CKIS—GIS in Cave and Karst Management

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Abstract

A Cave and Karst Information System (CKIS) is a specialized type of geographic information system (GIS). Common tasks and issues are found in developing a CKIS when compared with other types of GISs, but developing a CKIS also presents a unique set of problems, issues, and considerations. ArcView GIS is a popular desktop GIS software product that includes tools, extensions, and customization capabilities that provide a robust framework for data management and visualization of cave survey data and inventories, as well as a substrate for both analytic and interpretive applications. Several prototypes have been implemented that have demonstrated the usefulness of cave and karst information systems and ArcView GIS. Preliminary work has yielded specialized code and techniques for visualization and data management. This work has also identified issues and shortcomings that future work will need to address.

In recent years the significance of karst and caves has achieved widespread recognition. As pointed out by the National Park Service's National Cave Management Coordinator, Ronal Kerbo, cave and karst systems are important for two major reasons:

Firstly, most of the nation's freshwater resources are groundwater. About 25% of the groundwater is located in cave and karst regions. The National Geographic Society notes that water resources are a critical concern as society enters the 21st century. The protection and management of these vital water resources are critical to public health and to sustainable economic development.

Secondly, caves are storehouses of information on natural resources, human history, and evolution. Many avenues of research can be pursued in caves. Recent studies indicate that caves contain valuable data that are relevant to global climate change, waste disposal, groundwater supply and contamination, petroleum recovery, and biomedical investigations. Caves also contain data that are pertinent to anthropological, archaeological, geological, paleontological, and mineralogical discoveries and resources.

None of the components of this interlocking set of resources can be wisely managed without understanding their systemic relationships with the many other components. Understanding, protecting, managing, and conserving such an extraordinarily rich and complex set of resources requires tools capable of integrating, manipulating, and querying the information used to describe their many facets.

In 1997, recognizing that Geographic Information Systems (GIS) technology was rapidly becoming one of the most effective approaches to cave and karst resource management, the Cave Research Foundation established a GIS Resource Development Program under the direction of Mike Yocum. The goal of the program is to assist Cave Research Foundation personnel, federal agency staff, and other researchers access and utilize spatial data, GIS applications, and other software tools for the purpose of cave and karst resource management. A longer-term goal is to use GIS to develop a collective knowledge and support base for cave conservation, protection and management.

The importance of cave and karst research was also recognized at leading GIS software vendor Environmental Systems Research Institute (ESRI), with the establishment of an ESRI Cave and Karst Conservation Program and an ESRI Cave and Karst Special Interest Group coordinated by Bernie Szukalski, an Environmental Systems Research Institute Product Manager.

The Cave Research Foundation GIS Resource Development Program is drawing together GIS expertise to assist in the development of Cave and Karst Information Systems (CKIS). Cave Research Foundation GIS personnel include individuals with broad and varied expertise, who can provide resources, support, assistance, services, and tools to aid researchers both understand and effectively manage caves and karst.

Critical requirements in the CKIS development process are a survey of currently used software and methods, an inventory of existing data and data formats, a user needs assessment, a knowledge of training needs, and the initiation of a core CKIS prototype that can be tested and elaborated to provide specific tools and applications suited to the varying needs of different users.

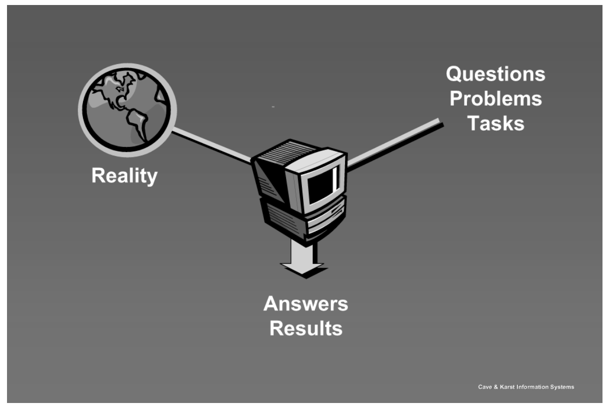
As a first step in developing a prototype CKIS, the Cave Research Foundation, in cooperation with the Kentucky Office of Geographic Information Systems, convened a CKIS Workshop in Frankfort, Kentucky on November 12 and 13, 1998.

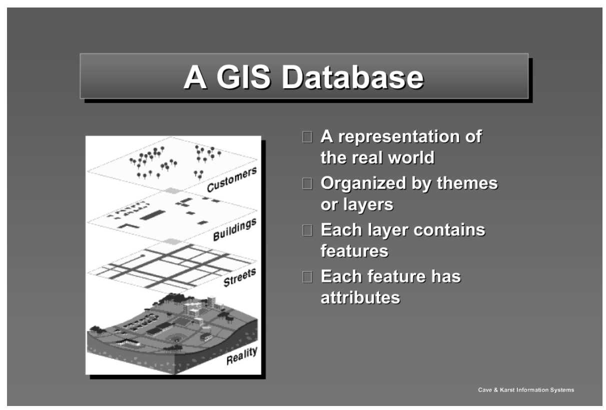
The workshop was devoted to discussing common GIS goals and problems, as well as individual needs of the agencies represented, which were: the Cave Research Foundation, the Center for Cave and Karst Studies, Ewers Water Consultants, Environmental Systems Research Institute, the Kentucky Division of Water, the Kentucky Geological Survey, the Kentucky Office of Geographic Information Systems, the National Park Service, and NCAD Corporation.

Meeting activities included a demonstration of some of the possible uses of ArcView GIS for managing, querying and analyzing data; discussions of methods participants currently use for managing cave and karst data; hardware; software, and data types and formats.

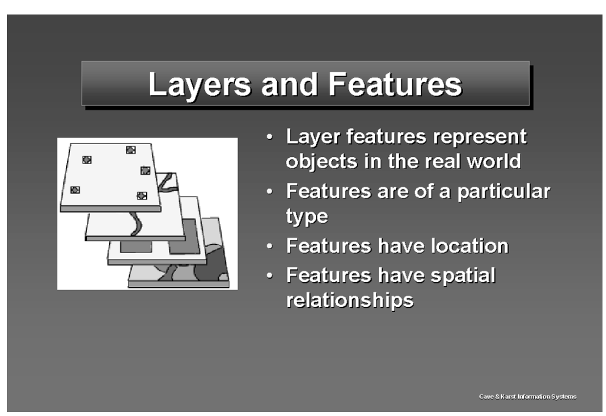
This meeting highlighted the need for both an introduction to GIS and to the potential uses of specialized GIS applications that focus on caves and karst.

What is GIS? GIS is a technology that incorporates various kinds of data and relates them to spatial data, enabling visualization of relationships among the various data sets. A GIS database is typically organized in various layers or themes that represent objects in the real world.

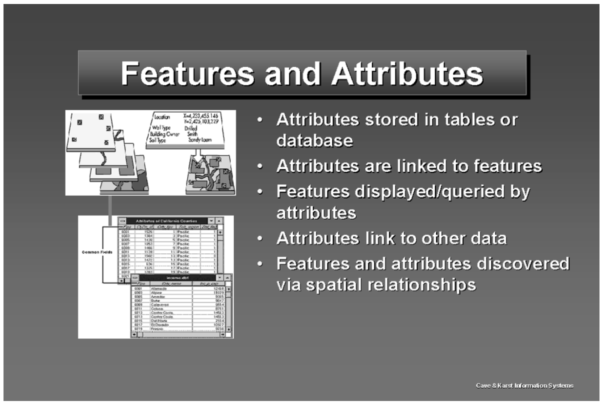




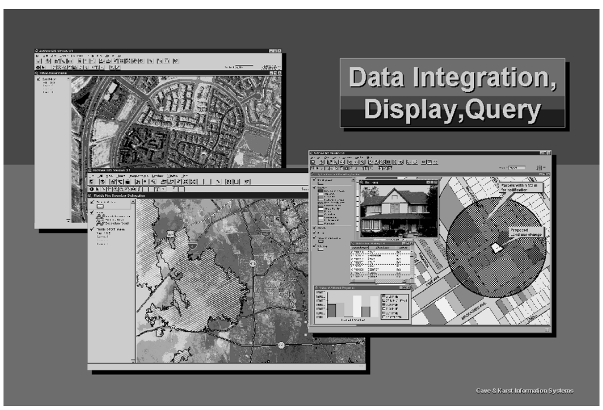
The range of data that is now routinely being integrated into GIS applications is enormous, as its usefulness is recognized in both government and private business. But regardless of the content, the data is organized in similar ways: layers or themes containing features that represent objects in the real world. The fea-

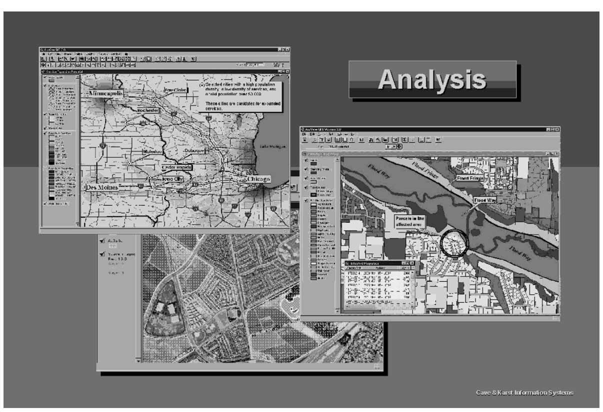


tures can be characterized by their attributes, which are stored in tables or databases linked to the features. The attributes can also be linked to other data. The features and their attributes can be displayed and queried by their attributes.



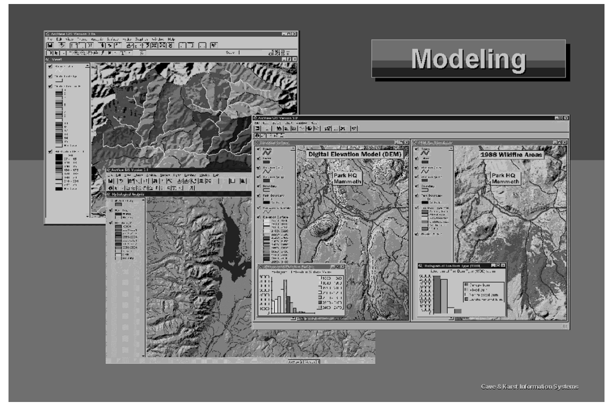
Using the tools provided by GIS software such as ArcView GIS and its extensions, data can be integrated, displayed, queried, and analyzed in many ways, depending upon the needs of the user.

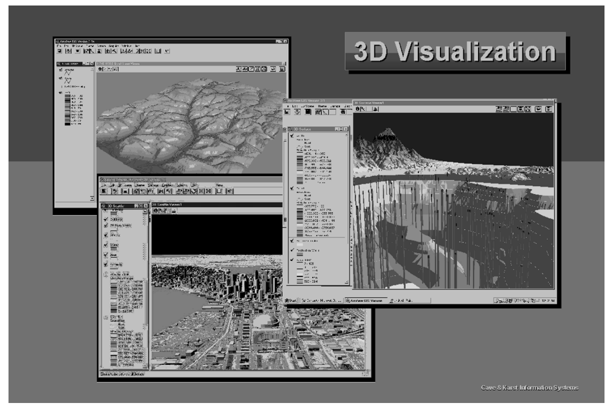




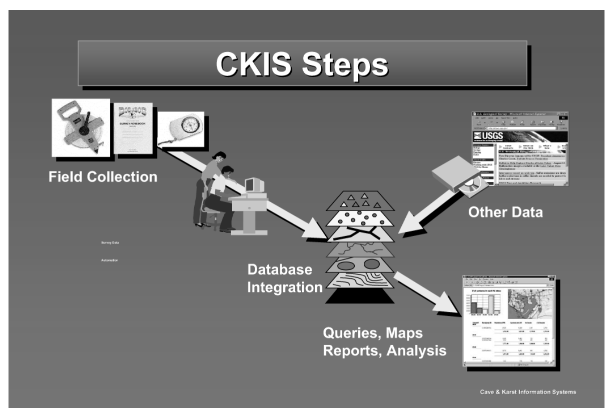
Data can also be used for modeling and visualization.

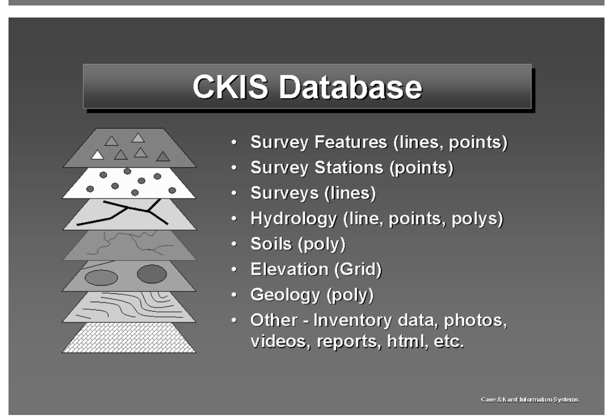
The first steps in building a cave and karst information system are to collect and integrate





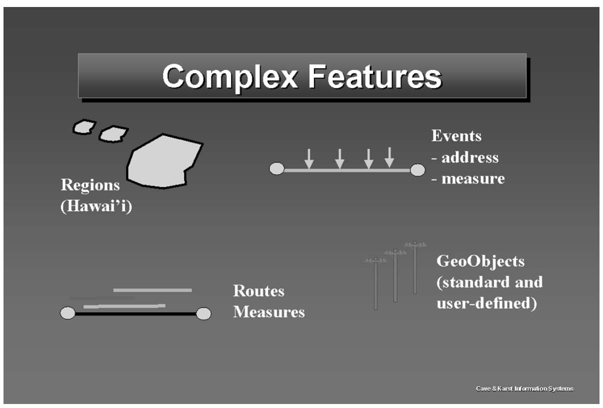
data. This begins with the collection of cave survey data in the field, adding other types of data as needed for the particular application.

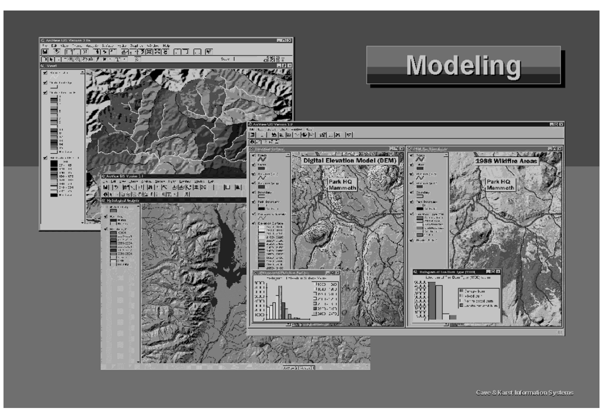




Data types can include such varied items as date, time, yes/no (presence or absence of data item), feature type (e.g., swallet), matrix, x-y coordinates, x-y-z coordinates, flow velocity, discharge rate, solute concentration, temperature, specific conductance, pH, stage (level), relative humidity, wind speed, wind direction, evaporation rates, number (e.g., of a species), air quality indicators, or microgravity readings. In addition to cave related data, the project may also include many types of surface data such as biological data for fire management or vegetation studies.

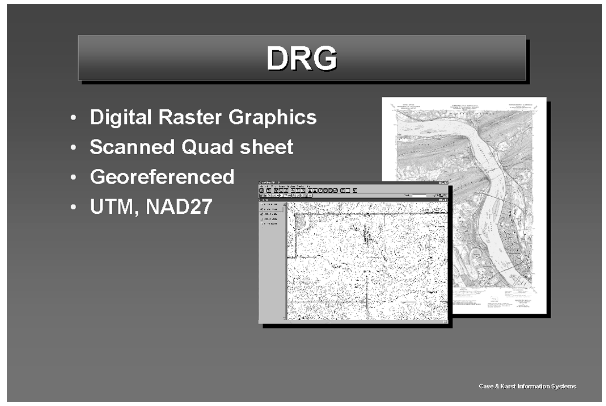
The format of the data included in the project may depend upon the nature of the output required for the final product. Are the features to be analyzed simple or complex? Does the project need raster or vector data?

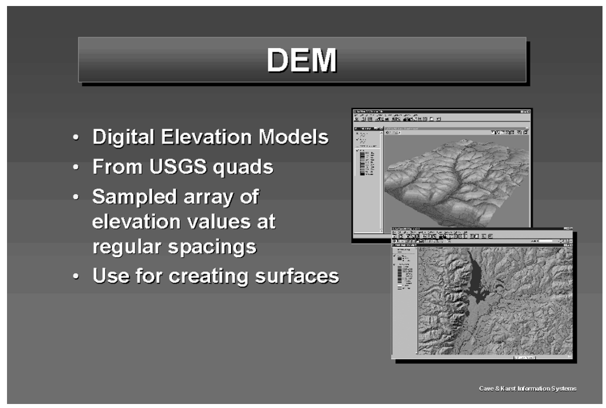


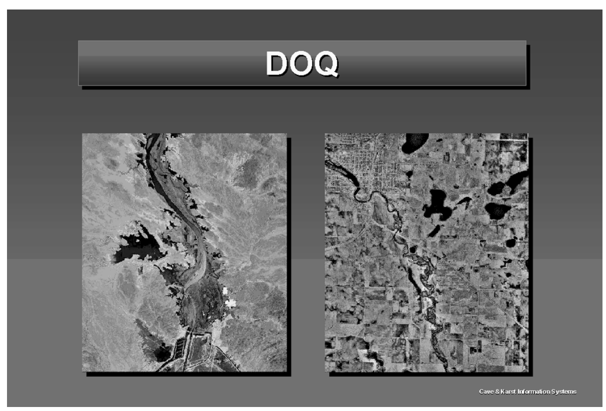


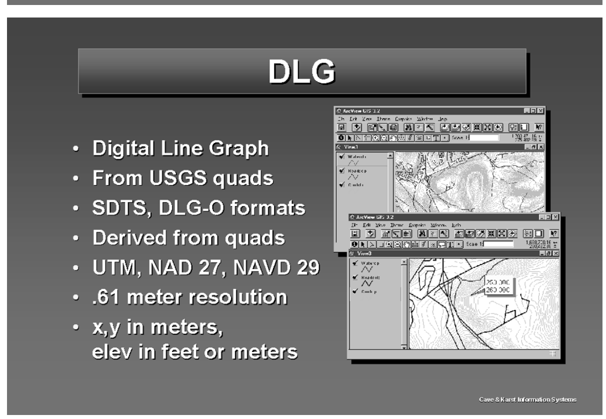
Of particular interest for cave and karst studies are the various types of surface data available from the U.S. Geological Survey. The formats are DRG, DEM, DOQQ, and DLG.

The DRG (Digital Raster Graphic) is simply a scanned and georeferenced topographic sheet. The DEM (Digital Elevation Model), a sampled array of elevation values at regular spacings, is a georeferenced raster format used for creating surfaces. The DOQQ (Digital Ortho Quarter Quadrangle) is a georeferenced aerial photograph. The DLG (Digital Line Graph) is derived from USGS topographic quads, and displays contour lines with their elevations as attributes.

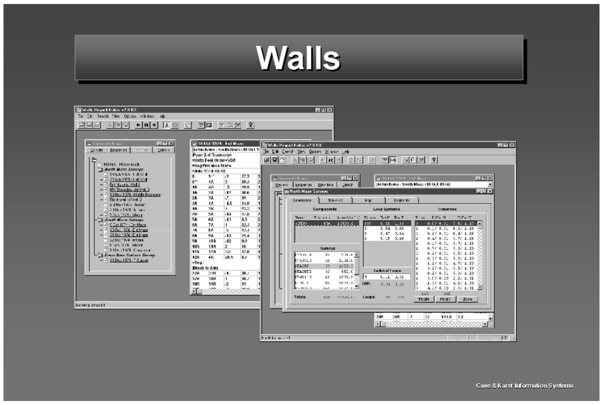


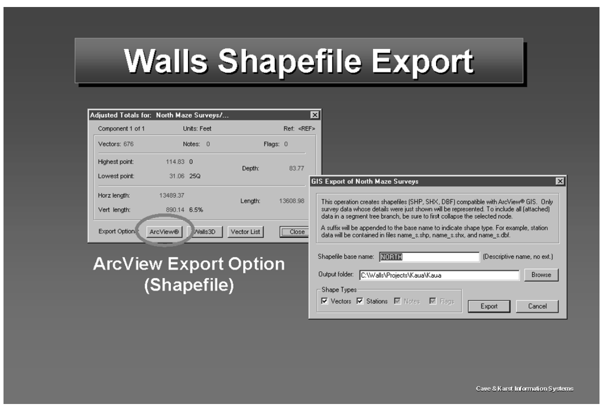




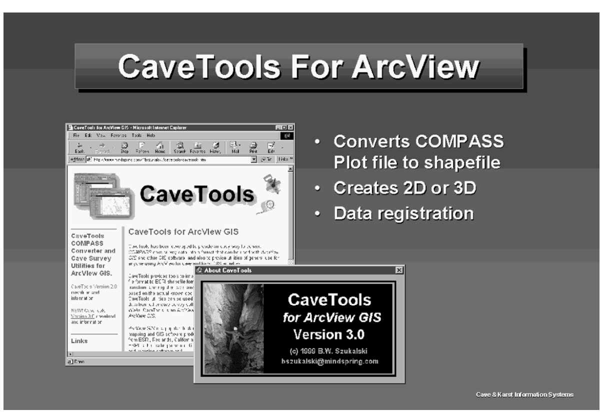


To integrate cave survey data into an ArcView GIS application it needs to be converted to a shapefile format. Currently there are two ways of doing this. Walls, by David McKenzie, exports shapefiles directly.

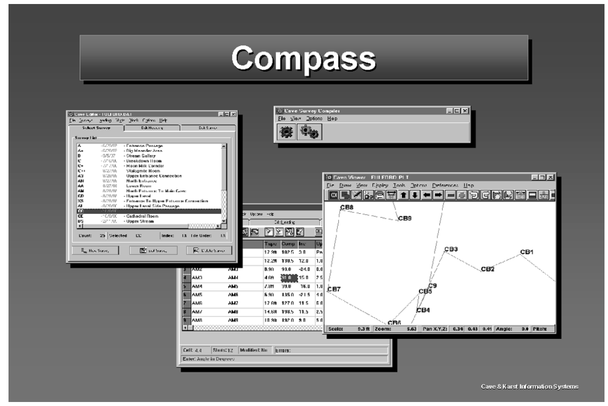




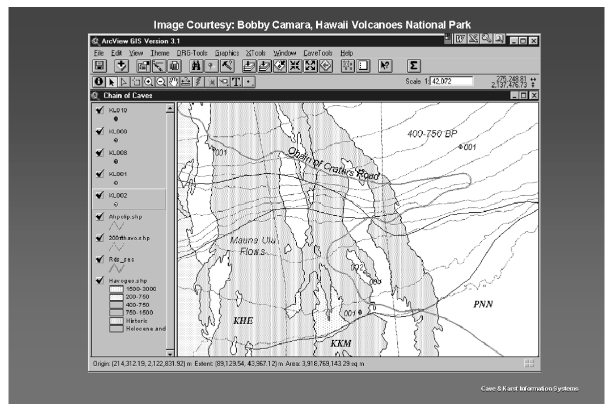
CaveTools, a free ArcView GIS extension, developed by Bernie Szukalski, converts the plot file output from Larry Fish's Compass program to shapefile format. CaveTools also allows registration of any station for which the real world coordinates are known, as well as an x, y or z shift of the shapefile.

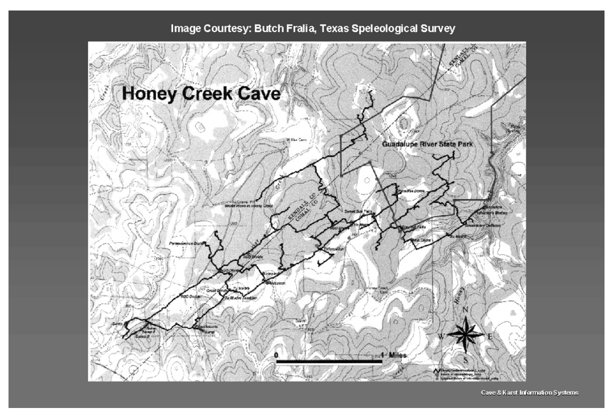


Once the cave survey data has been converted to a GIS compatible format, integration with other data types can take place. The sim-



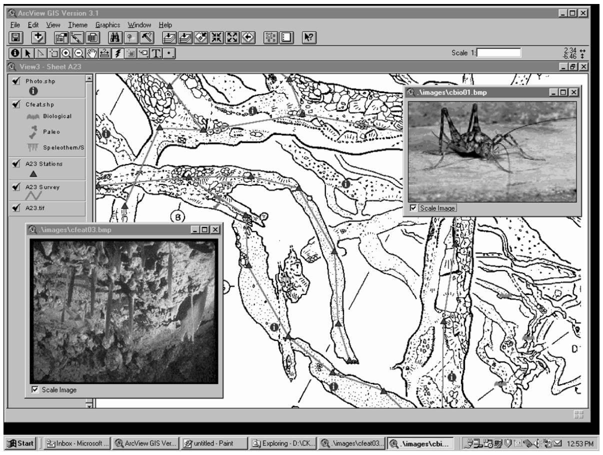
plest display is simply cave survey data as a shapefile line plot, which can be either two- or three-dimensional. This can be overlaid on other data as shown below.

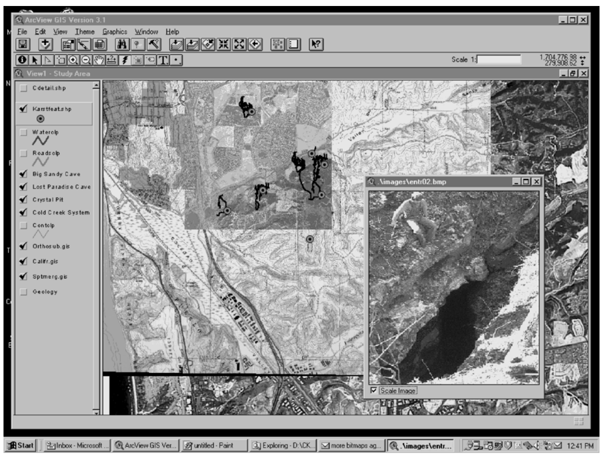


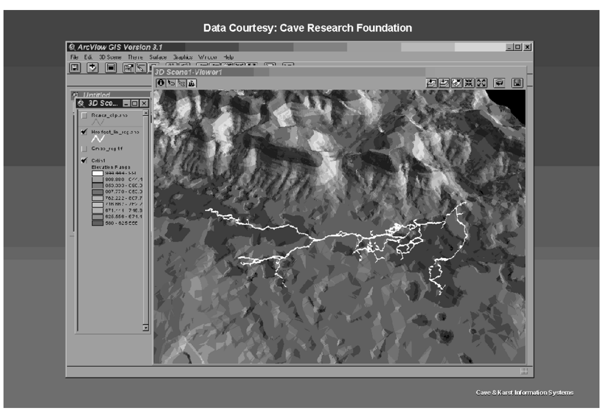


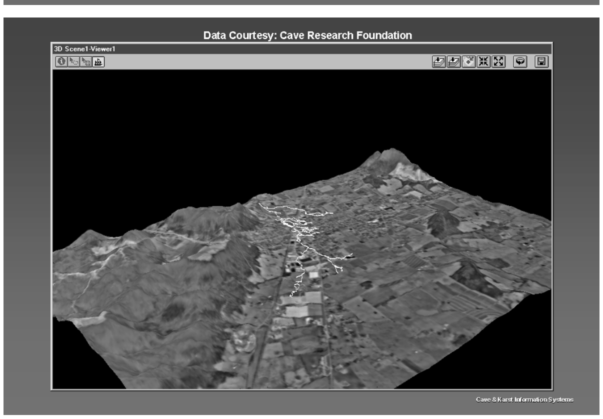
Uses and data types will vary with the needs of the project. GIS can incorporate not only tabular data, but also graphics files and even video (AVI files) that can be linked to specific features.

One of the currently most popular uses for cave survey data in GIS is three-dimensional visualization. The examples below show Hidden River Cave, in Horse Cave, Kentucky. On the left the shapefile of the cave survey data is overlaid on a relief map of the area. On the right the same shapefile is overlaid on a DOQQ which in turn is draped over the relief map.

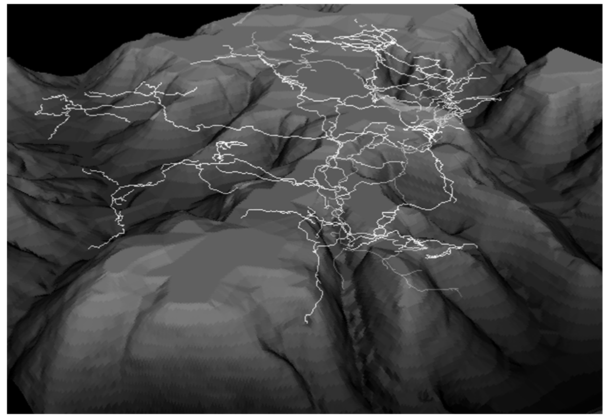


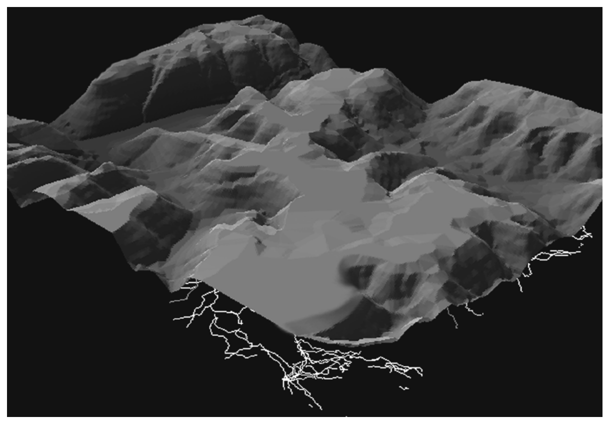






The images below also illustrate three-dimensional visualization. Both show aspects of the Mammoth Cave system in Kentucky.





The use of GIS in cave and karst resource management is at the earliest stages. The primary challenges facing those who would use it are gaining familiarity with GIS software and collecting and storing data in a format that is sufficiently standardized for GIS application. In terms of the software's capability, it is a trivial matter to query: "Find all springs with at least 20cfm flow within 500 feet of the quartzite/marble contact that are located within 1,000 feet of a fault and within a zoning area permitting industrial usage." In terms of data availability and compatibility, that query would be difficult for most researchers.

At this stage, resource managers who are contemplating the use of GIS need to consider several issues:

- the questions that researchers seek to answer by querying data,
- data layers (themes) that might be included,
- existing types and formats of data,
- a "candidate" list of suggested data fields, along with their source,
- metadata, and
- the possible need for systems management and support in developing cave and karst specific GIS applications.