CHAPTER 1

Get started with Web GIS

This chapter introduces the basic concepts and workflows of Web GIS and the Esri® geospatial cloud. The chapter begins with an overview of Web GIS and its advantages; introduces Esri's geospatial cloud including ArcGIS® Online and ArcGIS Enterprise; illustrates online, on-premises, and hybrid deployment patterns; lists the technical evolutions in Web GIS; explains the content types, hosted feature layers, app types, and user types in Web GIS; and demonstrates the workflow to build Web GIS apps using the Attachment Viewer instant app template. This chapter familiarizes you with ArcGIS Online and ArcGIS Enterprise basic operations and workflows and introduces flexible ways to build Web GIS apps that you will explore in other chapters.

Objectives

- Grasp the concept and advantages of Web GIS.
- Understand the deployment patterns of Web GIS.
- Learn the components of the new-generation Web GIS.
- Understand the technical evolutions and trends in Web GIS.
- Understand the concepts of web services and hosted feature layers.
- Publish hosted feature layers from CSV files.
- Learn the workflow for creating web maps and web apps.

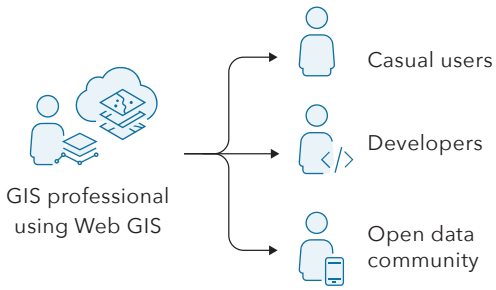
Web GIS and the geospatial cloud

Web GIS is the combination of the web and geographic information systems (GIS). The web removed the constraint of distance and thus allows people the freedom to interact with GIS apps globally and access information almost instantly. Web GIS uses web technologies, including but not limited to Hypertext Transfer Protocol (HTTP), Hypertext Markup Language (HTML), Uniform Resource Locator (URL), JavaScript, Web Graphics Library (WebGL), and WebSocket.

The first operational GIS was developed in the 1960s by Roger Tomlinson (who developed the Canada Geographic Information System). Since then, GIS has evolved from a local file-based, single-computer system to a central database client/server system, often with multiple servers and many more client computers. The invention of the internet in the 1980s and the growth of the World Wide Web in the early 1990s laid the foundation for an evolutionary leap toward Web GIS. In 1993, the Palo Alto Research Center (PARC), a Xerox company, developed a mapping web page, which marked the origin of Web GIS. In the 2000s, Web GIS evolved into a new generation—a system of distributed web services in the cloud you can access anywhere, represented by ArcGIS.

Inheriting the power of the web and the cloud, Web GIS offers many advantages:

- **Global reach:** You can share your geographic information easily, within your organization and with people all over the world.
- **Large number of users:** You can share your app with dozens, or even millions, of users supported by scalable cloud technology.
- **Low cost per user:** The cost of building one Web GIS app is often lower than building a stand-alone desktop solution and installing it for every user.
- **Better cross-platform capabilities:** Web apps, especially those built with JavaScript, can run on desktop and mobile browsers running a wide range of operating systems, including Windows, Mac OS, and Linux, along with iOS, Android, and Windows Phone.
- **Easy to use:** Web GIS apps typically incorporate simplicity, intuition, and convenience in their design. Public users can use these apps without a technical background (see figure).
- **Easy to maintain:** Web clients can benefit from the latest program and data updates each time they access a web app. The web administrator does not have to update all the clients separately.



Web GIS offers a collaborative environment and a pattern for delivering GIS capabilities. GIS professionals share information to Web GIS and extend geospatial intelligence to users across organizations and throughout communities.

GIS is the science of locations—The Science of Where®. The term has two meanings. One meaning is that GIS is itself a science, as the scientific basis for GIS technology. The other meaning is that GIS has been used for science as an effective tool for making scientific discoveries. The Science of Where is now recognized as a force for solving problems and understanding our world. Web GIS takes the science to a whole new scale, transforming how we share and collaborate and revealing deeper insight into data. The common patterns of Web GIS applications include mapping and visualization, data management, field mobility, monitoring, analytics, design and planning, decision support, constituent engagement, sharing, and collaboration. Web GIS unlocks and delivers this science to offices and homes and puts GIS technology in the hands of billions of people. Web GIS provides immense value to government, business, science, and daily life. In recent years, the concept and importance of spatial location have become more mainstream, and Web GIS awareness is growing more prominent in many organizations:

- **Government:** Web GIS offers an ideal channel for sharing public information services and delivering open data, an engaging medium for encouraging public participation, and a powerful framework for supporting decision-making.
- **Business:** Web GIS helps create novel business models and reshapes existing ones. It enhances the power of location-based advertising, business analysis, and volunteered geographic information, generating tremendous revenue directly and indirectly.
- **Science:** Web GIS creates research areas and renews existing avenues of research.
- **Daily life:** Web GIS helps people decide where to eat, stay, shop, and learn how to get from place to place.

Table 1.1 describes patterns of Web GIS applications, including mapping and visualization, data management, and analytics.

Table 1.1. Common patterns of Web GIS applications

Pattern name	Description
Mapping and visualization	Understand locations and relationships with maps and visual representations.
Data management	Collect, organize, and maintain accurate locations and details about assets and resources.
Field mobility	Manage and enable a mobile workforce to collect and access information in the field.
Monitoring	Track, manage, and monitor assets and resources in real time.
Analytics	Discover, quantify, and predict trends and patterns to improve outcomes.
Design and planning	Evaluate alternative solutions and create optimal designs.
Decision support	Gain situational awareness and enable information-driven decision-making.
Constituent engagement	Communicate and collaborate with citizens and external communities of interest.
Sharing and collaboration	Empower everyone to discover, use, make, and share geographic information.

The geospatial cloud powers Web GIS

Esri's Web GIS capabilities are provided by ArcGIS Online and ArcGIS Enterprise, which are at the core of the geospatial cloud.

- ArcGIS Online is a software-as-a-service (SaaS) offering of Web GIS. ArcGIS Online is hosted on the Amazon Web Services (AWS) cloud and Microsoft Azure cloud platforms and is managed by Esri. There is no hardware infrastructure for an organization to maintain. ArcGIS Online hosts hundreds of millions of content items and registered users. It serves billions of maps per day with high performance, scalability, and availability. With the benefits of cloud computing, ArcGIS Online has been quickly adopted by government and commercial organizations around the world.
- ArcGIS Enterprise is a Web GIS software product that organizations can acquire and deploy. ArcGIS Enterprise includes four basic software components: Portal for ArcGIS, ArcGIS Server, ArcGIS Data Store, and ArcGIS Web Adaptor. These components support flexible ways for deployment, from a single-machine deployment to multiple-machine deployments, highly available (HA) deployment, on Windows, Linux, and the Kubernetes platform, in on-premises data centers or in AWS, Microsoft Azure, Google Cloud, and many other cloud platforms.

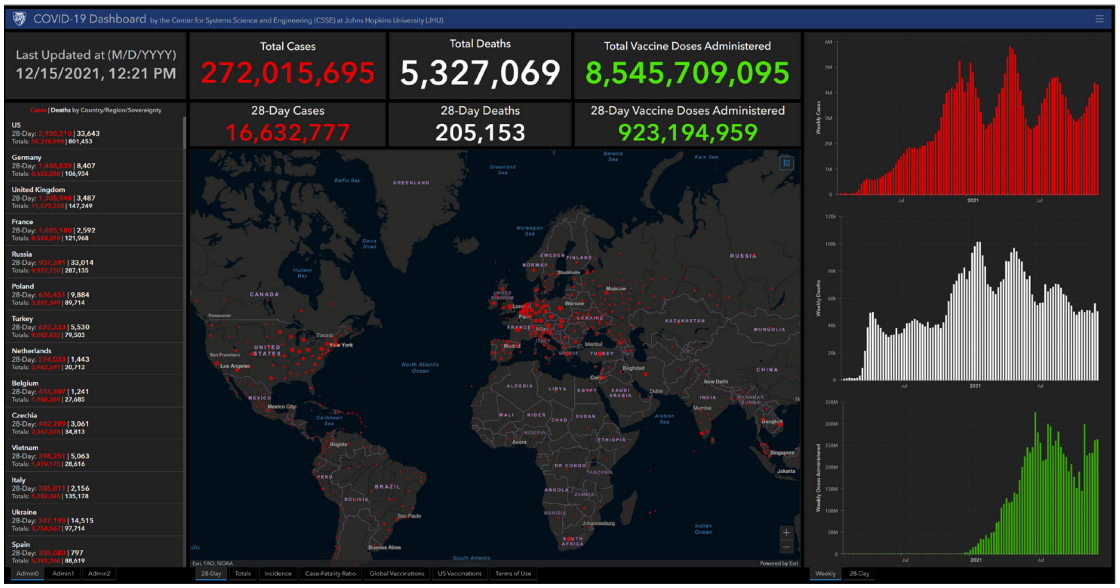
Table 1.2 lists these deployment patterns.

Table 1.2. Esri Web GIS deployment patterns

	Online	Hybrid	On-premises or in cloud
Esri managed	ArcGIS Online	ArcGIS Online	
Customer managed		ArcGIS Enterprise	ArcGIS Enterprise

Although on-premises data center technology is not necessarily on the verge of extinction, cloud computing is an option with many benefits, including scalability, agility, and cost efficiency. During the COVID-19 pandemic, cloud usage increased rapidly because people use the cloud platforms to work and shop from home. Today, more organizations are adopting ArcGIS Online or deploying their ArcGIS Enterprise to the cloud, such as AWS, Microsoft Azure, Google Cloud, and others (see figure). Many organizations adopt a hybrid model by integrating ArcGIS Online and ArcGIS Enterprise.

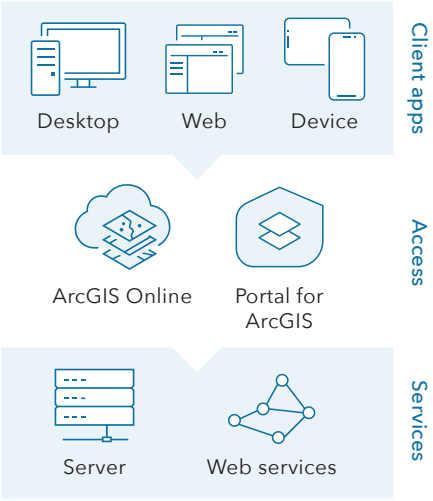
ArcGIS Online and ArcGIS Enterprise benefit from an effective framework to enforce security and protect user privacy. They are certified as compliant with many federal and international security and privacy standards. For more information, see the ArcGIS Trust Center page at doc.arcgis.com/en/trust/compliance/compliance-tab-intro.htm.



Built on ArcGIS Online, the Johns Hopkins COVID-19 Dashboard, a real-time pandemic tracker, has become a global reference for the pandemic and one of the most cited resources to track the spread of coronavirus around the world. It has received billions of views and remained highly efficient under a massive amount of web traffic.

New-generation Web GIS architecture and trends

ArcGIS Online and ArcGIS Enterprise represent the new generation of Web GIS. Although the two have some differences (see chapter 5), they generally share similar architecture, similar capabilities, and similar workflows for creating content, as shown in this figure.



ArcGIS is a new-generation Web GIS that provides mapping, analysis, data management, and collaboration.

This new-generation Web GIS architecture is described as follows:

- At the center of the new Web GIS architecture is a portal—ArcGIS Online or Portal for ArcGIS—which represents a gateway for accessing all spatial products in an organization. The portal helps organize, secure, and facilitate access to geographic information products.
- On the back end, the portal is powered by two components: GIS servers that allow you to create content and ready-to-use content such as ArcGIS Living Atlas of the World, which provides tens of thousands of data layers and maps.
- On the client side, users can search, discover, and use the layers, maps, and apps on desktops, in web browsers, and on mobile devices anywhere, anytime.

Technology evolution and trends in Web GIS

Since its inception, Web GIS has coevolved with geographic science and information technology (see figure). This evolution and these trends are discussed in greater detail in later chapters.

Web GIS has coevolved with geographic information science and information technology.

Web GIS has exemplified the following evolution of stages and trends in technologies:

- **From closed websites to open geospatial web services**. Early Web GIS apps were developed as independent websites. These websites were isolated from one another. It was difficult to share information and functions between them and difficult to remix the content to create apps. In the later 1990s, web services technology was conceived. Web services can be thought of as building blocks that can be shared and remixed in versatile ways for building web apps. The GIS industry adopted the concept of web services in manufacturing Web GIS products. For example, ArcGIS Web GIS products fully support the web services architecture. The server side provides ready-to-use services and allows users to create their own services, whereas the client side can consume and combine these services to create apps.
- **From one-way to two-way information flow**. Early Web GIS products and applications mainly supported one-way information flow, which was from server side to client side. Users were merely the receivers of information. As we entered the 21st century, user-generated content (UGC) became a significant phenomenon and created a reversed information flow, from client side to server side. Volunteered geographic information (VGI) is the UGC of a geospatial nature. For example, ArcGIS facilitates VGI through editable layers, Mobile GIS apps, and browser-based apps. Users can view maps and perform queries, as well as conduct field surveys, collect data, and report events they see.

- **Portal technology is becoming essential**. The word **portal** means gate or entrance. It was adopted in the mid-1990s to form new terms such as **web portal**, referring to a website that serves as the gateway to other websites or web resources. **Geoportals** are gateways to geospatial information. Portals have become a core component of Web GIS technology. For example, ArcGIS Online and Portal for ArcGIS have geoportal capabilities. They facilitate the management, search, discovery, configuration, security, and remix of GIS data layers and services. Today, portal collaboration allows different organizations to replicate selected content as hosts and guests, creating a portal of portals—a distributed Web GIS pattern. ArcGIS Hub℠ and ArcGIS Enterprise Sites are examples of subject- or initiative-based portals. They provide an easy-to-configure community engagement platform that organizes people, data, and tools through information-driven initiatives. Organizations can create websites to share data, documents, videos, and web maps on a certain subject or for a certain initiative. For instance, the COVID-19 GIS Hub (coronavirus-resources.esri.com) provides GIS resources, solutions, and a collaboration platform for the world to combat the coronavirus pandemic.
- **Cloud GIS delivers GIS functionality and ready-to-use contents**. Cloud GIS, which uses public and private cloud computing to provide GIS software and contents, has become the primary way to deliver GIS—not just functionality but also content. Cloud GIS advantages include vast content and functionality, the flexibility of pay-as-you-go or subscription pricing, reduced complexity, and increased availability of services. Because of these advantages, cloud GIS, such as ArcGIS Online, has penetrated organizations that have not used GIS before or been able to afford GIS on their own.
- **Mobile is becoming the pervasive Web GIS client platform**. In the post-PC era, mobile devices have surpassed desktops and notebooks as the primary platform for accessing online information. Mobile devices are a part of everyone's life and work. "Mobile first" is a strategy of many industries, including the Web GIS industry. Vendors have given extra attention to Mobile GIS. For example, Esri provides numerous mobile-native apps and mobile-friendly browser apps to support the needs of users and organizations for Mobile GIS. Mobile GIS is also associated with many frontiers in Web GIS, such as augmented reality (AR). AR can superimpose GIS data on top of a user's camera views and thus augment a user's sense of reality. With the rapid advances in Mobile GIS, the vision of using GIS for anything, anytime, anywhere, and by anyone is being realized faster than we can imagine.
- **Map visualization goes from 2D to 3D and virtual reality**. With the increased client-side graphics processing power and the broader support of WebGL (a JavaScript application programming interface [API] that renders interactive 2D and 3D graphics in a browser), Web GIS products such as ArcGIS Online and ArcGIS Enterprise can smoothly create and display

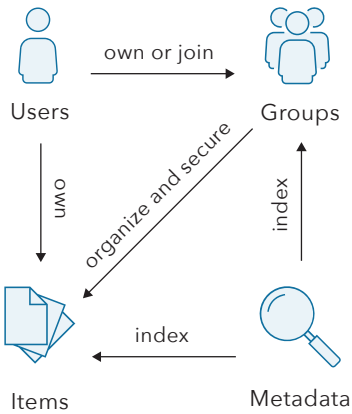
thematic and photo-realistic 3D web scenes. Representing a big step from 2D online maps, 3D web scenes provide users a more intuitive means to understand their data. Web scenes are also important for indoor mapping, an ongoing trend in GIS. Even more intuitive than 3D, virtual reality (VR) allows users with certain visual wearables to immerse themselves in 3D city models by transporting themselves into static viewpoints and comparing different urban design scenarios. This immersive experience brings GIS data and geospatial understanding even closer to users. The GIS community can play an important role in building the metaverse and can assist with getting real work done in the virtual world environment. The term **metaverse** refers to the fully immersive 3D expansion of existing internet technologies to include AR and VR.

- **Data source goes from static to real time and spatiotemporal big data**. Many elements in Web GIS are of a real-time nature, such as the incidents immediately reported by field crews, citizens using mobile devices, concurrent measurements from sensor networks, and smart cities. This massive amount of data presents challenges in real-time intake, processing, analysis, visualization, and storage. ArcGIS GeoEvent™ Server and ArcGIS Velocity use cluster computing and can ingest millions of sensor readings per second, process them, and store them in real time. Such products and research allow Web GIS to meet the requirements of the sensor web and the Internet of Things (IoT).
- **Web GIS is becoming more intelligent**. Map visualization is the first step toward data analysis. ArcGIS smart mapping can analyze the data automatically and suggest the best mapping style and best defaults. This can help both expert and novice users quickly create aesthetic and informative maps. Web GIS goes far beyond mapping. Web GIS can perform big data analysis using distributed computing, aggregate data in the context of both space and time, extrapolate new ideas from raw data, and bring superior intelligence to business decisions. More recently, Web GIS has started to use artificial intelligence (AI), especially machine learning and deep learning. For example, AI significantly improves the accuracy of online imagery classification. AI can quickly identify the damaged locations from millions of facilities' photos and ensure that the damaged facilities are repaired early.

Web GIS information model: Users, web layers, maps, and apps

Web GIS elements include users, groups, content items, and metadata (see figure).

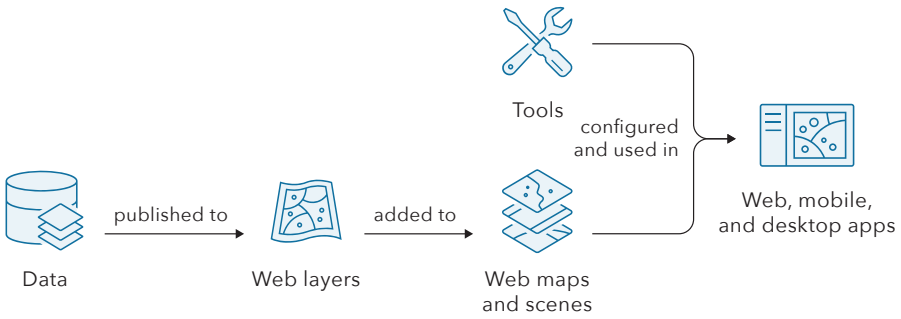
- Users with necessary privileges can create and join groups.
- Users sign in to create and share content items (with certain privileges), which include a large variety of data, web layers, tools, web maps, web scenes, and web apps.
- Content items have metadata, including title, summary, description, categories, and tags, and additional standards-based metadata. Metadata is indexed so users can search and discover items more efficiently.
- Users can keep information to themselves, share with certain groups (rather than individual users), share with their organizations, or share with everyone—even the public if the organization allows anonymous access. This allows other users to see and access the items.



The ArcGIS Online and Portal for ArcGIS high-level information model.

Main types of content items

Web GIS has five main types of content: data, layers, tools, web maps and scenes, and apps. Data can be used to publish web layers; web layers can be used to create web maps and web scenes; web maps and scenes and web tools can be used in apps or to create apps, as shown in the figure.



The main types of content in Web GIS and their relationships.

These five main content types are described as follows:

- **Data:** ArcGIS Online supports data in a variety of formats, including CSV, shapefiles, GPS Exchange Format (GPX), JavaScript Object Notation (GeoJSON), photos, imagery, geodatabases, and so on.
- **Layers:** The Esri geospatial cloud can host layers, including feature layers, tiled layers, vector tiles, map image layers, image layers, scene layers, CSV layers, tables, and Open Geospatial Consortium (OGC) standard layers such as Keyhole Markup Language (KML), Web Map Service (WMS), Web Map Tile Service (WMTS), and Web Feature Service (WFS).
- **Web maps and scenes:** A web map, which is 2D, or a scene, which is 3D, comprises one or multiple layers and allows sophisticated layer configuration, including styles, pop-ups, labels, and access permission.
- **Tools:** Tools perform analytical functions, such as geocoding, routing, generating PDF files, summarizing data, finding hot spots, and analyzing proximity.
- **Apps:** GIS apps are lightweight mapcentric programs that can be used on mobile devices, in web browsers, or on desktops. Developers can program with ArcGIS web APIs to build web apps. However, you do not have to be a developer to create a web app. ArcGIS provides many ready-to-use web apps and mobile apps that can be used without programming.

Apps: The face of Web GIS

Apps bring Web GIS to life. Web GIS end users directly interact with apps. The back-end data, web layers, and server computation power of Web GIS become live and useful through apps. ArcGIS provides ready-to-use apps out of the box and provides APIs and software development kits (SDKs) for developers to create custom apps.

The ready-to-use apps include configurable apps (also referred to as ArcGIS Online and Portal for ArcGIS web app templates), ArcGIS StoryMaps℠ stories, mobile apps, app builders, and more. ArcGIS organizes these apps into bundles:

- **Essential apps bundle:** ArcGIS StoryMaps, ArcGIS Experience Builder, ArcGIS Web AppBuilder, ArcGIS Dashboards, instant apps, ArcGIS Hub Basic, Map Viewer, Scene Viewer, and so on
- **Field apps bundle:** ArcGIS Field Maps, ArcGIS Survey123, ArcGIS QuickCapture, and so on
- **Office apps bundle:** ArcGIS for Office, ArcGIS for SharePoint, and so on
- **ArcGIS Pro**
- **ArcGIS Insights℠**
- **Add-on apps:** ArcGIS Drone2Map®, ArcGIS Navigator, ArcGIS Business Analyst™, and so on

ArcGIS user types consist of Viewer, Storyteller, Editor, Field Worker, Creator, GIS Professional, and Insights Analyst (see table 1.3). Different user types have included access to different app bundles and apps. Apps that are not included with a user type can be acquired and assigned as add-on licenses. To finish most of the tutorials in this book, a Creator user type with a Publisher role is required.

Table 1.3. Main ArcGIS user types, privileges, and included apps

Type	Privileges	Included apps
Viewer	Can view items Can't create, edit, share, or analyze items	Essential apps bundle
Storyteller	Can create stories and express maps Can't create other types of content	Essential apps bundle
Editor	Can view and edit data Can't analyze, create, or share items	Essential apps bundle
Field Worker	Same as Editor	+ Field apps bundles
Creator	Can edit, create, share content, and do analysis	+ Office apps bundles
GIS Professional	Same as Creator	+ ArcGIS Pro
Insights Analyst	Same as GIS Professional	Insights

"+" means including the apps from the user type listed earlier in the table.

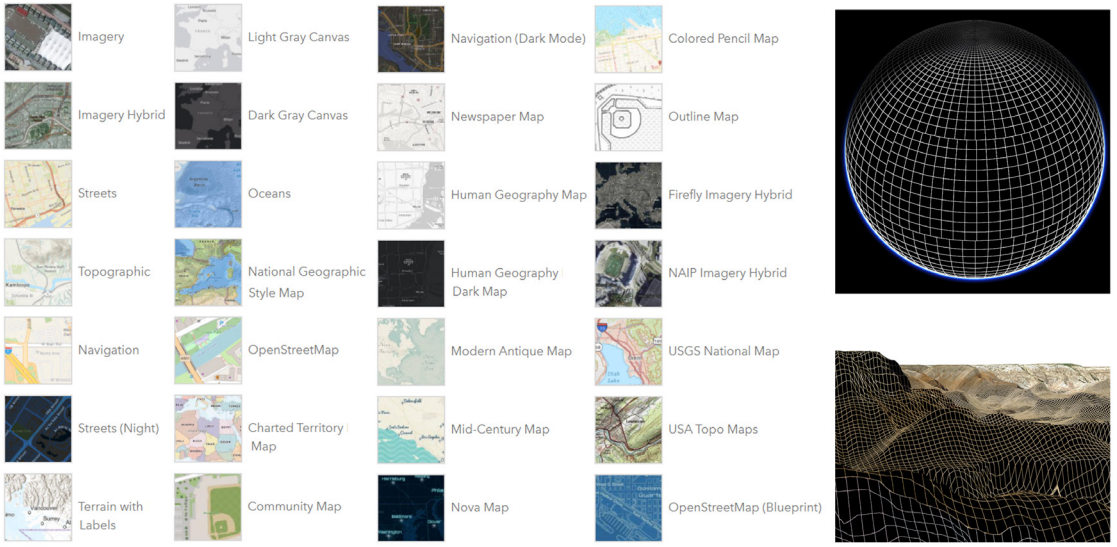
Basic components of a Web GIS app

Today's best practices recommend that a GIS app have basemaps, operational layers, and tools (see figure). ArcGIS supports this practice and allows you to create Web GIS apps.

The basic components of a Web GIS app.

The components of a Web GIS app are described as follows:

- **Basemap layers:** Basemaps provide a reference or context for your app. ArcGIS provides a collection of fast-responding 2D and 3D basemaps (see figure). In addition, you can create and use your own basemaps.



ArcGIS provides a gallery of basemaps and an elevation service to support 2D and 3D web maps and apps.

- **Operational layers:** Operational layers are theme layers that you and other users can use and interact with. You can use existing layers from ArcGIS Online and ArcGIS Living Atlas of the World as your operational layers. These layers span a range of subjects and can support

maps and apps of almost every subject. You can search these collections and discover layers that fit your needs. You can also create and use your own operational layers.

- **Tools:** Tools perform tasks beyond mapping, including common tasks such as query, geocoding, routing, and more specialized tasks. ArcGIS Online provides extensive spatial analysis tools for you to ask questions and solve spatial problems. ArcGIS Enterprise provides tools for standard analysis, big data analysis, and raster analysis, and allows you to publish custom web tools—in other words, geoprocessing services.

Web layers or services: The building blocks of Web GIS

Web services technology is at the foundation of today's Web GIS. The previously mentioned three types of components of Web GIS apps are typically all based on web services. To make it easier to understand, web services in ArcGIS are also called web layers or web tools. For example, basemaps are often tile services or tile layers, operational layers are often feature services or feature layers, and many tools are based on geoprocessing services or web tools.

Early Web GIS was not based on web services; instead, it consisted mostly of stand-alone websites in which GIS data and functions were available only to their own clients and couldn't be reused in other systems. This situation greatly limited the reusability of Web GIS resources. In the late 1990s, web services technology was conceived. A web service is a program that runs on a web server and provides programming interfaces for clients to consume over the web. Web services have many advantages, such as flexibility in being reused and remixed in many web apps.

The GIS industry quickly adopted web services technology and reformed Web GIS products based on web services architecture in the early 2000s. Today's Web GIS products are designed to support the publication, discovery, and use of GIS web services. A GIS service represents a GIS resource—such as a layer, map, locator, or toolbox—that is located on the server and made available to web clients. For example, ArcGIS Living Atlas provides collections of ready-to-use GIS services. The Esri geospatial cloud allows publishers to publish many types of GIS services and allows users to discover and use GIS services in web maps, web apps, and mobile apps.

This chapter introduces feature layers and services. Other chapters introduce raster tile services, vector tile services, 3D scene services, map services, image services, stream services, geoprocessing services, geocoding services, and more. To support interoperability, ArcGIS supports OGC standards such as WMS, WMTS, WFS, and KML.

Hosted and nonhosted feature layers

Feature layers are the most used layer type for operational layers. Feature refers to vector data: points, lines, and polygons. Feature layers can be hosted or nonhosted, depending on where the underlying data is stored.

- Hosted refers to a situation in which a web service is based on ArcGIS-managed data: for instance, the data is stored in the ArcGIS Online cloud database (which is managed automatically by Esri) or in ArcGIS Data Store (which is managed automatically by ArcGIS Enterprise).
- Nonhosted refers to a situation in which a web service connects directly to user-managed data: for instance, the data is stored in your organization's own database, and the database is managed by your own organization.

Feature layers published to ArcGIS Online are always hosted feature layers. Feature layers published in ArcGIS Enterprise can be hosted if the data is stored in ArcGIS Data Store or nonhosted if your feature layers reference your organization's own geodatabase—for example, SQL Server, Oracle, or PostgreSQL.

Hosted feature layers are often easier to publish because you don't have to worry about the underlying database. You don't have to (and you won't be able to) directly connect to the database and manipulate it. To change the database schema and edit the data, you must go through the hosted feature layer web interface. Nonhosted feature layers require that you have and manage your own database. You can directly connect to the database and perform various operations on it.

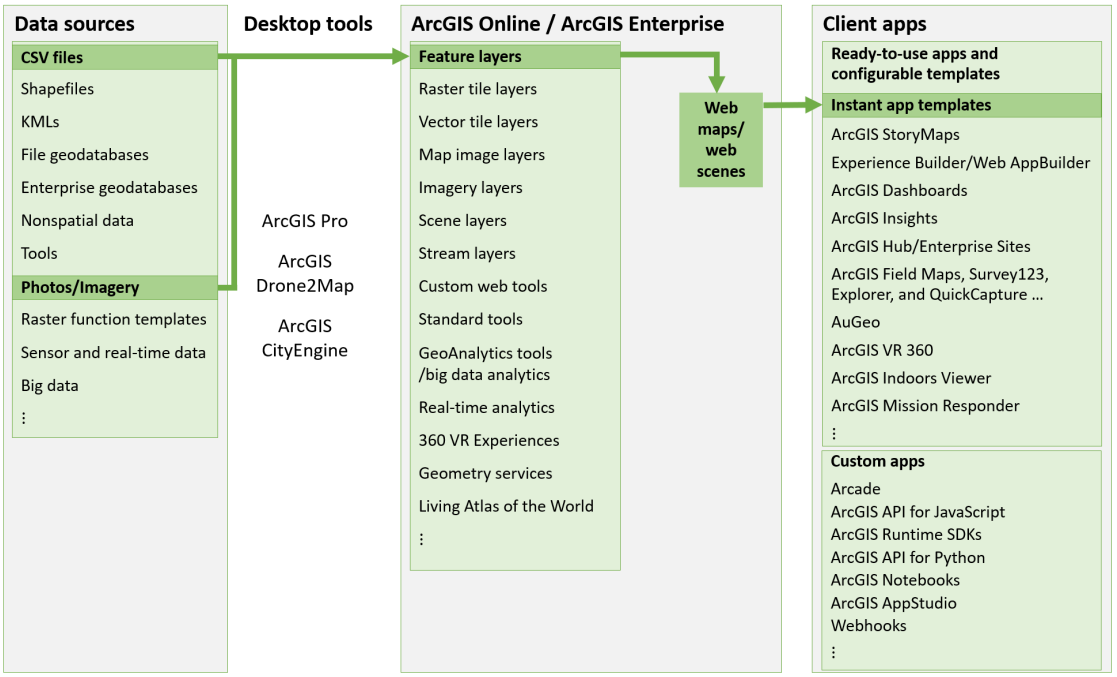
This book teaches many ways to publish hosted feature layers—from CSV files, zipped file geodatabases, ArcGIS Pro, and so on. You can also create empty feature layers and add fields in ArcGIS Online (see chapter 4).

Web maps and web scenes: The bridge between layers and apps

Web GIS provides Map Viewer and Scene Viewer for creators to integrate multiple layers, style these layers, configure layer pop-ups, and make many other configurations. After a web map or web scene is created, it can be used in one app or reused in many apps. This makes it easier for creators to create apps. Without web maps and scenes, creators would often have to integrate the layers directly and configure them in the apps, which can be cumbersome.

Paths to building Web GIS applications

The tutorials in this book teach readers how to build Web GIS apps. ArcGIS offers many paths to this goal, as shown in this figure, which will be used throughout the book.



ArcGIS offers many ways to build web apps. The green arrows in the figure highlight the workflows and technology presented in this chapter.

The figure presents the generic workflow to build Web GIS apps:

- The data tier contains formats that range from simple CSV files managed with Microsoft Excel to sophisticated geodatabases managed with enterprise databases.
- You can publish desktop resources to ArcGIS Online or ArcGIS Enterprise as web layers, tools, or other services. You can also use layers provided by ArcGIS Living Atlas. You can add layers to web maps and web scenes and configure the styles and pop-ups in these layers.
- On the client side, you can use various ready-to-use apps or custom apps. The former can be configured without programming. The latter can be developed using various web APIs or SDKs.