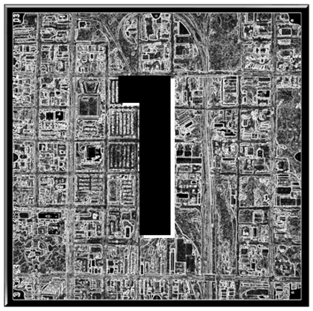


Introduction to GIS

How GIS Is Affecting Our Lives

In This Chapter…

Any organization interested in assets or activities distributed over some geographic area can use a GIS. That would include a lot of organizations. This chapter presents examples of the many uses of GIS, and the benefits it produces. The chapter describes the origins of GIS and how it works, and includes the perspectives of an industry leader on the future of GIS.

A Dramatic Story

Responding to the robbery of an armored truck, Metropolitan Toronto Police spot the getaway car and give chase, eventually following it into the suburbs. Back at MTP headquarters, a dispatcher coordinates the pursuit using a new computerized dispatch system. She sits in front of two computer screens. One shows the status of this and other incidents, as well as the status of available police units. The other shows a computerized map of the city, red and yellow "snowflakes" pinpointing the location of both the incidents and the police cars. She can view the entire city, or zoom in to see details. The system can even show her which unit is closest to an incident, and trace its fastest route to the scene.

When the robbery suspects abandon their vehicle and flee on foot to a nearby golf course, MTP officers find themselves in very unfamiliar territory. "Our people really didn't know the rolling topography of the golf course very well," says Richard Coulis, MTP staff sergeant and acting inspector. "But the dispatcher could see all the roads, cart trails, creeks, and even the water hazards right on her computer screen." Windowing the golf course on her map display, the dispatcher instructs some police cruisers to take up strategic positions at possible exit points, then directs the officers pursuing on foot.

According to Coulis, "An officer would be running along and say, 'I'm going to turn and head west up this hill,' and she'd answer, 'No, don't do that. There is a creek up there and you won't be able to get across.'" All of the suspects are eventually rounded up, most of them right on the golf course. "The information we had was so thorough that our officers returning to the station asked, 'Where were the video cameras?'" Coulis adds. "With an old fashioned paper map this kind of operation would have been impossible." (The following illustration shows a computer-aided dispatch station.) A GIS is the foundation of Toronto's computerized dispatch operation.

Computer-aided dispatch station.

A GIS is a computer system that can store virtually any information found on a paper map. But it can be much more helpful than a traditional map. Whereas the GIS can display maps on a computer screen, it can also provide detailed information about their features, including roads, buildings, streams, and so forth. Moreover, the computer can quickly search and analyze these map features and their attributes in ways that are not possible with paper maps.

For instance, suppose you are looking at the GIS display of a state highway map. Point at a particular road and click the computer's mouse button to find out that the roadway is state route 29, four lanes wide, paved with asphalt, and has a 45-mph speed limit. Click again to see the location of all traffic accidents that have occurred on that stretch of the highway. Click once more to view a picture of the pavement and road signs at that location. Or, ask the GIS to highlight all parts of the state highway system that serve more than 5,000 vehicles per day. In just seconds you see the results.

GIS are being used to help manage forests, utilities, petroleum exploration, and even the taking of the U.S. Census. Corporations, public safety officials, and the military use them. They have been linked to many other technologies, using satellite images to help farmers manage their crops, using global positioning system (GPS) data to help dispatchers locate an available taxi, using seismic data to locate the epicenter of an earthquake, and using bathymetric data gathered by a deep sea submersible to map the ocean floor. The following illustration shows satellite imagery analyzed by a GIS.

Satellite imagery analyzed by a GIS.

The Origins of GIS

GIS was pioneered in the 1960s by the Canadian forestry mapping initiative and continued to develop as Canadian, U.S., and other government and university researchers sought to represent the earth's geography using a computer database, display it on a computer terminal, and plot it on paper. They also developed computer programs to quickly search and analyze this data. Several corporations were founded in the 1970s to develop and sell systems for computer mapping and analysis. Today's two leading GIS software developers trace their roots to these early days, although at first each one emphasized two different aspects of the technology.

Intergraph Corporation of Huntsville, Alabama, focused on efficient input and storage of GIS data, as well as the preparation of computer-generated maps that rivaled traditional maps for their cartographic quality. The Environmental Systems Research Institute (ESRI) of Redlands, California, focused on providing a "tool kit" of computer commands for the analysis of GIS data. Over the years, both companies have rounded out their systems' respective capabilities.

At first, only the largest government agencies, utilities, and corporations could afford GIS because of their expense. Based on mainframe and minicomputers, a typical GIS workstation cost the owner more than $100 thousand, considering all of the hardware, software, and training involved. Nonetheless, the market for GIS expanded steadily in the early 1980s, as trade magazines, conferences, and professional associations spread the word of its benefits. It mushroomed, however, with the advent of the personal computer. GIS software was quickly adapted to this new, less expensive "platform," and the cost fell within the reach of many more users.

Even then, GIS was used primarily by a select few who had both the GIS software on their computer and the training to use it. Although tens of millions of dollars had been invested in GIS databases built from paper maps, aerial photographs, and satellite imagery, this data was still largely inaccessible until GIS specialists plotted it out on paper to distribute it. Then in the 1990s the Internet threw the doors to this valuable GIS data wide open to the public.

Today there are hundreds of web sites that publish "live" GIS data on the World Wide Web. Literally anyone who can use a web browser can now access and view GIS data. As a result, the worldwide market for all GIS products and services was about $7 billion in 1999, split almost evenly between sales in North America and the rest of the world, and is growing nearly 13 percent per year, according to Daratech, a computer market research firm.

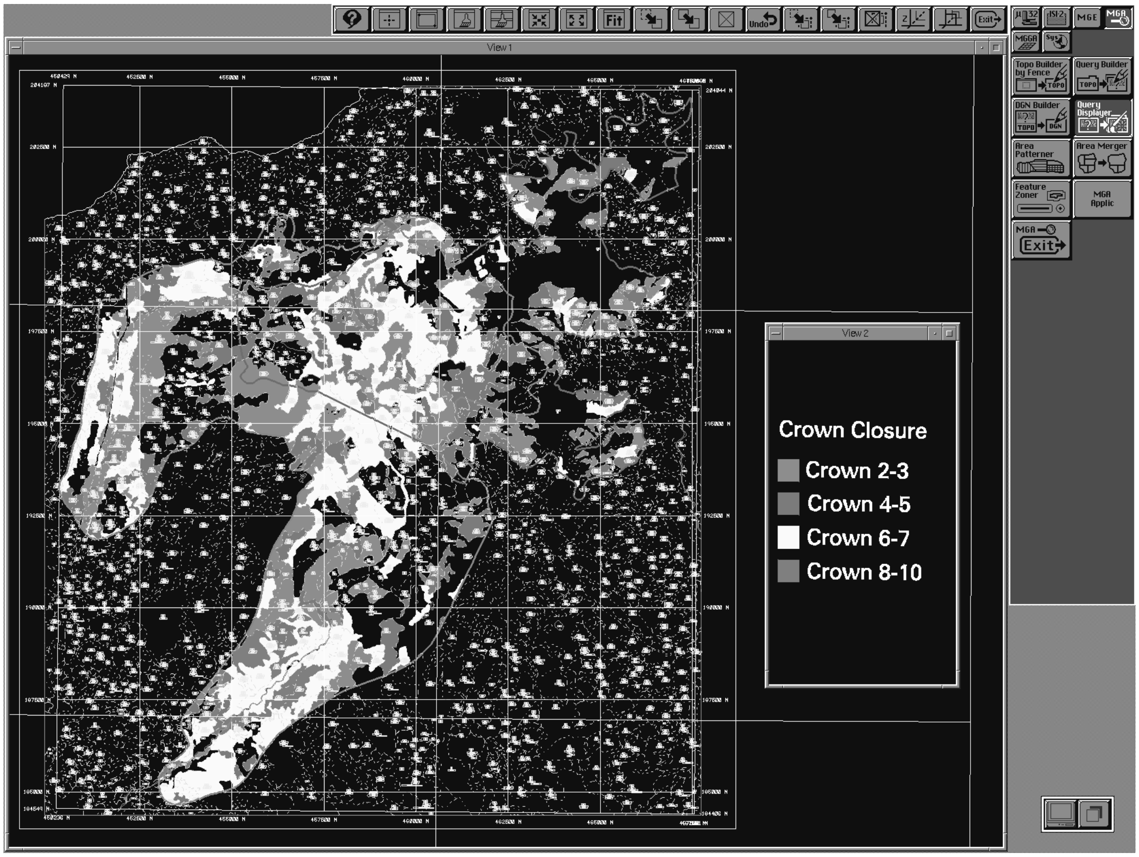
The typical GIS is founded on several basic concepts. First, real-world features on the earth's surface are related to a map grid coordinate system and recorded in the computer. The computer stores the grid coordinates of these features to show where they are, and the attributes of these map features to show what they are. Second, map features can be displayed or plotted in any combination and at virtually any map scale, making computerized mapping data far more flexible to use than traditional paper maps. Third, the GIS can analyze the "spatial" (locational) relationships among map features. Thus, the GIS can determine how many acres of land zoned for commercial use are located within a town's flood plain.

The Many Uses of GIS

The Willapa Bay area, located in the southwest corner of Washington state, boasts abundant natural resources that support thriving timber, oyster, and fishing companies, as well as fertile soils for farming and an ideal environment for cranberry bogs. In 1992, local residents formed the Willapa Alliance to find an effective means of managing and preserving these natural resources on which they depend for their livelihood. The alliance used a GIS to map and analyze an area roughly the size of Rhode Island. The GIS provided data about the health and status of the region's ecosystem in a format that enabled the members of the alliance to understand the environmental issues affecting the bay area.

Data from dozens of sources were consolidated on 80 GIS overlays, and then used to examine the various factors that affect local industries. These include geological, environmental, biological, and developmental factors, as well as fishing, forestry, and farming practices, such as the use of pesticides. Moreover, changes in these factors can be monitored over time, providing a tool for measuring the impact of policy decisions.

"All this data would have been impossible to analyze without GIS," says Allen Lebovitz, natural program resource director of the Willapa Alliance. "We're also using it to present very complex and technical data to the average person," he adds. "So far, we have learned that there are definitely some (areas) that will never be highly productive regardless of management. That's important in deciding where you want to spend your conservation and restoration resources." The following illustration shows GIS data for a forested area.



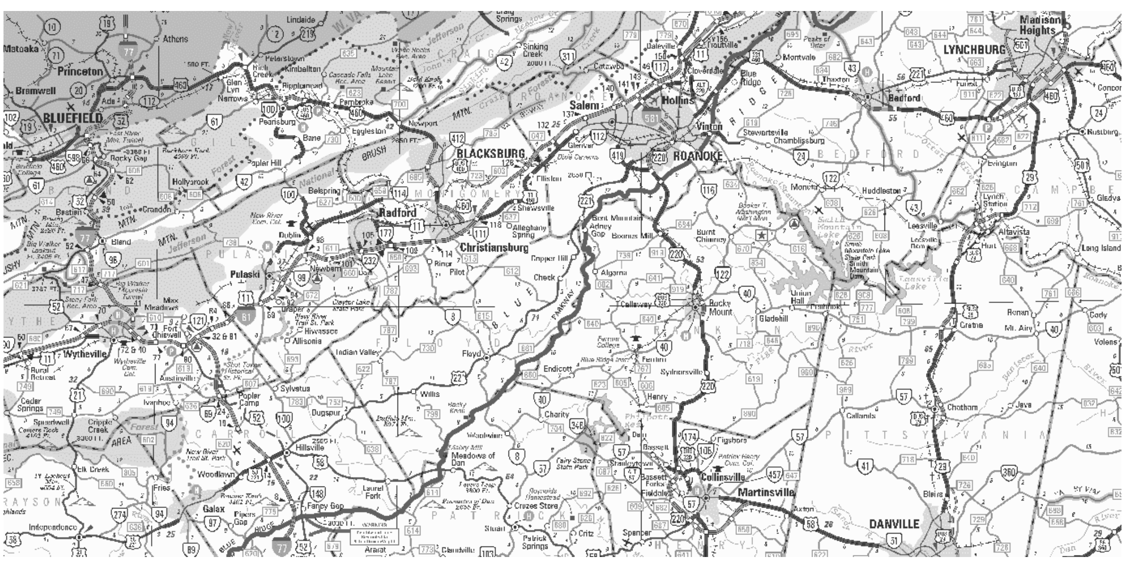
Forest data in a GIS.

In 1984, a propane truck accident caused a four-hour shutdown of the Cross-Bronx Expressway in New York City. The New York Port Authority police were first on the scene, followed by the city's fire and police departments, then the New York State Department of Transportation; however, the ensuing disagreements between the agencies about jurisdiction and disposition of the accident slowed the overall cleanup and road-reopening effort. This and similar incidents prompted the formation of TRANSCOM, a consortium of 14 New York, New Jersey, and Connecticut transportation and public safety agencies located within a 50-mile radius of Manhattan.

The coalition transcends territorial boundaries to solve regional transportation problems, acting as an information clearinghouse for its members. TRANSCOM uses GIS as a tool to coordinate and speed the process. Member agencies notify the TRANSCOM operations center in Jersey City about traffic incidents, construction, and special events. This information is disseminated to other agencies, which view the TRANSCOM GIS data over a communications network to aid their planning and emergency response efforts.

At the local level, the New York City Department of Transportation uses GIS to help manage and maintain 6,500 miles of roadway, traffic signals at 10,000 intersections, 63,000 parking meters, 300,000 streetlights, and 1.3 million street signs. Traffic engineers use GIS to map accidents and pinpoint problems, such as intersections with poorly timed traffic signals. The Division of Parking has used GIS to analyze the use and location of parking meters, as well as the most efficient routes for meter readers.

The Bureau of Bridges maps bridge locations, and engineers can point to a bridge displayed on the GIS to retrieve close-up photographs of its structural details. The Highways Operations Division tracks potholes and planned utility construction projects to help schedule roadway paving projects. "The department has few doubts about the benefits if the GIS effort," reports Fred Cohn, the deputy director of the city's Department of Transportation responsible for the GIS. "The system has paid for itself." The following illustration shows a detail from a Virginia Department of Transportation highway map generated from a GIS.



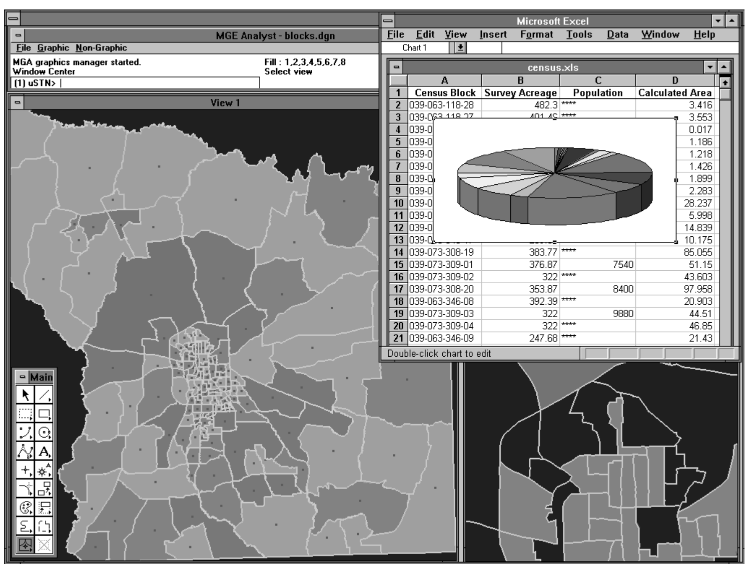
Highway map generated by a GIS.

Business has also turned to GIS to help develop market strategies, determine the best locations for new retail stores, fine tune product delivery routes, dispatch taxis and service trucks, and analyze sales territories. For example, direct mail firms use GIS to help find those households most receptive to the products they market. According to the Direct Marketing Association, advertisers spend more than $30 billion on direct marketing yearly, with direct mail accounting for a large percentage of this figure. Atlanta-based Cox Enterprises is one of the largest media companies in the nation.

One subsidiary, Cox Direct, conducts cooperative mailings (multiple advertisers sharing the cost of printing, postage, and production) in brown envelopes to 30 million homes 10 times a year. The envelopes contain promotional offers for household products, including medications, shampoo, cleaning products, and food. Cox Direct breaks down its large address database into subsets based on demographic data available from the U.S. Census Bureau.

This data is summarized for each census block, and includes household data on marital status, family size, age, income, education, race, and so forth. Cox Direct analysts help clients draw profiles of their ideal consumers, then determine the addresses that best fit those profiles. "One of the ways we use GIS is to simplify the process of making those matches," says David Zeph, Cox information technology manager. The following illustration shows census data analyzed by a GIS.

Census data analyzed by a GIS.

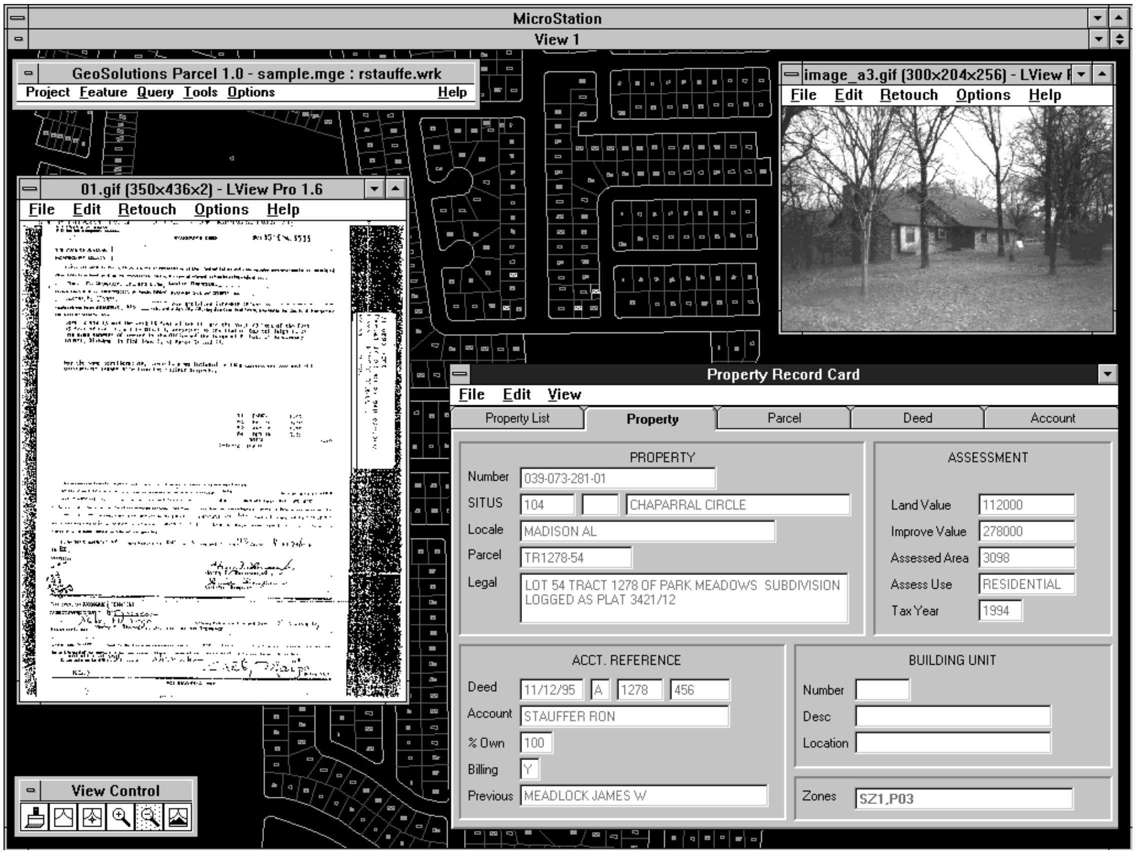


When Hurricane Andrew came ashore in southern Florida on August 24, 1992, it left behind not only human suffering but property losses and damages estimated at $15.5 billion. Property and business owners who were insured filed claims in record numbers. For insurance companies with policyholders concentrated in the hurricane's path, the settlements were staggering and seriously affected their financial stability.

Therefore, insurance companies have turned to GIS to help predict and model catastrophes, to avoid concentrations of policies in areas of high risk exposure, to determine the amount of risk to transfer through reinsurance (selling policies to a secondary underwriter), and to help in the pricing of both the original policy and the reinsurance contract. They can analyze natural risk factors such as flood-, fire-, tornado-, and earthquake-prone areas, as well as crime rates, accident frequency, and the availability of fire protection. They can use this data to help evaluate the risk of insuring a property.

For example, an application for property insurance from a chemical factory located near a major geologic fault and across the street from an elementary school would probably be turned down. According to David Langdon, a systems analyst in the Weatogue, Connecticut, office of Tillinghast, a worldwide actuarial and risk management consulting firm, "With the help of GIS, insurance companies are finding it easier to analyze, visualize, and prepare for the many issues in today's insurance market."

Today, municipalities and utilities throughout the nation have generally embraced the concept of GIS, hampered only by the tremendous cost of converting mountains of paper map data to a computer format. Wake County, North Carolina, encompasses 12 municipalities within 864 square miles. The county tracks more than 184,000 tax parcels representing a population of 460,000. The county's planning and assessment departments first implemented GIS to manage property records, including tax parcel, zoning, and land-use maps. An example of tax assessment data retrieved by a GIS is shown in the following illustration.



Tax assessment data retrieved by a GIS.

Today, the GIS database is used by numerous other departments and agencies, including the Fire Services, Inspections, and Emergency Management departments, as well as the county school system, the Board of Elections, and the Soil and Water Conservation Service. Several cities and towns within the county, including the city of Raleigh, use its GIS data as an accurate foundation upon which they can add specifics about their own infrastructure, including water and sewer lines, roadways, utility networks, administrative districts, and so forth.

Charles Friddle is the Wake County GIS director: "Overall, the system is improving the county's responsiveness to our municipalities and the public we serve. With GIS, we not only save money by consolidating information, but we are now poised to provide those who need geographic information with a means to access it."

Likewise, utilities such as West Ohio Gas in Lima, Ohio; Pacific Bell of San Francisco, California; the Washington Suburban Sanitary Commission of Laurel, Maryland; and Consumers Power Company of Jackson, Michigan, are using GIS to automate the "outside plant" records of their telephone, cable TV, gas, electric power, water, and sanitary sewer systems.

These GIS are not only mapping the location and attributes of the utility networks, they are used in the planning, design, and construction of new lines, to dispatch repair crews, to route meter readers, to schedule maintenance and repair work, and to answer customer inquires. "West Ohio Gas must reduce costs to become more efficient, while simultaneously offering new services and improving customer service," says Ty Lotz, the company's superintendent of engineering. "GIS is helping us to do this." The following illustration shows details from an electric utility's GIS.

Electric utility data in a GIS.

An Industry Leader's Comments

Larry Ayers is Executive Vice President of Intergraph Corporation's Mapping Sciences Division. Asked about the most interesting GIS application he's been involved with, he replied, "A military base is like a small city, but with only one landowner, one landlord, and one owner of all the utilities. The management of one of these bases is complicated enough, but is made even worse by the very unusual, sometimes dangerous, things that go on there. The military, Patrick Air Force Base in Florida is one example, has used GIS to bring together all types of information about its property and assets and put it right at the base commander's fingertips."

Asked about the future of GIS, he replies, "So far, GIS has been a specialty in the world of computer science, used by a small group of experts. In the future it will be just another computer function to aid in decision-making. I suppose the average homeowner might use it to plan the itinerary for Saturday morning errands."

This prediction might be so far-fetched, because the forerunners of "GIS for the common man" are already here. For example, a program from Road Scholar of Houston, Texas, (called City Streets) provides street addresses and locations in more than 170 metropolitan areas. It gives details down to one-tenth of a mile, including streets, intersections, and addresses. Using the Washington, D.C., database, a tourist marks the sights she wants to visit and the route she wishes to take. The program calculates the distances from point to point, shows which routes can be traveled by car or taxi, and which ones require walking.

Rental car leaders such as Hertz and Avis provide vehicles equipped with "in-vehicle navigation" systems. The systems combine GPS technology with GIS to pinpoint the vehicle's location on a map displayed by a small computer screen mounted on or under its dashboard. They provide an address finder, place finder, and city finder to help the driver locate his destination. Hotel, restaurant, and entertainment locations are also available. Ordinary citizens can even take advantage of large, sophisticated GIS databases.

Kevin Byrne, a teacher at the Minneapolis College of Art and Design, visits the Ramsey County, Minnesota, Public Works Division. After a brief visit with a county GIS technician, he leaves with a computer file on a small diskette that was extracted from the county's massive GIS database, one of the largest in the state. He manipulates the file on his Macintosh computer to produce maps of his Midland Hills neighborhood in Rosedale, Minnesota, for its Crime Watch committee.

GIS applications are also appearing on the Internet. Web sites such as MapQuest (*http://www.mapquest.com*) and MapBlast (*http:/www.mapblast.com*) provide quick and simple maps. Users can enter a postal address to recall a map of the area around that location, and view "points of interest," including landmarks and public services.

Summary

One problem facing GIS users today is the many different formats in which GIS data is stored. This can make it difficult to merge data from different sources, or for someone using one GIS software program to read the data created using another program. David Schell, President of the Open GIS Consortium (OGC) of Wayland, Massachusetts, is leading an effort to standardize the means of reading and using GIS data: “The exciting thing [about GIS] is that geographic information really is valuable in many human endeavors, and with GPS, high-resolution satellite images, the Internet, and the simple fact that layers of data for the earth’s sphere accumulate, we’re rapidly entering an era in which geographic information will play a more important role.”

Another dramatic example of that role is the use of GIS as a tool for disease control. Recent outbreaks of Ebola virus in Zaire; cholera in India, Bangladesh, and Latin America; dengue fever in Australia and Central America; and Hantavirus in the American Southwest have focused public attention on emerging and reemerging diseases. Researchers have found that epidemics of new diseases, as well as the resurgence of age-old afflictions, are partly linked to the environment.

GIS helped researchers in Mexico study the relationship of the landscape to malaria in isolated areas plagued by the disease, and then create maps showing malaria risks over large regions. This enables public health agencies to target their resources they are most needed. Likewise, a UNICEF-sponsored study in West Africa used GIS to map villages with high rates of Guinea-worm disease and evaluate the effectiveness of policies designed to combat its spread. The analysis demonstrated the power of GIS to determine areas with a high disease prevalence and a large number of cases.

It was also useful for identifying and locating areas that are most in need of assistance. “Areas of high infection can be identified, and programs such as health education, Guinea-worm intervention, and water supply treatment can be targeted for these areas,” says Barbara Tempalski, a GIS technician in the Department of Geology and Geography at Hunter College in New York City that worked on the project. “The opportunities for using this technology in epidemiology and disease-related fields are immeasurable.”

Larry Ayers believes that in the future GIS will be almost as prevalent as computers themselves. “Employees who learned to use word processing and spreadsheet programs over the past ten years will be learning to use GIS in the next ten.”