Geographic Information Systems In Emergency Management

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Introduction

Geographic Information is information which relates to specific locations. It involves the physical environment with data associated with it. **Geographic Information System** is an organized collection of computer hardware and software designed to efficiently create, manipulate, analyze, and display all types of geographically or spatially referenced data. A GIS allows complex spatial operations that are very difficult to do otherwise.

The term **geographic** concerns data that is related to geographic scales of measurement, and is referenced by some coordinate system to locations on the surface of the earth. Other types of information systems may contain details about location, but in a GIS spatial objects and their locations are the very building blocks of the system.

It is possible to use GIS to ask questions of the geographic database, obtaining "information" about the geography world. This represents the extraction of specific and meaningful information from a diverse collection of data, and is only possible because of the way in which the data are organized into a "model" of the real world.

The geographic information "system" involves the environment and allows data to be managed in association with geographic references and questions to be posed. In the most general sense, a GIS need not be automated (such as a traditional roadmap), but should be an integrated set of procedures for the input, storage, manipulation and output of geographic information. Such a system is most readily achieved by automated means.

A Geographic Information System (GIS) is thus a data handling and analysis system based on sets of data distributed spatially in two dimensions. It is a geobased or geocoded information system. It is an information system but one in which the data is geographically referenced. Thus a GIS would have a means of creating and editing lists of schools, hospitals, nursing homes, or shelters but also have the capability to display records in the tables in a graphic or map format.

The data sets may be map oriented, when they comprise qualitative attributes of an area recorded as lines, points, and areas (polygons). Lines, points, and polygons are used in a Vector format. A second type of format is image oriented; the data in this format has quantitative attributes referring to cells in a rectangular grid.

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GIS as a System

A GIS involves the following elements to use spatial data:

1. Input (encoding) (collection of phone listings, census information by geographic area – block groups or tracks -)
2. Data Management (storage and retrieval) and Analysis (GIS systems such as ArcView, MapInfo, GeoMedia, LandView / Marplot)
3. Output (Maps showing risk zones, vulnerable population, phone listings in vulnerable areas.)

As a system, a GIS stores, retrieves, manipulates, analyzes and displays these data according to user-defined specifications. Ideally the GIS is used as a decision support system involving the integration of spatially referenced data in a problem solving environment.

Risk analysis occurs in emergency management from two perspectives including ex ante (prior to the event) and ex post facto (after the event). Newkirk (1993) sees that a geographic information system provides critical views of potential disasters and their impact both prior to an event and in the post event analysis. His concern is that the commercial GIS encourage the user to assume that the data is exact. The system should be used to allow for a broader examination of the risks and their potential or actual (as calculated) impact. There is a need for the broad based emergency management community to have a risk assessment tool that allows for close examination of events and their outcomes.

Benefits of a GIS

Benefits center on providing information to enhance decision making associated with emergency planning, response, recovery, and mitigation efforts.

A GIS can provide regular maps of the local community and of areas of special interest to emergencency management.

A GIS can conduct spatial queries and display the results. Such queries could include: what residents are within a 100 year flood zone; which schools or nursing homes are within 300 yards of a rail line or major state highway; or how may people live within a 100 year flood zone.

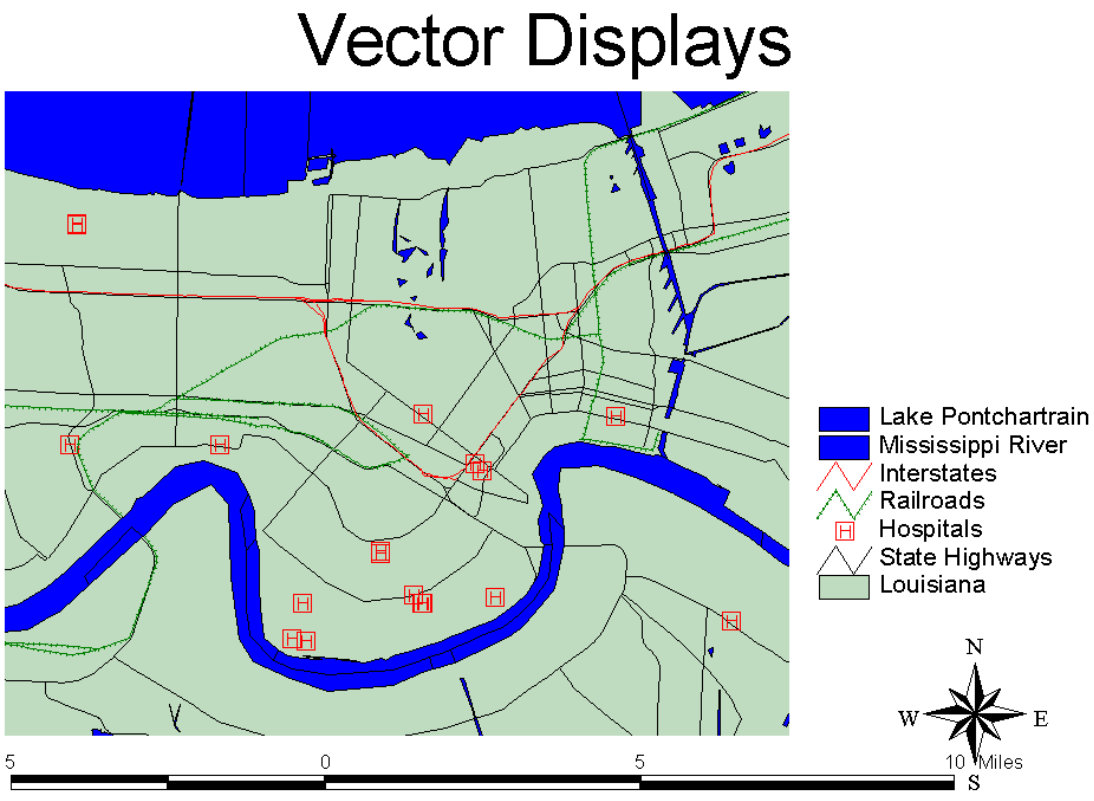
Conduct complex spatial analyses such as the area, residents, and businesses that would be vulnerable from a chemical release from a fixed facility or an intersection.

Geographic Spatial Object Concepts

Geographic information systems include graphics that illustrate the information about an area. Two types of data provide the basis for a GIS including vector and raster data.

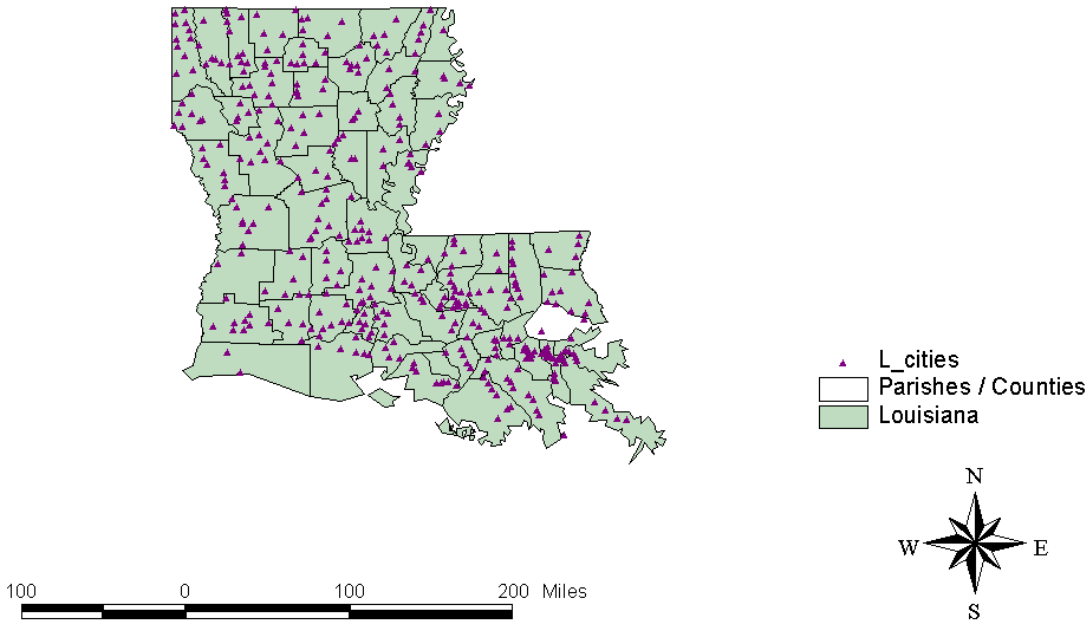
Vector Layers

Vector layers include a set of data including lines, points, and polygons. It is based on a coordinate-based data structure commonly used to represent map features. Each object is represented as a list of sequential x,y coordinates. Attributes may be associated with the objects. The illustration below includes lines such as streets or roads, the Interstate, railroads, and water features. Hospitals illustrate points on the map. The polygons include the boundaries of the City of New Orleans, Orleans Parish, Lake Pontchatrain, and the Mississippi River.

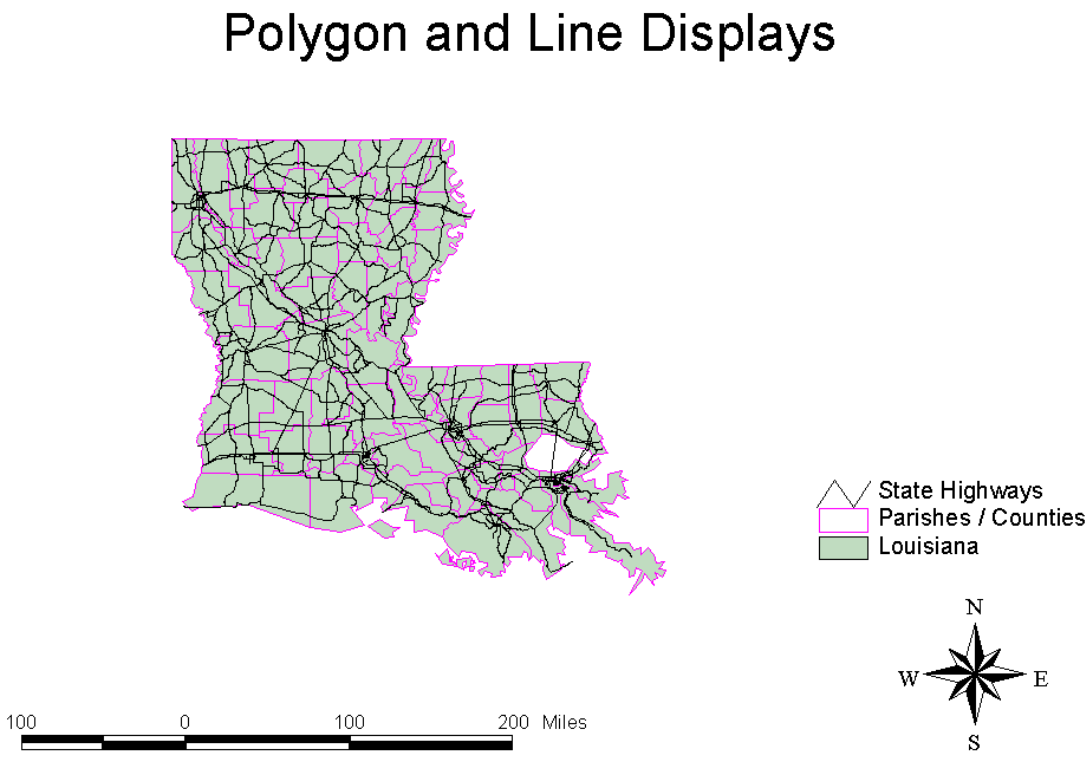


Point: An object on the map represents a specific location for information. The map object is defined by a single x,y coordinate pair. Each point object is represented by a symbol style (e.g., circle, square, triangle, etc.). The following map of Louisiana shows the location of cities in the state. The cities would be points on the map.

Polygon and Point Displays



Line: A straight line feature joining two points. The line is a map object defined by a set of sequential coordinates that may represent the generalized shape of a geographic feature (e.g., street centerlines, railroads, cables, stream or river). A street map is a collection of thousands of line segments joined together objects. The following illustration shows segments of the Louisiana State Highway system.



Polygon (area, parcel): A polygon is an area feature whose perimeter is defined by a series of enclosing segments and nodes. A simple bounded region, simple in the sense that it does not consist of more than one polygon (where a boundary can consist of more than one polygon).

Tiger Files

The Bureau of the Census developed TIGER (Topologically Integrated Geographic Encoding and Referencing System). Tiger Files are some of the best data layers available for GIS applications in emergency management. They were developed by the U.S. Department of Commerce Census Bureau to assist in the census. Street and water layers were taken from U.S.G.S. maps and edited to include street and water feature names. The street files also include address ranges. These files thus have been enhanced to allow for geocoding of data files that include street addresses. The Tiger files are the only national source of street files that include address ranges. Although many commercial vendors suggest that their maps are better than the

Tiger Files, in reality their maps were drawn from the Census Bureau Tiger Files. Few commercial vendors have really enhanced these files. If the Tiger Files have been enhanced, it has been done by local communities that know the street names and have spent great effort to correct street names, delete streets that are private roads, and add street names to "unnamed street" files. The editing of the Tiger Files must be done in collaboration with local officials.

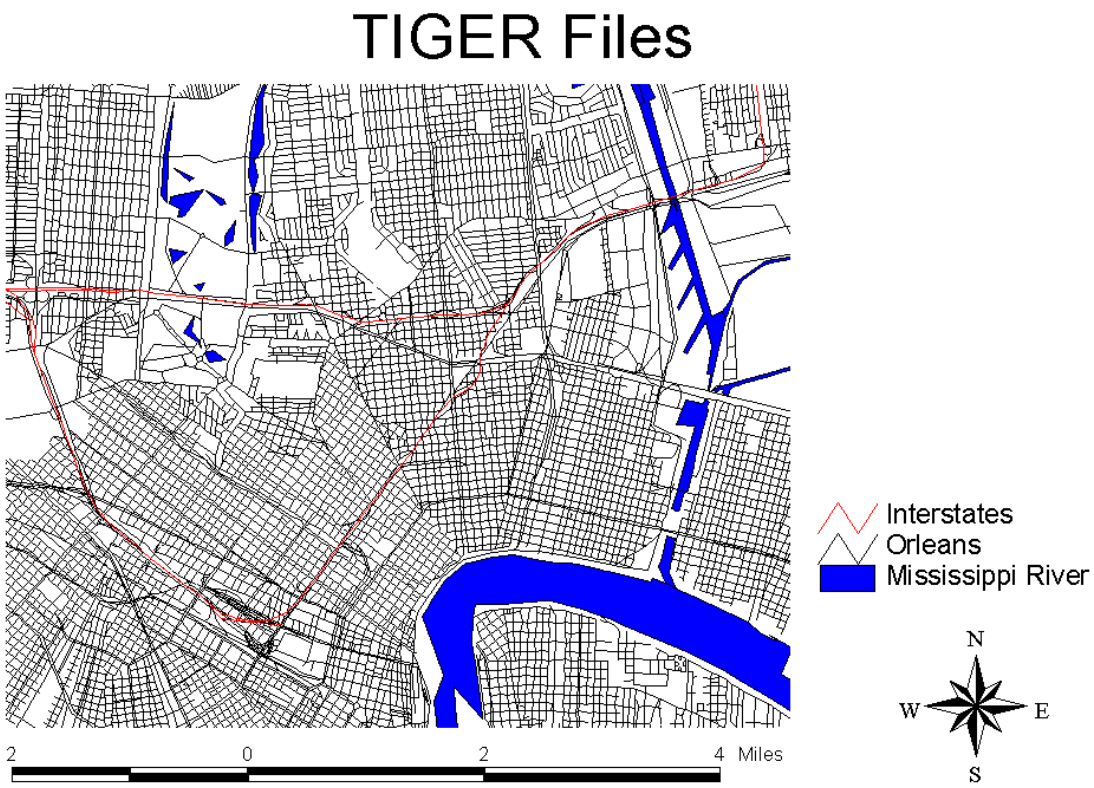
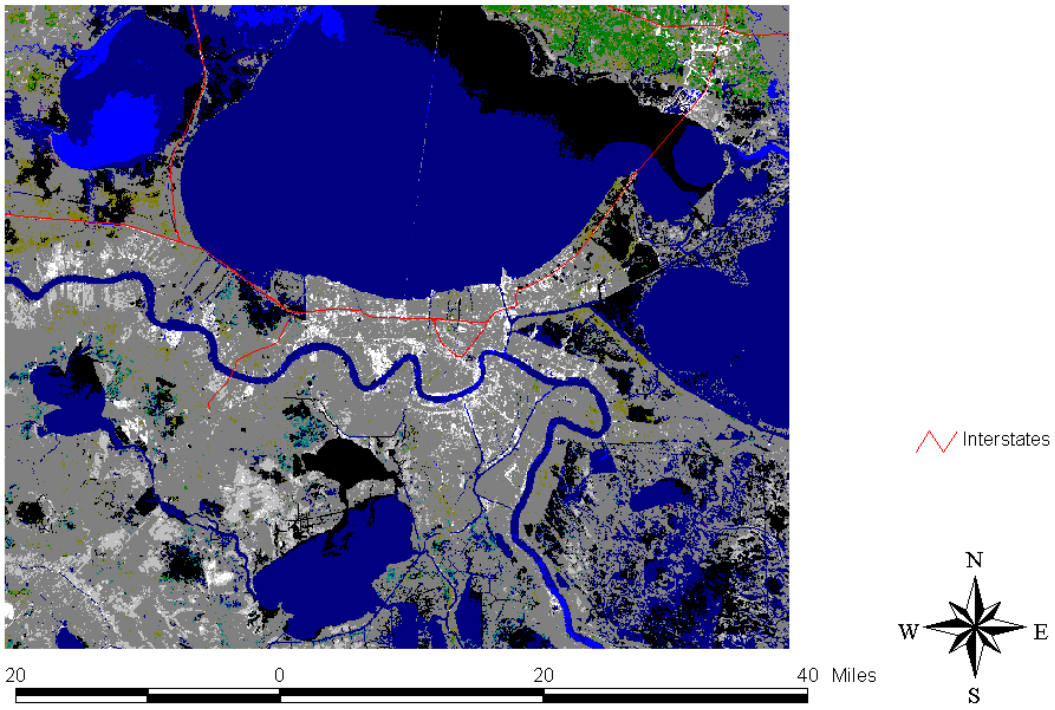


Image or Raster Data

Raster displays or image data is a graphic representation of an object that is typically produced by an optical or electronic device. Some common examples of image data include satellite images, scanned pictures, and photographs. It is a type of computerized picture consisting of rows of tiny dots (pixels). Raster images are sometimes known as bitmaps.

Raster Displays



With a GIS you can display image or raster data along with feature-based spatial data. The TIGER street network (feature-based data) can be placed over an image (photograph). Combining these types of data is very useful to the emergency manager.

A photo or satellite image is a **raster image**. It is a type of computerized picture consisting of row after row of tiny dots (pixels). Raster images are sometimes known as bitmaps. Aerial photographs, scanned pictures, and satellite images are common types of raster data found in GIS.

A U.S.G.S. Quad Sheet is a common map used by emergency managers. These maps appear to be similar to a state transportation road map available from state transportation or tourist agencies. The Quad Sheet Maps produced by the U.S. Geological Survey provide additional data beyond roads and water ways such as wetland areas. The detailes of local areas are available on a national basis from the U.S. Geological Survey as well as from many local

surveying, mapping, or blueprint vendors. The following illustration was scanned from a U.S.G.S. quad sheet.

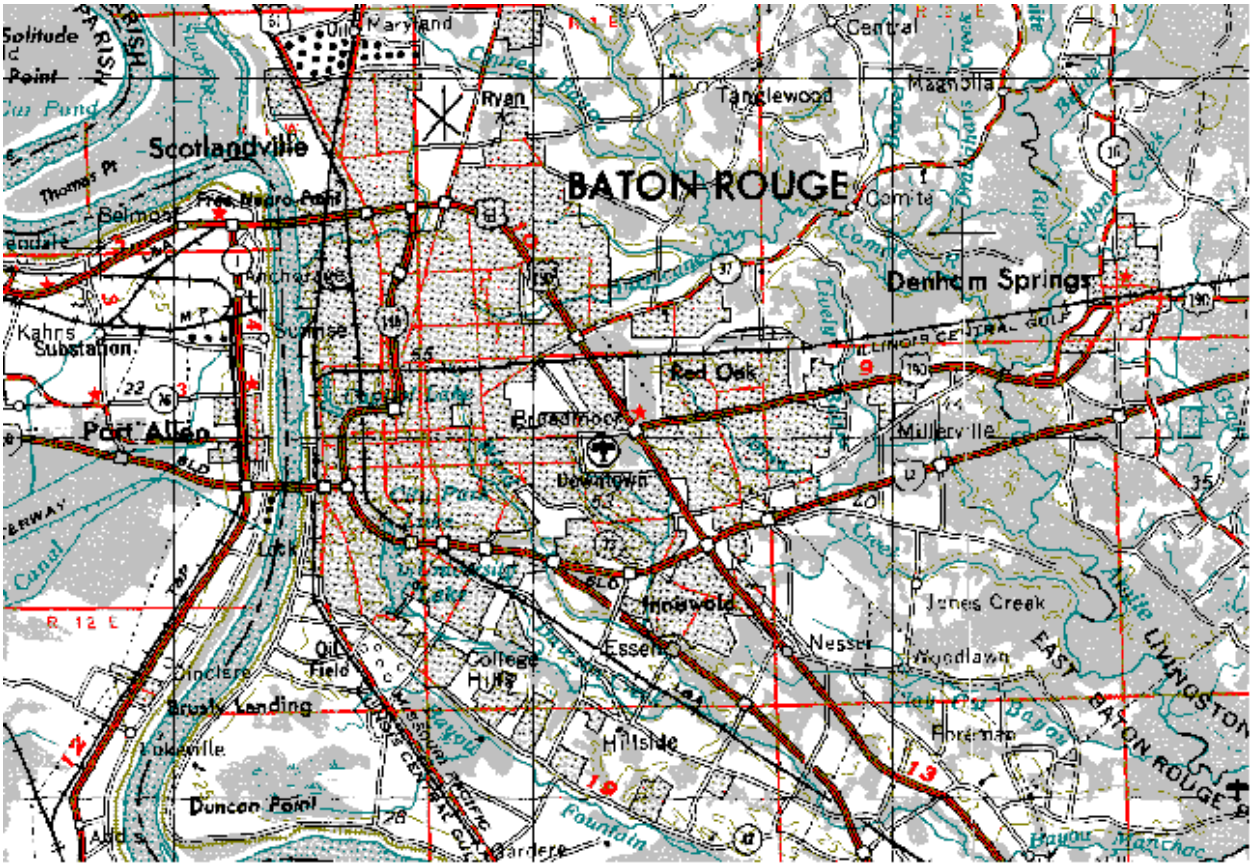
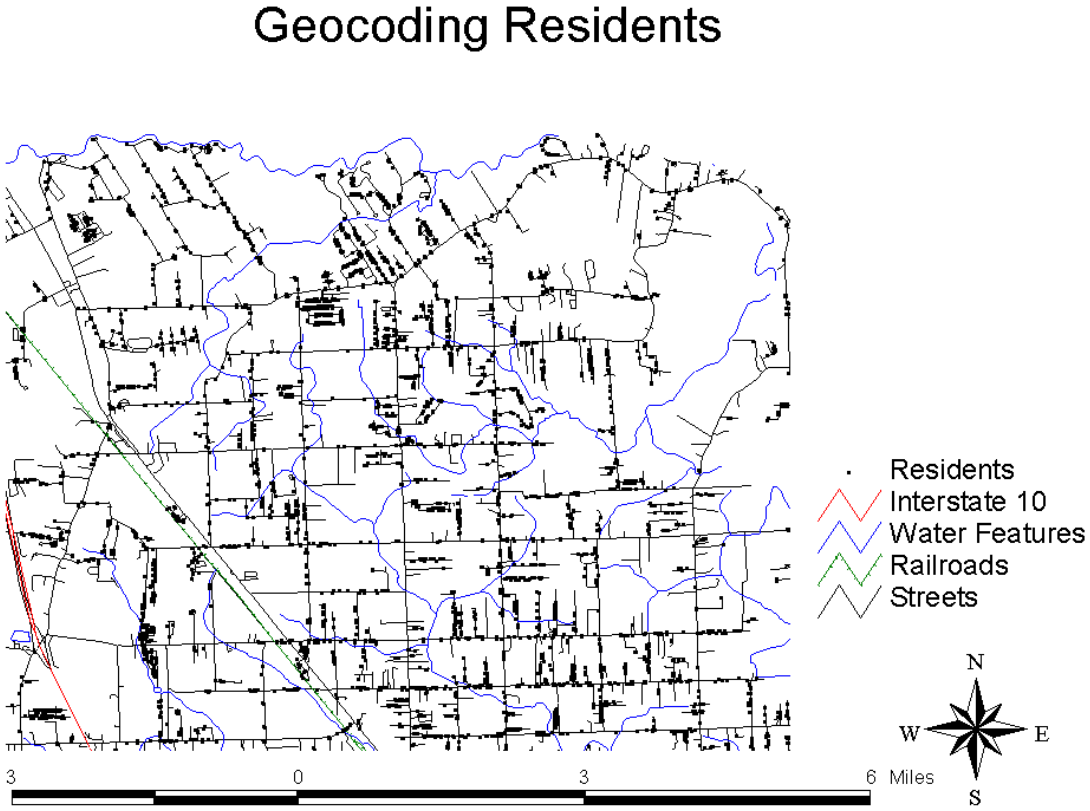


Image data can be organized in a number of ways depending upon the particular image format. Typically, the image data file contains a header record that stores information about the image such as the number of rows and columns in the image, the number of bits per pixel, the color requirements and the geo-referencing information. Following the image header is the actual pixel data for the image. The internal organization of the image data is dependent upon the image format. Some formats contain only a single band of data, while others contain multiple bands.

GIS as a Analysis Tool

Spatial Analysis: An operation that examines the data with the intent to extract or create new data that fulfills some required condition or conditions. It includes such GIS functions as polygon overlay or buffer generation and the concepts of contains, intersects, within or adjacent.

Geo-coding Many organizations maintain large databases of events by address, such as accident and crime reports, customer records, and tax and parcel records. Addresses are, in fact, the most common form of storing geographic data. With geocoding, you can display the tabular information in a computerized database containing addresses as points on a map and find their locations on a map easily. Address geocoding can allow you to locate fire stations by entering their addresses, show where all the students live in relation to the schools they attend, or locate customers and thereby site facilities where the customers are concentrated.



An address specifies a location in the same way that a geographic coordinate does. But since an address is merely a text string containing the information of house number, street name, direction, and/or zip codes, an address needs a mechanism to calculate the geographic coordinate for the address and then display the location on a map based on the assigned coordinate. To do so, addresses stored in tabular data files must first be associated with a geographic feature, usually in a street network. The coordinates of a data source can be used to calculate and assign

coordinates to addresses if the data source features also have addresses. Geocoding is the mechanism that allows you to use addresses to identify locations on a map.

Geocoding allows for the following functions:

- You can create pin maps to show locations of various events by addresses. It is just the same as pushing stick pins on a wall map to mark the locations of all branch offices of a bank.
- You can query and find geographic features using addresses.
- You can perform point-in-polygon analysis such as finding all customers within a trade zone.

There are a variety of planning, administrative and operational activities which use geographic data in the form of addresses A company can match customer addresses against a street network of their distributor service areas in order to know which distributor will handle a customer. The information could also be used by emergency managers to perform the following functions:

- To analyze crimes by address. These locations can be mapped and analyzed with other demographic data.
- To enter an address, determine who should respond, and route emergency vehicles and personnel to the address.
- To match student addresses against a street map of a city. Once the homes of students are located, school assignments and busing plans can be created and analyzed.
- Identify potential impacts of storage facilities for hazardous materials in populated areas by matching the site addresses to a theme containing census data.

Managing Geographic Information Systems

The "Manager's Overview (1997)" states that "GIS belongs to the class of computer syems that require the building of large databases before they become useful. Unlike many other micro-computer applications where a user can begin use after the purchase of the hardware and software, the use of a GIS requires that large spatial databases be created, appropriate hardware and software be purchased, applications be developed, and all components be installed, intergrated and tested before users can begin to use the GIS (p. 4)." The authors suggest that because this is a complex and difficult task extensive planning is required. Problems often occur because:

- The GIS is not integrated with other systems where interaction may be desired;
- Staff do not fully understand the technology prior to extensive training;
- Development time estimates differ from actual task time;
- GIS involves greater uncertainty about costs;

- A greater likelihood exists that programmatic changes (to other parts of the emergency management system) will be needed during the development phases.

"The significant management point here is that these are normal conditions in the adoption of a new technology. Management needs to anticipate that such events will happen, and when they do, take appropriate management action (p. 4)." Since the introduction of a GIS affects other elements of the emergency management process, it is an opportunity to introduce fundamental change into the way emergency management operates. Emergency managers must thus be involved in the adoption of this new technology and help plan, implement, and monitor the process.

> A key factor in the success of computer system adoption in the business world is the concept of the "enterprise" or "corporate" database. As implied by the name, the corporate database is a single, organization-wide data resourse. The advantages of the corporate database are first, that all users have immediate and easy access to up-to-date information and, secondly that the construction of the database is done in the most efficient manner possible (The Manager's Overview, p. 5). . . Establishing a corporate database is much more a question of policy, management cooperation and coordination, than some technical requirement.

The authors suggest that effective implementation of GIS is more than technology. GIS requires data (databases, images, pictures, and graphis) that are fundamental to the entire state or local agencies. The emergency manager should realize that other agencies will be interested in data layers especially those that are maintained by the emergency management unit (shelters, special populations, resources, etc.). Emergency managers should thus seek out other local or state units that are interested in jointly developing a GIS (planning, public works, public safety, and education).

Obtaining Maps

The Internet, provides an excellent means of obtaining spatial data to be used in a GIS. Take a look at some of the following sites:

U.S. Environmental Protection Agency: EPA has a comprehensive GIS Program. See their Internet site at http://www.epa.gov/ngispr

FEMA Map Service Center: FEMA's Map Service Center (MSC) provides online access to National Flood Insurance Program (NFIP) Map Products. The MSC Web site is designed to provide the latest information and support services to users on flood related data.

U.S. Geological Survey: GIS technology can be used for scientific investigations, resource management, and development planning. Access to FGDC Manual of Geographic Data Products, and USGS node of the National Geospatial Data Clearinghouse. See: http://info.er.usgs.gov/research/gis/title.html

National Geophysical Data Center (NGDC) Natural Hazards Databases. A collection of databases and data on natural hazards. See http://www.ngdc.gov

Resources Required for a GIS

Developing a GIS involves investment in five areas: computer hardware, computer software, geographic data, procedures, and trained staff.

Computer Hardware: Desktop personal computers are increasing with dramatic speed, the emergency manager should purchase the fastest computer on the market, with at least 64 Mb RAM with a large monitor (at least 17"). A color printer that is capable of printing 17 by 14 inches is essential; a plotter is useful for preparing large 36" wide maps. A scanner is useful for including photographs or maps in a GIS.

Computer Software: Several software companies are providing local and state governments excellent GIS programs. Intergraph's GeoMedia, ArcView, and MapInfo all have reasonably priced powerful software. Each of the shell software is fully capable of enabling emergency management agencies in completing complex hazards analysis.

Geographic data: Data will include relational databases that have street address that can be geocoded or geograhic coordinates. The above software can either geocode the databases or create points from the coordinate fields. Census Bureau TIGER Street, highway, rail, and water features are available from distributors in common map projections. Feature image data (photos, satellite images, or USGS Quad sheets) are also available from either Federal or state agencies or commercial distributors in common projection formats. The development of GIS layers must address the following concerns.

- What will be the source for each data layer (shelter locations, schools, hospitals, nursing homes, or emergency management resources)?
- Who will own the data layer?How will the new GIS layer be integrated with existing data files (lists of schools, hospitals, nursing homes, etc.)?
- Who will be responsible for updates to the data?
- How will the cost of the data be allocated?
- Will access to the data be made available to the public? How? By whom?
- Who will be responsible for archiving and retention of the data layer? .

Procedures: The manner in which data is stored, analysis performed, maps prepared, files stored, or files shared must be established. Determine who has access to the programs and data. Clarify who should be contacted if maps are to be prepared. Establish how changes will be made in data and who will perform the changes.

Training Staff and Technical Support: Training and techical support are critical to efficient operations and effective program operations. Select training sessions that support the needs of individal staff members.

Staffing Requirements: The GIS technical staff person must understand file management, database formatting, and computer aided graphics drawing programs. If the staff member has these skills, the GIS program can be learned easily. In addition, skills in understanding computer networks will be helpful in ensuring that printers function, scanners work, and server files are available to the staff. Data layers may be prepared as a team effort with other administrative agencies that are involved in the emergency management system and who may use these up to date data layers. The team approach in setting up the GIS will ensure that the maps and analysis suit the needs of agency organizational units. Planning and input from a variety of public agencies is critical in facilitating realistic expectations of the GIS.

The Emergency Manager's Role in Integration

GIS development is a process of technological innovation and requires management attention appropriate to this type of activity. It should be active as opposed to passive management involvement in the project (The Manager's Overview, p. 2). Failures of GIS in the past result not from technical difficulties but from a "lack of realistic expectations of all parties associated with the project including GIS technicians, potential users, managers, and officials). The emergency manager should get involved in planning for the development of a "GIS." Fortunately, the emergency manager is in an excellent position to facilitate realistic expectations from technical staff, users, and other support staff who might assist in the development of GIS data.

Geographic information systems can be an excellent tool for the emergency management community in hazards analysis and risk assessment, in making operational decisions concerning evacuation routes or street closings. More public, private and non-profit agencies are using GIS in their operations and finding it a useful resource in preparing for and responding to disasters.

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