Geographic Information System Applications in the Heart of Illinois Highway Feasibility Study

ISABEL CAÑETE MEDINA AND KAREN B. KAHL

Local governments and businesses in central Illinois believe that a new highway connection between the metropolitan areas of Peoria and Chicago will shorten travel times and foster economic development. A geographic information system (GIS) that was used to determine the feasibility of alternative corridors being considered for an improved highway within the 10-county, 7,700-km^2 (3,000 mi^2) study area is discussed. The development of the GIS required the compilation and integration of large amounts of geographic and environmental data. The data base was developed using a personal computer based GIS. Overlay analysis was used to map environmentally sensitive areas and possible engineering constraints. Previously developed corridor alternatives were entered into the GIS, and their locations and alignment designs were adjusted to avoid major engineering obstacles and environmental impacts. After the corridor locations were finalized, the GIS was used in the alternatives evaluation to assess the effects of the proposed corridors.

Geographic information systems (GIS) in transportation have been widely used in such applications as travel demand modeling, traffic forecasting, intelligent vehicle highway systems and traffic management systems, and road management systems, including highway facilities inventory and pavement data management. However, only recently have the capabilities of GIS been explored for highway planning and route location studies.

A GIS was developed for the Heart of Illinois Highway Feasibility Study to serve as a decision support tool in determining suitable corridor locations and in evaluating their potential impacts. The GIS was used to (*a*) inventory the location and feature descriptions of known environmental resources, (*b*) revise and adjust corridor alignment, and (*c*) evaluate corridor impacts. In addition, the GIS was used for address-matching of origin-and-destination (O-D) data and for map and report production.

PROJECT BACKGROUND

Support for a direct highway connection between Peoria and Chicago has continued to grow among business and government leaders in north central Illinois. The Heart of Illinois Highway Feasibility Study was conducted to examine potential corridor locations for a new freeway or expressway between the two metropolitan areas. The feasibility of corridor alternatives was based on engineering, environmental, and economic considerations.

I. C. Medina, CM Technologies, 1034 Asbury Avenue, Evanston, Ill. 60202. K. B. Kahl, CH2M Hill, 411 E. Wisconsin, Suite 1600, Milwaukee, Wis. 53202.

The Heart of Illinois Highway Feasibility Study began in May 1993 and is scheduled for completion in the spring of 1995. The project is funded by the Illinois Department of Transportation (IDOT) and the FHWA. The study area covers more than 7,700 km^2 (3,000 mi^2) encompassing rural and metropolitan areas within 10 counties, as well as scenic and environmentally sensitive regions along the Illinois River. More than 1,000 km (620 mi) of corridor alternatives (80 segments) were developed from previous studies and reports, field reconnaissance, and extensive input by members of the Study Advisory Group and the community (Figure 1). Because of the large project area, the corridor alternatives were divided into three bands representing directions of travel: north, northeast, and east.

After the identification of alternatives, the corridors within each study band were evaluated using a three-step screening process in which each level of screening increased in detail. The initial screening eliminated alternatives that clearly did not merit further analysis. The criteria used in the elimination process included: redundancy because of an existing freeway, adverse travel conditions discontinuity or overlap, and diagonal severance of agricultural land. The second step was a preliminary screening of several groups of corridor alternatives, which would provide essentially the same traffic service over slightly different routes. The corridors were evaluated and one alternative in each group was selected for inclusion in the more detailed screening. The third step involved the evaluation of the remaining corridors based on transportation cost, planning and accessibility, and environmental factors to select one or more corridors for each study band. After the three-step screening process, the "finalist" corridors were then the subject of more detailed engineering, environmental, and economic analyses. The GIS was used in the assessment of corridor alternatives in the preliminary and detailed screening steps.

DATA BASE DEVELOPMENT

Hardware and Software

The GIS was implemented using a personal computer (PC)-based system. The computer hardware included a 486 DX/66 MHz work station with 8 megabytes of extended memory and 350 megabytes of disk storage. A Summagraphics 30.48 × 45.72cm (12-in. × 18-in.) digitizing tablet was used for data input. The software chosen for implementation was Atlas GIS, version 2.1, by Strategic Mapping, Inc. (Palo Alto, Calif.). An import and export utility from the same company was used in translating existing GIS data bases such as TIGER/Line and Arc/Info files into Atlas GIS format. The

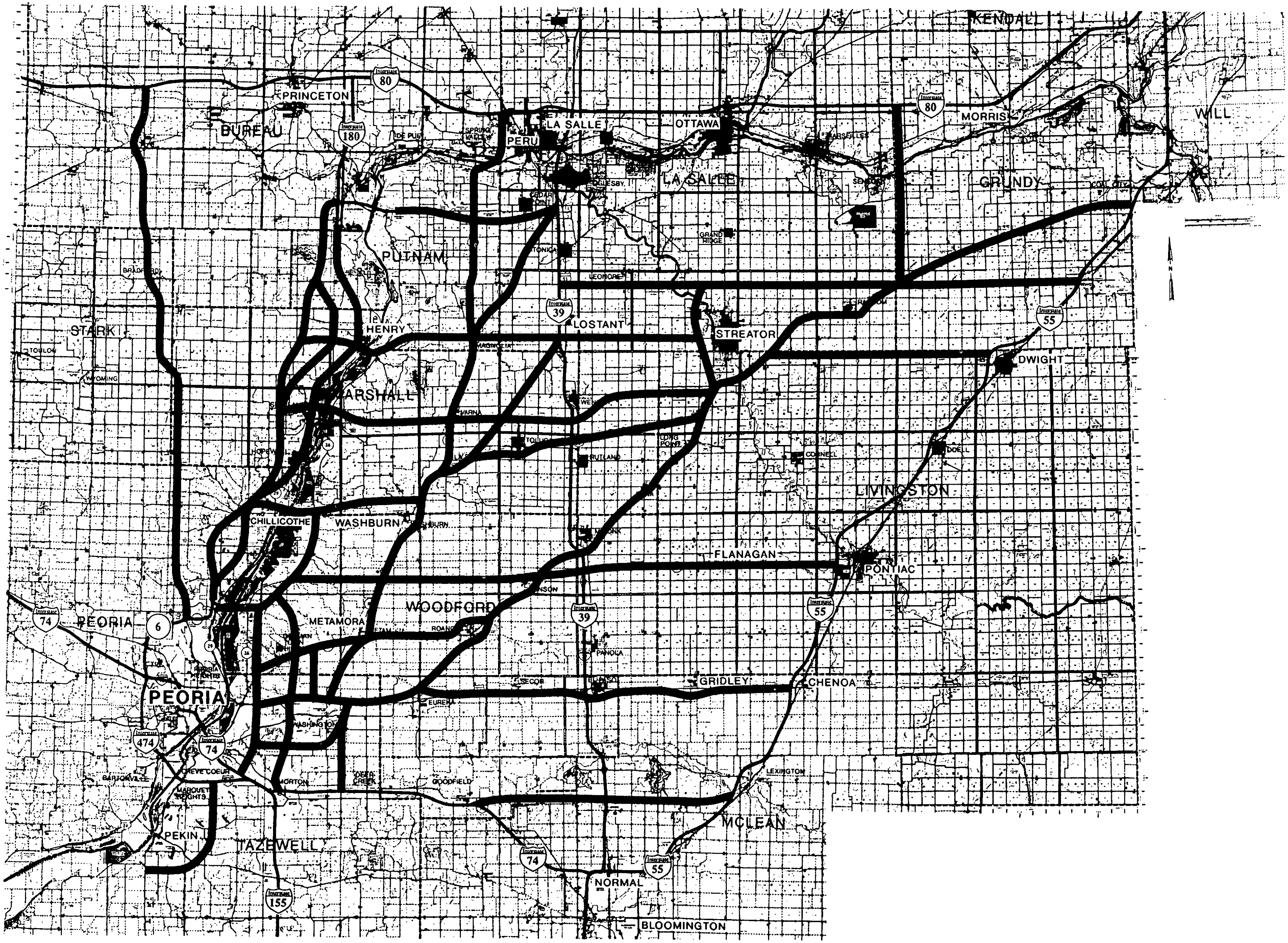

FIGURE 1 Preliminary corridor alternatives.

Excel spreadsheet program was also used for entering data base information such as street addresses, which were later imported into Atlas GIS.

Data Sources

The sources of information for the GIS data base are shown in Table 1. The data were available in both digital (computer file) and analog (printed map) formats and were provided in various scales and map projections. The geographic and environmental features were originally compiled using latitude-longitude coordinates. The geographic data were later projected to Universal Transverse Mercator, Zone 16 (UTM-16) coordinates.

Data Integration

The compilation and integration of data for such a large study area involved considerable work, with an enormous amount of data entered into the GIS. The base map for the data base was developed from TIGER/Line files translated to Atlas GIS format. GIS data bases from state agencies also were imported into Atlas GIS. Problems occasionally occurred in file translation, requiring manual edits of imported data. After the base map was completed, other types of geographic data were entered into the system. The most common problem encountered during data input was discrepancies with map information provided by different sources (e.g., United States Geological Survey maps versus county plat books). Researchers had to decide which sources provided the most accurate information for various types of geographic data. Information also was updated based on the most recent aerial photographs and field reconnaissance. Wetlands and flood plain information were not included in the GIS because the data were too detailed and extensive.

GEOGRAPHIC INFORMATION SYSTEM APPLICATIONS

The implementation of a GIS for the Heart of Illinois Highway Feasibility Study provided opportunities for developing new techniques in highway planning and route location studies. GIS applications are compared with current practices and methods in the following sections.

Origin-and-Destination Study

An (O-D) study was performed as part of the Heart of Illinois Highway Feasibility Study. The results of the O-D study were used to project travel demand between Peoria and Chicago for the purpose of identifying alternative highway corridors. The data collection for the O-D study used a combination of roadside personal interviews and mail-back questionnaires at 14 sites. The primary data collected from approximately 11,000 motorists included the trip origin and destination by address or nearest cross streets.

The survey processing required developing traffic analysis zone (TAZ) codes for each origin and destination address. The TAZ were based primarily on 1990 census tract boundaries and were delineated in the GIS using tract boundaries from TIGER/Line files. With information from the TIGER/Line data base such as street names and street numbers, the GIS was able to match 75 percent (572 of 747) of the addresses collected on the O-D survey forms to their corresponding TAZ codes. Approximately 6 person hours were required to process the address matches, which were primarily performed on origins and destinations in the Peoria metropolitan area. For the remaining data, the TAZ codes were determined by locating addresses using detailed street maps. The results of the O-D study were used to develop traffic forecasts to compare the costs and benefits of various corridor alternatives.

Environmental Resources Inventory

The base map for the environmental resources inventory consisted of county and municipal boundaries, roadways, railroads, and hydrographic features. Other geographic features were added to the base map using various data sources (see Table 1). The boundaries of some environmental features were digitized using printed maps. Others were available in digital format from state agencies. The location of hazardous waste sites and historic resources was entered into the system by matching their addresses to corresponding map coordinates.

The geographic features considered in the inventory include:

- Archaeological sites
- Cemeteries
- Community facilities
- Other developed areas
- Gas storage areas
- Hazardous waste sites (CERCLIS)
- Historic resources
- Surface and underground mines
- Natural areas and wildlife refuges
- Nature preserves
- Pipelines (gas)
- Power lines (transmission lines)
- Power plants and substations
- Prime farmland
- Protected agricultural lands
- Pumping stations
- Quarries, pits
- Radio towers
- Sewage disposal areas
- Steep slopes
- State parks, conservation areas and recreation areas
- Other public lands and parks
- Park trails
- Threatened and endangered species
- Unique and highly valued aquatic resources
- Woodlands

Each feature was represented as a single layer on the GIS. The layers were combined and overlaid to produce an environmental resources inventory map. The most sensitive land uses are located along the Illinois River and included archaeological sites, developed areas, hazardous waste sites, historic resources, natural areas and nature preserves, public lands and parks, habitats of threatened and endangered species, wooded areas, and steep slopes. The remaining sections of the study area are primarily composed of prime farmland.

The conventional procedure for developing an environmental resources inventory map is to compile the necessary information and manually draw or delineate the features on an aerial photo mosaic or USGS map. Maps of environmental features are usually provided in various scales (Table 1) and have to be manually transformed or translated into the appropriate scale and coordinate system used for the base map. Because of the time and work effort

TABLE 1 Sources of Information

Data/Map Name	Source	Date Compiled	Data Format(1)	Map Scale(2)	Map Projection(3)
TIGER/Line Census Files	Bureau of Census	1990	F	1:100,000	Latitude-Longitude
USGS Topographic Maps	US Geological Survey	1985-1991	M	1:100,000 1:24,000 1,250,000	UTM-16
County Plat Books	Rockford Map Publishers	1988-1993	M	ns	ns
General Soil Maps	Soil Conservation Service	1972-1993	M	various	ns
Illinois Coal Mines	Illinois State Geological Survey	Jan. 1989	M	1:62,500	UTM
Coal Industry in Illinois	Illinois State Geological Survey	July 1984	M	1:500,000	Lambert Conformal Conic
Biologically Sensitive Areas	Illinois Natural History Survey	1993	F (Arc/Info)	1:52,000	Latitude-Longitude
Illinois Official Highway Map	IL Department of Tansportation	1993	M	1"=12 miles	ns
Official Highway Map	Peoria County	1993	M	1"=1 mile	ns
General Highway Maps	IL Department of Tansportation	1987-1990	M	1"=2 miles	State Plane Coordinate
Archaeological Sites	Illinois State Museum	1993	F	ns	Lambert Conformal Conic
The National Register of Historic Places	Illinois Historic Preservation Agency	1993	D	na	na
Historic Illinois Places	Illinois Historic Preservation Agency		M	ns	ns
A Directory of Illinois Nature Preserves	Illinois Department of Conservation	1991	D;M	ns	ns
Inventory of Public Recreation Lands	Illinois Department of Transportation	1977	D;M	ns	ns
Forest Park Foundation	Forest Park Foundation		M		
Illinois Land Atlas & Gazetteer	Delorme		M		
CERCLIS List	US EPA Superfund Program	1993	D	na	na
Gas Storage Areas	Ancona Gas Company	1993	M	ns	ns
Protected Agricultural Lands	US Dept. of Agriculture	1993	M	ns	ns

(1) F=Computer Files; M=Printed Maps; D=Documents
(2) na=not applicable; ns=not specified
(3)na=not applicable; ns=not specified

involved, not all features are added to the base map. Instead, several maps are compiled and used as references for the engineering and environmental analysis.

With GIS, geographic features can be digitized using their specific map scale and coordinate system and translated into the scale used for the base map. Moreover, a variety of environmental data from state agencies are already available in GIS format, allowing the integration of data in an inventory map. Using GIS, it took two people approximately 4 months to develop the data base. With manual techniques, it may take less time to prepare an inventory because not all environmental features are added to the base map. A GIS map containing a variety of features, however, provides a more comprehensive description or visual representation of the study area.

Location Engineering

The preliminary alternatives for the study represented the broadest range of possible corridor locations and were the starting point for alternatives evaluation. Before screening the alternatives, the GIS was used to revise and adjust corridor locations and alignments.

Preliminary alignments of the corridor alternatives were entered into the GIS and represented more than 1,000 km (620 mi) of potential highway. These initial locations disregarded any impacts to the surrounding areas and were based mostly on the alignment of existing roads and highways. The corridors were plotted as a 1-km (0.62-mi) band on an overlay to the environmental resources inventory map. The corridors were narrowed to a width of 0.5 km (0.31 mi) within the 1-km band, avoiding as much of the major engineering obstacles and environmentally sensitive areas as possible. If a large impact area could not be avoided within the 1-km band, the preliminary alignments were adjusted to reduce or eliminate the impacts. For example, a bypass around a town was relocated from the south side to the north side to avoid a forested area and a new residential development. The corridor alternatives were never narrowed to the width of a highway right-of-way, because the objective of the study was to determine the feasibility of corridors and not to determine the best alignment.

Current methods for adjusting corridor locations involve a process of mapping corridors, assessing impacts, and revising corridors. Often, adjustments made to avoid impacts on one resource result in additional impacts to other resources. Several corridor revisions are usually required to minimize overall impacts.

With a GIS base map, route locations are adjusted and revised not only to avoid impacts on certain resources, but also to reduce overall impacts on the environment and avoid major engineering obstacles. The cumulative effects of corridor impacts can be visually represented when the alternatives are overlaid on an environmental resources map. GIS allows the designer to adjust route locations and at the same time visually assess environmental effects. This process can be performed without the use of GIS as long as a base map is developed containing most, if not all, of the environmental data. The use of a GIS, however, facilitates the integration of information from various sources.

Environmental Impact Assessment

After the corridor locations were finalized, the GIS was used to calculate the impacts of the proposed corridors. Two methods were employed in assessing environmental impacts. The first method used the printed environmental resources inventory map with corridor overlays. The second method utilized GIS analytical operations such as buffering and intersection techniques. Impacts were calculated by counting the number or extent of resources within the 0.5-km (0.31-mi)-wide corridors. Aerial photographs and other more detailed maps (e.g., flood plain and wetlands maps) also were used as references in assessing the effects of the corridor alternatives. Table 2 provides examples of impact calculations.

Existing methods for evaluating impacts involve overlaying corridor alternatives on maps compiled for the environmental analysis. Areas, lengths, and number of sites affected are calculated using a planimeter and a scale. If the environmental data are not contained in one base map, corridor overlays must be prepared for each environmental map to be analyzed, especially if the maps are of different scales. With GIS, the base map contains most of the environmental features to be analyzed, hence requiring only one corridor overlay. Areas, lengths, and number of sites affected can be calculated by the system in one-fourth the time it would take using manual methods.

Maps and Presentation Graphics

For this project, maps were easily generated by the GIS for report production and graphic display purposes. An environmental resources inventory map was produced using a Novajet Inkjet Plotter and printed on photographic bond at a scale of 1:50,000. Maps of corridor alternatives (approximate scale 1:150,000) were also generated using a Versatec Color Plotter and printed on bond paper. The GIS maps were mounted on boards and used as exhibits in public meetings and informational drop-in centers. For report production, 30.48 × 45.72 cm (8-in. × 11-in.) maps were produced using a Hewlett Packard Laserjet printer and a Versatec Color Plotter. Color transparencies of corridor alternatives also were generated for presentations to IDOT officials and the study advisory group.

The GIS was able to produce maps in one-eighth the time it would normally take using manual or other computer graphics methods. This capability is extremely valuable for future studies and evaluations and for presentations of study results to a concerned and perhaps more demanding public when it comes to environmental assessments.

Costs and Benefits of Using Geographic Information System

The development of the data base was the most time-consuming and costly aspect of the GIS implementation. Nevertheless, the use of GIS for analysis and map production provided many benefits. GIS reduced the work effort involved in matching addresses to TAZ codes, in assessing environmental impacts, and in generating graphics for presentation purposes. The data base that was developed will also be used for future planning studies in the project area, providing deferred cost savings. Most importantly, it was the ability of GIS to integrate and visually represent data that was beneficial to the designers, planners, and decision makers.

The application of GIS did not significantly affect the overall cost of the project because of the extensive data input process. The techniques that were developed for the study, however, made significant contributions in improving the planning and design process.

TABLE 2 Environmental Impact Assessment

	Alt. N3	Alt. N4	Alt. N5	Alt. N6
Farmland Impacts Illinois Agricultural Areas Affected - Number - Area Prime Farmland Affected Area > 75% prime 25-75% prime < 25% prime	 4 570 ha (1,410 ac) 2,690 ha (6,640 ac) 840 ha (2,070 ac) 350 ha (860 ac)	 2 220 ha (540 ac) 1970 ha (4,870 ac) 870 ha (2,150 ac) 350 ha (860 ac)	 3 510 ha (1,260 ac) 3,100 ha (7,660 ac) 700 ha (1,730 ac) 220 ha (540 ac)	 1 160 ha (400 ac) 2,330 ha (5,760 ac) 460 ha (1,140 ac) 220 ha (540 ac)
Conservation/Natural Areas Affected, Area	o Root Cemetery Nature Preserve, Status Pending, 1 ha (2 ac) o Magnolia Hill Prairies Natural Area, 10 ha (25 ac)	o Root Cemetery Nature Preserve, Status Pending, 1 ha (2 ac) o Magnolia Hill Prairies Natural Area, 10 ha (25 ac)	o Root Cemetery Nature Preserve, Status Pending, 1 ha (2 ac) o Sparland State Conservation Area, 10 ha (25 ac)	o Root Cemetery Nature Preserve, Status Pending, 1 ha (2 ac) o Sparland State Conservation Area, 10 ha (25 ac)
Threatened and Endangered Specie Sites Encountered	0	0	Invertebrate found along IL River adjacent to corridor	Invertebrate found along IL River adjacent to corridor
Parkland Affected	Adjacent to Forest Park Foundation Land	Adjacent to Forest Park Foundation Land	Adjacent to Forest Park Foundation Land	Adjacent to Forest Park Foundation Land
Area of Woodland Affected	480 ha (1,190 ac)	480 ha (190 ac)	410 ha (1,010 ac)	330 ha (820 ac)
Cultural Resources Encountered Archaeological sites Cemeteries	 11 small sites 1 medium site 0	 8 small sites 1 medium site 0	 10 small sites 0	 7 small sites 1
Hazardous Waste Sites (CERCLIS) Encountered	Adjacent to site	0	Adjacent to site	0
Steep Slopes Encountered	330 ha (820 ac)	330 ha (820 ac)		
Mining Areas Encountered	1 gravel pit; 1 mining area 10 ha (20 ac)	1 mine	1 gravel pit; 1 mining area 10 ha (20 ac)	0

CONCLUSION

For the Heart of Illinois Highway Feasibility Study, the GIS was used to process O-D survey forms, compile and integrate data to create an environmental resources inventory map, revise and adjust corridor locations and alignments, quantify the effects of proposed alternatives on environmentally sensitive areas, and produce maps and exhibits for presentation and report production. These functions were performed using a PC-based system,which did not require software customization. The development of the GIS data base for an area covering 7,700 km^2 (3,000 mi^2) was the most expensive and time-consuming aspect of GIS implementation. When the data base was completed, however, the GIS was able to produce maps quickly and easily, and reduce the work effort involved in assessing and quantifying corridor impacts.

The experience gained from the Heart of Illinois study indicates how GIS can influence decision making and improve the process of identifying and evaluating corridor alternatives. If state agencies continue to inventory their resources using GIS, then data base development may become less costly and state departments of transportation may use geographic information systems more frequently for roadway location studies. Furthermore, as planners and engineers are required to consider environmental issues along with engineering and cost issues, GIS can be used to synthesize and analyze data for highway planning. GIS has the potential to affect roadway planning as significantly as computer-aided design has changed the process of roadway design.

GLOSSARY

TIGER/Line files: GIS data base developed by the Bureau of Census containing a variety of information, including roadways, municipal boundaries, hydrographic features, railroads, etc.

Arc/Info files: GIS data bases developed and stored using Arc/Info software by Environmental Research Systems, Inc.

Buffering techniques: A type of GIS operation in which an area is generated or delineated around a point or a line. For example, a 5-mi radius buffer around a point results in the generation of a circle 10 mi in diameter around the point.

Intersection techniques: A type of GIS operation in which two areas are overlaid and a new area is generated or delineated based on their intersection.

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