



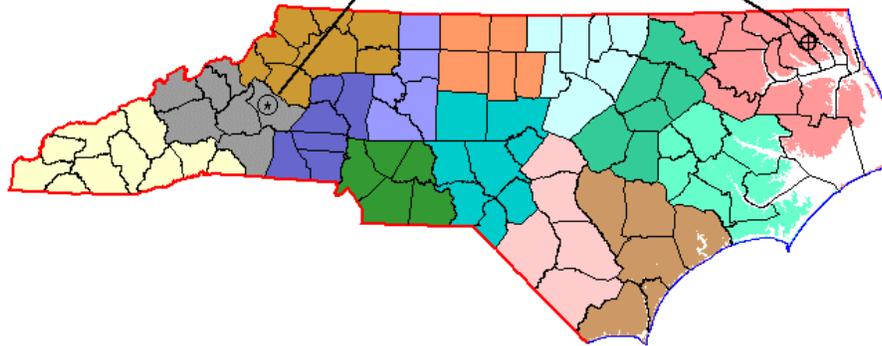
# Transportation Case Studies in GIS

## Case Study 3: NCDOT: Use of GIS to Support Environmental Analysis During System Planning



### North Carolina DOT

Case study project locations



- ⊕ Halstead Blvd Extension, Elizabeth City, Pasquotank County
- ⊕ Morganton Western Connector, Morganton, Burke County

### Project Summary

Many State DOT's are starting to use GIS as a tool to support a range of transportation decision-making processes. This case study explores the successful use of GIS as a key part of a new approach: "The Phased Environmental Approach," initiated by NCDOT as a pilot to improve its process for integrating environmental issues into the transportation System Planning Process. This project has established the ability of GIS to support a major change in NCDOTs systems planning process. Benefits highlighted throughout this case study regarding the use of GIS should not be viewed apart from the Phased Environmental Approach.

### Project Benefits

- Earlier Consideration of Environmental Issues in the Planning Process
- Faster, More Effective Environmental Analysis Process
- Enhanced Participation of Regulatory/Resource Agencies
- Improved Data Credibility
- Better Decisions at the System Planning Level
- Greater Commitment to Decisions
- Savings of Time and Cost

## What Role Did GIS Play in Supporting an Improved Transportation Systems Planning Process in NCDOT?

In January of 1995, NCDOT began a proactive effort to effectively address environmental issues early in the transportation planning process, using GIS as an important tool. This move was in response to the rules for Statewide and Metropolitan Planning promulgated by the FHWA/FTA in 1993, which reinforced the requirement that states address environmental issues not only during project planning, but also during the initial systems planning process.

Systems Plans at NCDOT are created to provide a picture of anticipated future transportation needs, and the anticipated projects designed to meet those needs. These projects are entered into the Statewide Transportation Improvement Program (STIP), as they are funded, and many local decisions are made around the locations shown on the plan for proposed projects.

The Phased Environmental Approach developed at NCDOT improves the systems planning process by integrating environmental considerations at this stage. This approach supplements the traditional transport needs-driven analysis that is conducted. It has been applied on a pilot basis and is currently being integrated in NCDOT's Systems Planning Process. The environmental issues addressed by NCDOT's improved Systems Planning Process include both the social and natural environments. This approach utilizes existing environmental information gathered in cooperation with the environmental resource/regulatory Agencies, which is subsequently presented in GIS format. The GIS presentation is used by NCDOT as a means of effectively highlighting all significant environmental, cultural, and social constraints to the participants in the Systems Planning Process, including participants from the agencies and the local area governments (as well as NCDOT planners and engineers). The goal of this approach is to address major environmental issues early in the transportation systems planning process, in order to identify and gain consensus on the most environmentally-acceptable corridor for each system improvement to be included in the systems plan and future STIPs.

The change in the Systems Planning Process at NCDOT is illustrated in the comparison of Figure A. The improved Systems Planning Process shown in Figure A

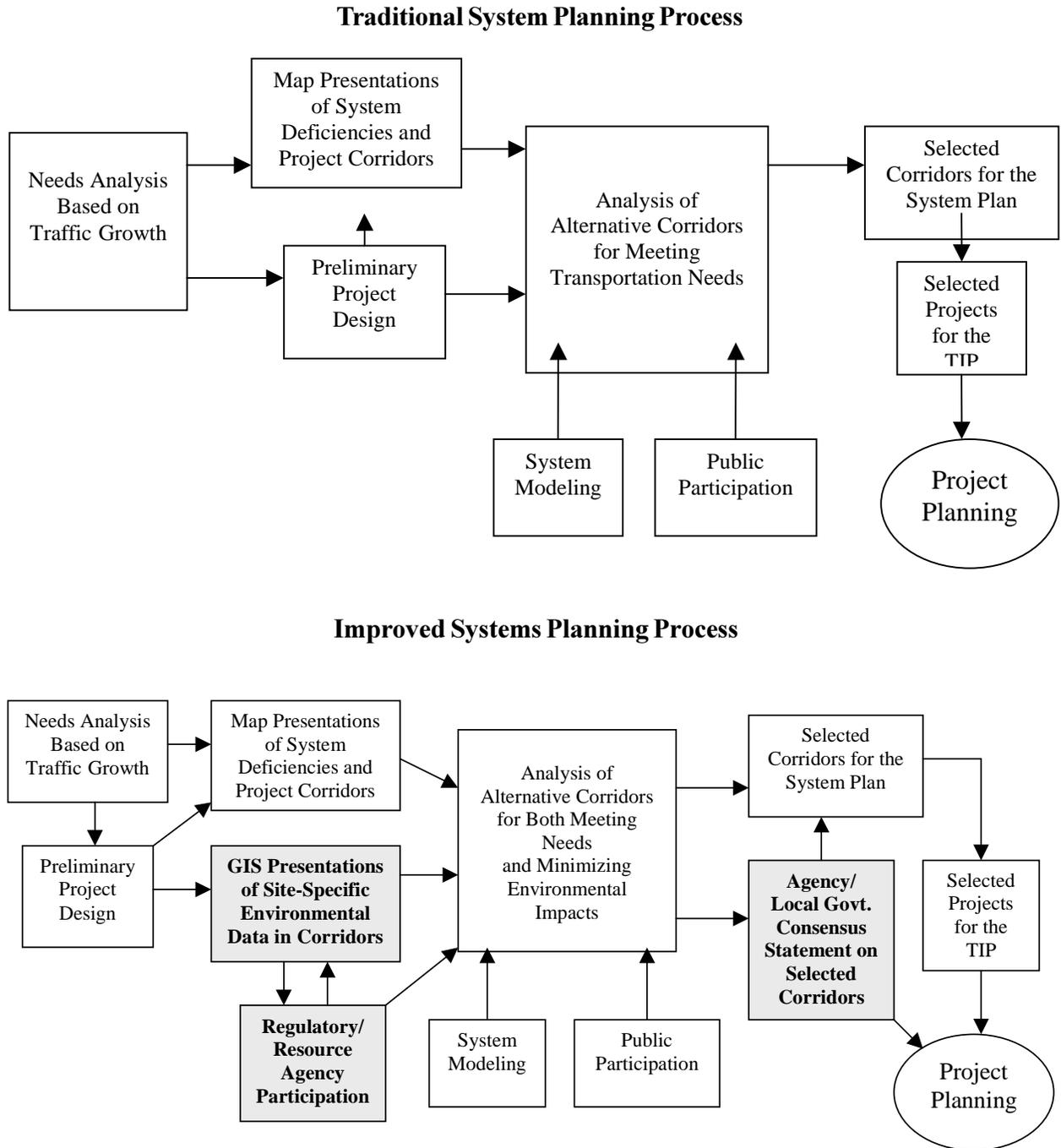
### Typical Public Organizations Involved in the Improved NCDOT Systems Planning Process

Federal Highway Administration  
North Carolina Department of Transportation  
MPO's and City Governments  
North Carolina Department of Environment and Natural Resources  
United States Corps of Engineers  
United States Fish and Wildlife Service  
National Marine Fisheries  
North Carolina Wildlife Resources Commission  
North Carolina Division of Water Quality (formerly the North Carolina Division of Environmental Management)  
North Carolina Division of Coastal Management  
North Carolina Division of Marine Fisheries  
North Carolina Division of Parks & Recreation  
North Carolina Department of Cultural Resources

incorporates the Phased Environmental Approach and is now supported by GIS data that conveys site-specific environmental information. There is also a specific early involvement in the Systems Planning Process by the regulatory/resource agencies who are responsible for safeguarding environmental, cultural and historical sites. The provisions of these GIS data and the earlier participation of resource/agency staff in the systems planning process allows a more cooperative analysis of alternatives to proposed corridors. This cooperation helps to defuse the later more confrontational process that traditionally takes place in the Project Planning Process.

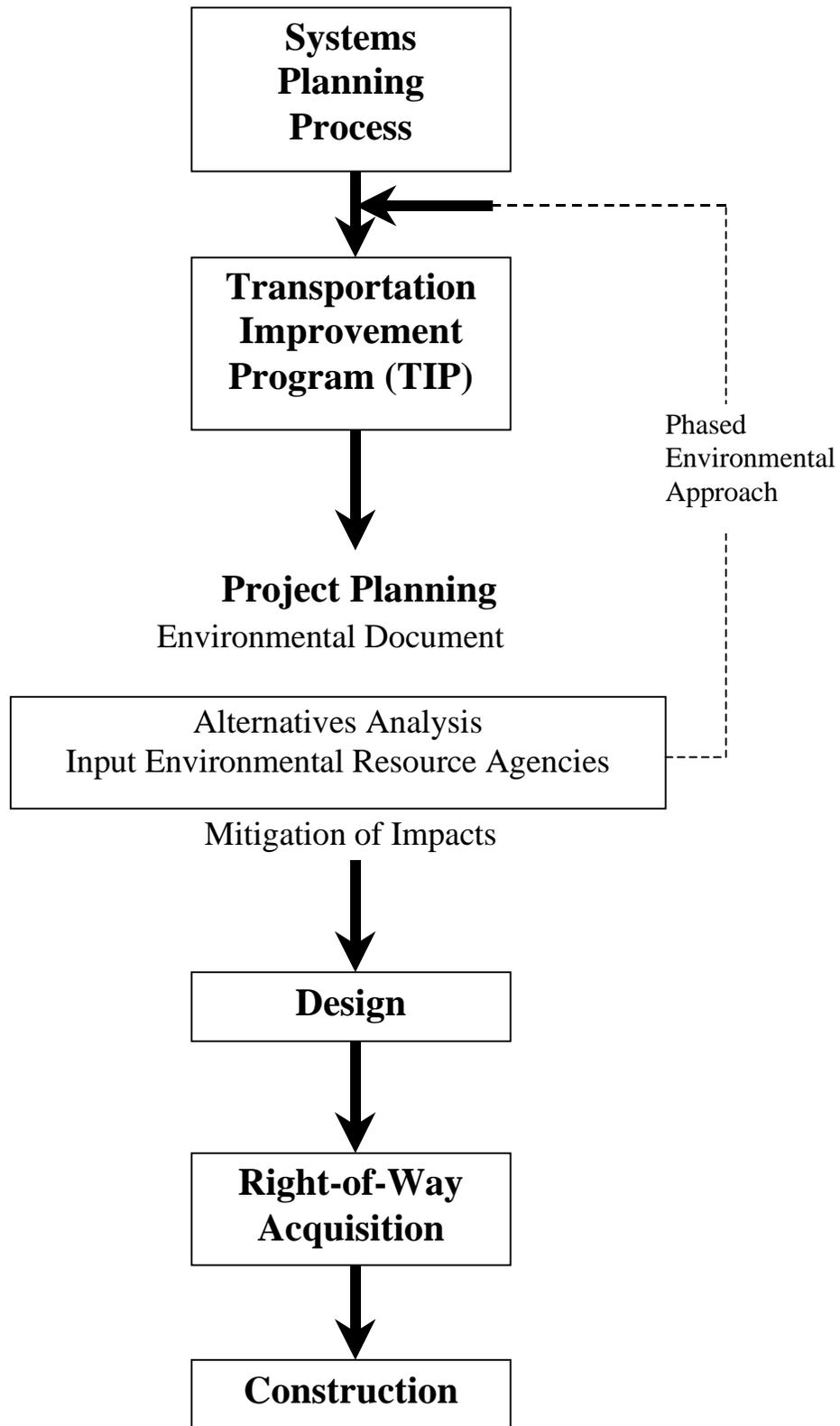
In many cases under the traditional process at NCDOT, the level of detail and complexity of the analysis during the project planning phase, where the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA) are applied, is dictated by the regulatory/resource agencies involved. Consequently, the more confrontational the process, the greater the amount of documentation that is insisted upon by the partner agencies and public interest groups. This attitude is due to a distrust in the existing process by NCDOT partners who often felt that (i) good environmental data were not used in selecting alternatives, (ii) projects went into the STIP and became commitments for NCDOT staff and (iii) the project implementation

Figure A  
 NCDOT Planning Process Before and After Improvement



1. The improved Systems Planning Process is currently being phased into NCDOTs operations.
2. The GIS data supplied in the improved process gives the agencies a basis for judging the relative size of impacts for different alternatives. This results in a quicker process and more commitment to the results.

Figure B. The Phased Environmental Approach in Highway Project Development



date drove the process rather than a rational and balanced consideration of the issues. This was often aggravated by the fact that the alternatives shown in the systems plan (selected without the benefit of environmental analysis) has already influenced many local decisions. The local authorities who had been involved in the systems planning process were confused and angered when alternatives differing from the systems plan were being reconsidered in the project planning phase.

On the other hand, NCDOT engineers and planners felt handicapped in that they could not easily put their hands on the most pertinent data for environmental analysis and data in which the agencies and interest groups would have confidence. This led to a feeling of frustration on the part of the engineers and in some cases a hardening of the position that project selection should be based primarily on transportation needs analysis. This also contributed to making the process more confrontational than cooperative.

By showing partner agency data in a GIS format, NCDOT generated increased confidence in the process. This GIS presentation maps could also be produced more rapidly, once the digitized data were available, and increased the responsiveness by NCDOT when data presentations could be produced with quick turnaround times. The GIS materials, therefore, increased the credibility of the process used by NCDOT, shortened turnaround time and increased the effectiveness of data presentation for decision-support purposes. This allowed NCDOT to create a more cooperative planning environment.

### **How Was GIS Used to Help Integrate Environmental Considerations in the Transportation Systems Planning Process?**

The improved use of GIS data in the NCDOT Systems Planning Process focused on two elements:

- The assembly of existing environmental and related data for specified study areas (such as National Wetland Inventory, Water Supply watershed, High Quality Water Zones, stream classification, zoning, development plans, etc.), as gathered from agency sources, in GIS format.
- The display of environmental information, along with

potential transportation solutions, over aerial imagery, in combination with written descriptions of the purpose and need for each solution, and tabular data on each corridor, all designed to facilitate decision-making and consensus by the agencies.

These data types were expanded as the GIS system was improved at NCDOT. The entire range of data categories shown in GIS format in four different applications of the improved planning process are listed in Table 1. The display of environmental information over the aerial images, in particular, has been found to be very important in helping the partner agencies and local government officials reach the level of comfort required for consensus on selected corridors at this stage of planning.

The sequence of events for the GIS support of the improved process to integrate environmental considerations is as follows:

1. Compilation of environmental data and mapping for the planning area. Most data from existing sources of data (See Table 1) but some field surveys of historical sites are carried out.
2. Identification of the transportation system deficiencies and possible project alternatives which need environmental analysis.
3. Preparation of aerial photographs of the project's scope of influence overlaid with the various improvement alternatives (500-foot corridors), environmental resources, and cultural resources in GIS format.
4. GIS presentation of other significant environmental data in the area of the alternatives for all major corridors.
5. Use of the GIS data in a series of meetings held with the agencies and local governmental officials to review the proposed alternatives, in order to field-check areas of interest or concern, and form a consensus as to which alternatives were the most environmentally acceptable. These data are also used in a series of public meetings, a public information workshop, and a public hearing to solicit input from the citizens of the community.

Table 1. Matrix of Map-Based Data Used in Improved System Planning

Document Type	Morganton	Elizabeth City	Asheville	N. Wilkesboro
<b>A. Environmental Data (GIS)</b>				
1. Aerial Photo Overlaid with		(see note)	(see note)	(see note)
- Hydrography	◆	◆	◆	◆
- Historic Districts	◆			
- Historic Sites	◆	◆	◆	◆
- Archaeological Sites			◆	
- Natural Heritage Sites	◆			
- National Wetland Inv.	◆	◆		
- NPDES Sites	◆	◆	◆	
- Superfund Sites			◆	◆
- Hazardous Waste Facility			◆	
- Solid Waste Facility			◆	
- Groundwater Incidents	◆		◆	
- Water Sup. Watersheds	◆			◆
- Water Sup. Critical Area				◆
- Surface Water Intakes	◆		◆	◆
- Nondischarge Systems	◆			
- Trout Streams			◆	◆
- Anad. Fish Spawn Areas		◆		
- Dam Sites				◆
- Hydric Soils			◆	◆
- Recreation Areas		◆		◆
- Cemeteries		◆		
- Corridor Alternatives	◆	◆	◆	◆
<b>B. Transportation Data (Map)</b>				
1. Traffic Analysis Zones	◆	◆		◆
2. Planned Land Use	◆			
3. Future Growth Areas		◆		◆
4. Traffic Volumes	◆	◆		◆
5. Problem Areas			◆	
6. Existing Deficiencies			◆	
7. Future Year Deficiencies with TIP Projects	◆	◆	◆	◆
8. Substandard Bridges				◆
9. Alternative Alignments		◆		◆
<b>C. Resulting Plan (Map)</b>	◆	◆	◆	◆

The NCDOT process was improved in stages with the first test cases in Asheville and North Wilkesboro (shaded above) carried out with base maps rather than aerial photos. In the case of Elizabeth City aerial photos were annotated by hand to create a kind of manual GIS. The Morganton case combined the most effective means of presentation with faster and more responsive, computerized GIS mapping and overlaid on aerial images.

6. Selection of an environmentally preferred alternative for the identified transportation improvements and the establishment of a Consensus Charter specifying which of the improvement alternatives appear environmentally preferable based on the existing data and fieldwork, and appropriate caveats concerning future changes in information, law or policy.

### Case Studies in NCDOTs Systems Planning Process

In all four cases where this improved system was applied, there were significant corridor deficiencies in handling future traffic and numerous environmental issues associated with the corridors proposed to alleviate these deficiencies. Also, in each case, there were multiple corridors that required significant investments and associated analysis. Despite these difficulties, in all cases, the agencies involved in the GIS-supported Phased Environmental Process came to a consensus regarding the environmentally preferred corridors for the future highway network (with appropriate caveats). The benefits of this approach are illustrated below for the two cases of Halstead Boulevard in Elizabeth City and the Western Connector in Morganton, North Carolina.

#### Halstead Boulevard Extension (Manual GIS)

In the case of the Halstead Boulevard Extension in the Elizabeth City Systems Plan, several alignments/corridors were considered for expanding the road's capacity, including locations both on and off the existing alignment. Figure C displays the project location of the Halstead Boulevard Extension.

A series of GIS maps and overlays (see Table 1, column 3) supported the process. These maps were produced as part of a manual GIS process. The process was based on a "blue line" print of an aerial photo covering the proposed project corridor locations. This image was scanned and digitized, then transferred to a mylar medium. The environmental data (wetlands areas and point locations) were then overlaid on the mylar and the information transferred by drawing a crosshatched pattern or boxes on the mylar and labeling them. The mylars were then printed in blue line format and the project location alternatives were drawn in color on the blue line prints. This process was effective for presen-

tation, but limited in quantity (12 sets), due to the handwork required. NCDOT does not recommend that other DOTs reproduce this process, as it could be done more efficiently, even as a manual method. It also did not encourage the redrawing of alternatives as they were suggested. However, it did prove that the computerized processing was not strictly necessary for GIS data presentations.

After carrying out the systems planning process, the group of participating agencies and the local government officials were able to agree that the best solution was a new alignment of the existing road system. The process was accelerated considerably through the use and presentation of annotated aerial photos and it gained considerable credibility for showing data that came from Agency sources. The presentation allowed the participants to review much of the data in the office and reduce the number of site visits. Site visits that were conducted were for the purpose of verifying existing data with resources in the field rather than discovering environmental resources for the first time.

The benefit of reaching this consensus during the systems planning process was realized when this project passed into project planning. At the first scoping meeting, the project planning engineer (who was not familiar with the work done during systems planning) suggested that widening of the existing alignment should be reviewed as an option in addition to the new location alternative that came forward from the phased environmental study during the systems plan. At this point the representative from the state water quality agency said, "Why? We have already agreed on the study corridor."

This response runs counter to the experience of NCDOT in the traditional, more confrontational planning process where the concerned agencies would normally insist on a detailed analysis of widening the existing alignment as part of the alternatives analysis in the NEPA/SEPA process. The fact that they did not require this second review during the project planning process is a strong testimony to the decision ownership that was established during the review of the widening alternative and consideration of environmental impacts in the improved systems planning process.

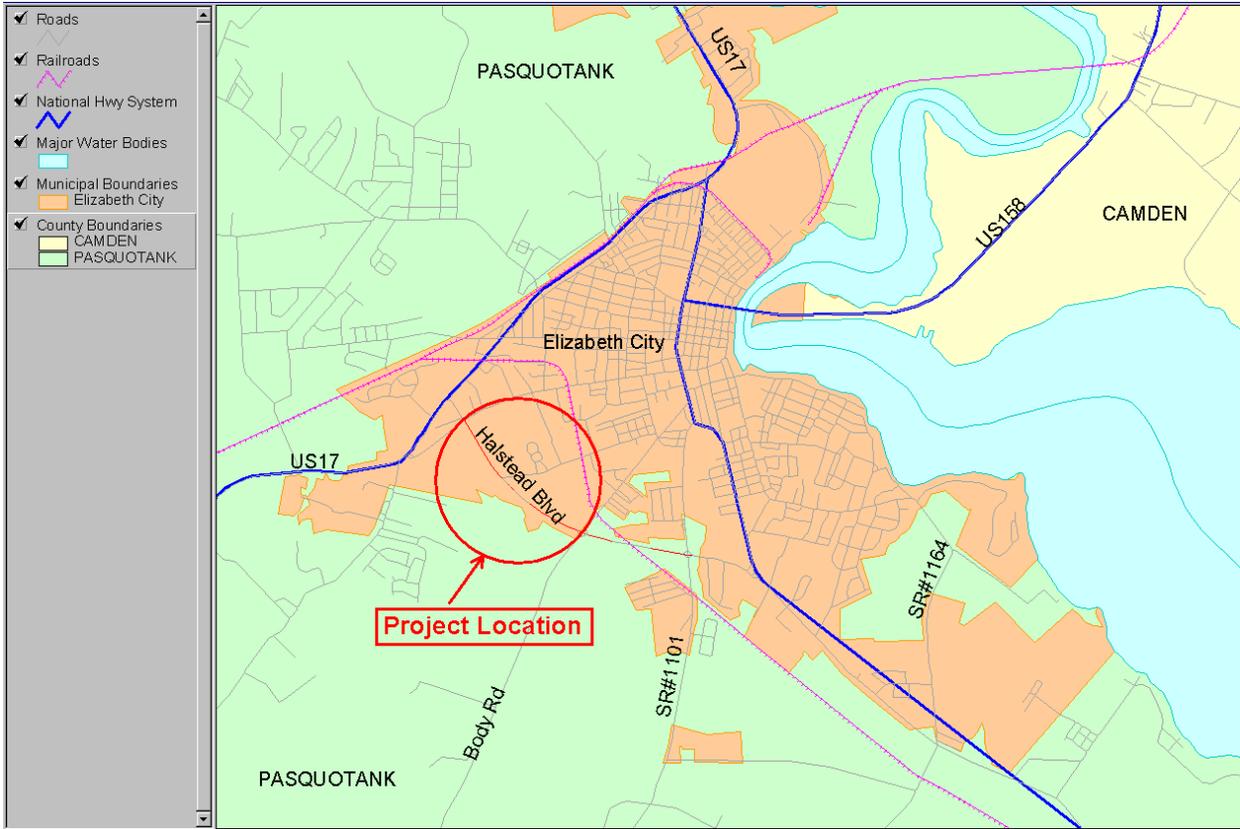


Figure C: Halstead Boulevard Extension Project Location

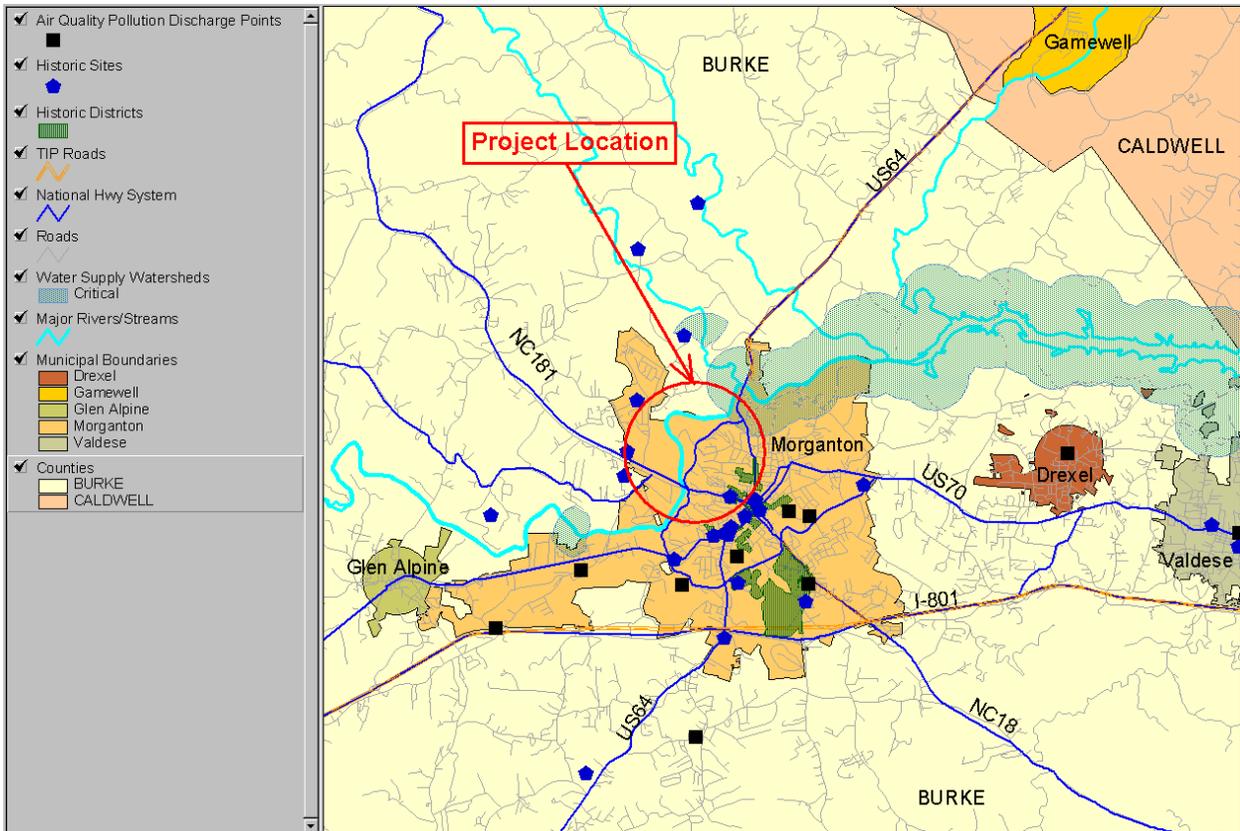


Figure D: Morganton Western Connector Project Location

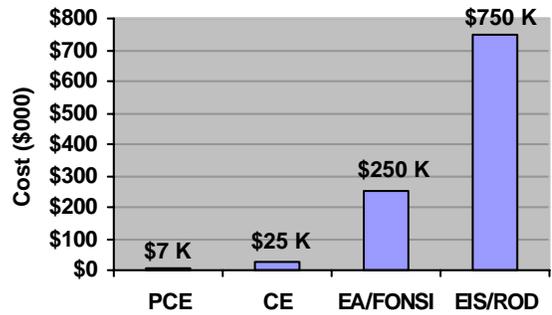
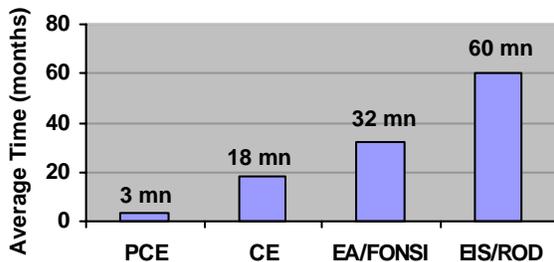
### Morganton Western Connector

The Morganton Western Connector involved a major project that was located primarily on a new location over 12-16 miles. Figure D displays the project location of the Morganton Western Connector. Several corridors were considered in the systems planning phase and with the improved process and GIS-support, NCDOT was able to reach full agency consensus on a single corridor ranging from 500' to 1000' in width (See example corridor analysis map over aerial photos in Figure E).

This was the first case that fully utilized GIS software for NCDOT systems planning. It involved the use of three different types of software: ARC/INFO, Descartes and Microstation. The environmental data (see Table 1, column 2) was exported from ARC/INFO to a common format file. The aerial image was rectified in Descartes to fit the locations of roads and streams from USGS digital line graphs. This modified image was brought into Microstation with the environmental layers and corridor outlines were drawn in from engineering files using Microstation, then the combined image was output to a plotter. This process allowed for multiple modifications and plots of alternatives as they were suggested. The time for creation of the initial images was reduced from two months to one week of processing time.

### Benefit and Cost Estimates of Case Study Projects

In understanding the estimates of time and cost associated with environmental planning in NCDOT, it's important to understand the average time and cost of the environmental documentation typically prepared during this process. The following chart demonstrates these averages:



PCE	Programmatic Categorical Exclusion
CE	Categorical Exclusion
EA/FONSI	Environmental Assessment/ Finding of No Significant Impact
EIS/ROD	Environmental Impact Statement/ Record of Decision

These charts provide the average time and cost ranges for the three types of NEPA/SEPA documentation carried out by NCDOT over the last five years ('92-'96).

### Halstead Boulevard Extension

The time for analysis of alternatives in the project planning stage took only 16 months, which is half of the average completion time for an Environmental Assessment (EA). This resulted in savings of approximately \$125,000 to NCDOT.

This savings was achieved at the expense of three months of extra work for an engineer in producing the GIS documentation, which cost NCDOT an estimated \$12-15,000 in additional staff time and associated costs. There was also a significant effort on the part of participating agencies during the three months of system planning time, but this was more than compensated by the time they saved in the project planning phase.

### Morganton Western Connector

Due to the early consensus established in the systems planning phase from the corridor alternatives analysis, this project will be handled as a simple EA with reduced scope. Traditionally, this type of project would be handled as a major EA or an Environmental Impact Statement (EIS) during project planning, requiring consideration of many alternative corridors and 12-24 months minimum time to reach consensus on a preferred corridor. The reduced level of analysis and documentation requirements agreed to by the participants now will allow NCDOT to save as much as \$250,000

Figure E: Morganton Western Connector Alternative Corridors

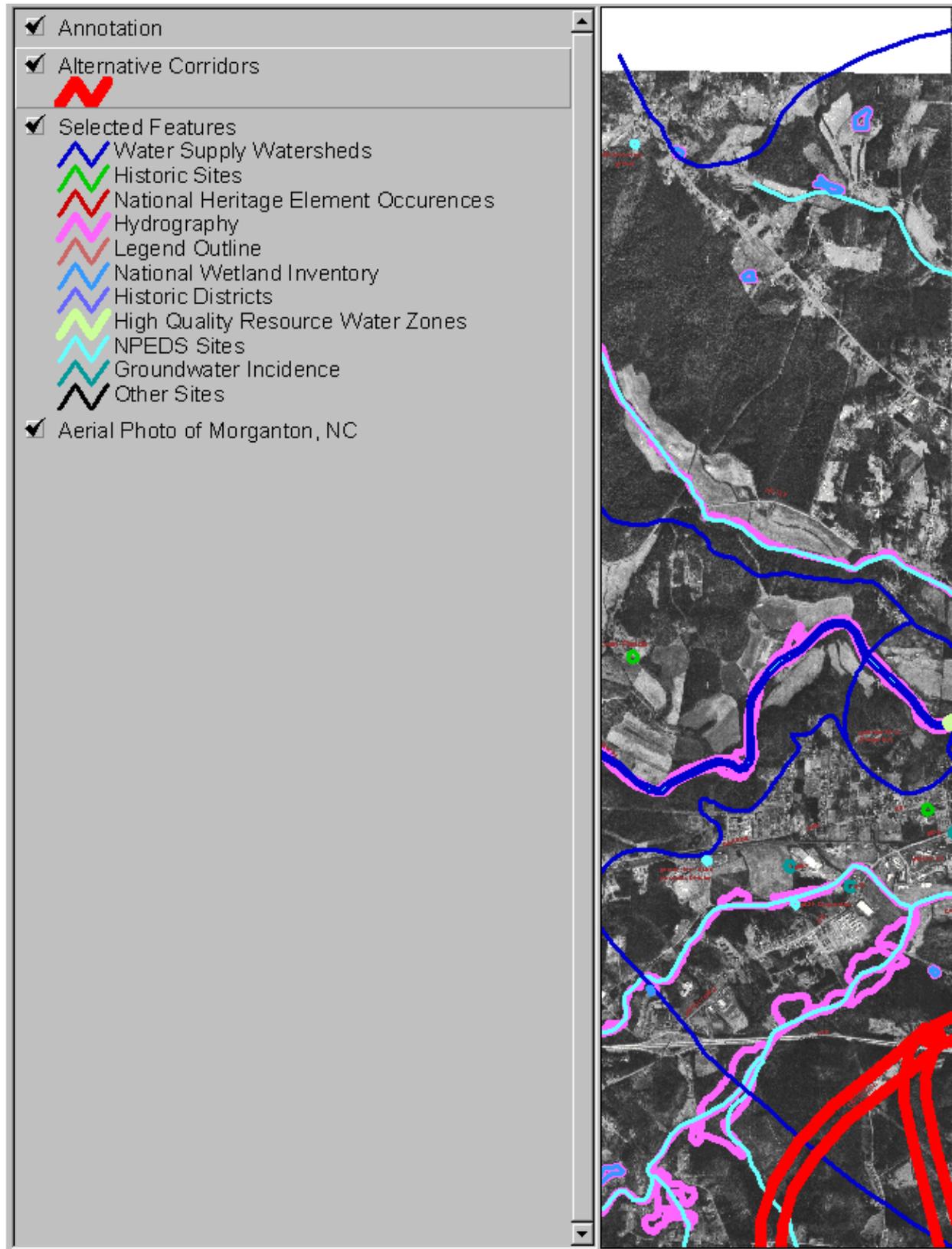
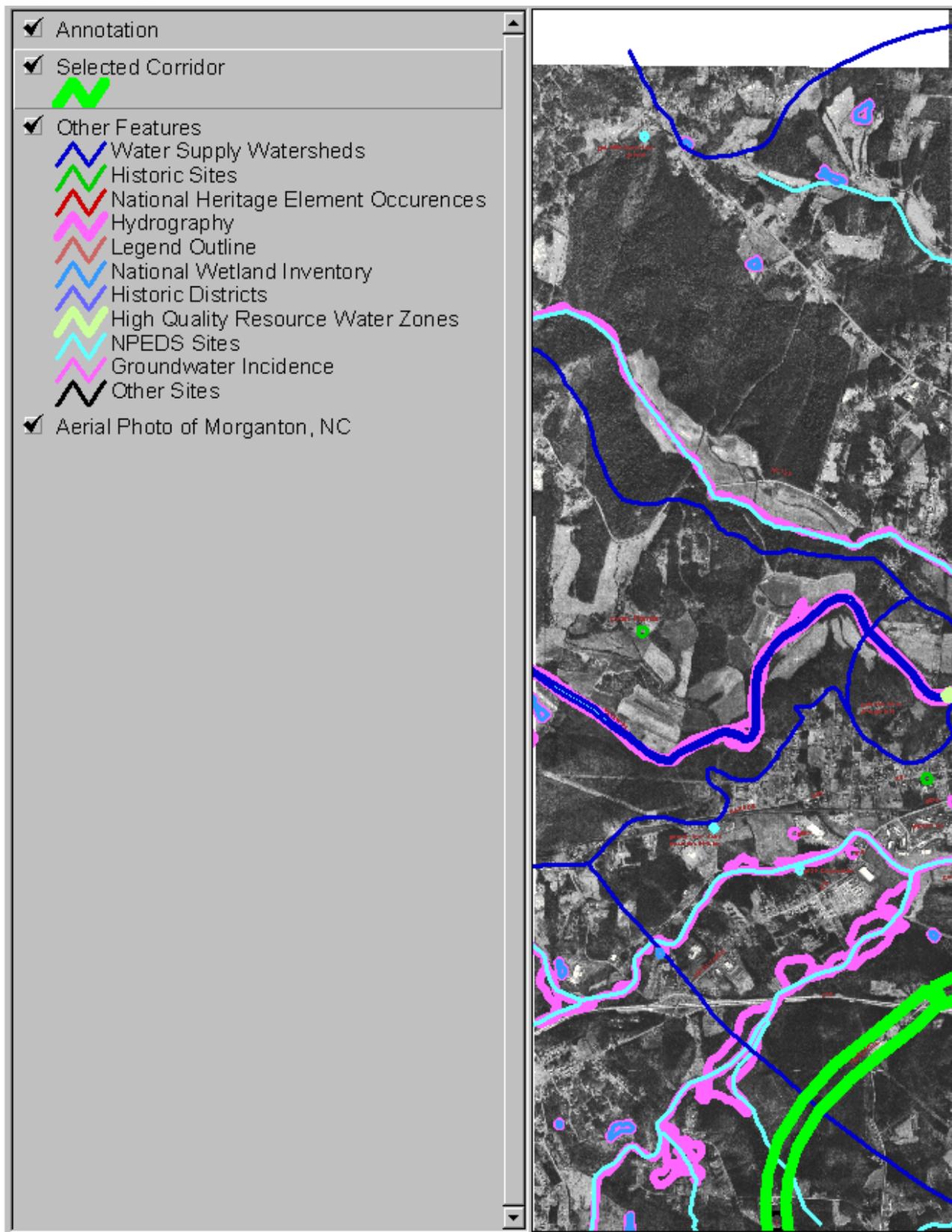




Figure F: Morganton Western Connector Selected Corridor

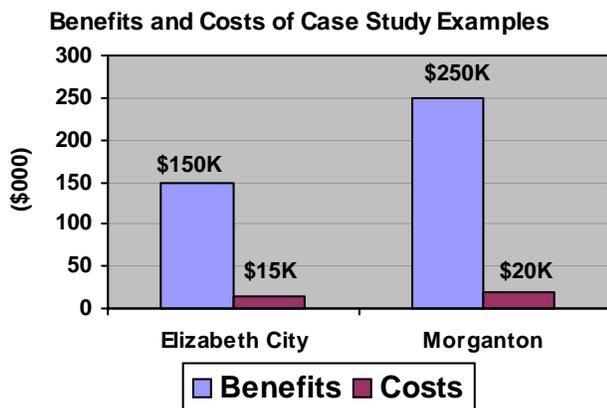




(possibly much more) in expenses and over 2 years in project preparation time.

The costs for producing these documents in GIS format was estimated at \$20,000.

In both of the above cases the benefits of using GIS to support this process far outweigh the costs as shown in the chart below. All costs referenced in this case study are estimates based on past averages.



Computerization promises to be more economically efficient due to quick turn around when doing mapping changes.

### What Are the Overall Benefits of the New Process with GIS to NCDOT?

There are many types of benefits that NCDOT has experienced due to the use of GIS and the change of process considered together as indicated in the above case studies. These benefits, which are summarized below, accrue to all parties involved in the process because they result from improved quality of decisions as well as cost and time savings in many cases.

#### Earlier Environmental Considerations

One important aspect of the NCDOT improvements is the earlier consideration of environmental issues in the planning process. This means that many important impacts can be considered at the initial corridor selection phase and that this phase can accomplish much of the analysis of alternatives that would normally be handled at the project planning stage. It is important to note that participation by the resource/regulatory agencies at this early stage is voluntary, as there has been no formal

notice of intent, or permit request. The agency participants should, if possible, be the same ones who will later have document and/or permit review responsibilities on the funded project.

#### Faster, More Effective Analysis Process

The Asheville Connector was a publicly contentious project that required much public involvement and consideration of numerous new location corridors during the systems planning process. GIS played a key role in quickly presenting the alternatives. Through the process, consensus was reached for a modification of the existing alignment. Despite their conflicting positions during the process, the public participants (a 17-member advisory committee), the Metropolitan Planning Organization, the agencies, and NCDOT were all pleased with the outcome. As a result, the head of the Transportation Advisory Committee announced: "We hope that this process will become standard operating procedure because it allowed the community to become involved and educated about this project in a very short time." This project also revealed the need for more preliminary design during the phased environmental process.

Source: Memorandum of Recommendation from the Asheville Connector Advisory Committee.

#### Enhanced Participation and Data Credibility

The participation of the regulatory/resource agencies in the initial system planning process and in the preparation of the basic environmental impact data in GIS format, significantly increases the credibility of the impact analyses used by NCDOT. Because the consideration of impacts precedes the selection of projects for the Statewide Transportation Improvement Program (STIP), these agencies now have greater ownership in the decision-making in those cases where the new process has been used.

**Greater Commitment to Decisions**

In the case of the Fletcher Bypass, in Asheville, new locations around both sides of town, as well as a widening through town on existing location, were examined during systems planning. Although there were historical considerations for the widening alternative, consensus was reached for this alternative (including concurrence from the State Historic Preservation Office). Due to this consensus and GIS documentation developed in the systems planning phase, the project moved into project planning and was processed as a Categorical Exclusion (CE) rather than an Environmental Assessment (EA), illustrating the strong agency and local government commitment to the earlier decision.

The data assembled under this process is more credible because it comes from the resource/regulatory agencies themselves and they participated in making it available in digitized format. This is a change from the traditional process where the data that NCDOT was able to produce for impact analysis often came from sources other than the resource/regulatory agencies who were evaluating it, or from a new presentation of data gathered from the agency files by NCDOT personnel. This is again important in meeting the agency comfort level required for consensus at this early stage.

**Better Decisions at the System Planning Level**

The improved process has led to better decisions that retain the commitment of the resource/regulatory agencies and the public. The participating agencies have ownership in decisions resulting from a balanced and informed process, and the local authorities and public have a better understanding of, and sensitivity to, the environmental regulations. There is also a much higher degree of confidence by the local officials in the systems plan, thus promoting a stronger local commitment to prevent encroachment within the preferred corridors.

Similarly, the projects selected for the STIP are now more likely to avoid significant environmental impacts, since they have been previously analyzed for environmental issues. The GIS analysis also allows a variety

of considerations to be incorporated into the process, such as the consideration of impacts on different socio-economic groups and aspects of social equity in project planning. These projects are much less likely to be rejected in later stages of implementation due to major environmental or social issues.

Better decisions are also made under this improved process because of the speed in the turnaround of data and analyses with GIS support. Where the participants used to wait months for NCDOT to come back with new analysis maps and impact tables, these are now available in only a few weeks. This means that the dialogue can be continued with new data presentations while the issues are still fresh in the minds of the participants. The result has been the ability to conclude a contentious corridor planning process in a period of 3-4 months while dealing with several corridors in an urban area. This short period was considered impossible with traditional project planning.

**Savings of Time and Costs**

The most important quantifiable benefit of this GIS-supported change in process is the ability to reduce the level of required NEPA/SEPA documentation in the Project Planning phase of the analysis (such as being able to do an EA instead of an EIS, or being able to focus studies on 1-2 corridors versus many corridors), with an associated reduction in time and cost for project implementation.

As demonstrated in the case studies, NCDOT has already experienced lower levels of documentation requirements for key corridors under the improved process, even though it is only two years old. Although the process is still under testing, it is possible to identify a major potential for time and cost savings.

### Potential Cost Savings to NCDOT

Over the last five years NCDOT has averaged 2 EIS starts, 28 EA starts, 108 CE starts and 18 PCE starts per year, not including bridges, re-evaluations or supplemental documents. If half of NCDOT's potential EIS requirements were reduced to EAs, and half of the EAs reduced to CEs, then, for a typical year, there would be a savings of 508 project team months and approximately \$4 million in costs. When several years of benefits are considered, there is clearly a huge payoff for the new process and its GIS support, even if only a fraction of these annual benefits were realized.

### Other Benefits of GIS Use

Other benefits of GIS use in the new process include the ability to use the GIS data for other purposes in NCDOT. The same applies to other agencies, which now have digitized data to use for their own purposes to improve internal decisions or speed up permitting processes. The benefits of having a more cooperative approach to interagency coordination could also show up in other areas.

In addition, the benefits of having good maps of environmentally sensitive areas in the field offices of NCDOT is also significant. The field engineers and crews are beginning to recognize when they are in sensitive areas, and they are responding appropriately. Without this information, they cannot effectively tailor their activities to the location.

Finally, there are spin-off benefits to the GIS unit and information system in NCDOT, where ad hoc requests for maps with the newly available data can now be satisfied. Also there is a related increase in productivity of the GIS unit with positive effects on unit morale.

### What are the Overall Costs of Developing NCDOT's GIS Infrastructure?

The cost of GIS includes infrastructure costs, direct support costs such as application development, map and image production and support costs for other agencies. However, it should be pointed out that the costs attributable to a GIS support system are difficult to separate

from costs of complementary support systems such as Computer Aided Design and Drafting (CADD). For example, NCDOT created a roads centerline file in CADD as part of a conversion from manual to digital production of county maintenance maps. The same lines were used in the GIS to create the principal roads coverage for the State. We have tried here to identify both types of costs.

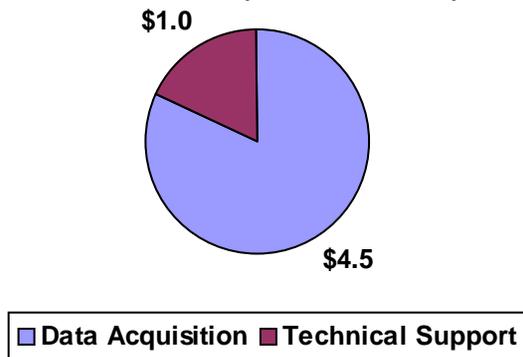
### GIS Infrastructure Costs

Since the inception of digital spatial data processing at the NCDOT in 1988, the cost of hardware, software and staff for GIS that can be attributed to environmental mapping has been approximately \$600,000 and for CADD mapping \$500,000. Most of this was funneled through the North Carolina Center for Geographic Information and Analysis (CGIA), which acted as a statewide clearinghouse for GIS development. This expenditure for environmental data amounts to about 15% of the statewide costs for GIS software, hardware and the development of data layers and institutional capabilities.

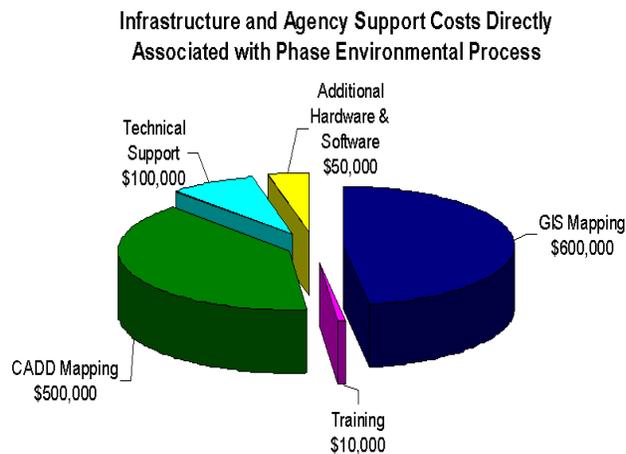
### Support Costs for Other Agencies

The largest cost associated with any GIS program is the cost of data. To support the overall environmental process from which the phased environmental process developed, the NCDOT committed to a major investment in data acquisition. Funds for this came from a combination of 60% FHWA grant money and 40% state matching funds. This work was contracted through CGIA beginning in 1991. Since that time, the support costs for other agencies that participated in the cooperative process amount to about \$4.5 million for data development and \$1 million for technical support. All of the data development cost is attributable to the overall environmental processes in the State and, by extension, to the phased environmental process. However, only 10% or \$100,000 of the technical support is attributable to the program covered in this case study. The training costs related to this process sponsored by NCDOT amounted to about \$10,000 and added hardware and software costs came to about \$50,000.

**Data Costs (Million Dollars)**



The total costs for GIS infrastructure and agency support that can be directly associated with the Phased Environmental Process, therefore amount to approximately \$1,260,000 during the period 1988 to 1997. This is only a fraction of the state expenditures on GIS for other uses. The pie chart below illustrates the division of the total costs associated with the Phased Environmental Process in the different areas.



### Conclusions

- The ability of GIS to support a major change in environmental impact management process has been established without doubt. The process has built successful partnerships with the resource/regulatory agencies and has resulted in higher quality decision-making.
- The main benefit of GIS, as identified by the NCDOT GIS unit, is in providing information to the Systems Planning teams in a flexible form that meets individual agency needs. This is more important than providing a specialized GIS application. In this case, hardcopy image and map presentation was the most effective method of distributing the data, after GIS software and image manipulation was used to get speed and responsiveness of information feedback.
- The costs of producing GIS data for the individual case studies were relatively small once the infrastructure was put in place. In each case study the quantitative benefits are greater than the costs by a substantial margin.
- The benefits of the improved, GIS-supported process change are real and substantial for NCDOT. These benefits are both qualitative and quantitative. The size of the quantitative benefits is more than sufficient to justify the program and the qualitative benefits are also significant.

“Visualizing the information on an aerial back-drop is key in reaching consensus.”  
*Quote from David Foster, NCDOT*

### Lessons for Other Agencies

The benefits received by the relatively low level of expenditure needed for the environmental analysis described above should encourage other DOTs and MPOs to learn from the experience of North Carolina. There was extensive investment in GIS infrastructure by North Carolina, but it is not necessary to make that level of expenditure to achieve some of the benefits indicated in the case studies.

In any case, the concept of the data package for partner agencies and interest groups incorporating GIS maps and their use for early introduction of environmental data into systems planning is highly effective. In addition, the use of the digitized data to create a set of maps of environmentally sensitive areas and their distribution to field offices is also effective in broadening the day-to-day consideration of environmental factors within a DOT or other planning organization.

In general, the idea of using GIS to reinforce business process change in environmental analysis tasks is viable, since the process can integrate a faster, more visually complete presentation of all relevant types of spatial data and faster turn-around of data changes in order to make better decisions. This change also supports public presentation of data and involvement of partner agencies, where these are goals of other planning agencies.

Other specific lessons that were gained by NCDOT's staff from the experience are:

- The need for a coordinator to be the point person for contacts with the resource/regulatory agencies for environmental data and other issues arising in the systems planning phase.
- The need to do adequate engineering design during the Phased Environmental Process to ensure that a "buildable" solution is chosen.
- The need for larger hardcopy maps and annotated aerial photos to speed the analysis and give a broader view of the data than a computer monitor. (This was more important than a computerized analysis system in working with the agencies.)
- The need for desktop (PC) access to the GIS data as opposed to more restrictive centralized systems. (In the future, NCDOT is planning to have Web Browser access to the GIS data and this will further expand availability of data to NCDOT and agency staff.)
- The need to customize information to address specific issues and concerns of the individual agencies and conduct one-on-one oral briefings with representatives of each agency using GIS information.



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