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<sup>1</sup>If this text is used in a classroom/laboratory setting, this preface is for the instructor and may be skipped by students. If you are using the book to learn GIS on your own you should probably read it.

emphasize the use of the topology capabilities of geodatabases, which is considerably different from those of coverages and completely absent from the shapefile format.

### Changes from the Previous Editions

- ❑ Use of and information about coverages has been demoted to an optional exercise on converting an Esri coverage to a geodatabase.<sup>2</sup> All references to ArcInfo Workstation have been removed, since its functions have been taken over by ArcToolbox, and Workstation has been “depreciated” (although many of us “appreciated” it a lot in times past!).
- ❑ A couple of the more arduous exercises (making feature classes by key entry and digitizing) have been improved so that the student or reader understands the concepts without having to experience the all-too-real tedium of data entry. Other exercises have input data provided for them on the DVD to cut down on digitizing and typing.
- ❑ More flexibility has been built into the text. I suggest exercises that might be omitted in the interest of compressing the learning of essential GIS material into a shorter time span.<sup>3</sup>
- ❑ All the figures in the book are reproduced, many in color, on the DVD that accompanies the text. At the beginning of each Step-by-Step section, I encourage students to open both the Color Figures file and their Fast Facts File (both to access reference information and to add new material). The Fast Facts File, into which the students write the information they consider relevant, thus making their own reference guides to ArcGIS Desktop, is emphasized. The past several years have convinced me that the Fast Facts File is an important tool for long-term learning of the material – as the software grows in facility and complexity.
- ❑ In previous editions, students were asked to write, in their textbook, the names of some menus and tabs. The third edition has no blanks for this. Instead students are encouraged to record the name of tabs and menu items in their Fast Facts Files – and to think about what each item might mean. Since there is no way to cover all of ArcGIS (except perhaps in an intensive, year-long, full time course), having a list that at least hints at the capabilities of the software that are not covered in the text (represented by these tabs and menus) is beneficial. Further, the lists in the student’s Fast Facts File can be updated as ArcGIS evolves in the years to come.

The purpose and structure of the book remains essentially the same. (Please see the Preface to the First edition). Chapters are divided into (a) Overviews (a top-down look at GIS theory and other relevant information) and (b) Step-by-Step (sequential) exercises. All the data needed for the exercises is provided on the included DVD. (The DVD does not include ArcGIS software. I assume that the several mechanisms that Esri provides (e.g., site licenses, student one-year licenses, and so on) for access to ArcGIS will be in place.)

This third edition is meant to educate a wider group than the first edition. The subtitle—A Workbook Approach to Learning GIS—is intended to convey that the book has been specifically revamped for

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<sup>2</sup> Some coverages are still used as data as part of exercises, but primarily to let the student know that such objects still exist and that a lot of data still resides in them.

<sup>3</sup> I want to emphasize, however, that everyone should take the time to read the Afterword by Dr. Michael Goodchild on GIScience at the end of the book, which will be critical for the effective use of GIS in the coming years.



community college and technical institute courses, where almost all students can become proficient with many ArcGIS software abilities in a single semester.

The combination theory-workbook approach is designed to bring the reader from GIS neophyte to well-informed GIS user—from both a general knowledge and practical viewpoint—in a single semester or, used by an individual outside of class, in about 60 hours of self-study.

It is appropriate to repeat some ideas and warnings from the First Edition Preface:

- ❑ Do not use any of the sample databases on the DVD for anything other than tutorial purposes. Many of the data sets are not current. Many have been modified for instructional purposes. Some of it is totally bogus.
- ❑ Exercise 5–8 is a cooperative exercise for eight to twenty-four students. Preparation and management on the part of the instructor is a really good idea. Information on the book's companion website at [www.wiley.com/go/kennedygis](http://www.wiley.com/go/kennedygis) can help.
- ❑ If you, as an instructor, are quite sure that your students will not need more than the most basic knowledge about coverages and shapefiles, you can have them skip considerable portions of Chapter 4. You should perhaps read those sections and, if needed, supplement the student's knowledge of the concepts that apply to geodatabases.
- ❑ If you serve ArcGIS, or even just its license manager, over a network, you should thoroughly test the process. Also, in Chapter 8, the unsupported CellTool is used. Students may not be able to install it, so someone from network services may have to be involved.
- ❑ Students learn the software at their own pace, pretty much regardless of what the instructor does. They learn by doing, and paying attention to and recording what they are doing. As the text proceeds, the sophistication required to operate the software increases. For students who aren't paying attention, the exercises will get harder and harder because it is expected that they will learn (or be able to quickly find in their Fast Facts Files (see next paragraph) how to perform operations that they have performed before. Careful explanation of basic procedures (e.g., finding the properties of something), which is extensive at the beginning of the book, is reduced gradually but considerably as the text unfolds. Warn your students about this: The handholding diminishes as the chapter numbers increase.
- ❑ Students are asked to develop a Fast Facts File in which they record what it is they have learned about the software. This is a computer file that they keep open during their work sessions, both for adding new material and ascertaining how to do a particular procedure that they have used previously but cannot remember. They periodically revise and augment this file. Then, at the end of the course, they have their own reference manual for the software. I have used this technique for some years now, and it pays dividends. Some students who have graduated and now work in the GIS field tell me they take their Fast Facts File with them and maintain it in their new positions. One failure of other workbooks and web-based courses is that, while students can go through the exercises and even pass a test at the end, they simply cannot operate the software when handed a new exercise. Now with twelve-plus years of teaching GIS with the Overview-Step method behind me, insisting that students make a Fast Facts File to provide themselves a guide through the very complex GIS software, I'm convinced that the not-always-popular-with-the-students Fast Facts File is more than worth the trouble.
- ❑ One way this book has been used is in a two-semester course sequence for advanced students with an intensive theory text (e.g., Longley, Goodchild, Maguire, Rhind) using *Introducing Geographic Information Systems with ArcGIS—A Workbook Approach* providing the needed practical experience.

## Preface

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I don't know if it's me, the students of today, the multi-media culture, or something else, but I find the traditional lecture to be less and less useful. Lately I have confined my lectures, which I keep short, to those topics that seem to give some students trouble conceptually. My teaching environment has not been an easy one; it has usually involved a mixture of civil engineering graduate students, geography sophomores, and students from other departments (29 such departments as of this writing.) Given the varied computer experience and maturity of students in such a diverse group, I find that an environment in which students work from the text at their own pace, with reasonable deadlines and the opportunity to ask questions individually, seems to work best.

Instructors who want answers to exercises: please write to me on school, college, or university letterhead and just ask.

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Or obtain the answers from the Instructor Companion website at [www.wiley.com/go/kennedygis](http://www.wiley.com/go/kennedygis)

For those who want to provide comments, criticisms, corrections (many thanks), or complaints: email me at [Michael.Kennedy@uky.edu](mailto:Michael.Kennedy@uky.edu).

## Acknowledgments for the Third Edition

For both the second and third editions, I must foremost thank my son, Alexander Kennedy, who edited the manuscript and worked all the exercises twice, using ArcGIS Desktop 10.0. No less a contribution was made by my daughter, Heather Kennedy, who also contributed to the editing and who developed the images on the cover from figures in the book itself.

I want again to thank

Jack Dangermond, President of Esri, for his encouragement and for writing the Foreword.

Michael F. Goodchild, Professor Emeritus, Department of Geography, University of California, Santa Barbara, for contributing the Afterword on GIScience.

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And finally, Bob Argentieri and Dan Magers—my editors at John Wiley and Sons—who had to put up with a number of issues beyond the normal problems in dealing with authors, and were assisted therein by Bob Hilbert, who managed production, and David Riedy who put the cover together with images from the book, after several iterations and challenges created by yours truly.

## Acknowledgments for the Second Edition

Great thanks are due to Mr. Mike Richie, Owner and President of Photo Science (which is among the most comprehensive aerial remote sensing firms in the United States, [www.photoscience.com](http://www.photoscience.com)) for the special effort in providing the LIDAR data for the second edition of the book.

The author is indebted (for help with the second edition) to Ms. Ryan Bowe, who read the text and worked all the exercises twice. She is a remarkably good editor, and her detailed knowledge of ArcGIS was invaluable.

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# Preface

## *to the First Edition<sup>1</sup>*

The purpose of *Introducing Geographic Information Systems with ArcGIS* is threefold.

1. To acquaint the reader with the central concepts of GIS and with those topics that are required to understand spatial information analysis.
2. To provide the person who works the exercises either (a) a considerable ability to operate important tools in the ArcGIS software or (b) a demonstration of other capabilities of the software.
3. To lay a basis for the reader to go on to the advanced study of GIS or to the study of the newly emerging field of GIScience, which might be described as the scientific examination of the technology of GIS and the fundamental questions raised by GIS.

*Introducing Geographic Information Systems with ArcGIS* is meant to serve as a text book for a standard one-semester course. It is suitable for a university, college, technical school, or advanced high school course, meeting for three hours per week. Between two and five additional hours per week are required for laboratory work, depending on the capabilities and computer experience of the students. The text may also be used for self-study.

The book, and any course taught from it, depend on having ESRI's ArcGIS Desktop and Workstation software, version 9.0, 9.1, or higher, available. The assumption is that the students will have access to full the ArcInfo package offered to colleges and universities under the generous site license agreement that ESRI offers to educational institutions. For more information about this program, point your browser at: <http://www.esri.com/industries/university/education/faqs.html>. However, if ArcInfo is not available, many of the exercises can be done with the ArcView level of ArcGIS, available to students with a free, one-year license.

While the author is impressed with the ArcGIS software (and with the aims of ESRI of being a force for conservation, preservation, and sustainable development worldwide), this book is not meant as a promotional text for ESRI. Like all large software packages, ArcGIS has its shortcomings, limitations, and

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<sup>1</sup>If this text is used in a classroom/laboratory setting, this preface is for the instructor and may be skipped by students. If you are using the book to learn GIS on your own you should probably read it.

bugs. When these arise in the process of working through the exercises, they are candidly pointed out to the reader. All bugs have been reported to ESRI, and most have been repaired or are scheduled for repair. By the way, the ESRI support staff is excellent responsive and friendly.

The function of GIS software is to make a computer think it's a map—a map with characteristics that let the user analyze it, display its elements in a variety of ways, and use it for decision making. This text is oriented more toward preparing the student for doing analysis with GIS, rather than display, mapping, or standard data processing.

## Contents of Introducing Geographic Information Systems with ArcGIS

- ❑ Part I: Basic Concepts of GIS
  - ❑ Chapter 1: Some Concepts that Underpin GIS (and introduction to ArcCatalog)
  - ❑ Chapter 2: Characteristics and Examples of Spatial Data (and introduction to ArcMap)
  - ❑ Chapter 3: Products of a GIS: Maps and Other Information
  - ❑ Chapter 4: Structures for Storing Geographic Data (and introduction to ArcToolbox and Workstation)
  - ❑ Chapter 5: Geographic and Attribute Data: Selection, Input, and Editing ( and introduction to ArcScene and ArcGlobe)
- ❑ Part II: Spatial Analysis and Synthesis with GIS
  - ❑ Chapter 6: Analysis of GIS Data by Simple Examination
  - ❑ Chapter 7: Creating Spatial Data Sets Based on Proximity, Overlay, and Attributes
  - ❑ Chapter 8: Spatial Analysis Based on Raster Data Processing (and introduction to Spatial Analyst)
  - ❑ Chapter 9: Other Dimensions, Other Tools, Other Solutions (and introductions to 3-D Analyst, Historical Data, Address Geocoding, Network Analyst, and Linear Referencing)

In my view, the pedagogical theme of a first course should be breadth, with depth in vital areas. The text covers virtually all the general GIS capability that ArcGIS has to offer. Vector and raster storage, analysis, and synthesis are, of course, discussed extensively, with many examples and exercises for the student. Other areas receive less attention, such as 3-D GIS, time and GIS, network analysis (path finding and allocation), surface creation, spatial analysis, statistical and numerical analysis, model builder, GIS & GPS, and so on. In some later instances, the exercises are primarily demonstrations of the capabilities of the ESRI software, but, in my opinion, a student in a first course needs to get at least a glimpse of almost all of what GIS can do. Omitted from the text is most of customization, programming, and the more esoteric capabilities of geodatabases, which I believe belong in a second course. Also not included is GIS on the Internet and the issues related to large, enterprise implementations of GIS. To mention it again the thrust of the text is to lay a foundation from which the reader can move toward doing analysis and synthesis with GIS.

The emphasis in terms of data structure is on geodatabases. However, extensive use is made of shapefiles and coverages, since most existing GIS data sets are in these formats. The student will become comfortable with switching and converting among the various formats. Another reason for using all three formats is that, at this stage of ArcGIS development, there are operations that can be done with coverages that cannot be performed with geodatabases.

ArcMap, ArcCatalog, ArcToolbox, ArcScene, and ArcGlobe are all explored in considerable detail. ArcInfo Workstation is introduced. Enough of command-line ArcInfo Workstation is used to make the student aware of its existence and its capability to perform operations that are cumbersome or impossible with the point and click software. This is a book that creates knowledge for the student that is realistic and at least touches on virtually all the ArcGIS capabilities and products.

In the four years the text has been under development, most of the exercises in the book have been performed by scores of students. All of the exercises have been tested and they work, both from a technical and pedagogical standpoint.

In terms of time required to do the exercises, most students will require:

Chapter 1—3:00 to 5:00 hours

Chapter 2—3:45 to 5:45 hours

Chapter 3—4:30 to 6:30 hours

Chapter 4—3:30 to 5:30 hours

Chapter 5—4:45 to 6:45 hours

Chapter 6—4:00 to 6:00 hours

Chapter 7—5:15 to 7:15 hours

Chapter 8—5:00 to 7:00 hours

Chapter 9—4:45 to 6:45 hours

## Theory and Practice

Of the myriad of GIS textbooks available, some are long on theory but don't train the student, while the rest are pretty much manuals on how to use software, but don't promote an understanding of what lies behind the mechanics. So frequently GIS is taught either with texts that teach only theory and leave it to the instructor to select software and data to illustrate points or taught with manuals and demonstrations.

The book is unusual, if not unique, in that it serves both as a general introduction to GIS (serving an education function) and a manual on ArcGIS software (serving a training function). This is accomplished by dividing each chapter into an

- Overview section, and a
- Step-by-Step section

The Overview section is descriptive. It is a top-down discussion of theory and ideas relating to GIS.

The Step-by-Step section is prescriptive. It operates in a sequential fashion—do this, then this, then this. Here the student learns about and practices ArcGIS. There are more than 60 exercises in the book, not counting the 9 review exercises. Almost 60 percent of the book consists of step-by-step instructions on how to use ArcGIS software.

All the data sets for the exercises are on the CD-ROM that accompanies the book.

## Teaching with This Book

The contents of the following folders on the CD must be available for downloading by students:

- ❑ IGIS-Arc—the primary source of data sets for the exercises
- ❑ IGIS-Arc\_AUX—a source for datasets occasionally needed for exercises
- ❑ IGIS\_with\_ArcGIS\_FastFactsFile\_Checklists—a combination chapter summary and set of Fast Facts File prompts
- ❑ IGIS\_with\_ArcGIS\_Selected\_Figures—full-color versions of some figures in the text that suffer from black-and-white reproduction

If you are an instructor, you should consider copying the four folders above from the CD-ROM to a location on a network where the students can access their contents.

Exercises are roughly put into categories of length or difficulty, with such notes as “Warm-up” (least effort), “Project” (greater effort), and “Major Projects” (most effort).

Some warnings:

Do not use any of the sample databases on the CD-ROM for anything other than tutorial purposes. Most of the data is old. Much of it has been modified for instructional purposes.

For students who aren’t paying attention, the exercises will get harder and harder because it is expected that they will learn (or be able to quickly find) how to perform operations that they have performed before. The “hand holding” diminishes as the chapter numbers increase.

Exercise 5–8 is a cooperative exercise for eight to twenty-four students. Preparation and management on the part of the instructor is a really good idea.

If you, as an instructor, are quite sure that your students will not need more than the most basic knowledge about coverages and shapefiles, you can have them skip considerable portions of Chapter 4. You should read the sections on coverages yourself and, perhaps in lecture sessions, supplement the student’s knowledge of the coverage concepts that apply to geodatabases.

If you serve ArcGIS, or even just its license manager, over a network, you should thoroughly test the process. Also, in Chapter 8, the unsupported CellTool is used. Students may not be able to install it, so someone from network services will have to be involved.



## More Resources for the Instructor

If you are an instructor who is using this text, you are encouraged to register on the website [www.wiley.com/college/kennedy](http://www.wiley.com/college/kennedy). There you will find advice on how to use the book to its fullest potential. Included there are answers to the questions posed in the text, sample assignments with blanks for the students to complete, test data for some assignments, and suggestions of how to use the text—avoiding some pitfalls that lurk, especially when the datasets are served across a network. The Instructor's Guide there can be a valuable resource for those teaching with this text. Also look at the folder IGIS\_with\_ArcGIS\_Instructor's\_Guide on the CD-ROM.

## Concepts, Devices, and Techniques that Underlie the Philosophy of the Book

How can one textbook touch on almost all of GIS when it takes thousands of pages of manuals to do this? Two ways:

- ❑ There are few figures, and, compared to the standard computer manual, there are few screen shots. When a student follows the instructions, he or she sees the proper screens. When a figure can be better understood by the use of color, the figure is available on the CD-ROM in the folder IGIS\_with\_ArcGIS\_Selected\_Figures. Such figures are designated in the text reference with three asterisks. For example, "See Figure 8-4\*\*\*."
- ❑ As the student progresses through the later chapters, the exercises do not contain detailed instructions. The students are expected to be able to do steps that were explained in detail earlier. For example, in early chapters, detailed instructions are given for finding or changing a property of a data set or data frame. In later chapters, the students will simply be told to take that action. When students can't either remember or find out how to perform an action that has been previously detailed, teachers should take it as a clue that the students are simply going through the motions of executing the software tools and that learning is not really taking place.

I believe that students learn best by doing—while observing and recording what it is they are doing. Students are asked to develop a Fast Facts File in which they record what it is they have learned about the software. This is a computer file that they keep open during their work sessions, both for adding new material and ascertaining how to do a particular procedure that they have used previously but cannot remember. They periodically revise and augment this file. Then, at the end of the course, they have their own reference manual for the software. I have used this technique for some years now, and it pays dividends. Some students who have graduated and now work in the GIS field tell me they take their Fast Facts File with them and maintain it in their new positions. One failure of other workbooks and web-based courses is that, while students can go through the exercises and even pass a test at the end, they simply cannot operate the software when handed a new exercise. Now with ten-plus years of teaching GIS with the Overview-Step method behind me, insisting that students make a Fast Facts File to provide themselves a guide through the very complex GIS software, I'm convinced that the not-always-popular-with-the-students Fast Facts File is more than worth the trouble.

The exercise material is project oriented; students learn the software as needed for the particular project at hand. So rather than learning everything about labeling features at one time or everything about selecting, the students learn as they complete projects and record what has been learned in their Fast

## Preface

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Facts Files, which are later reorganized. At the risk of losing adoptions and sales, please let me candidly point out that this textbook does not serve very well as reference material. The idea behind the book is to make things click in the students' brains, to promote comprehension of concepts, not to serve as a reference guide to the software. However, the diligent students—indeed even those who follow the instructions—will emerge from the course with their own reference guides, done in a style suitable for each student the Fast Facts File. Some students resist creating the file, so I make it count for 5 percent of their grade. Further, the Fast Facts File will be a reference document that the learners can maintain and upgrade in future months and years. A student of mine of a decade ago came to my class to give a guest lecture. He was in charge of the GIS program of a state unit. He brought his Fast Facts File with him to show to the class. Over the years, he had updated it many times.

The text is workbook-like in that there are blanks in the text which the students are asked to complete, showing that they have performed and comprehended a particular section. This also serves as a mechanism for letting the instructors know how students are progressing. The Web site [www.wiley.com/college/kennedy](http://www.wiley.com/college/kennedy) contains forms with these blanks, in context, so an instructor can copy and paste the material into assignment sheets. Student progress can be monitored using these assignments.

The text is set up so students can work at their own pace, respecting different learning styles and speeds of the students. For example, some students create entries in their Fast Facts Files with each step. Others make two passes through the material.

In a few places in the text, students are asked to record the names of menu choices or tabs in windows. Of course this information could have been printed for them, but having them write it in reinforces the words and the concepts behind them in the students' minds. It is also a modest protection against software changes (e.g., addition of menu or tab items).

The last exercise in each chapter is a checklist that can serve the students in development of the Fast Facts File. The students are given prompts that they fill in. The prompts appear in the text and also on the CD-ROM in the folder `IGIS_with_ArcGIS_FastFactsFile_Checklists` so they are available in machine readable form to the students. This allows students to copy the prompts into their Fast Facts Files and complete them.

The book simulates a teacher sometimes a lecturer, standing in front of students, imparting information or giving directions. More often the instructor is a colleague, sitting beside the student, making suggestions, prompting, and, occasionally, making mistakes that he or she and the student rectify. One might describe the tone of the book as conversational. I believe the most important thing, after correctness, is engaging the student. I believe economy in writing is important. But sometimes additional words can set a tone. I actually use several tones in the text to provide variety. I change pace. I change style. I change attitude. I change the level of formality.

The writing style, for the most part, is informal—to convey the idea that the author is closely involved with the student, guiding her or him. Humor is used, but sparingly. Irony is used, but sparingly.

The ArcGIS software is so complex that there is no way to explore it “depth first.” We must look at an overview. The book attempts to teach, or at least demonstrate, the major capabilities of ArcGIS. As you can tell from the weight of ESRI manuals, compared with the size of this text (which also serves as a general GIS theory text), I could hardly cover even a large portion in detail. However, the student will come away with considerable facility with the software and will know how to find and use additional capabilities.

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Finally, I believe it is important to emphasize that computer is not a black box. An educated GIS professional should have some understanding of what makes a computer tick. So there is some general material on computers and representation of information, especially as they impact answers from a GIS.

## Acknowledgments

This book was something of a family affair. My daughter Heather Kennedy provided help with the 3-D material<sup>2</sup>. My son Alex Kennedy carefully worked all the exercises in all chapters, making corrections and providing insightful observations. He also helped collect some of the GPS data.

Jack Dangermond, for his encouragement in general and writing the Foreword in particular, and ESRI for allowing use of numerous datasets and figures. In fact, this text was originally conceived of as a new edition of *Understanding GIS—The Arc/Info Method (UGIS-tiam)* reworked for the ArcGIS point-and-click version of the software, beginning with ArcGIS 8.x. It has clearly grown way beyond that first idea, with the addition of textual matter dealing with GIS itself, discussion of other capabilities of the software besides vector-based GIS site selection (such as a discussion of Spatial Analyst, the addition of material on several of the other important extensions to the software, and the major emphasis on geodatabases). Teachers who in the past used *UGIS-tiam* (last published almost a decade ago) will, however, recognize the site selection problem of that text (a laboratory to do research in “Aquaculture”) as the Wildcat Boat Testing Facility of this text, albeit highly modified.

I am indebted to Dr. Michael Goodchild for writing the Afterword. As mentioned before, the aim of this textbook is to provide a general introduction to GIS and prepare students to use ArcGIS primarily for analysis. Some of those students will want to go on to study GIScience, and I commend Dr. Goodchild’s Afterword to them.

Many colleagues and friends contributed to bringing this book to fruition. In particular, I want to thank:

Christian Harder, founding publisher, *ESRI Press*, for suggesting and encouraging the development of the text.

Gary Amdahl, an early, helpful editor with *ESRI Press*.

Randy Worch of ESRI, for support and encouragement over the years.

Damian Spangrud, ArcGIS product manager for ESRI, for being the person I could always count on when I had difficult questions about the software.

Ken Bates, extension specialist with Kentucky State University, for working through many of the exercises with the ArcView level of ArcGIS.

Dan Carey, Ph.D., of the Kentucky Geological Survey and the University of Kentucky, for his thorough reading.

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<sup>2</sup>She is author of *Introduction to 3D Data: Integrating and Modeling with ArcGIS 3D Analyst, Virtual Earth, and Google Earth* (John Wiley & Sons, 2009, ISBN 978-0-470-38124-3), *Data in Three Dimensions: A Guide to ArcGIS 3D Analyst* (Onward Press, 2004, ISBN 1-4018-4886-9) and editor of *The ESRI Press Dictionary of GIS Terminology* (2001, ISBN 1-879102-78-1).

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I greatly appreciate the help of Richard Greissman, who facilitated my finding the time to write.

Demetrio Zourarakis of the Division of Geographic Information, Commonwealth Office of Technology for Kentucky-wide data.

The staff of ESRI technical support—friendly and helpful people too numerous to mention.

Jim Harper and Amy Zarkos of John Wiley and Sons, who facilitated the editing process in spite of the author's frequent lack of organization and tardiness.

Richard Peal of Publishers' Design and Production Services, Inc. in Sagamore Beach, MA, who looked after the figures, again against complications created by the author.

Teaching assistants Chris Blackden and Amber Ruyter worked through the exercises and helped both students and me over rough spots.

Scores of students at UK had early drafts of the text inflicted on them. In particular Rebecca McClung, who reviewed the text exhaustively and helped prepare the index and Travis Searcy, who combed through the later chapters.

I also wish to thank:

Taylor and Francis (and CRC Press) for allowing me to use portions of my textbook *The Global Positioning System and GIS* (ISBN 0-415-28608-5).

Chris Kimball of Digital Data Services, 10920 West Alameda Avenue, #206, Lakewood, CO (www.usgsquads.com, 303-986-6740) for the data behind Figure 2-3: Frankfort, MI and Crystal Lake DOQQs.

*The Lexington Herald Leader* for the photograph of the water facility on the Kentucky River.

Sue McCowan, account manager, GIS Markets of Tele Atlas, for San Francisco Street data for the Network Analyst exercise.

I'm appreciative of the University of Kentucky and its College of Arts and Sciences and Department of Geography, for providing the opportunity to develop the text.

# Introduction

A geographic information system (GIS) software package is basically a computer program designed to make a computer think that it's a map. This new sort of map is a dynamic entity, designed to assist people in making decisions. Such decisions might be as simple and short range as determining an efficient way to get from place A to place B. Or as complex as designing a light rail transportation system for a city or delineating flood planes. The difference between a paper map and a GIS map is that the latter exhibits "intelligence." You can ask it a question and get an answer.

Geographic information systems are transforming all the activities and disciplines that formerly used maps as the basis for decision making. It's about time. Most fields of human endeavor have long since been heavily impacted by the digital computer; in fact it's hard to think of one that hasn't. Fifty years have gone by since computers began changing accounting, census taking, physical sciences, and communication, to name a few. Even the field of music has been altered. Most of these "nonspatial" fields already couched their problems in terms of discrete symbols (such as A, r, 5, and \$) that are easily converted to the binary language (using only the symbols 0 and 1) that the computer understands. The spatial fields such as geography, planning, and land use management, had to stick with maps because, while maps also use symbols, they are not so neat and tidy as to fit on the keys of a keyboard. A symbol for a road might be three feet long! Determining how to efficiently represent the real-world environment in the memory of a computer turned out to be quite a challenge. So until a decade or so ago, those who relied on maps usually could not use computers effectively as the primary source of data from which to work.

Why has computer-based GIS come to influence how decisions are made about land use planning, navigation, resource allocation, and so on? First, the shortcomings of maps for decision making are many. Second, computers have become greatly faster, bigger (in terms of memory size), and cheaper. And, third, we have developed sophisticated data structures and learned how to efficiently program computers to represent the huge, almost infinitely detailed environment that we live in. So those of you who are just now beginning to learn about GIS are not pioneers, but if you enter the field now, I bet that in a decade you will feel like a pioneer because the field is growing so rapidly. You are off on a great adventure!



PART I

# Basic Concepts of GIS





## CHAPTER 1

# Some Concepts That Underpin GIS

## OVERVIEW

IN WHICH you begin to understand the rather large and complex body of ideas and techniques that allow people to use computers to comprehend and design the physical environment. And in which you use Esri's ArcCatalog to explore geographic data.<sup>1</sup>

### You Ask: “What Is GIS About?”

A poem “The Blind Men and the Elephant” tells the story of six sightless men who approach an elephant, one by one, to satisfy their curiosity.

*It was six men of Indostan  
To learning much inclined  
Who went to see the Elephant  
(Though all of them were blind)  
That each by observation  
Might satisfy his mind.*

*The First approached the Elephant,  
And happening to fall  
Against his broad and sturdy side,  
At once began to bawl,  
“God bless em! But the elephant  
Is very like a WALL!”*

*The Second, feeling of the tusk  
Cried: “Ho! what have we here  
So very round and smooth and sharp?  
This wonder of an Elephant  
Is very like a SPEAR!”*

*The Third approached the animal,  
And, happening to take  
The squirming trunk within his hands,  
Thus boldly up and spake:  
“I see,” quoth he, “the Elephant,  
Is very like a SNAKE!”*

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<sup>1</sup>Esri is the Environmental Systems Research Institute. Esri makes the software, ArcGIS, which you will use in this text to understand the concepts of geographic information systems.

## Chapter 1

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*The Fourth reached out an eager hand,  
And felt about the knee  
“What most this wondrous beast is like  
Is mighty plain,” quoth he:  
“’Tis clear enough the Elephant  
Is very like a TREE!”*

*The Fifth, who chanced to touch the ear,  
Said: “E’en the blindest man  
Can tell what this resembles most;  
Deny the fact who can,  
This marvel of an Elephant  
Is very like a FAN!”*

*The Sixth no sooner had begun  
About the beast to grope,  
Than seizing on the swinging tail  
That fell within his scope,  
“I see,” quoth he, “the Elephant  
Is very like a ROPE!”*

*And so these men of Indostan  
Disputed loud and long,  
Each in his own opinion  
Exceeding stiff and strong  
Though each was partly in the right  
And all were in the wrong!*

[. . .]<sup>2</sup>

*Excerpted from “The Blind Men and the Elephant”  
(based on a famous Indian legend)  
John Godfrey Saxe  
American Poet (1816–1887)*

## And So You Ask Again: “What Is GIS About?”

Poet Saxe’s lines could apply to geographic information systems (GIS) in that relating to the subject may well depend on your point of view. Asking what GIS<sup>3</sup> is about is sort of like asking “What is a computer about?” The capabilities of GIS are so broad and its uses so pervasive in society, geography, urban and regional planning, and the technical world in general that a short, meaningful description is impossible. But for starters, here is a generic definition of GIS that you might find in a dictionary:

*A geographic information system is an organized collection of computer hardware and software, people, money, and organizational infrastructure that makes possible the acquisition and storage of geographic*

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<sup>2</sup>[. . .] indicates an omission.

<sup>3</sup>In this text “GIS” stands for “a geographic information system,” or for the plural “geographic information systems,” depending on the context.

*and related attribute data, for purposes of retrieval, analysis, synthesis, and display to promote understanding and assist decision making.*

To better understand one facet of GIS, consider how you might use the technology for a particular application. Solve the following site selection problem:

## Exercise 1-1 (Project)

### Finding a Geographic Site by Manual Means

Wildcat Boat Company is planning to construct a small office building and testing facility to evaluate new designs. They've narrowed the proposed site to a farming area near a large lake and several small towns. The company now needs to select a specific site that meets the following requirements:

- The site should not have trees (to reduce costs of clearing land and prevent the unnecessary destruction of trees). A regional agricultural preservation plan prohibits conversion of farmland. The other categories (urban, barren, and wetlands) are also out. So, the land cover must be "brush land."
- The building must reside on soils suitable for construction.
- A local ordinance designed to prevent rampant development allows new construction only within 300 meters of existing sewer lines.
- Water-quality legislation requires that no construction occur within 20 meters of streams.
- The site must be at least 4000 square meters to provide space for building and grounds.

Figure 1-1 is a key to the following maps. It shows the symbols for land cover, soil suitability, streams, and sewers.<sup>4</sup>

Figure 1-2 is a map showing landcover in the area from which the site will be chosen. Different crosshatch symbols indicate different types of land cover; the white area in the northern part of the map is water. The land cover codes (LC Codes) and categories (LC Type) are as follows:

<b>LC CODE</b>	<b>LC TYPE</b>
100	Urban
200	Agriculture
300	Brush land
400	Forest
500	Water
600	Wetlands
700	Barren

<sup>4</sup>These maps are also available on the DVD that accompanies the text. They are the image files: Key\_to\_maps.jpg, Landcover.jpg, Soil\_suitability.jpg, and Streams\_&\_Sewers.jpg located in the folder IGIS-Arc\_AUX.