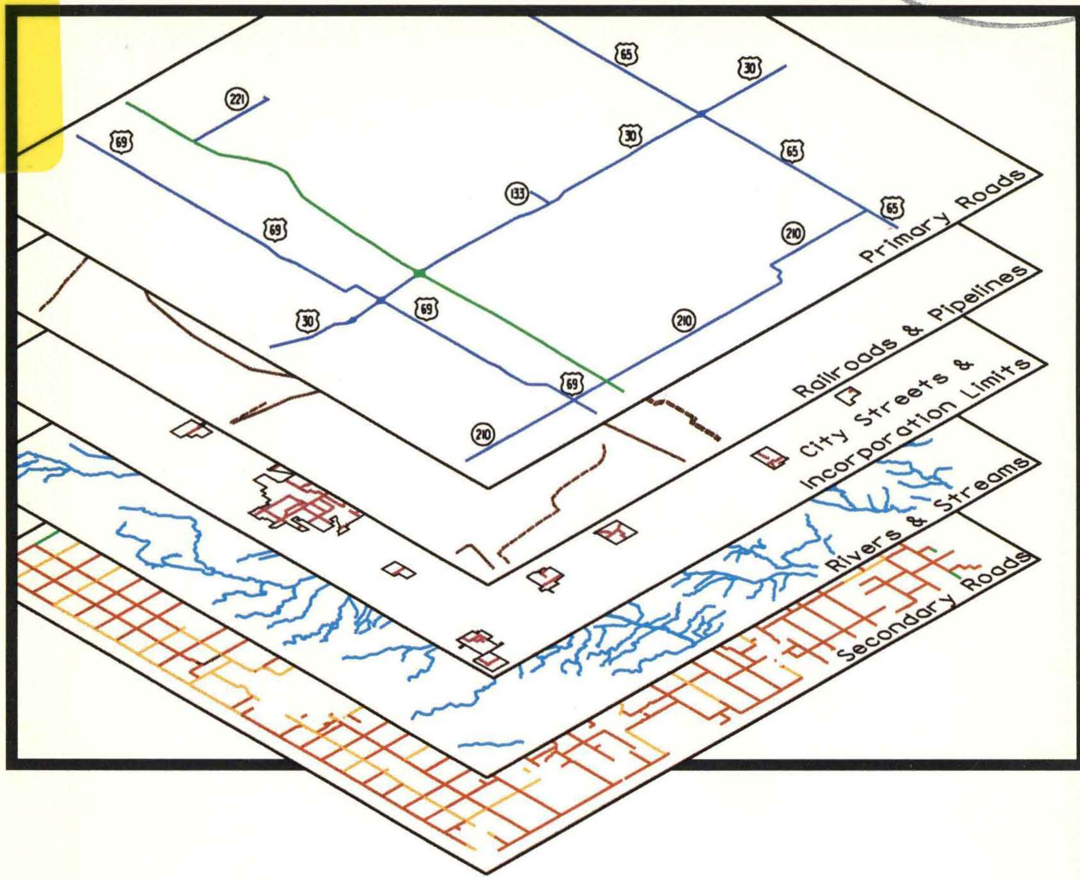

GIS

Demonstration Project

Iowa Department of Transportation

March 1992

GIS Demonstration Project

Iowa Department of Transportation

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United States Department of Energy

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Acknowledgements

This report represents the DOT"s involvement in the Joint GIS Demonstration Project with the Iowa Department of Natural Resources (DNR). The Iowa DOT would like to thank the Iowa DNR for their cooperation and support. A special thanks to Kevin Kane as our principal contact.

Funding for this project was made possible by the U.S. Department of Energy (DOE) through a grant derived from Exxon oil overcharge monies. The following disclaimer is from Grant Contract No. 90-GISS-01, General Conditions, Section 7.0 Publications:
"This report was prepared with the support of the U.S. Department of Energy Grant No. 90-GISS-01. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of DOE."

The Iowa DOT would like to thank Intergraph Corporation for the GIS software loan, and for the support that they made available through the services of Chris Henshaw, an applications engineer.

A special thanks to the Iowa DOT's Bureau of Information Services for the support and time dedicated to make this project a success.

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Abstract

In June 1991 the Iowa Department of Transportation (DOT) completed a joint Geographic Information System (GIS) demonstration project with the Iowa Department of Natural Resources (DNR). The U.S. Department of Energy provided funding through a grant derived from Exxon oil overcharge monies. The focus of the project was to demonstrate energy savings through evaluation of potential uses of GIS software, and to facilitate exchange of the DNR's natural resource data and DOT's transportation data.

The Iowa DOT, like many DOTs across the country, is using an Intergraph VAX system for the planning and design of its highways. The DOT chose to utilize Intergraph's MGE products for this demonstration project, and in June 1990 purchased an Intergraph UNIX workstation. The Intergraph GIS software was loaned to the DOT for the duration of the project.

An important goal of this project was to exchange data files between the Iowa DOT and DNR, to eliminate the redundant input and maintenance of identical files. The Iowa DNR has been utilizing an ARC/INFO system for GIS since 1987, and had collected information useful to the DOT for highway planning. Graphics files were exchanged between the DNR and the DOT using Digital Exchange Format (DXF). An ASCII character data file was used for the attributes exchange.

In addition to exchange with the DNR, the DOT also established exchange procedures for the DOT's existing IBM Cullinet Database Management System. Primary road data were successfully loaded from the base record history file into the GIS Informix database. This allowed the DOT's geographic information system access to the vast amount of information maintained concerning Iowa's primary road network.

To fulfill the requirements of the joint project, the DOT initiated a corridor analysis study. The study corridor chosen was along U.S. Highway 151 between the cities of Cedar Rapids and Dubuque. The DOT was able to save data input time by utilizing the existing county maps created by the DOT's Cartography section as the base maps for the three-county area. The DOT's goal for this corridor study was to show an increase in efficiency in its project planning studies, and some of the advantages of utilizing GIS in the DOT environment.

As part of the corridor project, the DOT had aerial photos scanned by Intergraph. Planimetrics for the same area were digitized by the DOT's Photogrammety section. The aerial photos and planimetrics are used by the DOT's Office of Project Planning for highway location studies. Currently, road design plans are transferred by hand to aerial photos for public hearings. With new software technology, scanned aerial photos could be warped to fit design plans in the CADD system instead of warping the highway design to fit paper copies of the photos.

This project proved to be successful. The DOT was able to examine many aspects of a GIS package before making a costly commitment. Results of this demonstration project have encouraged investigation of GIS uses in the Planning and Research Division and the Highway Division of the DOT. Applications could include advance planning, project planning, cartography, maintenance and pavement management. The methods developed to incorporate information from the DNR, the DOT's IBM system, planimetrics and aerial photos will benefit further GIS development. The DOT plans to pursue additional applications of GIS technology in a pilot project for corridor analysis.

Introduction

With the aid of advancements in computer and Geographic Information System (GIS) technologies, it is possible to demonstrate a great degree of efficiency in the storage, retrieval, analysis and display of spatially related information. Files maintained on paper can now be maintained in computer format. This storage format allows the efficient sharing of information collected and managed by various state agencies.

In June 1991 the Iowa Department of Transportation (DOT) and the Iowa Department of Natural Resources (DNR) completed the joint project entitled "Geographic Information System Database for Energy Planning." The project, begun in November 1989, was designed to develop practical and effective interagency cooperation through defining complimentary roles in developing compatible digital data sets and sharing digital geographic resource information. Both the DNR and DOT hope to utilize these digital data in their energy-related programs.

The purpose of the project was to investigate the feasibility of exchanging digital geographic information between state agencies, and the applicability of a GIS to each agency's energy-related programs. Additional objectives include determining the application of GIS to management decision making, policy analysis, data maintenance, systems compatibility, and energy planning projects. The scope of the project included the analysis and comparison of the form and format of information to be exchanged, determination of spatial compatibility, establishment of a hardware/software platform for data exchange, and preparation of shared files for mapping information.

Data Formats

The first task in this project was to determine what data were available from each agency and in what format. The DOT's highway and transportation (H&T) maps **(see Figure 1)**, developed by the Cartography Section from the U.S. Geological Survey's (USGS) digital line graphs (DLG), are stored on the Intergraph Corporation VAX system. These maps were the most appropriate graphics base for the DOT's part of the joint GIS project. The H&T maps contain the transportation network, which includes all road systems, railroads, pipelines, airports and streams. Also included on the H&T maps are city incorporation limits and other political boundaries, route symbols, bridges, cemeteries, state parks and state institutions. Each of these map features, which had no attribute attachments, were stored on separate levels and coded by line symbology.

All of the DOT's roadway inventory records are stored on an IBM mainframe in a Cullinet database management system. In addition to this existing information, other technologies were used to create information needed for this project. Planimetric data from nine aerial photographs around the City of Cascade were input by the Photogrammetry Section using the DOT's stereo-digitizer **(see Figure 2)**. The data layers included: contour lines (five foot interval), flow lines, control points, road survey data, city streets, primary road alignment, culverts, rural buildings, rural driveways, fences, power poles, houses, buildings, sidewalks and bushes. In addition, the same photographs were scanned by Intergraph at 200 dots per inch and delivered in a format that could be used with the Intergraph IRAS software **(see Figure 3)**.

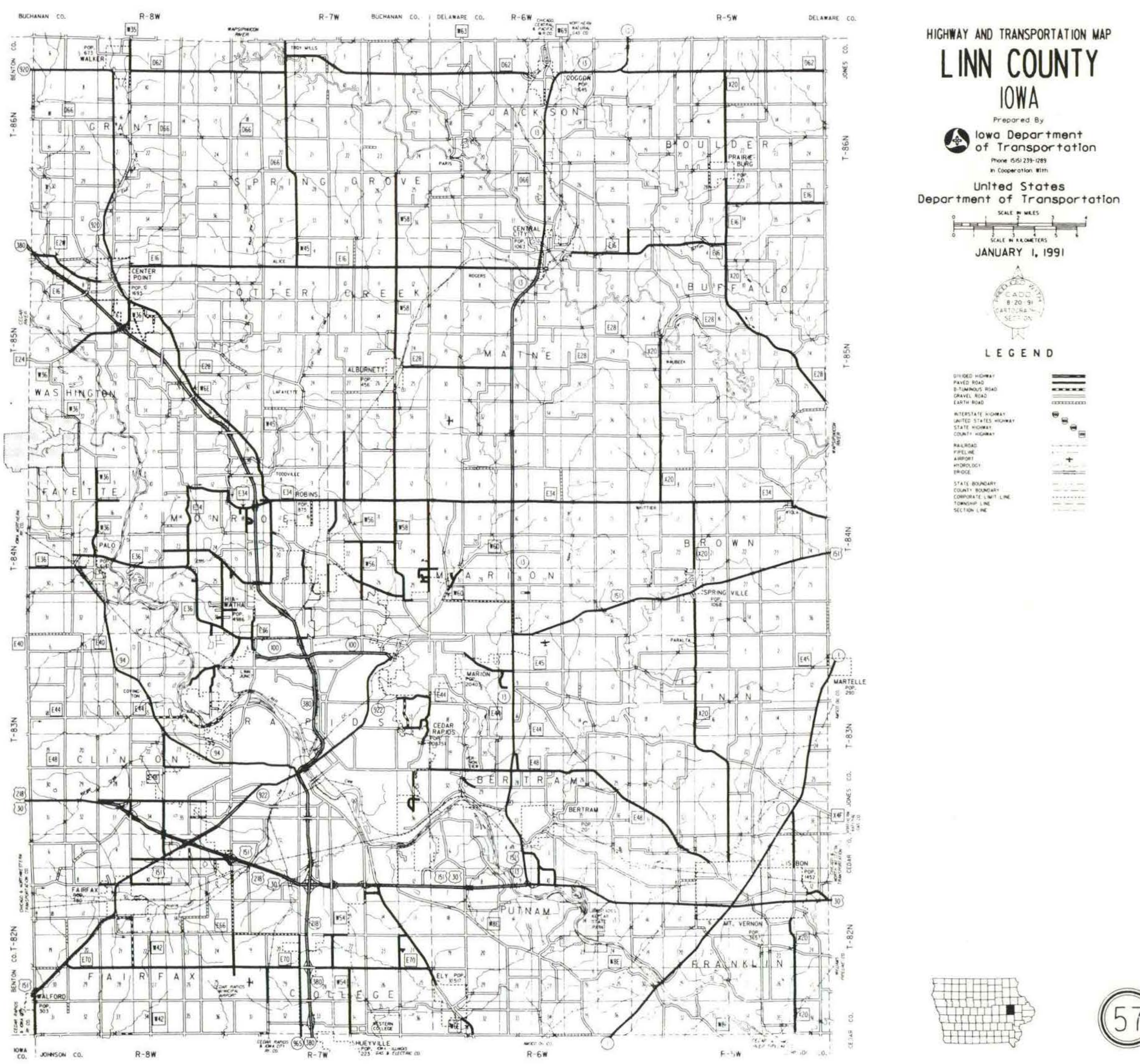

FIGURE 1

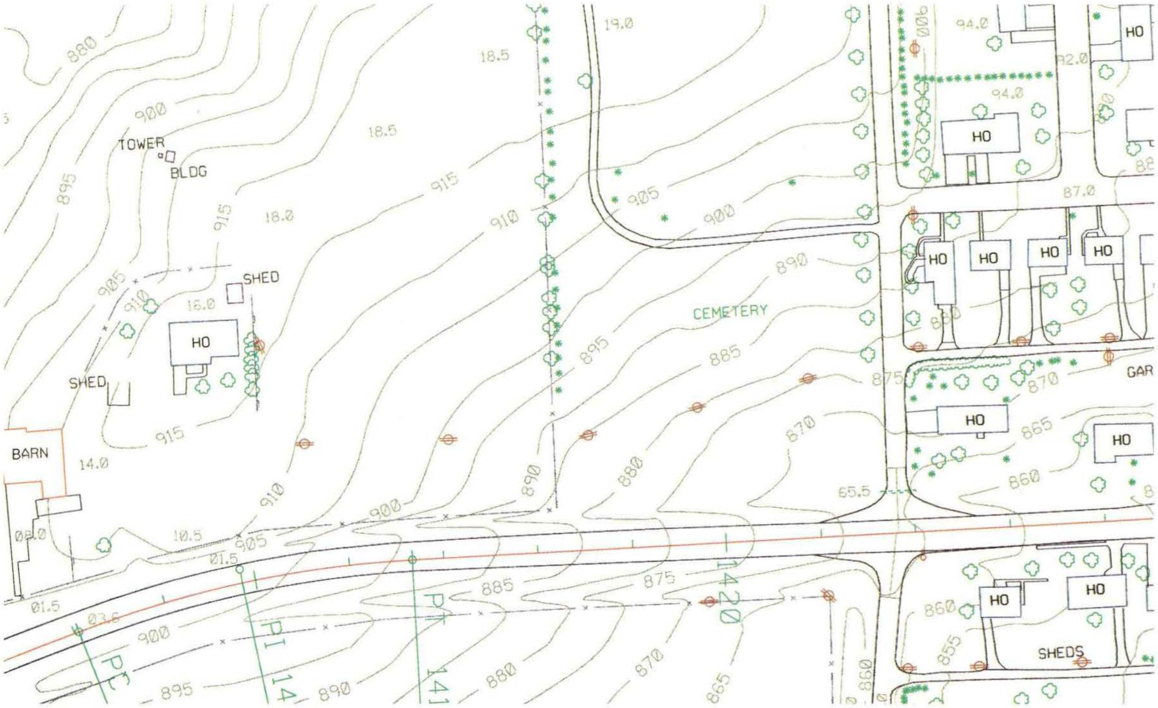

FIGURE 2

FIGURE 3

The Iowa DNR had a major commitment to Environmental Systems Research Institute's (ESRI) PC ARC/INFO, using Compaq 386 personal computers as their base GIS. The majority of the DNR's data were either in PC ARC/INFO, Minnesota State Planning Agencies Environmental Planning and Programming Language (EPPL7), or paper format. Files stored in digital format were hazardous waste sites, public lands, sanitary landfills and public and municipal wells. Files the DNR planned to input into ARC/INFO over the course of the project were underground storage tanks, land use/land cover, coal and mineral resources, energy resources, archeological sites, wetlands and wildlife areas. It was desirable to include these files in the project because they represented point, line and area data. The ability to transfer each of these types of data implies the ability to transfer most data available.

Database Compatibility

The next step in the project was to determine compatibility of DOT and DNR files. The DNR currently uses a Universal Transverse Mercator projection, while the DOT uses a Lambert Projection with two standard parallels (33° and 45°). The translation between these two projections can be accomplished by most map conversion software. The DNR's files in the ARC/INFO system seemed to be spatially compatible with the DOT's Intergraph CADD files and overlayed satisfactorily.

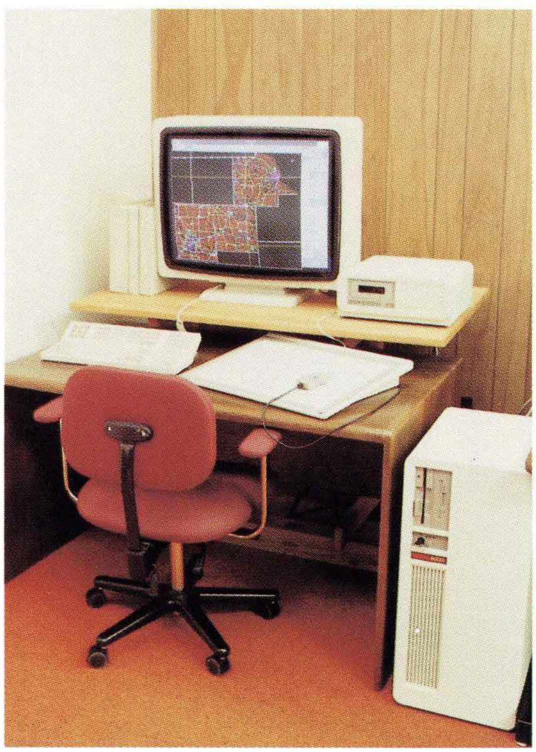

FIGURE 4

The transportation network graphic files the DNR would require from the DOT were maintained on the Intergraph VAX system without attributes. For this project, the DNR did not need any of the inventory data maintained in the DOT's Cullinet database management system. However, at a later date it may be desirable to transfer transportation attributes along with the graphics.

Hardware and Software Platform

After determining the compatibility of DNR and DOT files, a suitable hardware and software platform for data exchange could be established. The DOT staff met with the GIS staff at the DNR to review their GIS experience, and to determine the types of equipment used for their ARC/INFO system. The group agreed that, across the country, two common preferences have been Intergraph's CADD system for state DOTs, and ESRI's ARC/INFO for state DNRs. (This situation holds true in Iowa; most of the data needed for this project resided on the DOT's Intergraph VAX CADD system, IBM mainframe, and DNR's PC ARC/INFO or EPPL7.) The DOT required a hardware and software solution that could provide data exchange with each of these systems.

Intergraph Corporation's Modular GIS Environment (MGE) software seemed to be the best fit for the DOT's predominantly Intergraph environment. The binary compatibility of Intergraph's workstations ensured complete data transfer of the DOT's existing CADD files. Therefore, the current maps residing on the VAX could be directly transferred into MGE, and attributes could be attached to the map features in a batch process. The Intergraph GIS was potentially able to exchange graphic files with the DNR's GIS. Based on experience with ARC/INFO, the ability to exchange graphic files with ARC/INFO, and the binary compatibility with the existing system, Intergraph's hardware and GIS software were selected by the DOT for the project (**see Figure 4**). NOTE: See Appendix for details on the final hardware/software configuration.

The MGE software combines graphics for mapping with a relational database for the storage and retrieval of attributes. The GIS software could be used to query the linkages between the graphics and the database, and to access the DNR's graphics and database information (**see Figure 5**). MGE's strengths are its graphical interface, method of data entry, interactive editing and map display. The geographical relationships created in MGE can be used in the Intergraph Modular GIS Analyst (MGA) software for spatial analysis. The MGA software can be used to graphically display results from database queries. MGA assists in the analysis of the spatial relationships that exist between geographic features, and allows for sophisticated topological queries. A topological query is an inquiry into the mathematical representation of the spatial relationships that exist among graphic elements.

The Intergraph Corporation made a commitment to provide support for the project through software training and access to the expertise of an applications engineer. The MGE and MGA software were loaned to the DOT by Intergraph for the duration of the project. The decision of which software packages to purchase would be made after the project was completed.

Information Management System

A consultant, C.W. Beilfuss and Associates, was hired to write a design specification document for a common highway location reference system. (The report is entitled "Highway Location Reference Procedure Project, Final Report," June 28, 1990). The consultant interviewed personnel from all of the divisions within the DOT, as well as personnel from the DNR, to identify the data

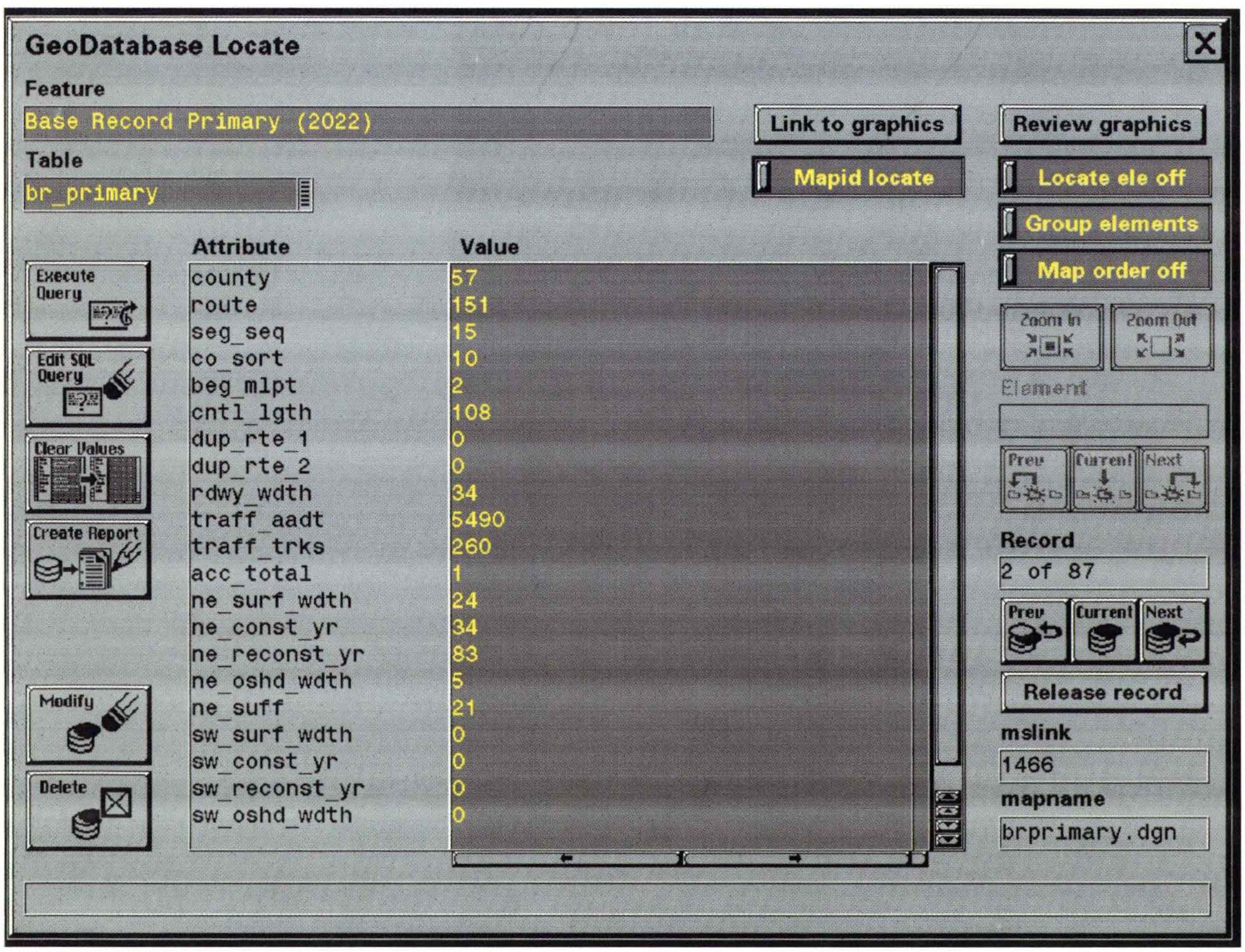

FIGURE 5

reference systems now in use. The purpose of the proposed highway location reference procedure is stated in the C.W. Beilfuss and Associates contract as follows:

> *"Establishment of a highway network locational reference process that will primarily allow for the proper correlation of pavement management data, and secondarily provide the basis for other existing and future database integration, and for the planned Iowa DOT GIS. In addition, the locational reference process will be able to correlate network applications with a statewide spatial location method to facilitate the relationship of Iowa DOT data to that of other agencies, and to allow for the graphic display of the network in map form."*

C.W. Beilfuss & Associates made the following recommendations:

Immediate action

1. Assign overall data management coordination responsibility for pavement management activities.
2. Revise the milepost reference system to reflect milepost number and positive or negative displacement. Eliminate "fractional milepost values" as a reference system. Redesignate all duplicate mileposts so there are no duplicate post numbers. Upgrade procedure related to moving mileposts.
3. Enhance milepost/milepoint cross reference scheme.
4. Align pavement management sections and test sections by milepost with base record section breaks. Include a pavement management segment designator on the base records and the pavement management sections.
5. Increase the number of pavement management sections and test sections by milepost to include all pavement type changes and age of pavement changes.
6. Take age of data into account when performing pavement condition rating calculations. Establish a procedure for identifying changes in the primary road system between the time pavement management related data are gathered and pavement condition rating calculations are performed.
7. Establish historical requirement criteria for pavement management data. Prioritize data sets for processing.

Near-term action

8. Implement a geographic node and shape description database as a precursor to a DOT GIS. Include linear/spatial conversion utility routines.
9. Define user requirements, application requirements and system requirements for a DOT GIS. Establish data layers and select GIS software and hardware.
10. Improve correlation of construction history records with pavement management related data records.
11. Begin processing high priority pavement management data to reflect historical significance.
12. Convert manual or PC-only pavement management data files to the mainframe. Convert PCR-3 equations to the mainframe.
13. Hasten implementation of automatic truck weight and classification system.
14. Implement a database system for pavement management data. Include a segment designator.
15. Prepare, distribute and maintain an instructional document, explaining the reference systems - both linear and spatial.

Long-term action

16. Implement dynamic (programmatic) subdivision of pavement management sections.
17. Establish additional monuments along the routes.
18. Continue processing pavement management data to reflect historical significance.
19. Implement the DOT GIS.

The DOT's Highway Division is implementing these recommendations as part of the pavement management project. An additional Bureau of Information Services support team has been formed to expedite this work.

Data File Preparation

The DOT transferred the Cartography Section's existing Highway and Transportation (H&T) maps from the VAX to the Intergraph workstation. The H&T maps were brought into Intergraph's Microstation GIS Environment (MGE) and sent through an MGE process called CLEANING, which made linework and intersections topologically correct. This topological correction process uses user-defined tolerances to eliminate duplicate line work, and ensure that all intersections are interpreted correctly by the software. The resulting linework was given a linkage pointing to a specific map feature (ie. primary road, railroad, etc.), and an associated user-defined database table. An additional attribute linkage was attached to each graphics elements which pointed to a newly created blank record in the database table. These blank records were then loaded with information pertaining to the graphic element.

Data were also transferred from the 1990 base record history file . Primary road data were loaded in a database table using the Informix SQL load utility. The corresponding graphic lines were made at the same time as the load file, on the VAX, using PRIMROAD_YR90.DAT as the source. This file contains line information combined with road controls in each record. The original linkages in the VAX file were created using DMRS.

Data Exchange

An important goal of this project was to exchange data files between the DOT and the DNR to eliminate the redundant input and maintenance of identical files. This project enabled the DOT and the DNR to investigate the process of exchanging a variety of point, line and area data files.

All of the DOT files needed by the DNR for this project were residing on the Intergraph VAX CADD system. The transfer of the DOT's files to the DNR took four steps (**see Figure 6**). First, the files were moved from the VAX to the Intergraph workstation. Second, the DXF utility in the base Intergraph Microstation 32 software was utilized to create a DXF file. Third, a "C" program was used to add a carriage return and line feed to the end of each element record in the DXF file. Fourth, the files were translated from

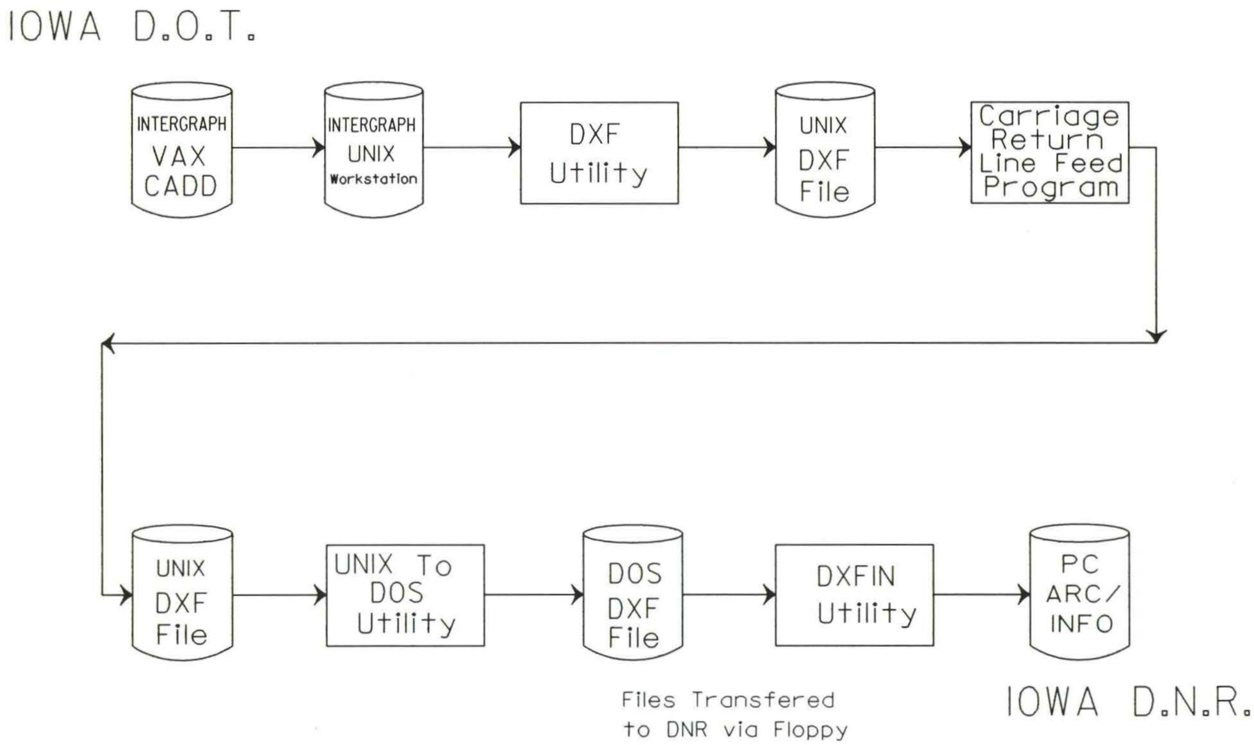

FIGURE 6

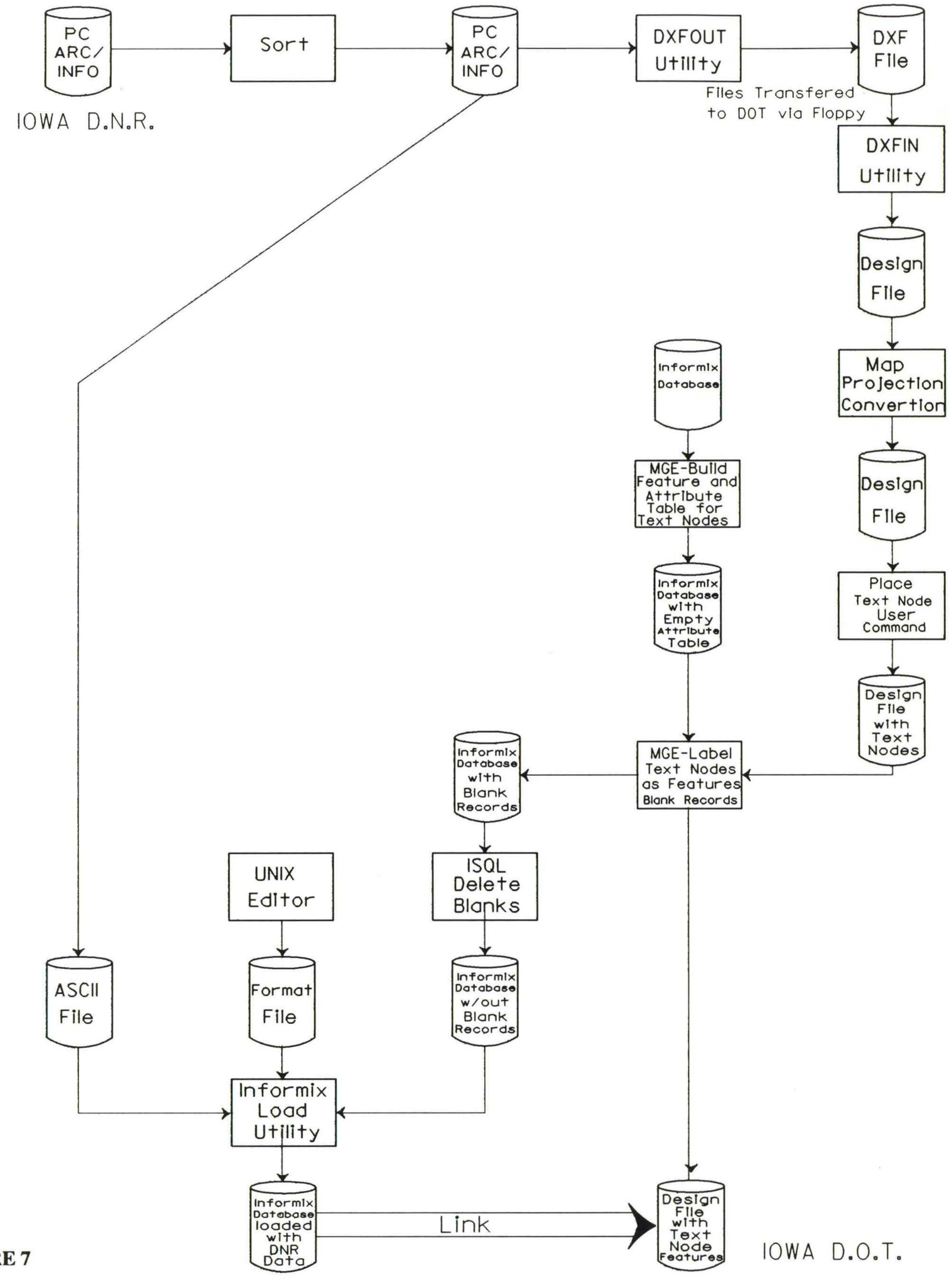
PC ARC/ INFO
Sort
PC ARC/ INFO
DXFOUT Utility
DXF File
IOWA D.N.R.
Files Transfered to DOT via Floppy
DXFIN Utility
Design File
Informix Database
Map Projection Convertion
MGE-Build Feature and Attribute Table for Text Nodes
Design File
Informix Database with Empty Attribute Table
Place Text Node User Command
Design File with Text Nodes
Informix Database with Blank Records
MGE-Label Text Nodes as Features Blank Records
UNIX Editor
ISQL Delete Blanks
ASCII File
Format File
Informix Database w/out Blank Records
Informix Load Utility
Informix Database loaded with DNR Data
Link
Design File with Text Node Features
IOWA D.O.T.

FIGURE 7

the UNIX operating system to the DOS operating system using a utility in Intergraph's UNIX product. The DOS files were then sent to the DNR on floppy disks and input into ARC/INFO.

The translation of files from the DNR's ARC/INFO software to the DOT's Intergraph system was much more complex **(see Figure 7)**. DXF was used for the graphics and an ASCII character data file for the database. The DNR translated the graphics into a DXF file using the standard translation package in the ARC/INFO base product. The graphics and database were not transferred as one unit. The database data were output to an ASCII file in the same order the graphic elements were output to the DXF file. The key to reassociating them was to have both the graphics and database files in exactly the same order. The DOT brought the DXF file into the Intergraph system by using the standard DXFIN utility found in the base Microstation package. This utility creates a design file from the information stored in the DXF file. There are many different areas that can affect the translation, including the seed file, coordinate adjustments, and the map conversion process. The DOT experimented with several methods of map projection conversion before finding a usable solution.

After bringing the graphic elements into the DOT's system, it was necessary to load a database table and reassociate the attributes with the corresponding graphic elements. A user command was written to place a text node to be used as a point feature. A new feature was made for the text nodes and a user- defined attribute table was associated with that feature. The text nodes were then labeled in the database with linkages pointing to the new feature, as well as given an additional linkage pointing to newly created blank records in the user-defined attribute table. Blank records in the new database table were deleted then reloaded with the ASCII file attribute information, using an Informix SQL load utility.

Demonstration Project

A corridor analysis is the detailed study of a selected route to evaluate its effectiveness and quality. A corridor analysis was conducted for this project to demonstrate the value of access to and incorporation of natural resources and transportation network data. The study of these relationships enables a detailed analysis of the movement and consumption of energy resources. The corridor analysis examined the potential uses of GIS in the DOT and the necessity of data exchange with other state agencies. Through this process, the power and potential problems of GIS and spatially relating data maintained by other agencies could be fully explored. For this project, the emphasis was on creating a base for geographically referencing files rather than on in-depth corridor analysis. Phase Two of this project will include an indepth corridor analysis for a project in the DOT's five-year plan.

A study area corridor concept was selected to narrow the amount of data needed for analysis. The corridor selected had to incorporate both the DOT and DNR information. A project group was formed with staff from several offices within the DOT's Planning & Research Division. The group helped to establish the project goals and to explain the GIS needs of other offices within the DOT. The project group and the DNR met to review the available data sources. After careful consideration, a corridor in eastern Iowa was selected, based on the availability of data.

The corridor chosen was located in Linn, Jones and Dubuque counties in eastern Iowa **(see Figure 8)**. The focus of the study was a section of U.S. Highway 151, beginning east of Cedar Rapids at the junction of U.S. 151 and Iowa 13, and ending at the City of Dubuque.

The data used in the corridor analysis came from several areas within the DOT and the DNR. The DNR provided the following files: public and abandoned wells, hazardous waste sites, sanitary landfills, and underground storage tanks. Some of the DNR files that the DOT could have utilized were not available in digital format. Those files included land cover, archeological sites, habitat characteristics, wetlands and mineral resources databases.

Information obtained from the existing DOT files includes: the transportation network and associated database information, cemeteries, state parks, city boundaries and city populations. The Photogrammetry Section used a stereo digitizer

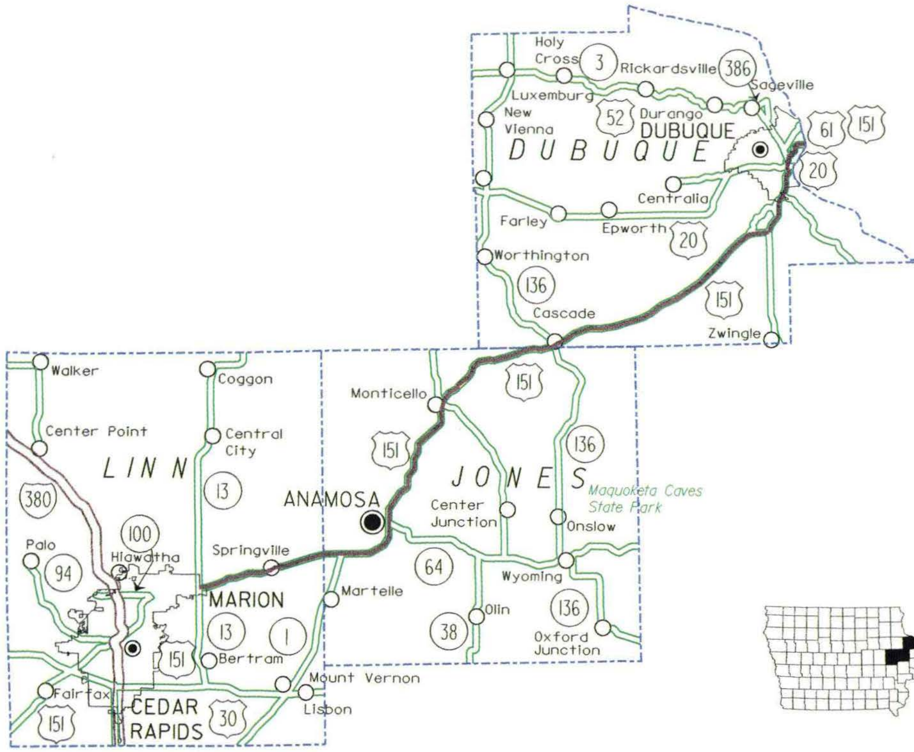

FIGURE 8

to create planimetrics and contours for a small area in the corridor. Digital aerial photos for the same area were scanned by Intergraph. The DOT staff used the Database Management and Retrieval System (DMRS) linkage, created in the Cartography Section, to attach selected information from the base record to linework in MGE. The base record information included: average annual daily traffic (AADT), surface width, sufficiency rating, shoulder width, construction year, and truck traffic volume. Historical bridge and site data were only available in paper format; therefore, these data were not utilized. All of this information was combined and analyzed to create thematic maps, length and area calculations, feature counts, and buffer zones.

Results and Discussion

The purpose of the project was to investigate (1) the feasibility of exchanging digital geographic information between state agencies, and (2) the applicability of a GIS to each agency's energy-related programs. The corridor analysis study provided a platform to study both of these concerns.

Effects of Sharing Information

The point, line or area information currently collected and maintained by state agencies can be exchanged. Exchanging data with other state agencies reduces the redundancy and the cost of collecting information. It also has the potential to increase the accuracy, as well as the amount of data available. This reduces duplication of effort and allows access to extensive amounts of data. Utilizing information maintained by the agency responsible for it facilitates the acquisition of more accurate data.

Feasibility of GIS

Geographic information systems permit the assembly of data from many different sources. This assembly allows for the analysis of the spatial relationships of data. Through the use of the GIS, additional criteria and information can be analyzed. There are many applications for data analysis within the DOT. Through the use of

GIS, the DOT can evaluate more alternatives to make adjustments or accommodations when searching for the most economical, environmentally conscious, and energy-efficient location for the roadways.

The most efficient alignment of the highways in Iowa ultimately obtains highest energy efficiency of road use. Reducing the number of steep grades, curves and excessive acceleration or deceleration areas allows for the highest energy efficiency to be obtained. Identifying the location of Iowa's energy resources aids in the planning of transportation networks for the most efficient movement of the natural resources.

Conclusions

The purpose of the project was to investigate the feasibility of exchanging digital geographic information between state agencies, and the applicability of a GIS to each agency's energy-related programs. This project proved to be successful. The DOT was able to examine many of the aspects of a GIS package before making a costly commitment. The environment created by the project facilitated the development of procedures for point, line and area feature exchange between the DOT and DNR (**see Figure 9**). Digital data maintained by each state agency can be feasibly exchanged. This exchange allows each agency to incorporate greater amounts of data into the GIS analysis for their energy-related programs.

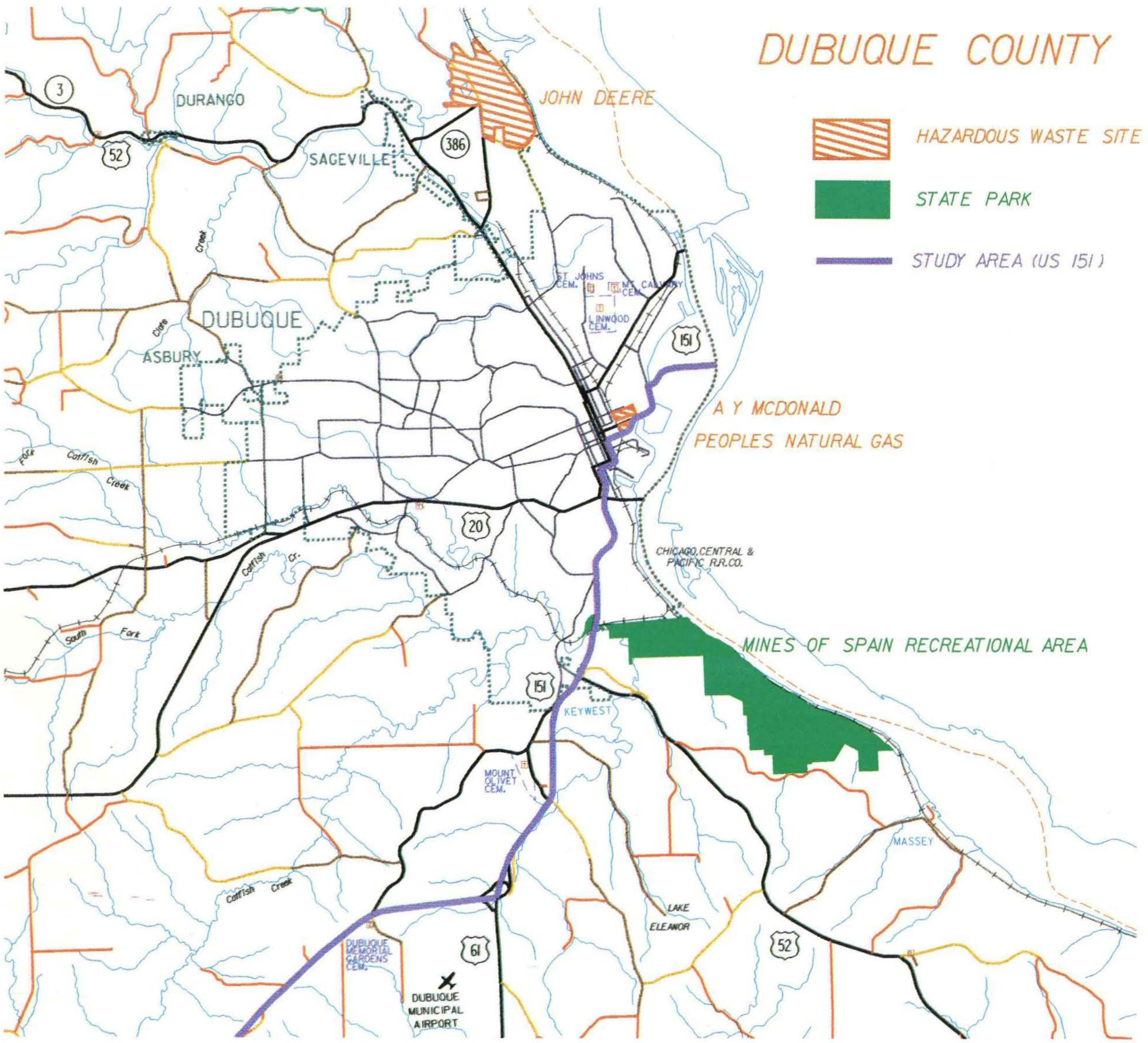

FIGURE 9

Digital exchange requires a time commitment from all of the agencies involved. Currently, the exchange process is not straightforward. Moving information from one GIS system to another involves: identifying the data needed, developing procedures for exchange, formatting the data, and verifying the data conversion accuracy. The exchange process used for this project could be enhanced to reduce the need for redundant data collection by several state agencies. To make the exchange practical on a larger scale, procedures will be developed by the state agencies involved.

One area that will greatly enhance digital data exchange is a common geographic base, such as the DOT H&T maps used in this demonstration. Some other areas for development will include: the type of information exchanged, data format, coordination of update cycles, and understanding of accuracies inherent in each agency's data.

The future utilization of GIS and the support of GIS operations were discussed during the course of this project. One of the issues developed through this project was how the DOT's CADD maps could be built to support a GIS. Related to this issue is the skill level of the GIS operators. The complexity of the software requires that the operators be well trained and have a working knowledge of CADD and GIS. The issue for the future is not if GIS will be useful to the DOT, but if support will be available to absorb the added work load. GIS software is complex and requires support persons that use the GIS products on a regular basis. The GIS software requires the establishment of procedures for software loading, customizing and updating. The inter-relationship of Intergraph's GIS software requires the products to be compatible and loaded in a specific order. For efficient use of the software, shell scripts and user commands may be written by support persons to automate redundant steps. Since this UNIX system operates differently than the existing VAX system, backup procedures must be established. This system also presents challenges when implemented in a production environment in the areas of data security, user training and hardware maintenance.

Recomendations

The long-term benefits of a GIS package at the DOT are numerous. This type of system could act as a new medium of exchange for information between state agencies and private concerns. The methods for collecting, maintaining and utilizing records may change to the point where it is no longer necessary for agencies to collect information redundantly. A GIS can also improve an agency's ability to analyze the large volume of data it is required to collect. Each agency must consider not only its own data, but how its data relate to the data maintained by other agencies.

Geographic information systems deserve further investigation. The enthusiasm displayed by many offices within the DOT throughout this project illustrates the need for GIS as a tool. (The results of this GIS demonstration project have encouraged the investigation of GIS uses in both the Planning and Research Division and the Highway Division of the DOT. Applications could include advance planning, project planning, cartography, maintenance and pavement management.) The Planning and Research Division is moving into a second phase of GIS development with a pilot project utilizing GIS for a corridor study in the DOT's production environment.

During the project DXF was used as the format for exchange. Although this method worked, it may not be the best format of exchange in a production environment. A translation format that maintains the attribute linkages may greatly enhance the exchange process. Some of the translation formats that should be considered are Interactive Graphics Exchange Standard (IGES), Standard Interchange Format (SIF), or other direct translators.

An applications engineer from Intergraph assisted in establishing procedures, goals and direction for the corridor project. The experience that he had gained from helping others set up similar GIS projects was very valuable. This type of experience is vital to the success of a GIS. It is recommended that an experienced GIS group, with a broad and objective perspective on the needs of the various DOT offices, be consulted during continued GIS development. This group should consist of DOT staff, outside consultants, or a combination of both.

The complexity of GIS hardware and software requires the examination of many issues for the support of operations. These areas include software loading, customization, procedure automation, workstation backup, and hardware maintenance. An additional area of concern is the education and experience of the GIS users. All the operators do not need to know the intricacies involved in the GIS software; however, it is important they understand the delicate link between the database and the graphics. Training of the GIS operators is essential for the DOT to fully realize the advantages of a GIS. These areas and more are critical to the success of a GIS in a large organization such as the DOT. Therefore, it is vital that the role of the support team and users of GIS be established prior to full implementation.

In the beginning, an all-encompassing GIS is not necessarily the best solution. If well planned, a GIS can be built on a project-by-project basis. Available information could be utilized until new data are entered into the system. For example, a GIS for the DOT could start with the primary road system and then incorporate other information (ie. secondary roads, railroads, etc.). As information is being assembled, accuracies should be considered; however, it should not limit the use of available information.

A goal for the future of GIS is continued energy savings through data exchange with other state agencies. The usefulness of data exchange between the DOT and the DNR has been shown through this project and will be expanded in the future to include exchange with various state agencies and private concerns.

Through studying GIS, the DOT has found that most of the GIS packages currently available have similar analysis capabilities. The most crucial decision to be made is not which package to buy, but how GIS can be implemented successfully. It is important to ensure that the GIS fits the organization's needs since a GIS is dependent on staff commitment and the support of upper management. A productive and successful GIS is an attainable goal.

For questions or further informaton, contact Peggi Knight, (515) 239-1380; or Kevin Kane (515) 281-5815.

Appendix — Hardware and Software Configuration

Transportation Inventory:

Hardware

InterPro 6040, 32Mb RAM, 670Mb disk, 27" monitor,
Floppy drives (3.5" & 5.25")
Menu Tablet & Cursor
Cartridge Tape Drive (8mm, 2.3Gb)
Digital Equipment Corporation VT320 Terminal
Shinko Color Thermal Plotter
Epson LQ-850 Line Printer

Software

MicroStation 32
Modular GIS Environment (MGE)
Modular GIS Analyst (MGA)
MicroStation Finisher (MGFN)
MicroStation Projection Manager (MSPM)
MGE GIS Translator
Intergraph Raster Editor (I/RAS 32)
Network File System
Soft PC (DOS emulation)

Cartography:

Hardware

InterPro 6040, 16Mb RAM, 670Mb disk, 27" monitor
Menu Tablet & Cursor

Software

MicroStation 32
Modular GIS Environment (MGE)

Project Planning:

Hardware

InterPro 6040, 32Mb RAM, 670Mb disk, 27" monitor
Menu Tablet & Cursor

Software

MicroStation 32
Modular GIS Environment (MGE)
Modular GIS Analyst (MGA)
Intergraph Raster Editor (I/RAS 32)

Information Services:

Hardware

InterPro 2020, 16Mb RAM, 340Mb disk, 19" monitor

Software

MicroStation 32
Modular GIS Environment (MGE)
Modular GIS Analyst (MGA)
Programming Language Compiler, 'C'
Customer Support Library (CSL)

Server:

Hardware

InterServe 6000, 10 MIPS, 5 Slot, 16Mb RAM, 1.67Gb disk

Software

Oracle (RDMS) base product
Fortran Software

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