ArcMap 10.8.2 Learning Series

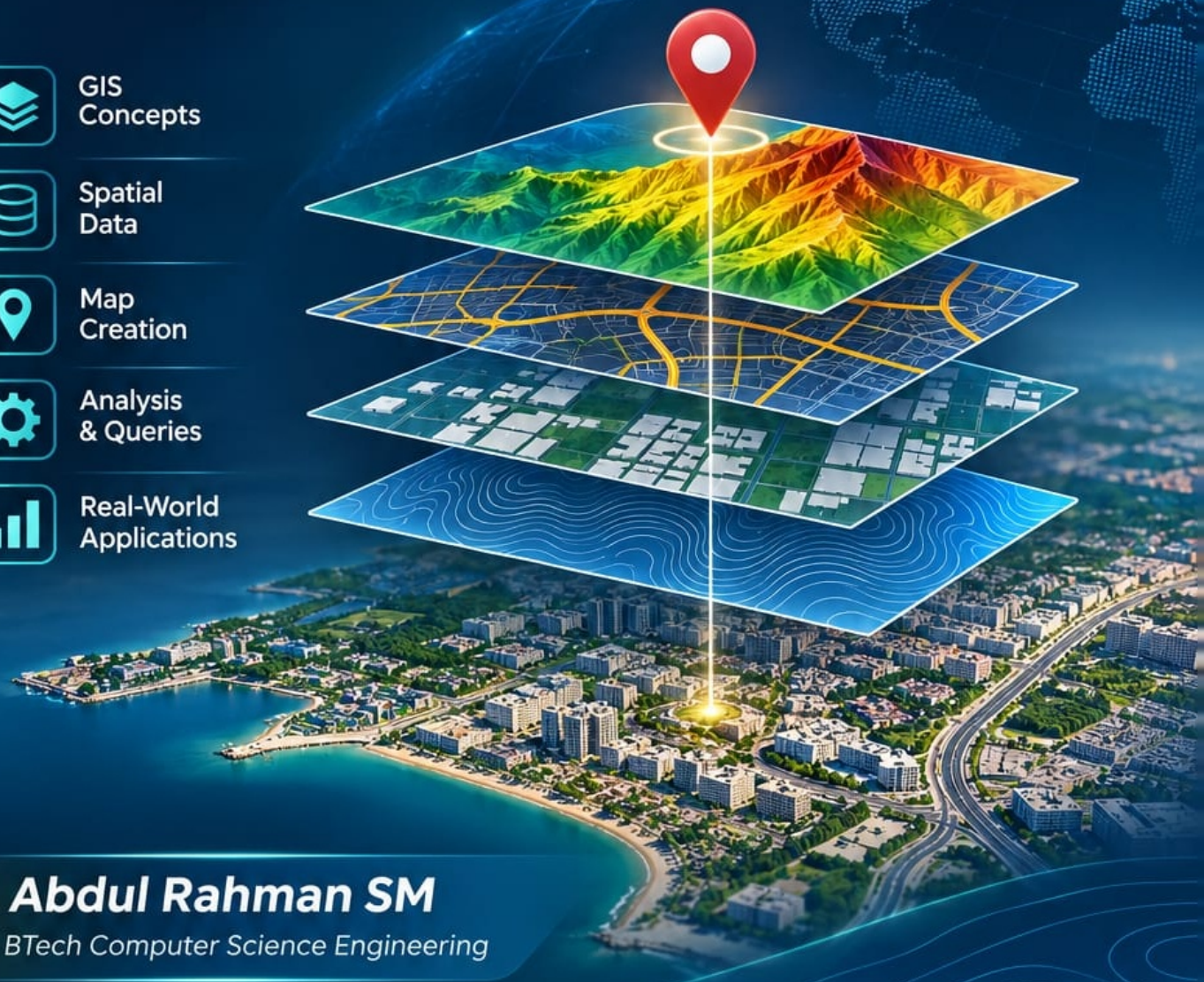
MODULE 1 | GIS FUNDAMENTALS

EBOOK 01
BEGINNER

Introduction to GIS

What GIS Is,
Why It Is Used, and
Real-World Applications

- GIS Concepts
- Spatial Data
- Map Creation
- Analysis & Queries
- Real-World Applications



Abdul Rahman SM

BTech Computer Science Engineering

CADGISTools

Available here:
www.cadgistools.com

PREFACE

Maps are among the oldest tools people have used to make sense of the world. Geographic Information Systems carry that idea into the digital age.

A GIS helps us understand places, interpret spatial information and support decisions in fields such as surveying, urban planning, transportation, utilities and environmental management.

For someone meeting the subject for the first time, however, GIS can seem difficult. The terminology is new, concepts such as layers, features and attributes are unfamiliar, and software workflows can feel crowded with options before the ideas behind them are clear. A clear, organised introduction can make that first step easier and give readers a reliable foundation for everything that follows.

This eBook exists for that reason. Useful technical knowledge should be easy to reach for people who are beginning their learning journey. The material has been gathered from relevant sources, compiled, organised in a logical order and presented in a reader-friendly format. It builds on established GIS knowledge developed by many practitioners, educators and organisations, and the sources consulted are listed in the references at the end of the book. The aim is clarity, logical progression and practical relevance.

It is intended for students who are starting to study GIS, beginners exploring geospatial technologies, surveying and mapping learners, people interested in how GIS is applied, and anyone who prefers to build knowledge step by step.

Educational material is most useful when it is shared, and this eBook is offered for the benefit of those who want to learn. It is a starting point, not a complete course. Readers are encouraged to use it as a base for further study, for practice with real data and for wider reading. More information about this series is available at www.cadgistools.com.



Abdul Rahman SM
BTech Computer Science Engineering
CADGISTools
www.cadgistools.com

PUBLICATION DETAILS

About This eBook

Edition, trademark and accuracy notes.

TITLE	Introduction to GIS: What GIS Is, Why It Is Used, and Real-World Applications
SERIES	ArcMap 10.8.2 Learning Series | Module 1: GIS Fundamentals | EBOOK 01 of 10 | Beginner level
PUBLISHER	CADGISTools | https://www.cadgistools.com/
AUTHOR	Abdul Rahman SM, BTech Computer Science Engineering
EDITION	First Edition, November 2026
COPYRIGHT	© 2026 CADGISTools. All rights reserved. [Rights and licence wording: placeholder, to be confirmed by the publisher.]
SOFTWARE COVERED	ArcGIS Desktop 10.8.2 (ArcMap). Software statements were checked against Esri's public documentation in November 2026. Esri may change its pages and policies at any time.
TRADEMARKS	Esri, ArcGIS, ArcMap, ArcCatalog, ArcScene, ArcGlobe and ArcGIS Pro are product names or trademarks of Esri. This eBook is an independent educational publication by CADGISTools. It is not produced, reviewed or endorsed by Esri.
ABOUT THE EXAMPLES	All maps, tables, coordinates and numbers in this eBook are invented for teaching unless a source is given. Do not use them as real geographic data or for real decisions. Pictures that look like software are schematic illustrations, not screenshots.
SERIES POSITION	Previous: none (this is the first eBook). Next: EBOOK 02, GIS Data Types.

Contents

Preface . . . 2

About This eBook . . . 3

Welcome to GIS . . . 9

What you will learn . . . 9

Why this topic matters . . . 9

Where this knowledge is used . . . 9

Before you start . . . 9

Learning objectives . . . 9

How to use this eBook . . . 10

Chapter 1 Why Location Matters . . . 11

1.1 A problem that depends on where . . . 11

1.2 Everything happens somewhere . . . 11

1.3 From paper maps to GIS maps . . . 11

1.4 Data and information . . . 13

Chapter 2 What Is GIS? . . . 14

2.1 A plain-English explanation . . . 14

2.2 The formal definition . . . 14

2.3 Breaking down the name . . . 14

2.4 What a GIS does . . . 15

2.5 GIS compared with things you may already know . . . 15

Chapter 3 Where GIS Came From . . . 17

3.1 John Snow and the 1854 cholera map . . . 17

3.2 Roger Tomlinson and the first computer GIS . . . 18

3.3 A short timeline . . . 19

Chapter 4 Seeing a Place in Layers 20

4.1 Layers in plain English 20

4.2 What a layer is, and what it is not 21

4.3 Why layers are so powerful 21

4.4 Drawing order: which layer is on top? 22

4.5 Combining layers to answer a question 22

Chapter 5 How a GIS Stores the World 25

5.1 From the real world to a model 25

5.2 Vector data: points, lines and polygons 25

5.3 Raster data: a grid of cells 26

5.4 Attribute data: the table behind the map 26

5.5 Coordinates: how a GIS knows where 27

5.6 Worked example: the distance between two points 27

Chapter 6 How a GIS Works 30

6.1 The five components 30

6.2 A basic GIS workflow 31

6.3 Five kinds of questions a GIS can answer 32

6.4 Data quality: an answer is only as good as its data 33

Chapter 7 Meeting ArcMap 10.8.2 34

7.1 The ArcGIS Desktop family 34

7.2 The status of ArcMap 10.8.2 35

7.3 The main parts of ArcMap 35

7.4 Try it: a guided exploration (optional) 37

Chapter 8 GIS at Work 39

8.1 Fields where GIS is used 39

8.2 Five illustrative scenarios 40

8.3 Who works with GIS? . . . 41

8.4 Responsibility and limits . . . 41

Chapter 9 Common Mistakes and Misunderstandings . . . 42

Chapter 10 Practice, Review and Next Steps . . . 43

10.1 Practice exercises . . . 43

10.2 Review questions . . . 45

10.3 Key takeaways . . . 45

10.4 What comes next . . . 46

Answers and Worked Solutions . . . 47

Glossary . . . 50

References and Further Learning . . . 52

C.1 Sources consulted . . . 52

C.2 Suggested further reading (not consulted for this edition) . . . 53

List of Figures

Figure 1.1 A paper map (left) and a GIS map (right) of the same invented town. 12

Figure 2.1 The three words in “geographic information system”, and what each one adds. 15

Figure 3.1 A schematic of the idea behind Snow’s map. 18

Figure 3.2 Key moments in the story of GIS and ArcMap. 19

Figure 4.1 One place seen as four layers. 20

Figure 4.2 A map document stores layers, and each layer points to a dataset on disk. 21

Figure 4.3 The same three layers in two different orders. 22

Figure 4.4 Overlay with four invented layers. 23

Figure 5.1 The same invented landscape stored as vector data (left) and as raster data (right). 26

Figure 5.2 The worked example drawn on a flat grid. 28

Figure 6.1 The five components of a GIS: hardware, software, data, people and methods. 30

Figure 6.2 A basic GIS workflow in six steps, with a loop back to the start. 31

Figure 7.1 The ArcGIS Desktop family. 34

Figure 7.2 A schematic of the main areas of an ArcMap window. 35

Figure 7.3 A broken data link. 36

Figure 10.1 Data for Exercise 8: three water pumps (P1, P2, P3) and four cases (C1 to C4). 44

List of Tables

Table I.1 The boxes used in this eBook 10

Table 1.1 What you can do with a paper map and with a GIS map 12

Table 2.1 The five main tasks of a GIS 15

Table 2.2 GIS compared with related tools 16

Table 5.1 The three basic vector shapes 25

Table 5.2 An invented attribute table for five schools. 27

Table 6.1 What each component means, with examples 31

Table 6.2 Five kinds of GIS questions, with examples from different fields 32

Table 7.1 Key ArcMap terms 36

Table 8.1 GIS in land and infrastructure work (general descriptions) 39

Table 8.2 GIS in other fields (general descriptions) 40

Table 9.1 Seven common beginner mistakes 42

Table 10.1 Module 1: GIS Fundamentals, at a glance 46

Table A.1 Exercise 8: straight-line distances in metres. 49

INTRODUCTION

Welcome to GIS

A first, friendly look at how we put information on a map and ask questions of it.

What you will learn

Almost everything around us has a location. A house, a road, a water pipe, a mobile tower, a school, a flood. When we know where things are, we can ask better questions. Where should we build? Which roads are near the river? Which areas have no clinic?

A **geographic information system**, or **GIS**, is the tool that helps us answer questions like these. This eBook explains what GIS is, how it works at a basic level, and where people use it in real work. You do not need to know anything about GIS before you start.

Why this topic matters

Every later eBook in this series builds on the ideas you meet here: layers, features, data and attributes. If you understand them well now, ArcMap will feel logical instead of confusing. Many beginners try to learn buttons and menus first. This eBook does the opposite. It builds the thinking first, because the thinking stays the same even when the software changes.

Where this knowledge is used

People use GIS in land surveying offices, city planning departments, road and transport agencies, water and power companies, telecommunications companies, environmental groups, emergency services, health departments, farms and shops. Chapter 8 gives a first tour of these fields.

Before you start

- You should know how to use a computer, open files and folders, and read a simple table.
- You need only simple arithmetic and a calculator that can do square roots. Every calculation is shown step by step.
- You do not need ArcMap to read this eBook. A short, optional hands-on exploration is in Section 7.4. You can skip it and come back later.
- You do not need any earlier GIS knowledge.

Learning objectives

When you finish this eBook, you will be able to:

1. Explain in your own words what a GIS is, using both a plain explanation and the formal definition.
2. Describe what the three words in “geographic information system” each add.

3. Tell the difference between a GIS and a paper map, a CAD drawing, a GPS receiver and a web map.
4. Explain the layer idea and show how layers are combined to answer a question.
5. Name the two main ways a GIS stores the shape of the world (vector and raster) and explain what an attribute table is for.
6. Calculate the straight-line distance between two points on a flat, metre-based grid, and explain when this method is valid.
7. List the five components of a GIS and describe a basic GIS workflow from question to decision.
8. Recognise five common kinds of questions that a GIS can answer.
9. Recognise the main parts of ArcMap 10.8.2 (map document, data frame, Table of Contents, layers, Data view and Layout view) and explain how they relate to ArcCatalog and the Catalog window.
10. Describe real problems that GIS helps to solve in at least five fields of work.
11. Avoid the most common beginner misunderstandings about GIS.

How to use this eBook

Read the chapters in order the first time. Each chapter starts with a short list of what it covers and ends with a summary. Boxes in the text use a fixed colour and label, so you always know what you are looking at.

TABLE I.1 The boxes used in this eBook

Box	What it tells you
KEY CONCEPT	An idea you must understand before moving on.
SIMPLE EXPLANATION	The same idea in everyday words.
REAL-WORLD EXAMPLE	How the idea appears in actual work. Examples are marked “illustrative” when they are invented.
IMPORTANT	A rule or warning that affects your results.
COMMON MISTAKE	A mistake beginners often make, and how to avoid it.
TECHNICAL NOTE	Extra detail for readers who want to go deeper. You may skip it on first reading.
STEP-BY-STEP	Numbered instructions to follow.
CHECK YOUR UNDERSTANDING	A few quick questions. Answers are in Appendix A.
PRACTICE TASK	An exercise to try on your own. Worked solutions are in Appendix A.

IMPORTANT Teaching data only

All maps and numbers in this eBook are invented for teaching, except the history in Chapter 3, which is based on the sources listed in Appendix C. Never use the examples as real data.

CHAPTER 1

Why Location Matters

Start with an everyday problem and see why “where” is the key to so many decisions.

IN THIS CHAPTER

- What “location” means in GIS
- How a GIS map differs from a paper map
- The difference between data and information

1.1 A problem that depends on where

Imagine that you work for a town council. The council wants to build a new health clinic. Many questions come up straight away:

- Where do most people live?
- Where are the existing clinics?
- Which roads can people use to reach a new clinic?
- Which land is safe from floods?

Every one of these questions has the word *where* hidden inside it. The answers are all tied to places on the Earth. A GIS is built to work with questions like these.

1.2 Everything happens somewhere

Location means the place where something is on the Earth’s surface. A house has a location. So does a road, a river, a mobile tower or a car accident.

Two words appear again and again in GIS: **geographic** and **spatial**. *Geographic* means “to do with places on the Earth”. *Spatial* means “to do with position in space”. In this series we use them almost as the same thing.

KEY CONCEPT Location is the link

Location links facts together. A road and a flood zone may look unrelated until you see that they share the same piece of ground. When two facts share a place, a GIS can combine them.

1.3 From paper maps to GIS maps

A paper map is a picture. Someone decided what to show, drew it once and printed it. It is useful, but it is fixed.

A GIS map is different. A computer draws it from data each time you look at it. Everything on the map is linked to information about that thing. So you can change what you see, ask questions and measure, without drawing the map again.

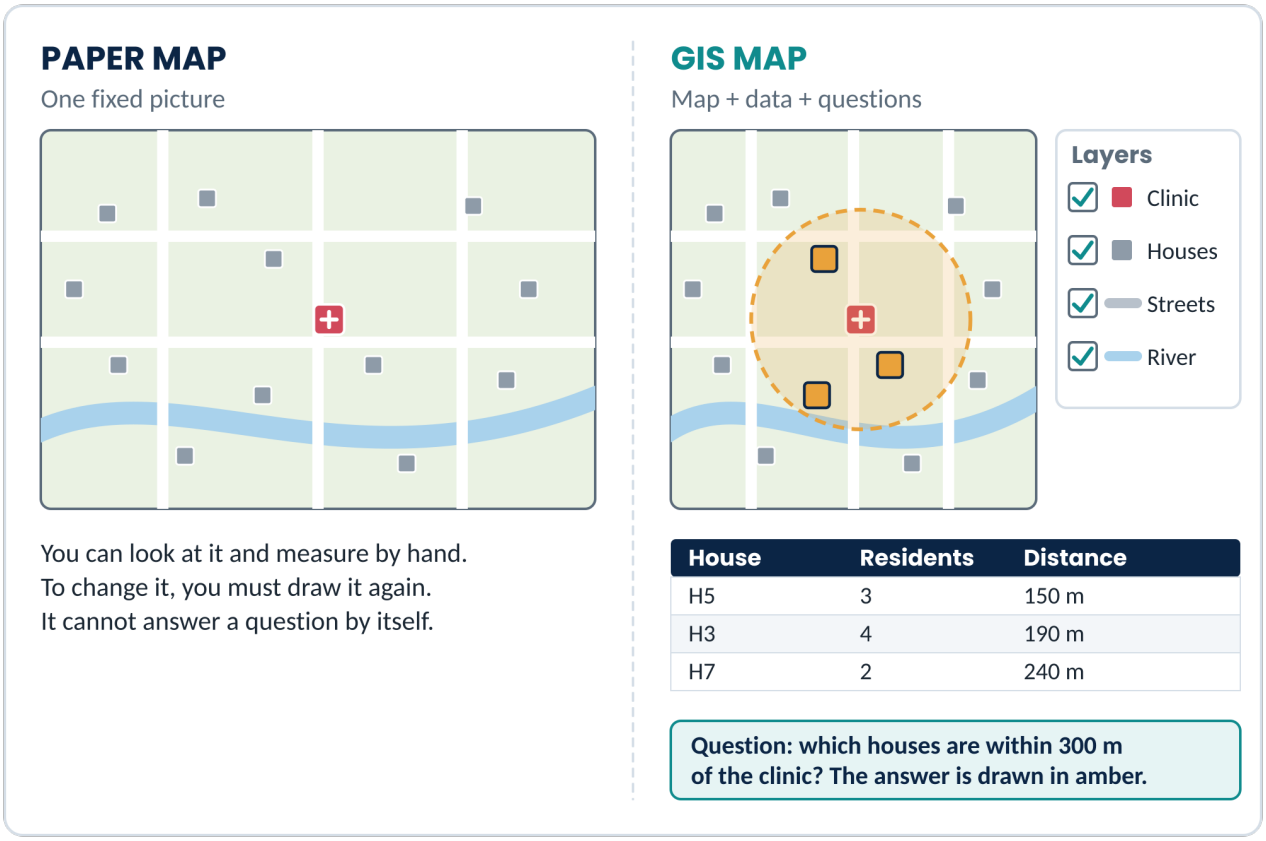


FIGURE 1.1 A paper map (left) and a GIS map (right) of the same invented town. In the GIS map, the three amber houses (H5, H3 and H7) are the answer to the question "which houses are within 300 m of the clinic?". The GIS measured the distances in the table from the map's coordinates.

Look at Figure 1.1. The left side is a paper map. You can look at it, but it cannot answer questions by itself. The right side shows the same town in a GIS. It has three extra parts. The **layer list** lets you switch themes on and off. The **table** holds facts about each house. The **question** at the bottom was answered by the computer, and the answer is drawn on the map.

TABLE 1.1 What you can do with a paper map and with a GIS map

Task	Paper map	GIS map
See an area	Yes, in one fixed style	Yes, and you can change the style
Measure a distance	By hand, with a ruler and the scale	The computer calculates it from coordinates
Find all houses near a clinic	Search by eye	Ask a question; the computer selects them
Add new information	Draw it again	Add a layer or a record
Update after a change	Print a new map	Edit the data; the map follows
Combine with other maps	Hard: trace or lay sheets over each other	Stack layers (Chapter 4)

1.4 Data and information

Data are facts or measurements on their own. For example, the number 412 is data. By itself it means very little. **Information** is data with meaning: “Hillview School has 412 students.”

In GIS we often talk about a **dataset**. A dataset is a collection of related data about one subject, such as all the road centrelines of a city or all the water-pipe records of a utility. When information is linked to a location, we can put it on a map and look for patterns.

SIMPLE EXPLANATION

Think of a GIS as three questions answered together: *Where is it? What is it? What is near it?* A paper map answers the first. A table answers the second. A GIS connects them and helps with the third.

CHECK YOUR UNDERSTANDING

1. Which of these have a location? (a) The street address of a school. (b) The number 412 on its own. (c) The position of a water pump. (d) The path of a river.
2. Name one thing a GIS map can do that a printed paper map cannot.

CHAPTER SUMMARY

- A **location** is a place on the Earth. Many decisions depend on it.
- **Geographic** and **spatial** both point to places and positions.
- A paper map is a fixed picture. A GIS map is drawn from data and can answer questions.
- **Data** are raw facts. **Information** is data with meaning. A **dataset** is a collection of related data.

CHAPTER 2

What Is GIS?

A plain explanation first, then the formal definition, then how GIS differs from tools you may already know.

IN THIS CHAPTER

- A plain-English explanation and a formal definition
- What each word in the name adds
- The main tasks a GIS performs
- GIS compared with maps, CAD, GPS and web maps

2.1 A plain-English explanation

A GIS is a computer system that lets you put information on a map, ask questions about it, and see the answers on the map. The key word is *connect*. A GIS connects **where** things are with **what** they are.

2.2 The formal definition

People define GIS in slightly different ways. A clear, general definition is this:

KEY CONCEPT Definition of GIS

A **geographic information system (GIS)** is a system for capturing, storing, managing, analysing and displaying geographic data, which is data about places on the Earth.

Esri, the company that makes ArcGIS, describes GIS in a similar way. It says that a GIS creates, manages, analyses and maps all types of data, and that it connects data to a map by joining location data with descriptive information [1]. Other organisations use different words, but the core ideas are always the same: data, location, analysis and maps.

2.3 Breaking down the name

The name has three words. Each word adds something.

- **Geographic** tells us the data are about places on the Earth.
- **Information** tells us we store facts about those places: what they are, how many, when, and so on.
- **System** tells us that several parts work together: computers, software, data, people and methods. You will meet these five parts in Chapter 6.

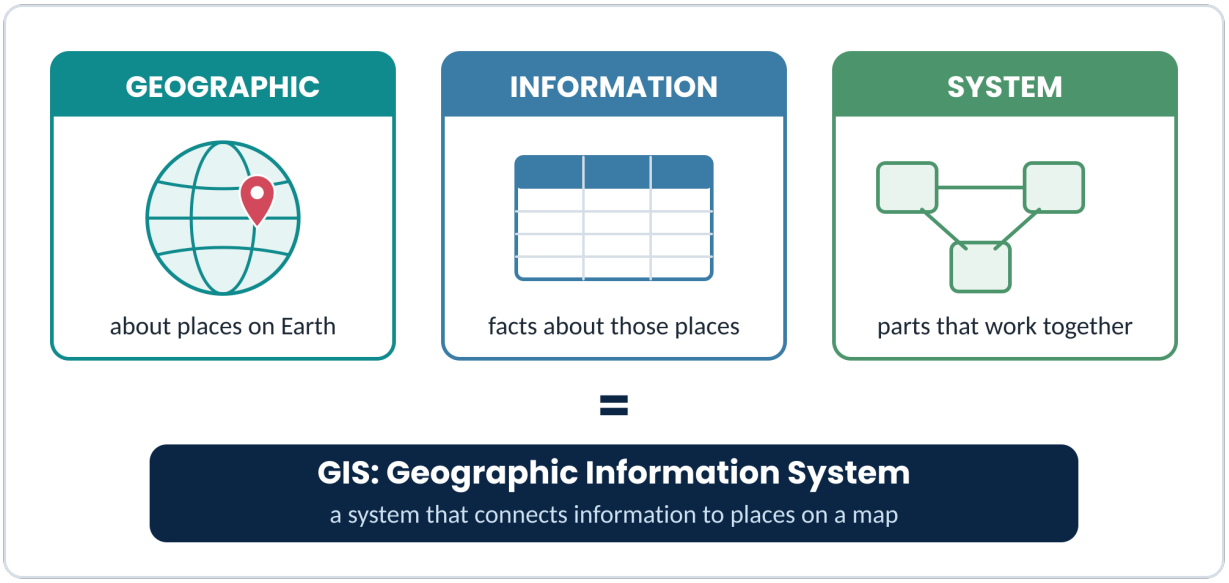


FIGURE 2.1 The three words in "geographic information system", and what each one adds.

> **TECHNICAL NOTE**
>
> Some people read the last letter of GIS as "Science" instead of "System". *Geographic information science* is the study of the ideas behind the technology. In this series, GIS always means Geographic Information **System**.

2.4 What a GIS does

A GIS does many things, but they fall into five main tasks. Table 2.1 gives a simple example of each.

TABLE 2.1 The five main tasks of a GIS

Task	What it means	Simple example
Capture	Get location data into the system	Record points with a GPS receiver; trace roads from an aerial photograph
Store and manage	Keep data organised, safe and up to date	Keep all water-pipe records in one organised database
Analyse	Ask questions and find patterns	Find all houses that lie inside a flood zone
Display	Show results as maps, tables and charts	Make a map of the houses at risk
Share	Give the results to the people who need them	Send the map to the council, or publish it online

2.5 GIS compared with things you may already know

Beginners often mix up GIS with other tools. These tools are related, and they often work together. They are not the same thing. Table 2.2 shows the main differences.

TABLE 2.2 GIS compared with related tools

Tool	Main purpose	How it relates to GIS
Paper map	Shows a fixed picture of an area	A GIS can print paper maps. A paper map cannot be queried or updated by itself.
CAD drawing	Designs and drafts objects such as buildings and roads, with exact geometry	CAD usually focuses on drawing and design. A GIS focuses on real-world locations, attributes and analysis. Survey and design drawings are often brought into a GIS.
GPS / GNSS receiver	Tells you where you are, using satellite signals	GPS gives coordinates. A GIS stores them, links them to information and analyses them.
Web map or map app	Lets you view maps and search for places	Built with similar technology. You usually look and search, but you do not manage or analyse the data yourself.
Spreadsheet or database	Stores facts in tables	A GIS also stores shapes and locations, and draws them on a map. Many GIS keep their facts in tables (Chapter 5).

TECHNICAL NOTE

GNSS (Global Navigation Satellite System) is the general name for satellite positioning systems. **GPS** is one of them. People often say "GPS" when they mean any of them. This eBook follows that habit.

COMMON MISTAKE

"GIS is just a map-making program." This happens because maps are the part you can see. The problem is that you start to care about how the map looks before you check the data or the question. The fix is to think of the map as the last step. Ask first: *What question am I trying to answer?*

CHECK YOUR UNDERSTANDING

1. What does each of the three words in "geographic information system" add?
2. A friend says: "GPS and GIS are the same thing." What would you reply?

CHAPTER SUMMARY

- A **GIS** connects where things are with what they are, so you can store, analyse and display them.
- The three words in the name mean: places on Earth, facts about them, and parts working together.
- Main tasks: capture, store and manage, analyse, display, share.
- GIS is different from, but works with, paper maps, CAD, GPS, web maps and databases.

CHAPTER 3

Where GIS Came From

The idea is older than computers. Two true stories show how location helped people solve real problems.

IN THIS CHAPTER

- John Snow's cholera map of 1854
- Roger Tomlinson and the first computer GIS
- A short timeline up to ArcMap

IMPORTANT Documented history

This chapter is based on the historical sources in Appendix C. The pictures in this chapter are **schematics** that illustrate an idea. They are not copies of historical maps.

3.1 John Snow and the 1854 cholera map

In 1854, a deadly outbreak of cholera hit the Soho area of London. Within about ten days, around 500 people died [12]. At that time many people believed that diseases like cholera spread through bad air. A doctor named John Snow believed it spread through contaminated water.

Snow plotted the cases on a map of the area and also marked the public water pumps. This kind of map is now called a *spot map* [14]. The map showed that most deaths were clustered around one pump, on Broad Street (today called Broadwick Street) [12]. The handle of that pump was then removed so that nobody could use it [12].

Snow also looked closely at the cases that did not fit the pattern. Some people who died lived nearer to a different pump. But, as one account explains, that other pump was harder to reach because of dead ends and the layout of the streets, so those people walked to the Broad Street pump instead [13]. This is an early lesson in GIS thinking: the nearest place on a ruler is not always the nearest place to walk.

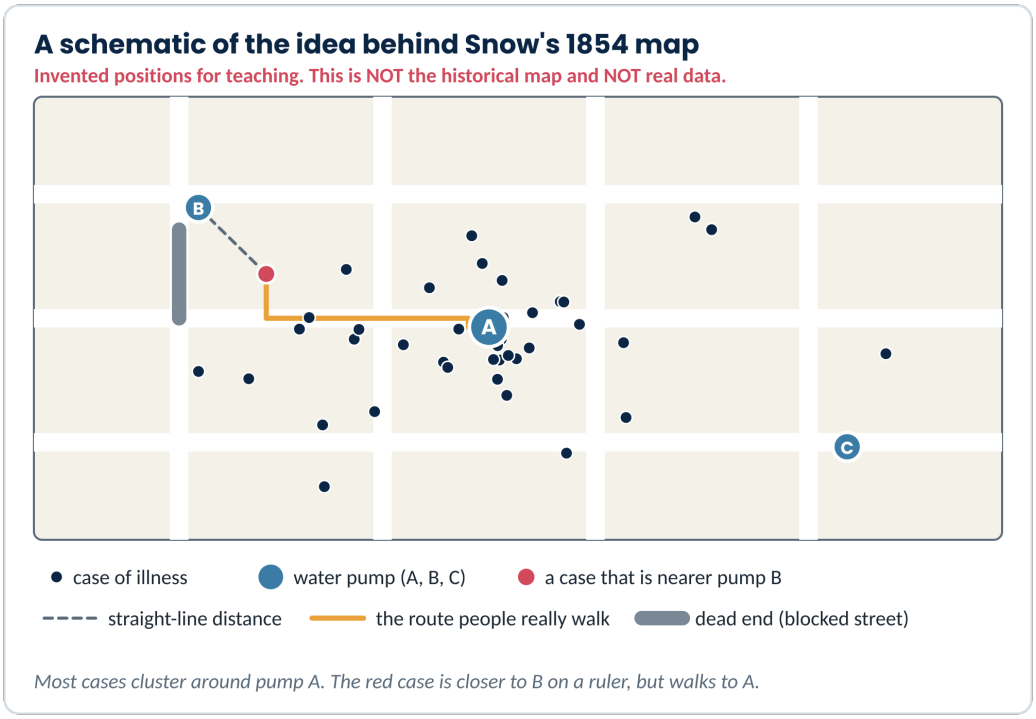


FIGURE 3.1 A schematic of the idea behind Snow's map. Positions are invented. Cases cluster around pump A. The red case is closer to pump B in a straight line, but a dead end blocks the way, so the person walks to pump A.

IMPORTANT Be careful with the legend

The pump-handle story is often told as if removing the handle alone ended the outbreak. In fact, the outbreak was already declining when the handle was removed [13]. Historians discuss how much the removal itself mattered. The lasting lesson of the map is different: **putting facts on a map revealed a pattern that lists of names could not.**

Snow's map had no computer. But it used the same thinking as a GIS. It combined two sets of facts, the cases and the pumps, on top of a street map. In Chapter 4 you will see that this is exactly what we call *layers*.

3.2 Roger Tomlinson and the first computer GIS

In the 1960s, Canada ran a project called the Canada Land Inventory, which gathered information about its land for planning how the land could be used. The project collected this information on a very large number of paper maps. A computer could help to store and compare that information.

Roger Tomlinson developed a computer system for this work at the Canadian Department of Forestry and Rural Development in Ottawa [11]. The system, called the Canada Geographic Information System (CGIS), used computer technology to collect, digitise, store, analyse and visualise Canada Land Inventory information [11]. The IEEE History Center recognises this work, dated 1962–1968, as the first geographic information system, and says Tomlinson introduced the term "geographic information system" in a 1968 paper [11]. He is widely known as the "father of GIS" [15].

KEY CONCEPT Overlay

CGIS offered tools such as overlay, measurement and spatial analysis [11]. **Overlay** means doing by computer what you do with clear sheets: to place one theme on top of another and study where they meet. Overlay is still one of the most important ideas in GIS. You will use it in Section 4.5.

3.3 A short timeline

The timeline in Figure 3.2 places these stories next to the history of the software used in this series. Esri says it has worked in the GIS field since 1969 [1]. ArcGIS Desktop, which includes ArcMap, is now at the end of its life cycle. You will read more about this in Section 7.2.

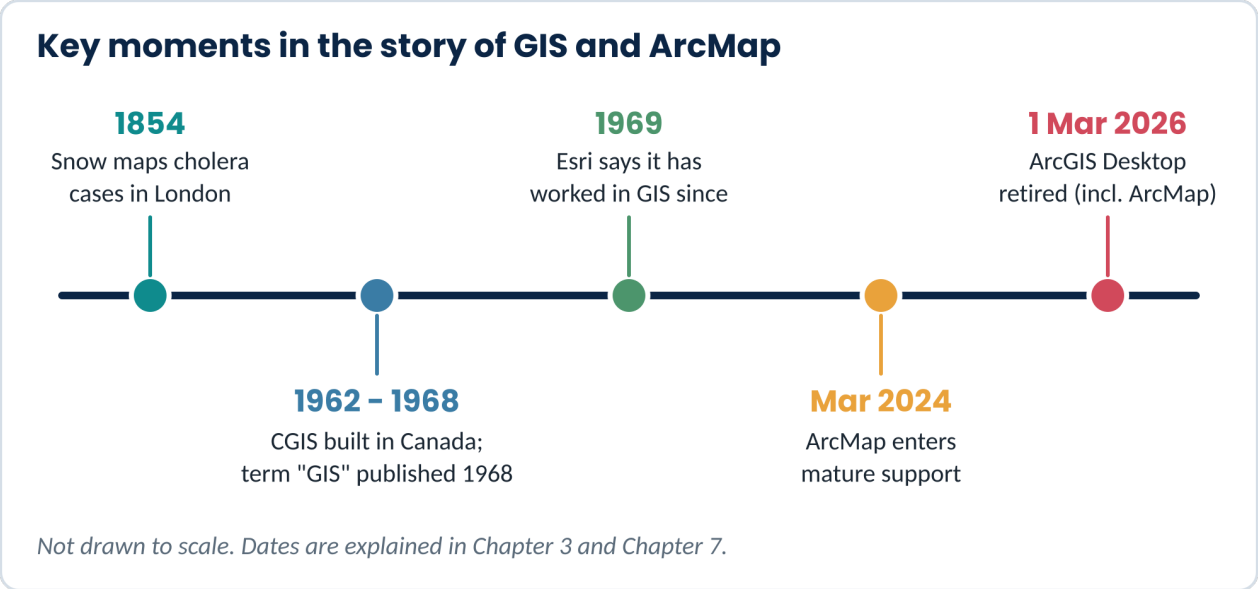


FIGURE 3.2 Key moments in the story of GIS and ArcMap. The 2024 and 2026 dates come from Esri's ArcGIS Desktop life-cycle announcements [9, 10]. The picture is not drawn to scale.

Today GIS is not limited to desktop computers. It also runs on the web, on mobile devices and in the cloud, and it can show live data, dashboards and satellite images [1]. The ideas in this series apply to all of them.

CHAPTER SUMMARY

- In 1854, John Snow mapped cholera cases and water pumps. The pattern pointed to one pump.
- The story shows the value of combining facts on a map, and of checking how people really travel.
- In the 1960s, Roger Tomlinson led the building of CGIS in Canada, usually described as the first computer GIS.
- Overlaying themes by computer became a core GIS idea.
- ArcMap belongs to a long history, and it is now at the end of its own life cycle.

CHAPTER 4

Seeing a Place in Layers

The layer idea is the heart of GIS. Once you understand it, most of ArcMap makes sense.

IN THIS CHAPTER

- What a layer is, and what it is not
- How layers line up and how they are drawn
- How overlay combines layers to answer a question

4.1 Layers in plain English

Picture a stack of clear plastic sheets. On the first sheet someone has drawn only the roads. On the second sheet, only the schools. On the third, only the land use. Each sheet shows one theme. When you place the sheets on top of each other, you see the whole place.

A GIS works in the same way. Each sheet is a **layer**. A layer holds one theme: roads, buildings, rivers, schools, land use, or elevation.

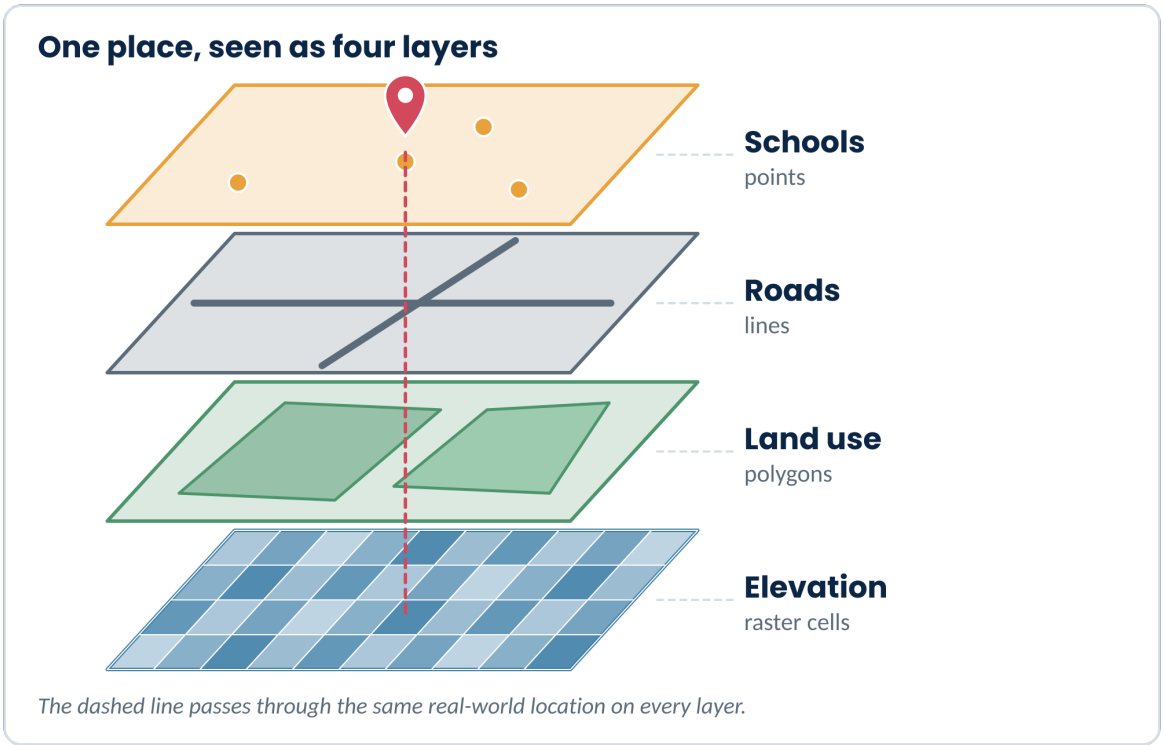


FIGURE 4.1 One place seen as four layers. Each layer has one theme and one type of data. The dashed line passes through the same real-world location on every layer.

Figure 4.1 shows four layers of the same area. The top layer holds schools as **points**. Below it are roads as **lines**, land use as **polygons** and elevation as a **raster**, a grid of cells. These words are explained in Chapter 5. For now, notice the dashed line. It goes through the same location on every layer.

> **KEY CONCEPT** Why layers line up
>
> Layers line up because every item on every layer has a **real-world location**, given by coordinates. A school in the school layer and the road in front of it are at matching places, so they fit together automatically.

4.2 What a layer is, and what it is not

In ArcMap, a layer defines how a GIS dataset is symbolised and labelled in your map views [3]. Think of a layer as a window onto a dataset: the layer says how to draw the data and where to find it, while the data stay in the dataset. This is why the link between them can break (see Chapter 7).

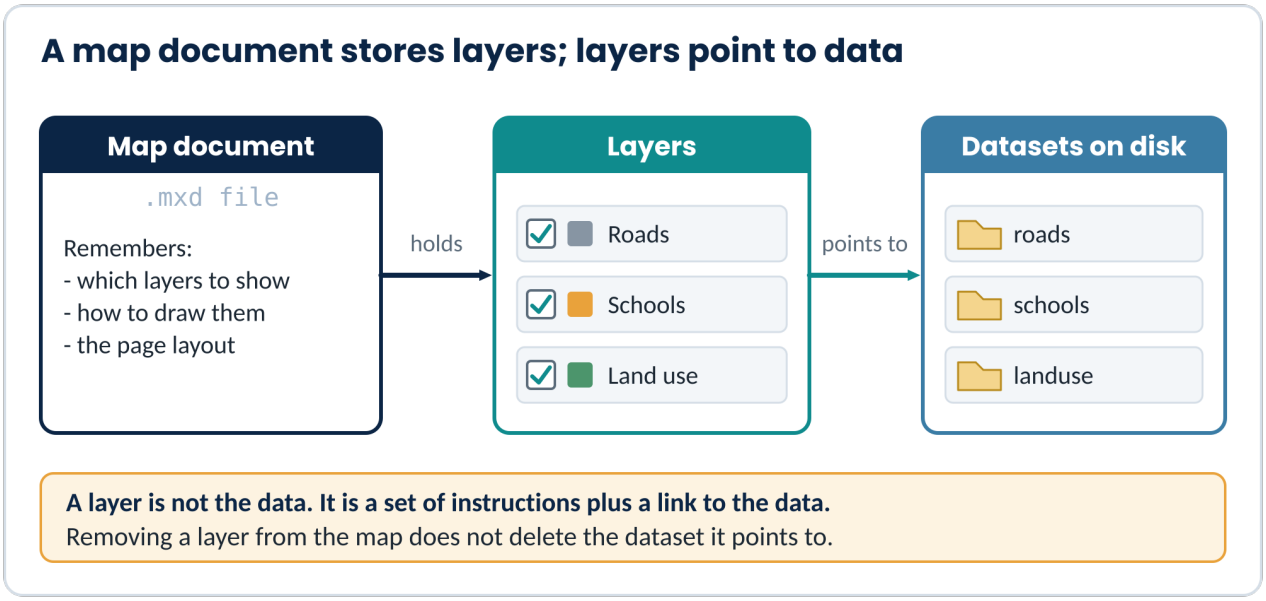


FIGURE 4.2 A map document stores layers, and each layer points to a dataset on disk. Removing a layer from the map does not delete the dataset.

The map is saved in a **map document**, a file with the extension `.mxd` [2]. It remembers which layers to show, how to draw them, and how the page is laid out [2]. The page on map documents describes what it holds as the specifications for layers, the page layout and other map properties [3]; the data stay in their own files. This is why a map document can be small even when the data are very large.

4.3 Why layers are so powerful

- **Switch themes on and off.** You can hide the roads to see the land use underneath.
- **Compare themes.** You can look at flood zones and schools together.
- **Combine themes.** You can ask which schools lie inside a flood zone.
- **Update one theme.** When a new road is built, you edit the road layer. You do not redraw the whole map.
- **Reuse themes.** The same road layer can appear in many different maps.

4.4 Drawing order: which layer is on top?

When two layers cover the same ground, one must be drawn over the other. In ArcMap, the order of layers in the **Table of Contents**, the list of layers in the map, sets the drawing order. Layers higher in the list are drawn on top of layers lower in the list [3, 5].

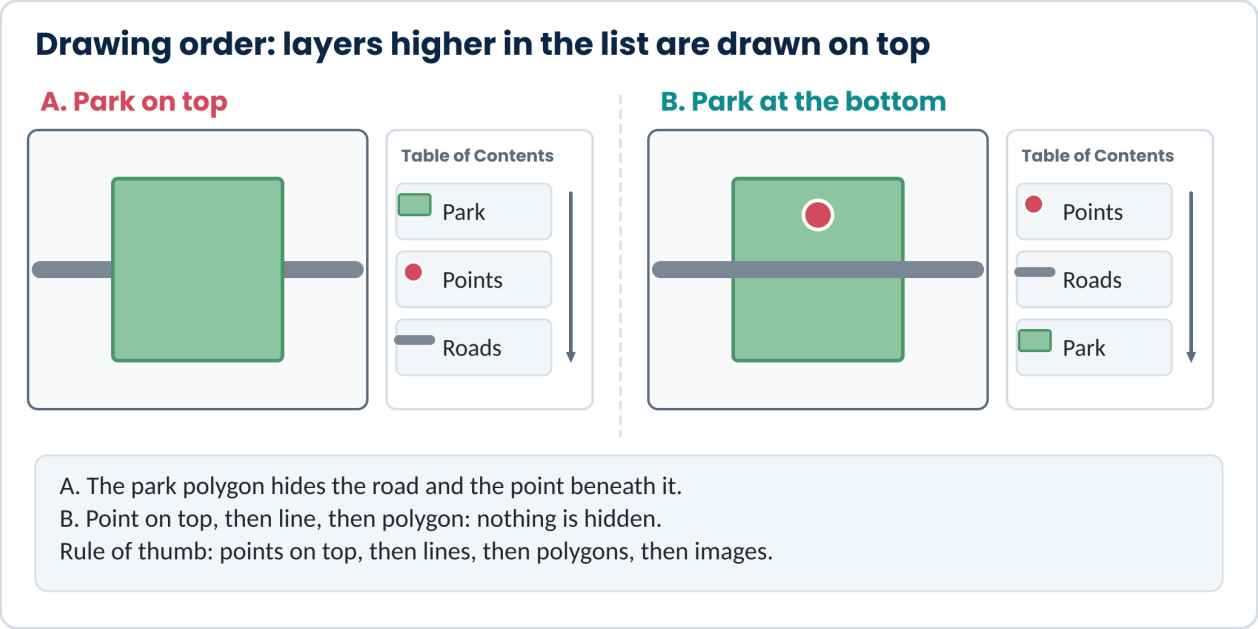


FIGURE 4.3 The same three layers in two different orders. In A, the park polygon is on top and hides the road and the point beneath it. In B, the polygon is at the bottom and everything is visible.

A good habit is to put **points on top, then lines, then polygons, and images at the bottom**. Then the small things are never hidden by big areas.

> **COMMON MISTAKE**
>
> **"My road layer has disappeared."** This happens when a polygon layer is placed above it in the Table of Contents. The polygon is drawn over the road and hides it. Nothing is wrong with the data. To fix it, drag the polygon layer lower in the list [5], or switch it off.

4.5 Combining layers to answer a question

Return to the town council's question from Section 1.1: *where could a new clinic go?* The council decides that a good place must meet four conditions:

1. Many people live nearby.
2. It is near a main road.
3. It is not already served by an existing clinic.
4. It is outside the flood zone.

Each condition becomes one layer. In the simple model in Figure 4.4, the town is a grid of 25 square cells. A teal or coloured cell means the condition is met.

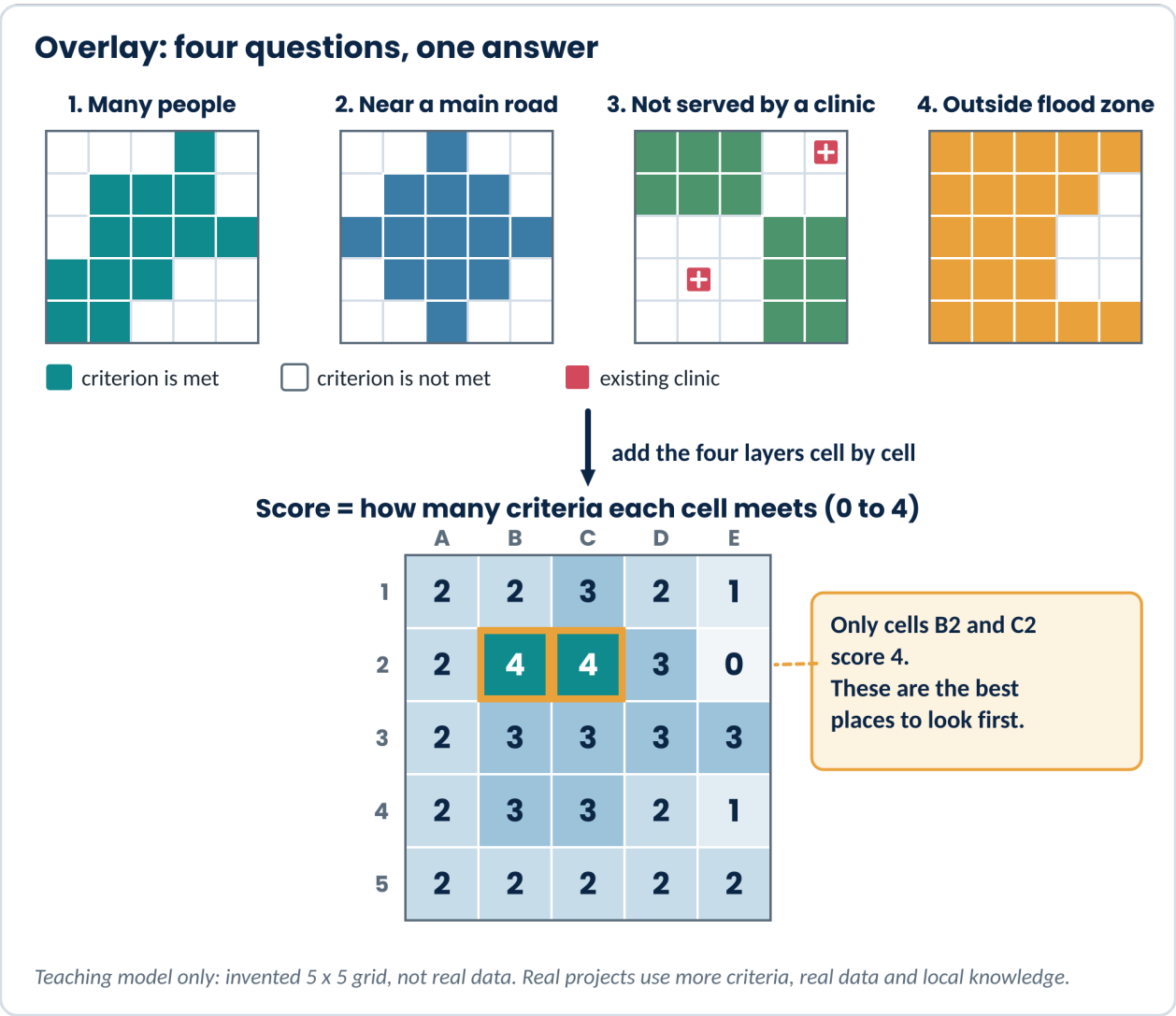


FIGURE 4.4 Overlay with four invented layers. Adding the four layers cell by cell gives a score from 0 to 4. Only cells B2 and C2 meet all four conditions.

To combine the layers, we add them cell by cell. A cell that meets all four conditions scores 4. Take cell B2 as an example. Many people live there (1), it is near a main road (1), no clinic serves it (1), and it is outside the flood zone (1). Its score is 1 + 1 + 1 + 1 = 4.

Now look at cell E2. It scores 0. Few people live there, it is far from the main road, and it is already served by an existing clinic. It also lies in the flood zone. It is a very poor place for a new clinic.

Only 2 of the 25 cells score 4: B2 and C2. The council now knows where to look first. This method is called **overlay analysis**. It is one of the most common ways to use a GIS.

> **TECHNICAL NOTE**
>
> This is a teaching model. Real site selection uses many more conditions, real data, and often gives some conditions more weight than others. People with local knowledge must also check the result. A high score is a place to look at first, not a final decision.

CHECK YOUR UNDERSTANDING

1. Why do layers from different sources line up on the map?
2. A map shows a park polygon, a road line and a school point. In what order, top to bottom, should the layers be listed so nothing is hidden?
3. If you remove a layer from the map, is the dataset it pointed to deleted?

CHAPTER SUMMARY

- A **layer** holds one theme. Stacked layers show the whole place.
- Layers line up because every feature has a real-world location.
- In ArcMap, a layer is a set of drawing instructions plus a link to a dataset. It is not the data.
- Layers higher in the Table of Contents are drawn on top. Put points above lines above polygons.
- **Overlay** combines layers to find places that meet several conditions.

CHAPTER 5

How a GIS Stores the World

A first look at GIS data: shapes, grids, tables and coordinates. Later eBooks cover each in depth.

IN THIS CHAPTER

- Models: turning the real world into data
- Vector data and raster data in one page each
- Attribute tables
- Coordinates, and how to find a distance

IMPORTANT A preview, not the full story

This chapter is a **preview**. It gives you just enough to follow the rest of this eBook. Vector and raster data are explained fully in EBOOK 02, vector shapes in EBOOK 03, raster data in EBOOK 06, and attribute tables in EBOOK 08.

5.1 From the real world to a model

The real world is full of detail. A computer cannot store everything. So a GIS stores a **model**, a simplified version of the real world. Someone decides what to keep and how to draw it.

For example, a well can be stored as a single dot. A river can be stored as a line. A lake can be stored as an outline of an area. The height of the ground can be stored as a grid of numbers. These choices depend on what the map is for.

5.2 Vector data: points, lines and polygons

Vector data store features as shapes made from coordinates. A **feature** is one real-world thing on the map, such as one school or one road. There are three basic shapes.

TABLE 5.1 The three basic vector shapes

Shape	What it represents	Examples	How it is stored
Point	A place with no useful size at this map scale	Well, school, bus stop	One pair of coordinates
Line (polyline)	A path or a thing that is long and thin	Road, river, pipeline	A series of connected coordinate pairs
Polygon	An area with a boundary	Lake, park, land parcel	A closed series of coordinate pairs

> **TECHNICAL NOTE**
>
> The same thing can be a different shape at a different map scale. A city may be a point on a map of a country, but a polygon on a map of the region. EBOOK 03 explains how to choose.

5.3 Raster data: a grid of cells

Raster data store an area as a grid of equal square **cells**, also called pixels. Each cell holds one value, such as a land type or a height. Rasters suit things that change smoothly across space, like elevation or temperature, and they are also how photographs and satellite images are stored.

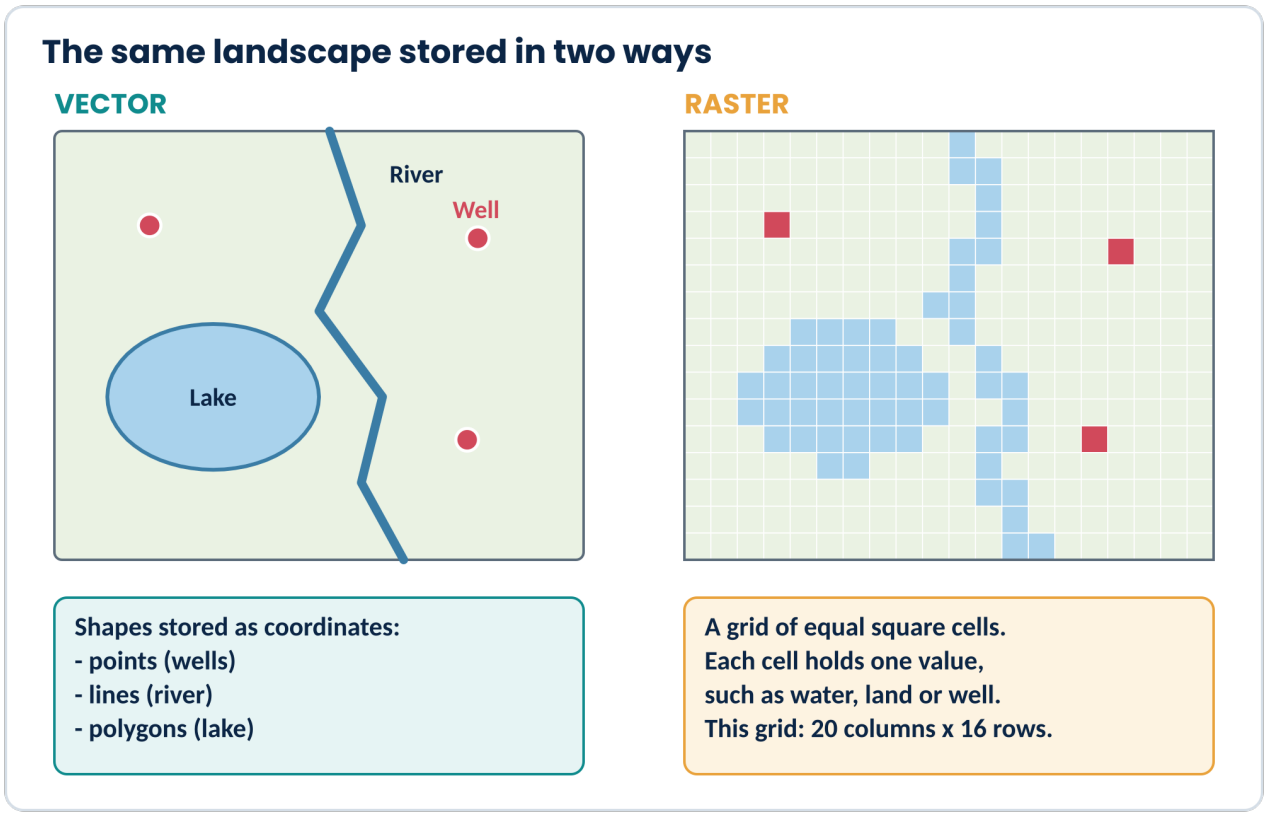


FIGURE 5.1 The same invented landscape stored as vector data (left) and as raster data (right). The raster has 20 columns and 16 rows, which makes 320 cells. Each cell holds one value: water, land or well.

In Figure 5.1, the vector side stores a lake, a river and three wells as shapes. The raster side stores the same scene as 320 cells. Notice that each well becomes a single cell, and the lake's smooth edge becomes a stepped edge. A raster cannot show detail smaller than one cell.

5.4 Attribute data: the table behind the map

A shape on its own only tells you *where*. To say *what* it is, a GIS links each feature to a row in a table. This is the **attribute table**. A row is called a **record**. A column is called a **field**. The values in the cells are **attributes**.

TABLE 5.2 An invented attribute table for five schools. The coordinates are in metres on a flat grid (see Section 5.5).

ID	Name	x (m)	y (m)	Students
S1	Hillview Primary	1200	800	520
S2	River Road School	2500	1900	310
S3	Oak Grove School	900	2600	450
S4	Market Street School	3200	700	280
S5	Lakeside School	1500	1100	610

In Table 5.2, each row is one school. The columns say what we know about each school: its name, its position and the number of students. The GIS keeps the link between each row and its point on the map. If you select the row for S1, the point for S1 is highlighted on the map, and the other way round.

KEY CONCEPT Where + What

A GIS stores **two kinds of data together**: **spatial data**, which say where a feature is and what shape it has, and **attribute data**, which say what the feature is like. The link between them is what makes a GIS different from a drawing or a spreadsheet.

5.5 Coordinates: how a GIS knows where

A **coordinate** is a set of numbers that says where a point is. On a flat grid, we use two numbers: **x** is the position east–west and **y** is the position north–south. We write a point as (x, y).

On the whole Earth, we often use **latitude** and **longitude**. Latitude is the angle north or south of the equator. Longitude is the angle east or west of the prime meridian. Both are measured in degrees. In GIS pairs, x is longitude and y is latitude.

IMPORTANT

Coordinates only have meaning inside a **coordinate system**, a set of rules that says where zero is, which direction is positive and which unit is used. A later eBook in this series explains coordinate systems. For now, remember: *numbers without a coordinate system are just numbers.*

COMMON MISTAKE

Swapping x and y. In speech we say “latitude, longitude”, but in GIS the pair is written (x, y), which is (longitude, latitude). If you swap them, your point lands in the wrong place, sometimes in the wrong ocean. Always check which number is which before you enter coordinates.

5.6 Worked example: the distance between two points

A GIS can measure distances for you. To see how, here is the calculation by hand. We use the invented data in Table 5.2. The clinic is at (1800, 1400). How far is Hillview Primary (S1) from the clinic?

WORKED EXAMPLE Distance from Hillview Primary to the clinic	
GIVEN	Hillview Primary, point 1: $(x_1, y_1) = (1200\text{ m}, 800\text{ m})$ Clinic, point 2: $(x_2, y_2) = (1800\text{ m}, 1400\text{ m})$ Both points are on the same flat grid, measured in metres.
REQUIRED	The straight-line distance d between the two points, in metres.
FORMULA	$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ d is the distance. $x_2 - x_1$ is how far apart the points are east–west. $y_2 - y_1$ is how far apart they are north–south. The formula comes from the Pythagorean theorem.
STEP 1	Find the east–west difference: $x_2 - x_1 = 1800 - 1200 = 600$ m.
STEP 2	Find the north–south difference: $y_2 - y_1 = 1400 - 800 = 600$ m.
STEP 3	Square both: $600^2 = 360{,}000\text{ m}^2$ and $600^2 = 360{,}000\text{ m}^2$.
STEP 4	Add them: $360{,}000 + 360{,}000 = 720{,}000\text{ m}^2$.
STEP 5	Take the square root: $d = \sqrt{720{,}000} = 848.528$ m.
ANSWER	**d ≈ 848.5 m** (about 849 m).
CHECK	Both legs are 600 m, so the straight line must be longer than 600 m and shorter than 1,200 m (600 + 600). 848.5 m is in that range. For two equal legs, $d = 600 \times \sqrt{2} = 600 \times 1.4142 = 848.5$ m. This matches. The coordinates are given to the nearest metre, so quoting more than one decimal place would claim more accuracy than the data have.

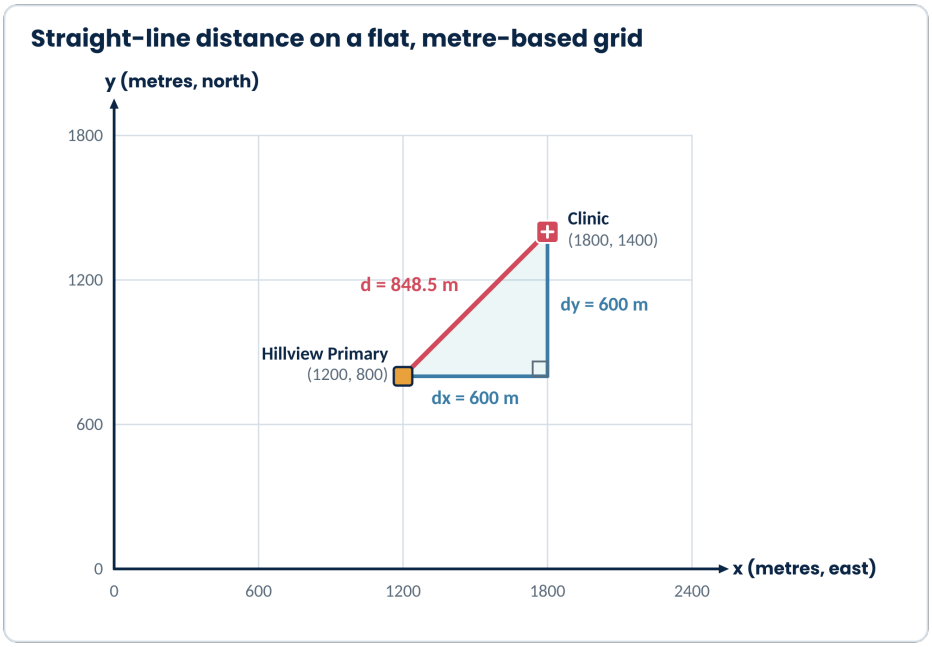


FIGURE 5.2 The worked example drawn on a flat grid. The two blue legs, dx and dy, form a right-angled triangle. The red line is the straight-line distance d.

IMPORTANT When the formula is valid

This formula works only when both points are on a **flat grid with the same unit in both directions**, such as metres. You must **not** use it directly on latitude and longitude values in degrees. One degree of longitude covers less ground the closer you are to the poles, so the two directions do not match. GIS software handles this correctly when you use its measuring tools. A later eBook explains why.

CHECK YOUR UNDERSTANDING

1. What is the difference between spatial data and attribute data?
2. In Table 5.2, what is a record? What is a field?
3. Why can't you use the distance formula directly on degrees of latitude and longitude?

CHAPTER SUMMARY

- A GIS stores a **model** of the world, not the world itself.
- **Vector** data use points, lines and polygons made from coordinates. **Raster** data use a grid of cells with values.
- An **attribute table** has one **record** (row) per feature and one **field** (column) per property.
- A GIS stores **spatial data** and **attribute data** together and keeps them linked.
- A **coordinate** gives a position. It needs a **coordinate system** to have meaning.
- On a flat metre grid, $d = \sqrt{((x_2 - x_1)^2 + (y_2 - y_1)^2)}$.

CHAPTER 6

How a GIS Works

The five parts of a GIS, the steps of a typical project, and the questions a GIS can answer.

IN THIS CHAPTER

- The five components of a GIS
- A basic GIS workflow
- Five kinds of GIS questions
- Why data quality matters

6.1 The five components

The word *system* in GIS means that several parts must work together. A common way to describe them is as five components.

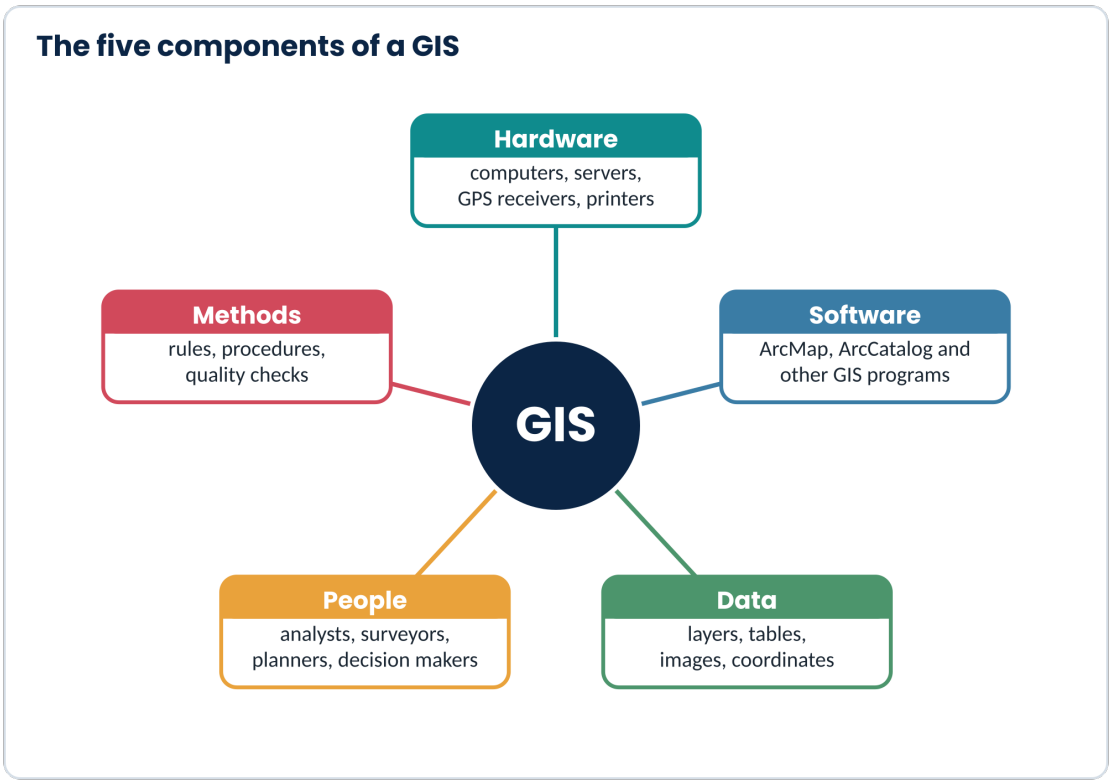


FIGURE 6.1 The five components of a GIS: hardware, software, data, people and methods.

TABLE 6.1 What each component means, with examples

Component	What it is	Examples
Hardware	The physical equipment	Desktop computers, servers, GPS receivers, printers
Software	The programs that work with the data	ArcMap and ArcCatalog (this series), other GIS programs
Data	The facts about places	Layers, attribute tables, images, coordinates
People	Those who build, run and use the GIS	GIS analysts, surveyors, planners, engineers, decision makers
Methods	The rules and procedures that guide the work	Naming rules, quality checks, standards for collecting data

> **TECHNICAL NOTE**
>
> Textbooks do not all list the same components. Some use four, some use six, and some give them different names. The five used here are a common teaching model. The idea is always the same: a GIS is more than software.

The last two components are the ones beginners forget. A powerful computer and the best software cannot give a good answer if the people do not know the right question, or if the methods for checking data are missing.

6.2 A basic GIS workflow

A **workflow** is a series of steps that takes you from a question to a result. GIS projects differ, but most follow the same pattern.

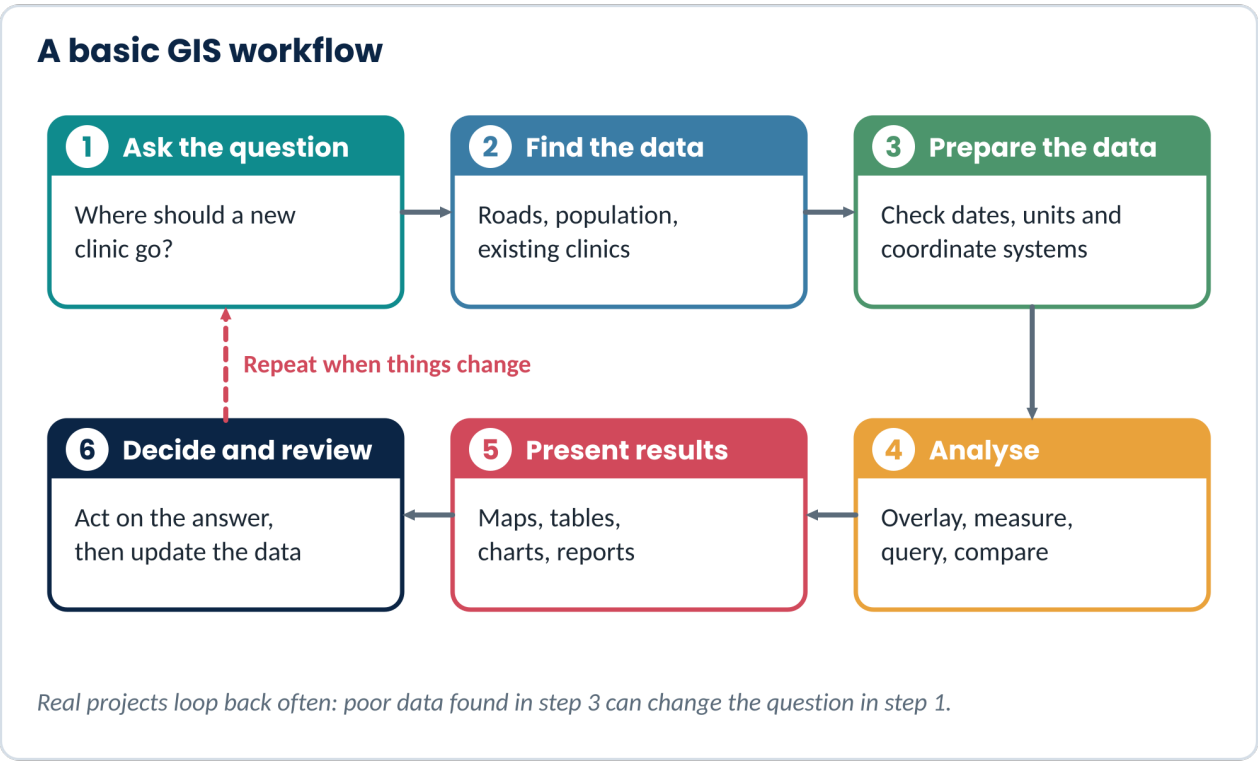


FIGURE 6.2 A basic GIS workflow in six steps, with a loop back to the start. The example in each box follows the clinic problem from Chapter 1.

1. **Ask the question.** Say clearly what you want to know. A clear question tells you which data you need.
2. **Find the data.** Look for datasets that cover your area. Check who made them and when.

3. **Prepare the data.** Check dates, units and coordinate systems. Fix errors. Put everything in one organised folder.
4. **Analyse.** Overlay layers, measure distances, ask questions of the tables.
5. **Present results.** Show the answer as maps, tables, charts or reports that suit your audience.
6. **Decide and review.** Use the result to make a decision. Later, update the data and repeat if things change.

Real projects loop back often. For example, you may find in step 3 that the flood data are 15 years old. Then you may need to change the question or look for new data.

6.3 Five kinds of questions a GIS can answer

It helps to know what *kinds* of questions a GIS can answer. One simple way to group them is into five kinds.

TABLE 6.2 Five kinds of GIS questions, with examples from different fields

Kind	The question	Example
1. Location	Where is it?	Where are all the fire hydrants on this street?
2. Condition	What is here? Which features have this property?	Which water pipes are made of cast iron?
3. Relationship	What is near, inside, touching or crossing?	Which homes lie inside the flood zone?
4. Pattern	Where are the clusters? What has changed?	Where do road accidents bunch together?
5. What-if	What would happen if…?	If this road is closed, how much longer is the ambulance trip?

Kinds 1 and 2 are the easiest. Kind 3 is where GIS becomes special, because it depends on the *position* of features compared with each other. You will study these relationships in EBOOK 09.

Many real questions mix kinds. The worked example below combines an *attribute* question (kind 2) with a *place* question (kind 3). It uses Table 5.2 from Chapter 5.

WORKED EXAMPLE Large schools near the clinic

GIVEN	The five schools in Table 5.2 and the clinic at (1800 m, 1400 m). A school counts as large if it has more than 400 students.
REQUIRED	Which large schools are within 1,000 m of the clinic?
STEP 1	Ask the attribute question: which schools have more than 400 students? Check each row: S1 (520), S2 (310), S3 (450), S4 (280), S5 (610). Schools with more than 400: S1 (Hillview Primary, 520), S3 (Oak Grove School, 450), S5 (Lakeside School, 610).
STEP 2	Ask the place question for these three schools. Use $d = \sqrt{((x_2 - x_1)^2 + (y_2 - y_1)^2)}$, as in Chapter 5. S1: dx = 600 m, dy = 600 m, d = 848.5 m S3: dx = 900 m, dy = -1200 m, d = 1,500.0 m S5: dx = 300 m, dy = 300 m, d = 424.3 m
STEP 3	Keep the schools with d ≤ 1,000 m: S1 and S5.

WORKED EXAMPLE Large schools near the clinic	
ANSWER	**Hillview Primary (S1) and Lakeside School (S5)** are large schools within 1,000 m of the clinic.
CHECK	S2 is also close (860.2 m) but has only 310 students, so it fails the first test. S3 has 450 students but is 1,500.0 m away, so it fails the second test. Both tests must pass.

6.4 Data quality: an answer is only as good as its data

A GIS gives you answers, but it does not tell you whether the data behind them are good. Always ask five questions about any dataset:

- **Who made it?** Is the source trustworthy?
- **When was it made?** Roads, buildings and rivers change.
- **How accurate is it?** Was it surveyed on the ground, or traced roughly from a small map?
- **How complete is it?** Does it cover the whole area, or is some of it missing?
- **What scale was it made for?** Data made for a country-sized map are too rough for a street-level question.

This information is often stored as **metadata**, which means "data about data". A good habit is to read the metadata before you trust a dataset.

> **TECHNICAL NOTE** Accuracy and precision
>
> **Accuracy** is how close a measurement is to the true value. **Precision** is how finely a value is stated or how repeatable it is. A number with many decimals is precise but not necessarily accurate. In the worked example, quoting 848.5281 m would be false precision, because the coordinates are only given to the nearest metre.

CHECK YOUR UNDERSTANDING

1. Name the five components of a GIS.
2. Which step in the workflow comes immediately before "Analyse"?
3. "Which homes lie inside the flood zone?" Which kind of question is this?

CHAPTER SUMMARY

- A GIS has five components: **hardware, software, data, people and methods**.
- A basic workflow: ask, find data, prepare data, analyse, present, decide and review. Projects loop back.
- Five kinds of questions: location, condition, relationship, pattern and what-if.
- Many questions combine an attribute test with a place test.
- Always check who made the data, when, how accurately and for what scale.

CHAPTER 7

Meeting ArcMap 10.8.2

A gentle tour of the software used in this series: what it is, what its main parts are, and what its status is today.

IN THIS CHAPTER

- ArcGIS Desktop, ArcMap and ArcCatalog
- The status of ArcMap 10.8.2
- The main parts of ArcMap
- An optional hands-on exploration

7.1 The ArcGIS Desktop family

ArcGIS Desktop is a software suite from Esri. This series covers version 10.8.2. The suite contains several applications. The main ones for this series are:

- **ArcMap**: the main application for working with maps and layers, and for analysing data [2].
- **ArcCatalog**: an application for organising and managing geographic data [7].
- **ArcScene** and **ArcGlobe**: applications for viewing data in 3D, as scenes and as a globe.

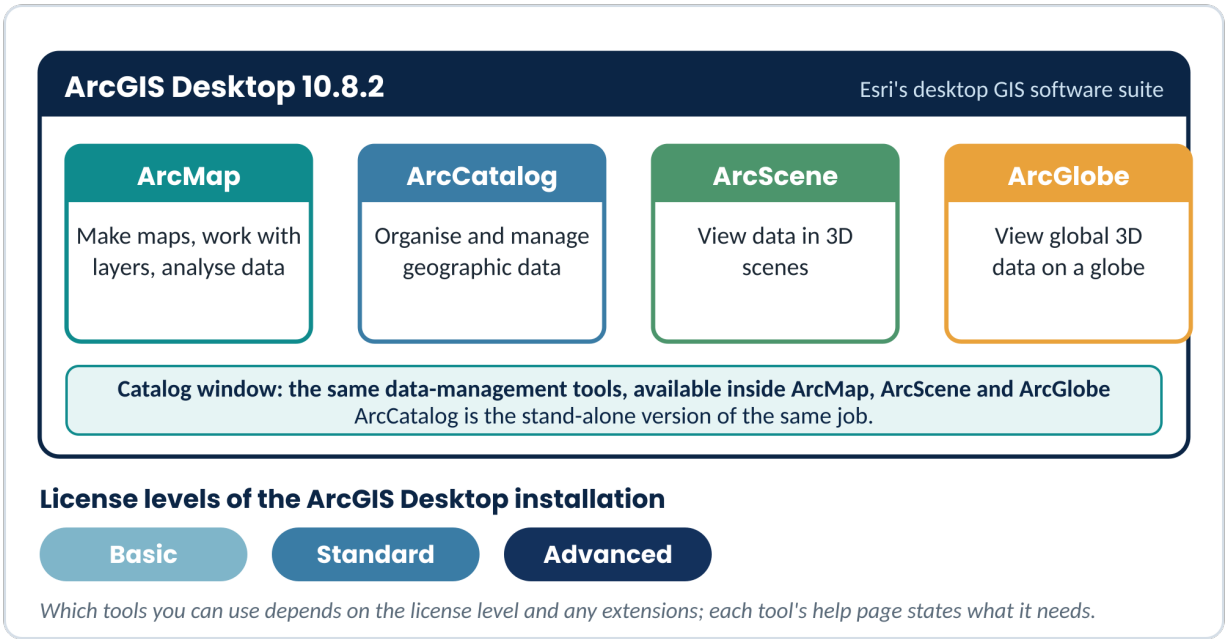


FIGURE 7.1 The ArcGIS Desktop family. ArcMap, ArcCatalog, ArcScene and ArcGlobe are separate applications. The Catalog window gives access to the same data-management tools inside ArcMap, ArcScene and ArcGlobe [7, 8].

ArcGIS Desktop is installed at one of three **license levels**: Basic, Standard and Advanced [9]. The level and any extensions decide which tools you can use. The help page for each tool says what it needs.

ArcCatalog can manage geodatabases, raster files, map documents, layer files, toolboxes and more, shown in a tree view [7]. The **Catalog window** inside ArcMap does the same jobs, so you can work with your data without leaving the map [7, 8]. You will use both in later eBooks.

7.2 The status of ArcMap 10.8.2

> **IMPORTANT** Read this before you invest time
>
> ArcMap 10.8.2 is the version this series covers, and it is the version Esri's current help pages describe [2, 9]. According to an Esri announcement, ArcMap entered *mature support* in March 2024. During mature support there are no more software updates, functionality-based patches or hotfixes, but technical support stays available [10]. Esri's ArcGIS Desktop quick start guide states: "ArcGIS Desktop was retired March 1, 2026. Start planning your migration to ArcGIS Pro" [9]. Esri's life-cycle pages are the official source. Check them for your situation.

What does this mean for you? Esri's pages announce the retirement but do not explain the details, so read Esri's life-cycle policy for what support remains. Your organisation must decide if it can keep using ArcMap, based on its own licensing, security and support rules. This eBook does not give licensing advice.

Why learn ArcMap, then? There are three honest reasons. First, the ideas in this series (layers, features, attributes, coordinate systems, analysis) are the same in every GIS, including Esri's current desktop product, ArcGIS Pro. Second, many organisations still hold maps, data and workflows built in ArcMap. Third, this series teaches the version you may find at work or in a course. When you learn the idea first, moving to another program is much easier.

7.3 The main parts of ArcMap

When you open ArcMap, you see several areas. Figure 7.2 shows a **schematic** with the parts we need. It is a teaching drawing, not a screenshot, so your own window may look different.

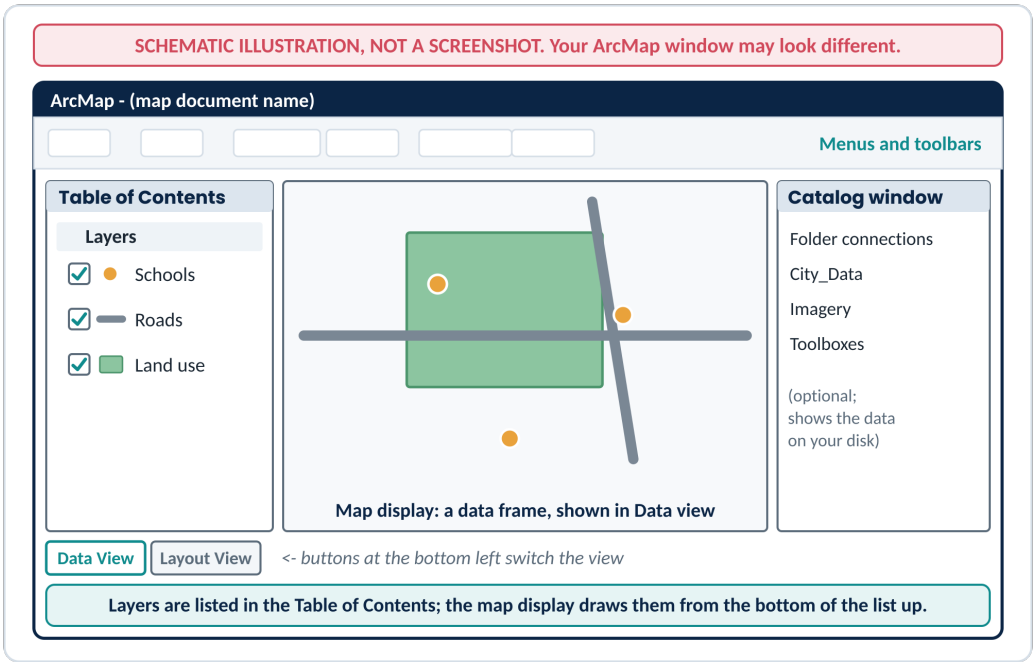


FIGURE 7.2 A schematic of the main areas of an ArcMap window. This is not a screenshot. Your screen may show different toolbars and windows.

TABLE 7.1 Key ArcMap terms

Term	What it means	Why it matters
Map document (`.mxd`)	The file where you save your map: layers, their properties, data frames and the page layout [2, 3]	It holds the map, not the data. Double-clicking an `.mxd` file opens it in ArcMap [2].
Data frame	A window on the map that draws a set of layers for a given area and projection [2, 3]	A map document can have more than one data frame.
Layer	Defines how a dataset is drawn, with its symbols and labels [3]	It points to the data. It is not the data (Chapter 4).
Table of Contents	The list of layers in the map. Check boxes switch layers on and off. The order sets the drawing order [3, 5]	Controls what you see and what is on top.
Data view	A window for exploring, displaying and querying the data, using real-world coordinates [4]	This is where you do most of your work.
Layout view	A page view for arranging titles, north arrows, scale bars and legends, using page units such as centimetres or inches [4]	This is where you prepare a map to print or export.
Catalog window	A tree view of folders and geodatabases inside ArcMap [3, 8]	It helps you find and manage data.

To switch views, use the **Data View** and **Layout View** buttons at the bottom left of the ArcMap window, or the **View** menu [4]. Use Data view while you work with data. Use Layout view when you want to arrange the final map for printing or for a PDF.

Layers can lose their data

Because a layer only points to its data, the link can break. If the dataset is moved, renamed or deleted, ArcMap cannot find it when the map opens. The layer then shows a red exclamation mark in the Table of Contents, and its check box is unavailable [6].

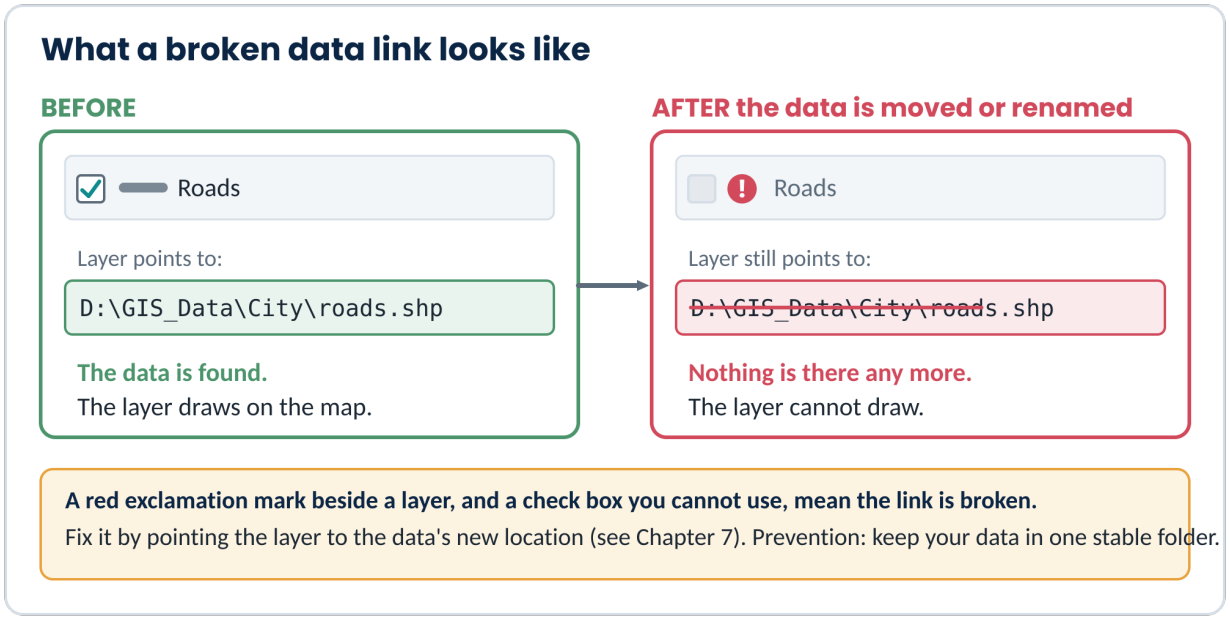


FIGURE 7.3 A broken data link. Left: the layer points to a dataset that exists. Right: the dataset has been moved or renamed, so the layer cannot be drawn.

PRO TIP

Avoid broken links by keeping each project's data in one stable folder, and by moving or renaming data inside ArcCatalog or the Catalog window rather than in File Explorer. If a link breaks, ArcMap can repair it: right-click the broken layer and choose Data, then Repair Data Source [6].

7.4 Try it: a guided exploration (optional)

This short exercise lets you see the ideas from this chapter in a real ArcMap window. You need ArcMap 10.8.2 and any existing map document (an `.mxd` file). If you have no map document, you can skip this section. Esri's quick start guide lists "ArcGIS Tutorial Data for Desktop" among the downloads for ArcGIS Desktop [9].

STEP-BY-STEP Explore a map document

1. Open ArcMap and open an existing map document. Or double-click an `.mxd` file, which opens it in ArcMap [2].
2. Find the **Table of Contents**. Write down the names of the layers you can see.
3. Switch a layer off and on again using its check box. Watch what happens on the map.
4. Change the drawing order. Drag a layer up or down in the Table of Contents. A black line shows where it will land. Release the mouse button to drop it [5].
5. Switch to **Layout view** using the buttons at the bottom left (or **View**, then **Layout View**). Then switch back to **Data view** [4].

Expected result: the map changes when you switch layers off and on, and when you reorder them. In Layout view, you see a page with the map on it. In Data view, you see only the map.

What it means: you have just used three ideas from this eBook. Check boxes control which layers are drawn (Chapter 4). The order in the Table of Contents controls which layer is on top. The two views serve two purposes: working with data and preparing a page.

TECHNICAL NOTE If something looks wrong

If a layer shows a red exclamation mark, its data link is broken (see above). If you cannot work out where the data went, you can leave the layer as it is or remove it [6]. Removing a layer from the map does not delete the dataset.

CHECK YOUR UNDERSTANDING

1. What does a map document (`.mxd`) contain, and what does it not contain?
2. What is the difference between Data view and Layout view?
3. A layer in your map has a red exclamation mark. What is the most likely cause?

CHAPTER SUMMARY

- **ArcGIS Desktop** is a suite. **ArcMap** is for maps, layers and analysis. **ArcCatalog** and the **Catalog window** are for managing data.
- Esri's documentation says ArcGIS Desktop was retired on 1 March 2026, and advises planning a migration to ArcGIS Pro.
- A **map document** (`.mxd`) stores layers, data frames and the page layout, but not the data.
- The **Table of Contents** lists layers. Higher layers are drawn on top.
- **Data view** is for working. **Layout view** is for preparing a page.
- A red exclamation mark on a layer means a broken data link.

CHAPTER 8

GIS at Work

A first tour of how GIS is used in real fields, with short examples of the problems it helps to solve.

IN THIS CHAPTER

- Ten fields where GIS is used
- Five illustrative scenarios
- Who works with GIS
- Responsibility and limits

IMPORTANT Illustrative, not documented

Chapter 3 contained **documented history**. The examples in this chapter are different. They are **illustrative**: invented scenarios written to explain how GIS thinking works. They are not case studies, and they do not prove that GIS produces any particular result. The field descriptions are general and follow the application areas that Esri lists on its website [1]. EBOOK 10 treats five of these fields in more depth.

8.1 Fields where GIS is used

The first group in Table 8.1 contains the five fields covered in EBOOK 10. They are closely linked to land, infrastructure and networks.

TABLE 8.1 GIS in land and infrastructure work (general descriptions)

Field	Typical problems	Typical data	Typical GIS tasks	Typical outputs
Land surveying and mapping	Record and check land boundaries and features	Survey points, boundary lines, parcels, aerial images, elevation	Store survey data; compare with neighbouring parcels; measure areas and lengths	Parcel and topographic maps; area reports
Urban and regional planning	Decide where to build and how to use land	Zoning, land use, population, roads, flood zones	Overlay layers; find suitable sites; compare plans	Suitability maps; planning maps
Transportation	Move people and goods safely and efficiently	Road network, traffic counts, crash points, transit stops	Find routes; find crash clusters; plan service areas	Route maps; hotspot maps
Utilities (water, power, gas, sewer)	Know where assets are and keep them working	Pipes and cables (lines), valves and poles (points), customer locations	Locate assets; find affected customers; plan maintenance	Asset maps; outage maps; work lists
Telecommunications	Plan networks and serve customers	Tower and cable locations, terrain, buildings, addresses	Study coverage; find gaps; plan cable routes	Coverage maps; route plans

TABLE 8.2 GIS in other fields (general descriptions)

Field	Typical problems	Typical data	Typical outputs
Environment and natural resources	Protect and manage land, water and forests	Land cover, rivers, protected areas, satellite images	Change maps; habitat maps
Emergency management	Prepare for and respond to floods, fires and storms	Hazard zones, roads, shelters, population	Evacuation maps; hazard maps
Public health	Understand where illness occurs and who is at risk	Case locations, clinics, population	Pattern maps; service-area maps
Agriculture	Manage fields and crops	Field boundaries, soil, elevation, images	Field maps; zone maps
Business and retail	Choose store sites; plan deliveries	Customers, competitors, roads, population	Site maps; delivery routes

8.2 Five illustrative scenarios

REAL-WORLD EXAMPLE Illustrative: land surveying

Problem. A survey office has measured the corners of 200 land parcels. It wants to check that no parcel overlaps its neighbour.

How GIS helps. The corners and boundaries are stored as points and polygons with an attribute table (parcel number, owner, area). The office overlays the parcel layer on itself to find places where polygons overlap, and measures areas by computer.

Output. A list of parcels to re-check on site, and a parcel map.

Note. In many countries a GIS parcel map is a working map and does not replace a legal survey plan. The rules depend on the country.

REAL-WORLD EXAMPLE Illustrative: urban planning

Problem. A city planner must propose areas for 2,000 new homes.

How GIS helps. She overlays zoning, flood zones, road access, school locations and existing land use (Section 4.5). Areas that fail a condition are removed.

Output. A suitability map showing the best areas to study first, which she presents to the council.

REAL-WORLD EXAMPLE Illustrative: transportation

Problem. A transport agency wants to know where road accidents bunch together.

How GIS helps. Each accident is a point with attributes such as date and type. The agency maps the points, looks for clusters and checks which road segments they fall on.

Output. A hotspot map and a list of road segments to inspect.

REAL-WORLD EXAMPLE Illustrative: utilities

Problem. A water utility wants to inspect old pipes first.

How GIS helps. Pipes are lines with attributes: material, diameter and year installed. The utility asks: *which pipes are cast iron and were installed before 1970?* It then finds which streets they run under.

Output. A map of pipes ranked for inspection, and a work list for field crews.

REAL-WORLD EXAMPLE Illustrative: telecommunications

Problem. A telecommunications company wants to find areas with many homes but weak signal.

How GIS helps. Tower locations are points. Their coverage areas are polygons. Home addresses are points. A GIS finds the homes outside every coverage polygon and counts them by neighbourhood.

Output. A coverage-gap map used to decide where to build a new tower.

Notice what these scenarios share. Each starts with a question, uses layers of different themes, and ends with a map or list that someone can act on. This is the workflow from Section 6.2.

8.3 Who works with GIS?

People who use GIS have many job titles. Some common roles are GIS analyst, GIS technician, land surveyor, cartographer (map maker), urban planner, civil engineer, environmental scientist and utility asset manager. Titles vary between organisations. Many professionals use GIS as one tool among many in their daily work.

8.4 Responsibility and limits

IMPORTANT Maps carry responsibility

A map can look very convincing, even when the data behind it are old, rough or incomplete. Always check the source and date of your data (Section 6.4). Remember also that location data about people, such as home addresses or movements, can be sensitive. Follow your organisation's privacy rules and the law.

CHECK YOUR UNDERSTANDING

1. Choose one field from Table 8.1. Write down one question a GIS could answer in that field.
2. In the illustrative water-utility scenario, which kind of question (from Table 6.2) is the first one?

CHAPTER SUMMARY

- GIS is used in surveying, planning, transport, utilities, telecommunications, environment, emergencies, health, agriculture and business.
- In each field the pattern is the same: a question, layers of data, an analysis and a result people can act on.
- The scenarios here are illustrative. Always separate documented case studies from teaching examples.
- A GIS result is only as reliable as its data, and location data can be sensitive.

CHAPTER 9

Common Mistakes and Misunderstandings

Seven mistakes that beginners often make, why they happen, and how to avoid them.

Most mistakes in GIS come from a wrong picture in the mind, not from a wrong button. Table 9.1 lists seven common ones. Each links back to a chapter where the idea was explained.

TABLE 9.1 Seven common beginner mistakes

Mistake	Why it happens	What goes wrong	How to avoid it
1. "GIS is just a map-making program."	Maps are the visible result.	You care about looks before data and questions.	Start with the question. The map is the last step (Chapter 2).
2. "A layer is the data."	The layer name looks like the dataset name.	You move or rename data and the layer breaks. You think removing a layer deleted the data.	Remember that a layer points to data. Keep data in one stable folder (Chapter 4, Chapter 7).
3. "More layers make a better map."	It feels thorough to add everything.	The map is cluttered and slow, and the message is lost.	Add only layers that help answer the question.
4. "If it is on a map, it must be true."	Maps look precise and official.	Old, rough or incomplete data give false confidence.	Check source, date, accuracy and scale (Section 6.4).
5. Using the distance formula on degrees.	Latitude and longitude are also x and y numbers.	Distances are wrong, especially far from the equator.	Use the formula only on a flat grid in metres or feet; use GIS tools otherwise (Chapter 5).
6. Swapping x and y.	We say "latitude, longitude" but GIS wants (x, y).	Points appear in the wrong place.	Always check which number is east–west and which is north–south.
7. Learning buttons without ideas.	Menus feel concrete and quick.	You can follow steps but cannot fix problems or adapt to a new task.	Learn the concept first, then the tool.

PRO TIP A quick checklist

When something looks wrong in ArcMap, ask these questions in order: *Is the layer switched on? Is another layer drawn over it? Is its data link broken? Is it in the area I am looking at?* Most problems are solved by one of these four.

CHAPTER SUMMARY

- Most beginner mistakes come from wrong ideas, not wrong clicks.
- Remember: a layer points to data, the map is the last step, data have a source and a date, and x comes before y.

CHAPTER 10

Practice, Review and Next Steps

Try the exercises on your own first. Worked answers are in Appendix A.

IN THIS CHAPTER

- Eight exercises, from easy to challenging
- Review questions
- Key takeaways and what comes next

10.1 Practice exercises

PRACTICE TASK Exercise 1 | Easy

Which of these tasks need a GIS rather than a plain spreadsheet or word processor? Say yes or no, and give one reason.

- (a) Adding up a list of school fees.
- (b) Finding all houses within 300 m of a clinic.
- (c) Printing a letter.
- (d) Showing where road accidents bunch together.
- (e) Drawing the structural parts of a bridge in fine detail.
- (f) Finding which water pipes lie under a flood zone.

PRACTICE TASK Exercise 2 | Easy

Say whether each object is best shown as a **point**, a **line**, a **polygon** or a **raster**, on a map of a whole city.

(a) A fire hydrant (b) A river (c) A lake (d) A land parcel

(e) The height of the ground (f) A bus stop (g) A satellite photograph (h) A road centreline

PRACTICE TASK Exercise 3 | Easy

A city engineer sits at a desktop computer and uses a handheld GPS receiver. She opens ArcMap and loads road and pipe data supplied by the water utility. She follows the office's written rules for naming and checking data. Then she prepares a map for the council.

Name the hardware, software, data, people and methods in this story.

PRACTICE TASK Exercise 4 | Moderate

A map has these layers: Roads (lines), Lakes (polygons), Hospitals (points), Satellite image (raster), Land use (polygons).

List them in a sensible order from top to bottom in the Table of Contents. Explain your choice in one or two sentences.

PRACTICE TASK Exercise 5 | Moderate

Use Table 5.2 and the clinic at (1800, 1400). Calculate the straight-line distance from River Road School (S2) and from Market Street School (S4) to the clinic. Which of them is within 1,000 m?

PRACTICE TASK Exercise 6 | Moderate

Using Table 5.2 and the clinic at (1800, 1400), find the schools that have **fewer than 400 students** and are **more than 1,000 m** from the clinic.

PRACTICE TASK Exercise 7 | Challenge

A fire department wants to choose a site for a new fire station. List (a) four layers you would collect, (b) whether each is points, lines, polygons or raster, (c) one question for each of the five kinds in Table 6.2, and (d) how the six workflow steps in Section 6.2 would apply.

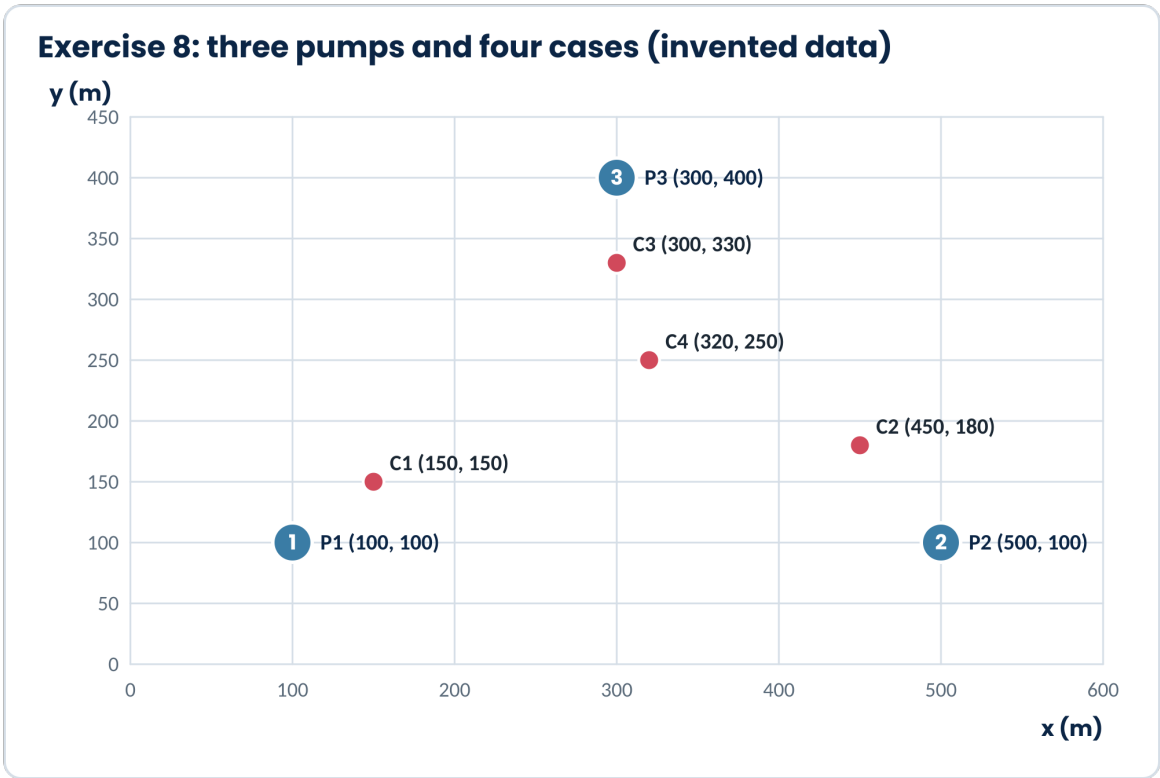


FIGURE 10.1 Data for Exercise 8: three water pumps (P1, P2, P3) and four cases (C1 to C4). The coordinates are invented and given in metres.

PRACTICE TASK Exercise 8 | Challenge

Figure 10.1 shows three pumps and four cases of illness, with their coordinates. For each case, calculate the straight-line distance to each of the three pumps and decide which pump is nearest. Then answer: if the cases came from the pump nearest to them, which pump has the most cases? What would you want to check besides straight-line distance? (Think about Chapter 3.)

10.2 Review questions

1. What does GIS stand for? What does each word add?
2. Give three differences between a paper map and a GIS map.
3. What is a layer? Why must layers share real-world locations?
4. In ArcMap, which layer is drawn on top: the one higher or the one lower in the Table of Contents?
5. What are the two main ways a GIS stores shapes of the real world?
6. Why can't you use the distance formula directly on latitude and longitude in degrees?
7. Name the five components of a GIS.
8. What happens to the dataset if you remove its layer from the map?

10.3 Key takeaways

- A GIS connects **where** things are with **what** they are, so you can capture, store, analyse, display and share information about places.
- Think in **layers**: one theme per layer, lined up by real-world location.
- A layer is a set of drawing instructions plus a **link** to data. It is not the data.
- A GIS stores **spatial** and **attribute** data together: vector shapes or raster cells, linked to table rows.
- A GIS has five components: hardware, software, data, people and methods.
- A project follows a workflow: ask, find data, prepare, analyse, present, decide and review.
- Always check the source, date, accuracy and scale of data.
- ArcMap is retired according to Esri's documentation, so its life-cycle status matters for planning. The ideas you learn here apply to every GIS.

10.4 What comes next

This is EBOOK 01 of 10 in Module 1. The next eBooks go deeper into the ideas you have just met.

TABLE 10.1 Module 1: GIS Fundamentals, at a glance

EBOOK	Title	What it adds
01	Introduction to GIS	This eBook
02	GIS Data Types	Vector, raster, spatial data and attribute data in detail
03	Understanding Vector Geometry	Points, polylines and polygons
04	Understanding Shapefiles	Components, limits and file management
05	Feature Classes and Geodatabases	How data is organised in ArcGIS Desktop
06	Raster Data Fundamentals	Pixels, cells, resolution and extent
07	Spatial and Non-Spatial Data	How place data and other data connect
08	Understanding Attribute Tables	Rows, columns, records and fields
09	Spatial Relationships	Location, distance, adjacency and containment
10	Real-World Applications of GIS	Surveying, planning, transport, utilities, telecommunications

APPENDIX A

Answers and Worked Solutions

Try each question yourself before you read the answer.

Check your understanding

Chapter 1

1. (a), (c) and (d) have a location. The number 412 on its own does not.
2. Example: a GIS map can answer a question (such as which houses are within 300 m of a clinic), measure distances by calculation, and update after a data change. A printed map cannot.

Chapter 2

1. Geographic: the data are about places on Earth. Information: we store facts about those places. System: several parts (hardware, software, data, people, methods) work together.
2. GPS gives you a position (coordinates). A GIS stores, links and analyses positions together with other information and shows the results on maps. They work together but are not the same.

Chapter 4

1. Every feature on every layer has a real-world location given by coordinates, so matching places fall on top of each other.
2. Point layer (school) on top, then the line layer (road), then the polygon layer (park) at the bottom.
3. No. A layer only points to the dataset. Removing the layer does not delete the data.

Chapter 5

1. Spatial data say where a feature is and what shape it has. Attribute data say what the feature is like (name, size, type).
2. A record is one row (one feature, such as one school). A field is one column (one property, such as Students).
3. A degree of longitude covers different ground distances at different latitudes, so the east–west and north–south differences are not in the same unit of length.

Chapter 6

1. Hardware, software, data, people, methods.
2. Prepare the data (step 3).
3. A relationship question (kind 3): what is inside what.

Chapter 7

1. It contains the list of layers, their drawing properties, the data frames and the page layout. It does not contain the data itself.
2. Data view is for exploring, displaying and querying the data. Layout view is for arranging the map on a page for printing or export.
3. The data were moved, renamed or deleted, so the link is broken.

Chapter 8

1. Any sensible question for the field you chose. Example (planning): which areas outside flood zones are near a school?
2. The first question (which pipes are cast iron and installed before 1970?) is a condition question (kind 2).

Practice exercises

Exercise 1

- (a) No: simple arithmetic.
- (b) **Yes**: distance from a place.
- (c) No.
- (d) **Yes**: a pattern on a map.
- (e) No: detailed structural drawing is design or CAD work, not GIS.
- (f) **Yes**: pipes and flood zone are two layers that overlap.

Exercise 2

- (a) Point. (b) Line. (c) Polygon. (d) Polygon. (e) Raster (or contour lines).
- (f) Point. (g) Raster. (h) Line.
- The answers depend on map scale. A wide river may be a polygon on a large-scale map.

Exercise 3

- Hardware: desktop computer, GPS receiver.
- Software: ArcMap.
- Data: the road and pipe data.
- People: the engineer (and the council who use the map).
- Methods: the office's written rules for naming and checking data.

Exercise 4

A sensible order, top to bottom: **Hospitals, Roads, Lakes, Land use, Satellite image.** Points and lines go on top so they stay visible. Lakes go above land use so that water is not hidden. The image goes at the bottom. If the land-use polygons are solid colours, they will hide the image, so make them partly see-through or switch one of the two layers off.

Exercise 5

S2: dx = -700 m (absolute value 700), dy = -500 m (absolute value 500). d = $\sqrt{(700^2 + 500^2)}$ = $\sqrt{740{,}000}$ = 860.2 m. **Within 1,000 m.**
S4: dx = 1400 m, dy = 700 m. d = $\sqrt{(1400^2 + 700^2)}$ = $\sqrt{2{,}450{,}000}$ = 1565.2 m. **Not within 1,000 m.**

Exercise 6

Fewer than 400 students: S2 (310) and S4 (280). More than 1,000 m from the clinic: S4 only (1,565.2 m), because S2 is 860.2 m away. **Answer: Market Street School (S4).**

Exercise 7

- (a) and (b), for example: existing fire stations (points), roads (lines), buildings or population (polygons or points), flood zones (polygons), elevation (raster).
- (c) Location: where are the existing stations? Condition: which roads are closed to heavy vehicles? Relationship: which buildings are within a 5-minute drive of a station? Pattern: where do fires happen most often? What-if: how would travel times change if a bridge closed?
- (d) Ask: where should the station go? Find data: the layers above. Prepare: check dates and coordinate systems. Analyse: overlay and travel-time analysis. Present: a map for the department. Decide and review: choose the site, then update the data after it opens.
- Other sensible answers are fine. Check that each answer links a question to a layer.

TABLE A.1 Exercise 8: straight-line distances in metres. The nearest pump for each case is in bold.

Case	To P1	To P2	To P3	Nearest
C1	**70.7**	353.6	291.5	P1
C2	359.0	**94.3**	266.3	P2
C3	304.8	304.8	**70.0**	P3
C4	266.3	234.3	**151.3**	P3

Exercise 8

Example for C1 and P1: $d = \sqrt{((150 - 100)^2 + (150 - 100)^2)} = \sqrt{5{,}000} = 70.7$ m. The other distances are in Table A.1.

Nearest pumps: C1 → P1, C2 → P2, C3 → P3, C4 → P3. **P3 has the most cases (two).**

Besides straight-line distance, check how people really walk (blocked streets, dead ends), which pump they actually use, the date of each case, and the water quality at each pump, as in Chapter 3. Four cases are far too few to draw a real conclusion.

APPENDIX B

Glossary

Key terms in simple English. Some are explained fully in later eBooks.

Accuracy	How close a measurement or a map position is to the true value.
Attribute	A fact about a feature, such as a school's name or number of students.
Attribute table	A table that holds the attributes of features. Each row is a record. Each column is a field.
Catalog window	A tree view inside ArcMap for finding and managing data such as folders and geodatabases.
Cell	One square of a raster grid. It holds one value. Also called a pixel.
Coordinate	A set of numbers that says where a point is, such as (x, y).
Coordinate system	A set of rules that says what coordinate numbers mean: where zero is, which way is positive, and the unit.
Data	Facts or measurements on their own, such as the number 412.
Data frame	A window on the map in ArcMap that draws a set of layers for a given area.
Data view	The ArcMap view for exploring, displaying and querying data in real-world coordinates.
Dataset	A collection of related data about one subject, such as all roads in a city.
Feature	One real-world thing stored in a GIS, such as one school or one road.
Field	A column in an attribute table. It holds one property of every feature.
GIS	Geographic information system: a system for capturing, storing, managing, analysing and displaying geographic data.
GNSS / GPS	Satellite systems that tell a receiver its position. GPS is one example of a GNSS.
Information	Data that has meaning, such as "Hillview School has 412 students".
Latitude	The angle north or south of the equator, in degrees.
Layer	In ArcMap, a set of drawing instructions for one theme, with a link to a dataset. It is not the data.
Layout view	The ArcMap view for arranging a map and its titles, scale bar and legend on a page.

Line (polyline)	A vector shape made from connected coordinates, used for long, thin things such as roads and rivers.
Location	The place where something is on the Earth's surface.
Longitude	The angle east or west of the prime meridian, in degrees.
Map document (.mxd)	An ArcMap file that stores layers, data frames and the page layout, but not the data.
Metadata	Data about data: who made it, when, how, and for what scale.
Model	A simplified version of the real world stored in a GIS.
Overlay	Placing layers on top of each other to find where themes meet or overlap.
Point	A vector shape made from one pair of coordinates, used for small things such as wells and schools.
Polygon	A vector shape that encloses an area, used for lakes, parks and land parcels.
Precision	How finely a value is stated, or how repeatable it is. A precise number is not always accurate.
Raster	Data stored as a grid of cells, each with a value. Used for images and smooth surfaces such as elevation.
Record	A row in an attribute table. It describes one feature.
Spatial	To do with position and space.
Spatial data	Data that say where a feature is and what shape it has.
Table of Contents	The list of layers in an ArcMap map. Its order sets the drawing order.
Vector	Data stored as points, lines and polygons made from coordinates.
Workflow	A series of steps that takes you from a question to a result.

APPENDIX C

References and Further Learning

Sources that were actually consulted, and suggestions for further reading.

C.1 Sources consulted

The web pages below were read on 2 November 2026 with a page-fetching tool that returns a summary of each page. Quotations in this eBook were checked against those summaries. Web pages can change. Items marked "search excerpt only" were seen as search-result excerpts and not opened in full.

[1] Esri. *What is GIS?* https://www.esri.com/en-us/what-is-gis/overview

[2] Esri. *A quick tour of ArcMap* (ArcGIS Desktop help). https://desktop.arcgis.com/en/arcmap/latest/map/main/a-quick-tour-of-arcmap.htm

[3] Esri. *Essential ArcMap vocabulary* (ArcGIS Desktop help). https://desktop.arcgis.com/en/arcmap/latest/map/main/essential-arcmap-vocabulary.htm

[4] Esri. *Displaying maps in data view and layout view* (ArcGIS Desktop 10.5 help; the 10.8 page was not opened). https://desktop.arcgis.com/en/arcmap/10.5/map/working-with-arcmap/displaying-maps-in-data-view-and-layout-view.htm

[5] Esri. *Changing a layer's drawing order* (ArcGIS Desktop help). https://desktop.arcgis.com/en/arcmap/latest/map/working-with-layers/changing-a-layer-s-drawing-order.htm

[6] Esri. *Repairing broken data links* (ArcGIS Desktop help). https://desktop.arcgis.com/en/arcmap/latest/map/working-with-layers/repairing-broken-data-links.htm

[7] Esri. *What is ArcCatalog?* (ArcGIS Desktop help). https://desktop.arcgis.com/en/arcmap/latest/manage-data/using-arccatalog/what-is-arccatalog-.htm

[8] Esri. *What is the Catalog window?* (ArcGIS Desktop 10.5 help; search excerpt only; the 10.8 page was not opened). https://desktop.arcgis.com/en/arcmap/10.5/map/working-with-arcmap/what-is-the-catalog-window-.htm

[9] Esri. *ArcGIS Desktop quick start guide* (10.8.2). https://desktop.arcgis.com/en/arcmap/latest/get-started/quick-start-guides/arcgis-desktop-quick-start-guide.htm

[10] Esri ArcGIS Blog. *ArcMap Enters Mature Support in March 2024.* https://www.esri.com/arcgis-blog/products/arcgis-desktop/announcements/arcmap-enters-mature-support-in-march-2024

[11] IEEE History Center (ETHW). *Milestones: First Geographic Information System (GIS), 1962–1968.* https://ethw.org/Milestones:First_Geographic_Information_System_(GIS),_1962-1968

[12] London Museum. *John Snow: Cholera & the Broad Street pump.* https://www.londonmuseum.org.uk/collections/london-stories/john-snow-cholera-broad-street-pump/

[13] *Observation and Visualization: John Snow and the Broad Street Pump* (online textbook chapter, Cornell University CS1380 course copy). https://www.cs.cornell.edu/courses/cs1380/2018sp/textbook/chapters/02/1/observation-and-visualization-john-snow-and-the-broad-street-pump.html

[14] Linda Hall Library. *John Snow.* https://www.lindahall.org/john-snow

[15] Esri Canada. *Esri Canada Honours the Life of Dr. Roger Tomlinson, the "Father of GIS"* (13 February 2014, reposted by Amerisurv). https://amerisurv.com/2014/02/13/esri-canada-honours-the-life-of-dr-roger-tomlinson-the-father-of-gis/

C.2 Suggested further reading (not consulted for this edition)

These suggestions come from general knowledge of the field and were not used to check facts in this eBook. Check the current edition and availability before you buy.

- Roger Tomlinson, *Thinking About GIS: Geographic Information System Planning for Managers* (Esri Press). A practical guide to planning GIS projects.
- Steven Johnson, *The Ghost Map* (Riverhead Books). A popular account of the 1854 cholera outbreak.
- The ArcGIS Desktop documentation at https://desktop.arcgis.com/ for the official help pages of ArcMap 10.8.
- Esri's product life-cycle pages (on support.esri.com), the official source for ArcMap support dates.
- EBOOK 02 of this series, *GIS Data Types*, as your next step.