Development of a Statewide Bridge Database and Data Retrieval System

Prepared for the

Alabama Department of Transportation

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UTCA Report Number 02403
May 30, 2003

Technical Report Documentation Page

1. Report No	2. Government Accession No.	3. Recipient Catalog No.
FHWA/CA/OR-		

4. Title and Subtitle	5. Report Date
Development of a Statewide Bridge Database and Data Retrieval System	May 30, 2003
	6. Performing Organization Code
7. Authors	**8. Performing Organization Report No.**
Dr. Andrew J. Graettinger and Mr. Scott Simmons	UTCA Report 02403
9. Performing Organization Name and Address	**10. Work Unit No.**
University Transportation Center for Alabama P O Box 870205 The University of Alabama Tuscaloosa, AL 35487-0205	**11. Contract or Grant No.** Alabama Department of Transportation Research Project No. 930519
12. Sponsoring Agency Name and Address	**13. Type of Report and Period Covered**
Alabama Department of Transportation 1409 Coliseum Boulevard, Montgomery, AL 36130	**14. Sponsoring Agency Code**

15. Supplementary Notes

16. Abstract

The Alabama Department of Transportation (ALDOT) has amassed significant quantities of information related to geotechnical subsurface data, construction drawings, and design information for transportation projects. This data is in a paper format that makes it difficult to locate and to use in the design of new projects. This research project developed a pilot-scale agency-specific GIS-based tool for a statewide geotechnical database and data retrieval system that can be expanded to include virtually all of the geotechnical and subsurface structural information from across the State of Alabama. This new geotechnical-GIS (Geo-GIS) application is a tool for storing both graphical and attribute geotechnical data that can be accessed both spatially and through queries.

This pilot study collected data from eight projects, which involved 18 bridges across the State of Alabama. The Geo-GIS was designed with four GIS point layers: project, bridge, foundation, and soil boring. All layers are linked to attribute database tables that have six to ten columns of object specific data. The layers are also linked to a HTML page to access pre-construction and construction reports for the projects and bridges respectively. This pilot study also investigated the level of effort and the file storage requirements for extending the scope of this project to the more than 18,000 bridges statewide, with a total estimated cost of $1.15 million.

17. Key Words	18. Distribution Statement
Geographic Information Systems (GIS), Geo-GIS, bridge database, data retrieval, geotechnical attribute data, digitizing, spatial querying, scanning	

19. Security Classification (of this report)	20. Security Class (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	23	

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Executive Summary

A new geotechnical-Geographic Information System (Geo-GIS) was developed and tested for the Alabama Department of Transportation (ALDOT) during this research project. ALDOT and other state highway agencies from across the nation have indicated the need to electronically (digitally) store information about transportation projects, such as geotechnical subsurface data, construction drawings, and design information that are typically archived in a paper format. Development of new transportation projects along with maintenance of existing infrastructure requires access to geotechnical data at specific locations. The ability to store and retrieve location-based data lead to a pilot-scale agency-specific GIS application for statewide geotechnical information. This research project developed a new Geo-GIS system for storing both graphical and attribute geotechnical data from transportation projects, which can be expanded to include virtually all of the geotechnical and subsurface structural information from across the State of Alabama.

This pilot study collected data from eight projects, which involved 18 bridges from across the State of Alabama. The Geo-GIS was designed with four GIS point layers: project, bridge, foundation, and soil boring, which are linked to attribute database tables that have six to ten columns of object specific data. The layers are also linked to HTML pages to access pre-construction and construction reports for the projects and bridges. The Geo-GIS only stores the path to scanned information; therefore, any ALDOT accessible database or data filling system can be readily linked to the points in the Geo-GIS.

This pilot study also investigated the level of effort and the file storage requirements for extending the scope of this project to the more than 18,000 bridges statewide. Scanning costs range from $0.18 per page for letter size pages to $7.50 per sheet for E sized plan sheets. For the 18 bridges in the pilot study of Geo-GIS, there were 533 letter sized sheets and 87 plan sheets. This information was stored in approximately 532 megabytes of disc space. From the average numbers generated during this pilot project, the cost estimate for statewide data entry is $720,000, data scanning is $413,440, and data storage is $10,600, with a total estimated cost of $1.15 million.

Recommendations developed during this pilot study focus on a second phase for the research before a statewide implementation is initiated. It is recommended that Phase II be accomplished by a joint team from ALDOT, University of Alabama, and Techni Graphics. The Phase II work should focus on improving data entry and data searching, testing the Geo-GIS on actual data being used for a project, and developing accurate cost estimates for statewide implementation.

Section 1.0
Introduction

The Alabama Department of Transportation (ALDOT) and other state highway agencies from across the country have amassed significant quantities of information related to geotechnical subsurface data, construction drawings, and design information for transportation projects within their respective states. This information is very beneficial in developing new projects that are planned in the vicinity of an existing project or bridge. The paper format of the archived data and records makes it difficult to access, thus affecting the efficiency of new projects. It was determined that a computer (software) system was needed to electronically store and access all of geotechnical and subsurface structural data for transportation projects in the state. This research project developed a data management system based on a Geographic Information Systems (GIS) to meet ALDOT requirements.

This new geotechnical-GIS (Geo-GIS) application is a tool for storing both graphic and attribute geotechnical data so that it can be accessed both spatially and through queries. This system is designed to be expandable to include virtually all of the geotechnical and subsurface structural information from across the state.

The remainder of this report discusses the methodology, database design, data maintenance, system requirements, effort and resources required, general guidelines for the go-forward strategy, and conclusions and recommendations identified during this pilot study.

Section 2.0
Technical Approach

Introduction

To develop a database - data management system to provide maximum benefit to ALDOT, an open line of communication was established early between ALDOT and the research team (University of Alabama and Techni Graphics), and it was maintained throughout the project. This provided an easy exchange of information wherein ALDOT indicated the collective needs of the data storage and retrieval system, while members of the research team described system capabilities and provided examples from other related projects. Meetings were conducted at ALDOT headquarters on a regular basis to update ALDOT on project progress, while at the same time gathering information and advice on how to improve the system. Throughout these exchanges the research team was aware of the overarching goal of this project: to develop a user-friendly system capable of handling all subsurface data from past, present, and future transportation projects in the state. The procedure used to develop Geo-GIS is described in the following paragraphs.

Compile Site-Specific Information

Actual bridge and project information from across the state was collected, scanned, and used to develop and test the Geo-GIS. The goal was to select nine representative bridges from across the state, of different age, size, and foundation type. ALDOT personnel in each division office were contacted and 18 bridges from seven counties, associated with eight projects, were collected. As shown in Table 2-1, each project was identified by its project number and each bridge was identified by its bridge identification number (BIN), which were used as the key fields to store and search the Geo-GIS. It can be seen that several projects had more than one bridge. Also listed in Table 2-1 are the bridge descriptions. In addition to the project numbers and BINs, Table 2-1 also indicates the number of soil borings associated with each project and the number of foundations associated with each bridge.

Geotechnical Database Design

From the site-specific data for the 18 bridges collected during the pilot study, four distinct sets of geotechnical data were identified: projects, bridges, foundations and soil borings. Each of these geotechnical data sets has three components: 1) location, 2) attributes, and 3) scanned information. It was determined that these four datasets could be represented as point features on a GIS map. The points were then associated to keyed-in attribute data that were related to scanned information. Therefore, four GIS point layers were developed for the Geo-GIS: project, bridge, foundation, and soil boring. A GIS layer is a collection of similar geographic features that can be thought of as a sheet of mylar laid over a paper map. The layer can be either active or inactive, added or removed from a GIS map depending on the analysis being performed.

Table 2-1. Details of Pilot Study Data

Division	County	Project No	Soil Borings	BIN	Foundations	Description / name
2	Marion	APD-471(74)	40	17630 17631	43	Bridge over New River (West bound) Bridge over New River (East bound)
3	Walker	APD-471(59)	68	16322 16323 16324 16325 16326	77	Bridge over Town Creek and Norfolk Southern (Right) Bridge over Town Creek and Norfolk Southern (Left) Bridge over Industrial Access (Left) Bridge over Industrial Access (Right) Bridge over Whitehouse Road
4	Lee	NHF-118(9)	21	17250	4	Bridge over Saugahatchee creek on US-280
5	Tuscaloosa	S-1649-B	75	10773	107	Hugh Thomas
6	Montgomery	I-65-I(60)169	0	10696 10697	18	I-65 South bound I-65 North bound
		NHF-65-1(236)	2	17290	5	I-65
8	Clarke	NHF-332(18)	8	17311	12	US 43 and 84 Bypass Bridge
9	Baldwin	I-10-1(17)	27	008520 008521 008523 008522 008526	21	Overpass for Barnhill Road (West bound) Overpass for Barnhill Road (East bound) Underpass for Brady Road (East bound) Underpass for Brady Road (West bound) Underpass for Wilcox Road
Total	**7**	**8**	**241**	**18**	**287**	

To display data spatially, a frame of reference is required. In a GIS, a base map is used as this frame of reference. The base map for this work consisted of Alabama counties, roads, railways, and water bodies as shown in Figure 2-1. Upon this base map the new point layers of projects, bridges, foundations and soil borings were placed in their correct locations. The base layer of Alabama roads includes all county roads, which provides the ability to include geotechnical data related to the county roadway system. The Geo-GIS is designed to work with improved base maps, i.e. increased detail and/or accuracy; therefore as these maps become available they will be incorporated into the Geo-GIS. Because the accuracy of some bridge locations are based on the accuracy of the base map, an improved base map results in improved geotechnical information locations.

Location data: Location data for ALDOT features were found to be in the form of: 1) latitude and longitude, 2) a written description 3) station-offset, or 4) scalable from plan sheets. Latitude and longitude were used to locate bridges for this study. Although latitude and longitude data exist for most bridges in the state, the data is not extremely accurate. An example is tandem bridges where each bridge has a unique BIN and information, but the two bridges share the same latitude and longitude stored in the Alabama Bridge Identification Management System (ABIMS) database. This inaccuracy is on the order of one hundred feet. Some of the latitude and longitude data in ABIMS were scaled off paper maps and are much less accurate than one hundred feet. It is anticipated that the latitude and longitude data accuracy will improve over time and the Geo-GIS is designed to take advantage of this improving accuracy.

Written descriptions of locations of bridges and projects were employed to overlay the new bridge and project locations on a digital base map, shown in Figure 2-1. At the scale of a single bridge or project, plan sheets and station-offset were employed to locate soil borings and individual foundation bents.

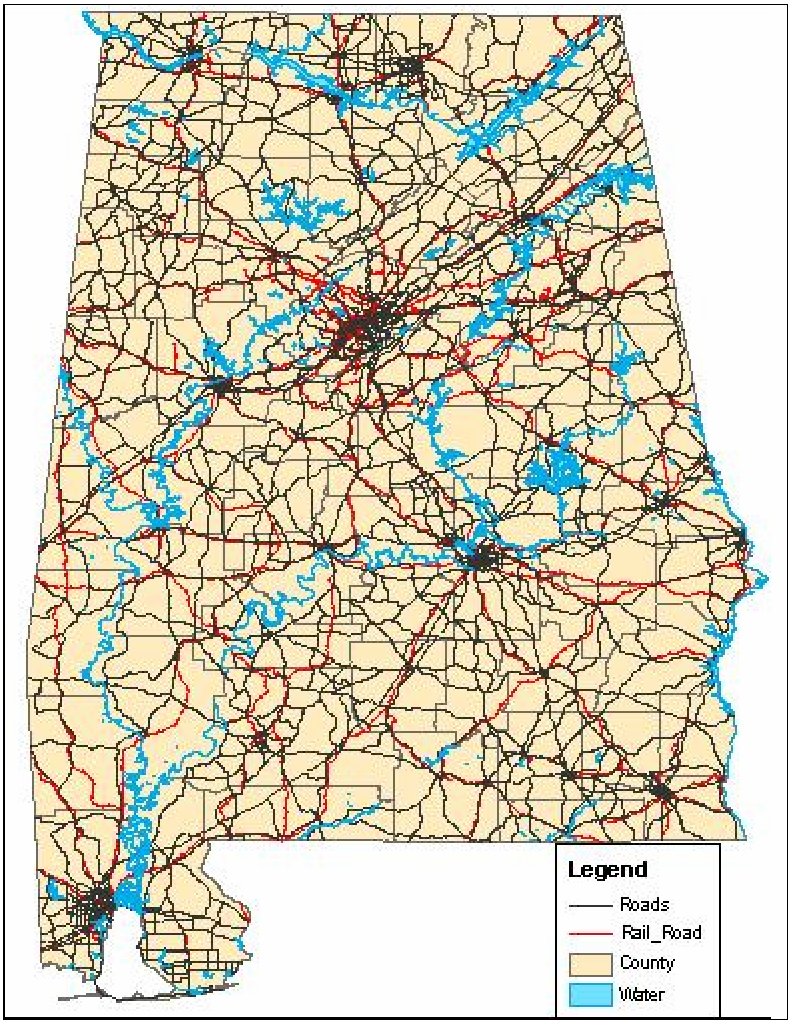

Figure 2-1. Base map showing counties, roads, railways, and water bodies

Location data within a GIS provides a fast, easily-understandable means of accessing both attribute and scanned data. It should be noted that most data generated about a transportation project comes from specific locations. Presenting that data on a map allows information from multiple projects to be combined based solely on proximity.

Attribute data: Attribute data is defined herein as information that is keyed into the GIS database to describe a graphical entity on a GIS layer. Each layer in a GIS has an associated table that stores attribute data. Attribute tables have table names and fields that store specific data about a point on a map. Table 2-2 shows the Geo-GIS tables and fields. It can be seen that each of the four layers in the Geo-GIS has an associated attribute table.

Table 2-2. Fields used in attribute tables to store data

Project	Bridge	Foundation	Soil Boring
1. Database_No 2. Project_No 3. Preliminary_Project_No 4. BIN 5. Decription 6. Start_Date 7. Images	1. BIN 2. County 3. Division 4. Name 5. Construction_Date 6. Images	1. Foundation_ID 2. Project_No 3. BIN 4. Bent_No 5. Side 6. Station 7. Type 8. Material 9. Size 10. Foundation_Image	1. Boring_ID 2. Project_No 3. BIN 4. Boring_Name 5. Station 6. Offset 7. Side 8. Boring_Image

The Geo-GIS tables have between six and ten attribute fields describing each point in the GIS. These tables intentionally have a small number of fields because keying-in data is a time consuming process. Keyed-in attribute data is most beneficial when it can be employed to query the GIS. If a field is not going to be queried to find specific data in the GIS, then the cost of capturing and entering data is greater than the benefit gained from that data. Each table in the Geo-GIS has an 'image' field that stores a link to a web page (for project and bridge tables) or an image file (for foundation and soil boring tables) that links to all scanned information associated to that point. Scanned data is described in the next subsection of this report. Attribute tables can be linked or joined, based on common fields in each table. As shown by solid lines in Figure 2-2, "joins" link common fields that are in all of the tables in Geo-GIS. These joins improve data accessibility. Links and joins are also employed to connect the GIS graphics (points) to the attribute tables. This process is briefly described later this section.

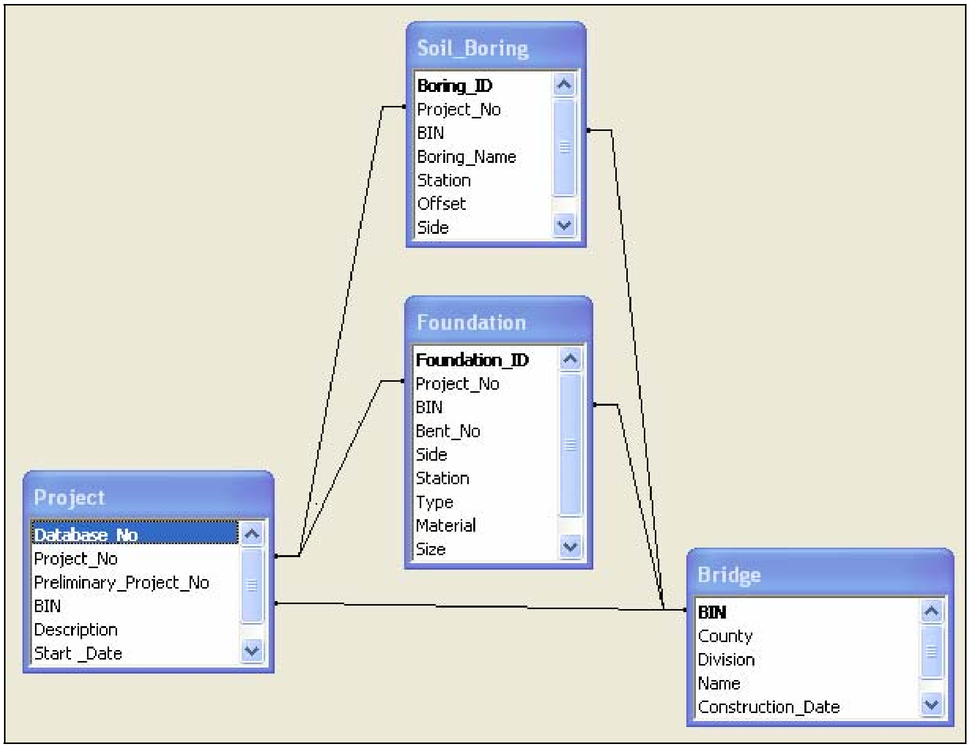

Figure 2-2. Database design showing relationship between attribute tables

Scanned Data: Archived reports on site investigations, bridge construction details, and subsurface information such as foundation and soil boring data were collected for the 18 bridges in this pilot study. To easily access site-specific information, these reports were classified into two categories: preconstruction and construction, as shown in Table 2-3. Preconstruction reports describe data that were generated during reconnaissance and site investigation for a project. Construction reports and as-built sheets describe data that were generated during and after construction. Preconstruction data is typically related to a project while construction data is typically related to a bridge. This information can be accessed through the project points, bridge points, foundation points, or soil boring points on the GIS map.

Table 2-3. Details of preconstruction and construction reports

PRECONSTRUCTION (project related)	**CONSTRUCTION (bridge related)**
1. Geohydro Report * 2. Geotechnical Report * 3. Soil Boring Records * 4. Lithology - Geological Description * 5. Soil Boring Sheets **	1. Bridge Card Image * 2. Hammer Submittals * 3. Drilled Shaft Pouring Records * 4. Drilled Shaft Excavation Boring * 5. Pile Driving Record * 6. Test Pile Driving Record * 7. Static Load Test Record * 8. Bridge Identification Information * 9. Foundation Sheets **
Note: * PDF or DOC, ** TIF or JPG	

All single page drawing sheets, records, and reports were scanned and stored in a TIF or JPG format. Multiple page reports that were scanned as a TIF or JPG format were then converted into PDF format so that an entire report could be accessed at one time. These scanned images and reports were organized and stored in a simple folder tree system. As shown on the left side of Figure 2-3, a main folder (ALDOT) consists of a set of subfolders organized by project numbers. Within each project folder are bridge folders organized by BINs. Documents specific to a bridge, such as a foundation construction report are in the bridge folder while reports and images related to an entire project, such as a geotechnical report are stored in the project folder. Two other folders ‘Tables’ and ‘Shapefiles’ contain all the attribute and graphic information for the Geo-GIS.

Geotechnical Database Data Entry

As with the design of the Geo-GIS, data entry can be divided into three categories: location data, attribute data, and scanned data. Location data was entered by screen digitizing points based on: 1) latitude and longitude, 2) existing features, 3) scanned images, or 4) station-offset.

- Latitude and longitude data were either keyed into the GIS or the curser was moved across the screen until the correct value of latitude and longitude was achieved.

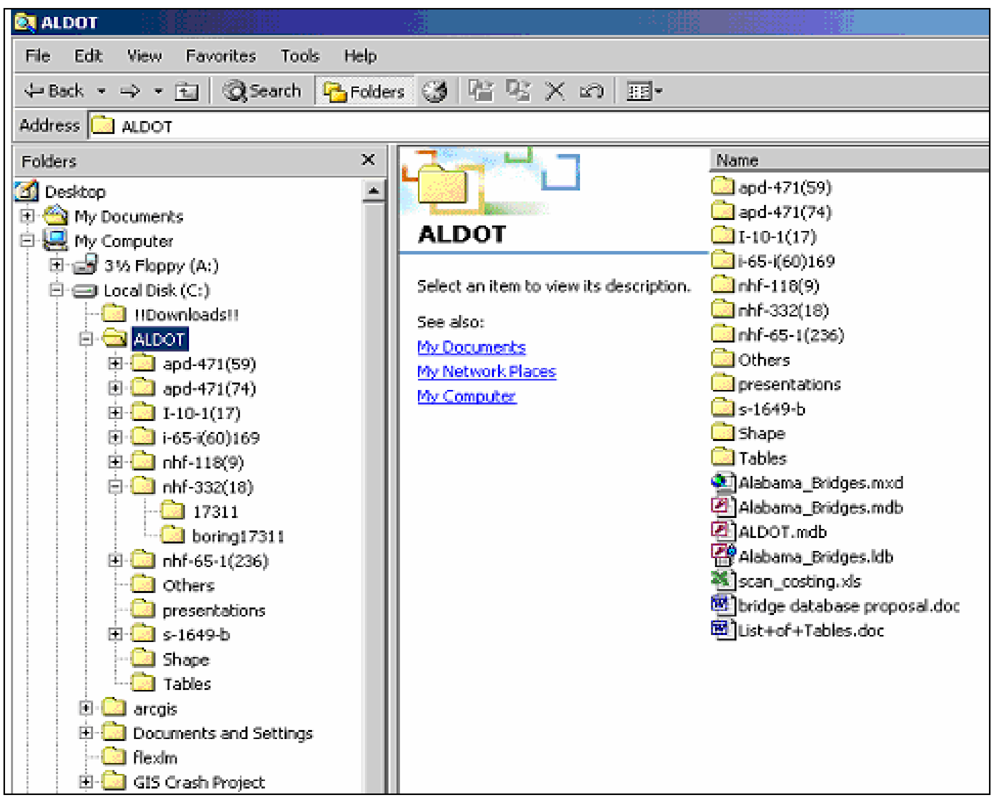

Figure 2-3. Organization of folders to store information

- A location where two features cross, such as road and road, road and river, or road and rail, is easy to identify, but the accuracy of that location relies upon the accuracy of the base map; therefore, this location is less accurate than using quality latitude and longitude data.
- Locating points based on scanned images relies not only on the accuracy of the base map, but also the accuracy in locating the scanned images on the map. Scanned images of plan sheets were scaled, oriented, and placed on the base map so that screen digitizing of foundation locations could take place efficiently. Once a plan sheet is in place, the cursor is moved across the image until it lines up with a desired location and then a point is placed.
- The final technique used to place points in the GIS was centerline, offset, and stations. Lines representing centerline, offset, and stations were temporarily created in the GIS to locate points for soil borings. Most soil boring location information was in the form of station and offset; therefore, it was necessary to recreate this coordinate system to accurately place soil boring points. Again, the centerline from the road on the base map was employed to orientate the soil boring points. Therefore, the accuracy of the soil boring points is equal to or less than the accuracy of the base map.

There are two tables associated with each layer. One is generated by the GIS while digitizing the graphic points and the other table is the attribute data table developed by keying-in information from records, drawing sheets, and scanned data. During digitizing, a unique object identification number (object ID) is generated by the GIS for each digitized point. This object ID is also entered into the attribute tables, and is the key column employed to join the graphic points to the attribute data. A join was made by matching common fields (columns) from the digitized points (for example, object ID) with the keyed-in column from the database spreadsheets (for example, foundation ID). Once joined, all attribute data could be accessed directly from the GIS. One column in each of the attribute tables is an 'image' column that stores an HTML address to access scanned data.

In the pilot project, all attribute data was first entered into Excel® spreadsheets and then transferred to the Geo-GIS. Four spreadsheets were required for the Geo-GIS, one for each layer. The column names for each spreadsheet are listed in Table 2-2, with each new point as a row in the spreadsheet. To incorporate spreadsheet data in a GIS, Dbase IV (DB-IV) format was required. DB-IV is a "save as" file format in Excel®; therefore, each table was saved as a DB-IV file. Once in DB-IV format, the data was directly accessed by the GIS software and linked to the graphics on a map.

Both large and small format paper documents were scanned in the pilot project. Large format is defined as sheets larger than 8.5 × 11 inches. Two sizes of large format sheets were scanned: 24 × 36 inches and 11 × 17 inches. Large format sheets must be hand fed into large format scanners, which was less efficient than scanning small format pages. Small format sheets can be scanned in bulk and can also have data on the front and back of each page. All sheets were scanned as single pages and then multiple page reports were combined into a single digital PDF document. All images associated with a project were stored in a single folder with sub folders related to individual bridges associated with that project. Scanned images are accessed through an HTML web page that is also stored in the project folder. The path to the HTTP web page is stored in the attribute table so that the images can be selected and viewed directly from the Geo-GIS.

For the eight projects and 18 bridges there were 533 pages of 8.5 × 11 inch format and 87 large format pages. The total space required for these scanned images was 532.61 megabytes. For an approximate estimate of the resources needed to store all 18,000 bridges in Alabama, the numbers above can be multiplied by 1000.

Geotechnical Data Retrieval

The goal of this task was to develop a user-friendly tool to retrieve digital geotechnical data stored in the database. As previously discussed, it was determined from the type of ALDOT data that a GIS could provide both a framework to store geotechnical data and also a means to retrieve the data. There were three ways data can be accessed within the Geo-GIS: 1) by selecting points spatially, 2) by querying attribute data, or 3) by selecting images through hyperlinks.

GISs have an advantage over other database systems in that a GIS allows spatial display, querying, and selection of database information. Spatial access of data can be as simple as selecting a point of interest from a digital map. The data can be stored in an attribute database or can be scanned information associated with a selected point. In addition to selecting a point on a map to retrieve data, the Geo-GIS allows for complex spatial queries that are useful in finding information-based locations, such as soil borings that are in the vicinity of a new project. An example of this is selecting all the soil borings in the database that are within 2000 feet of the location of a new road. Figure 2-4 shows all the soil borings that are within a buffer region of 2000 feet of a segment University Boulevard in Tuscaloosa. Spatial queries can also be based on point features such as a bridge location, or area features such as within a city limit.

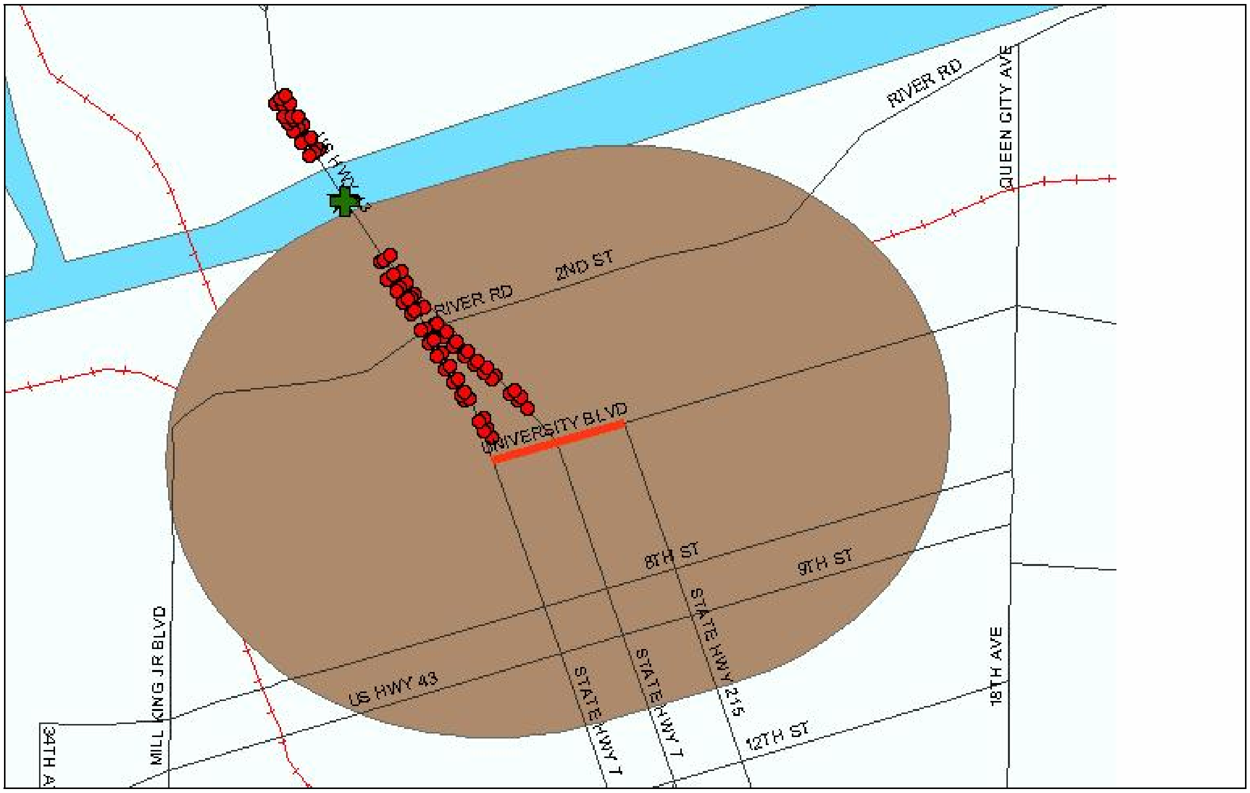

Figure 2-4. Spatial query locating all soil borings within 2000 feet of target location

Querying the attribute database is the second method to access the Geo-GIS data. Queries are constructed directly in the GIS application and are used to filter the database to only show records that match a selection criteria. An example of this is shown in Figure 2-5 where all the bridges that have driven piles in Montgomery County are selected. Note that the selected foundations are highlighted on the GIS map.

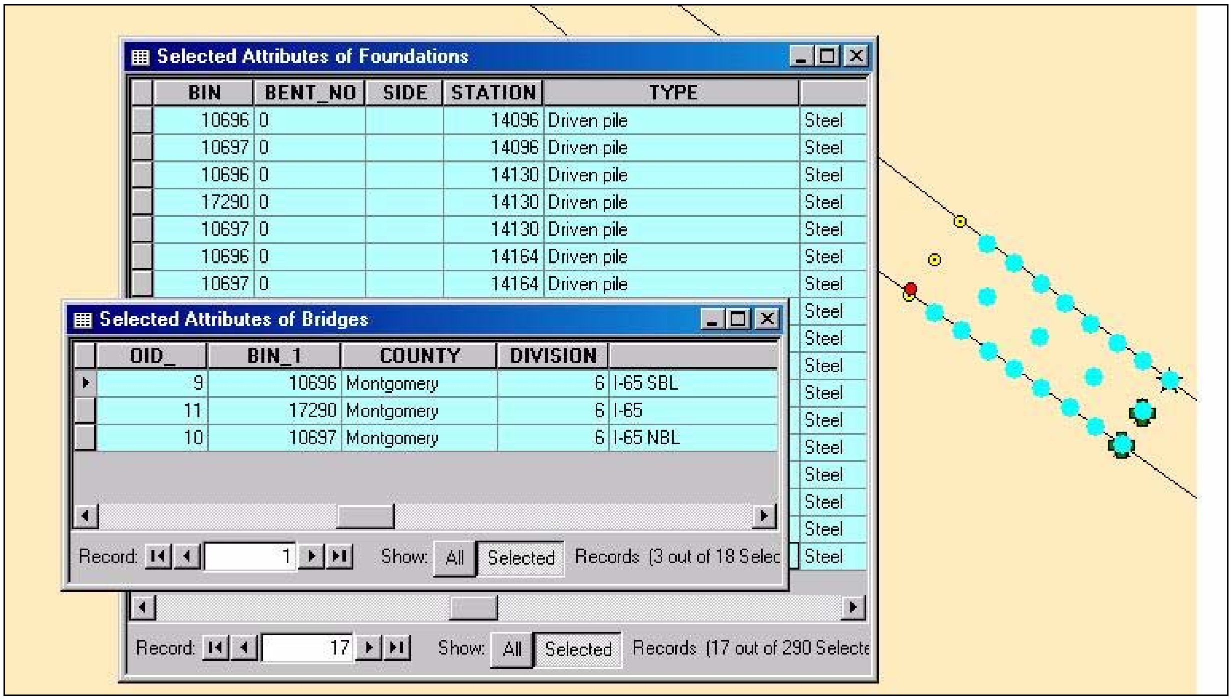

Figure 2-5. Query showing all the bridges that have driven piles in Montgomery County

Finally, the third method to access data in the Geo-GIS is to view images and documents related to the four layers in the Geo-GIS through hyperlinks. This is done by adding document paths to a field in the layer attribute table. Depending upon the type of document, GIS hyperlinks "kick-off" other applications such as Internet Explorer®, Adobe®, or MS Imaging®.

Each project and bridge is related multiple scanned documents. Since a single point feature in a GIS layer can only be hyperlinked to a single document, an HTML page was created using Microsoft FrontPage® for each project and bridge point in the Geo-GIS. This HTML page is the index to all scanned information associated to a project or bridge. An example of this type of hyperlink is shown in Figure 2-6. This page is for Project NHF-118(9) which has one bridge, BIN 17250. Every report or sheet that is underlined on this page has an associated scanned document. The user can navigate through these links to view the required document. As seen in Figure 2-6, preconstruction and construction records from both the project and bridge are hyperlinked.

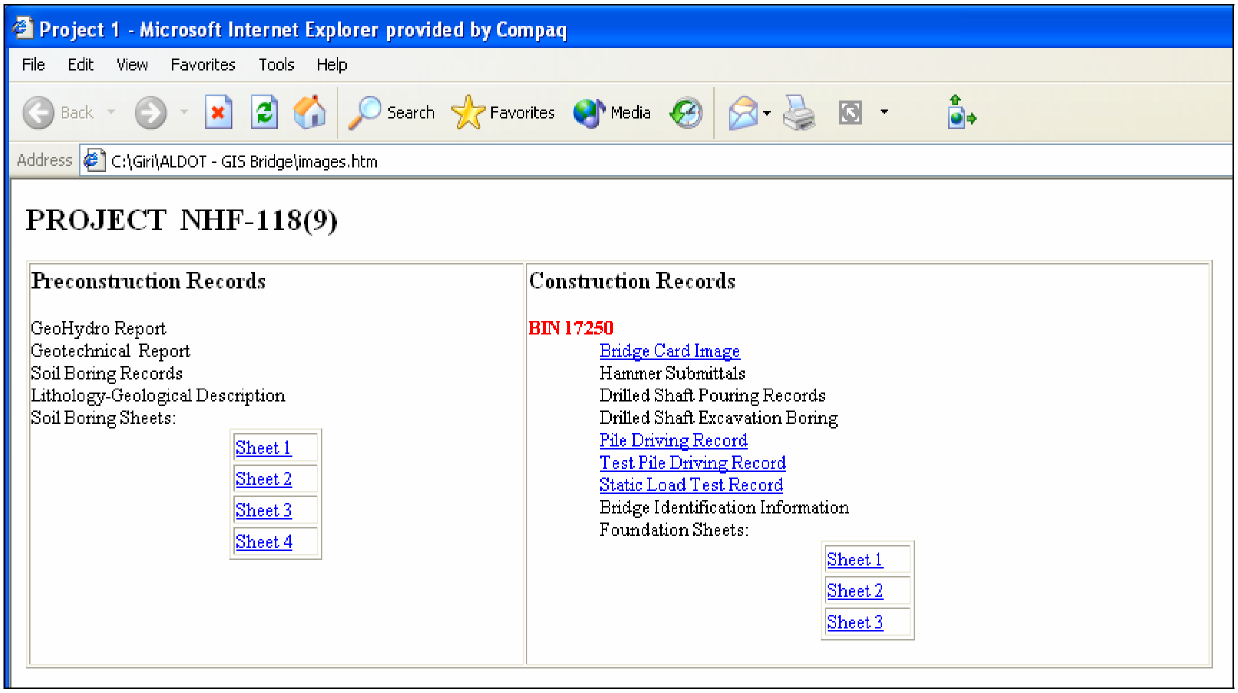

Figure 2-6. Example of a HTML hyperlink

Clicking on a hyperlink brings up the image or HTML file. Hyperlink paths for different entities that were used during this pilot project are shown in Table 2-4. Figure 2-7 shows a plan sheet for Project No. NHF-118(9), a bridge US 280 over Saugahatchee Creek in Lee County.

Table 2-4. Hyperlink paths for the four layers

Layer	Hyperlink path
Project	C:\ALDOT\project number\images.html
Bridge	C:\ALDOT\project number\bridge number\images.html
Foundation	C:\ALDOT\project number\bridge number\foundation image.jpg or. tif
Soil Boring	C:\ALDOT\project number\boring\soil boring image.jpg or. tif

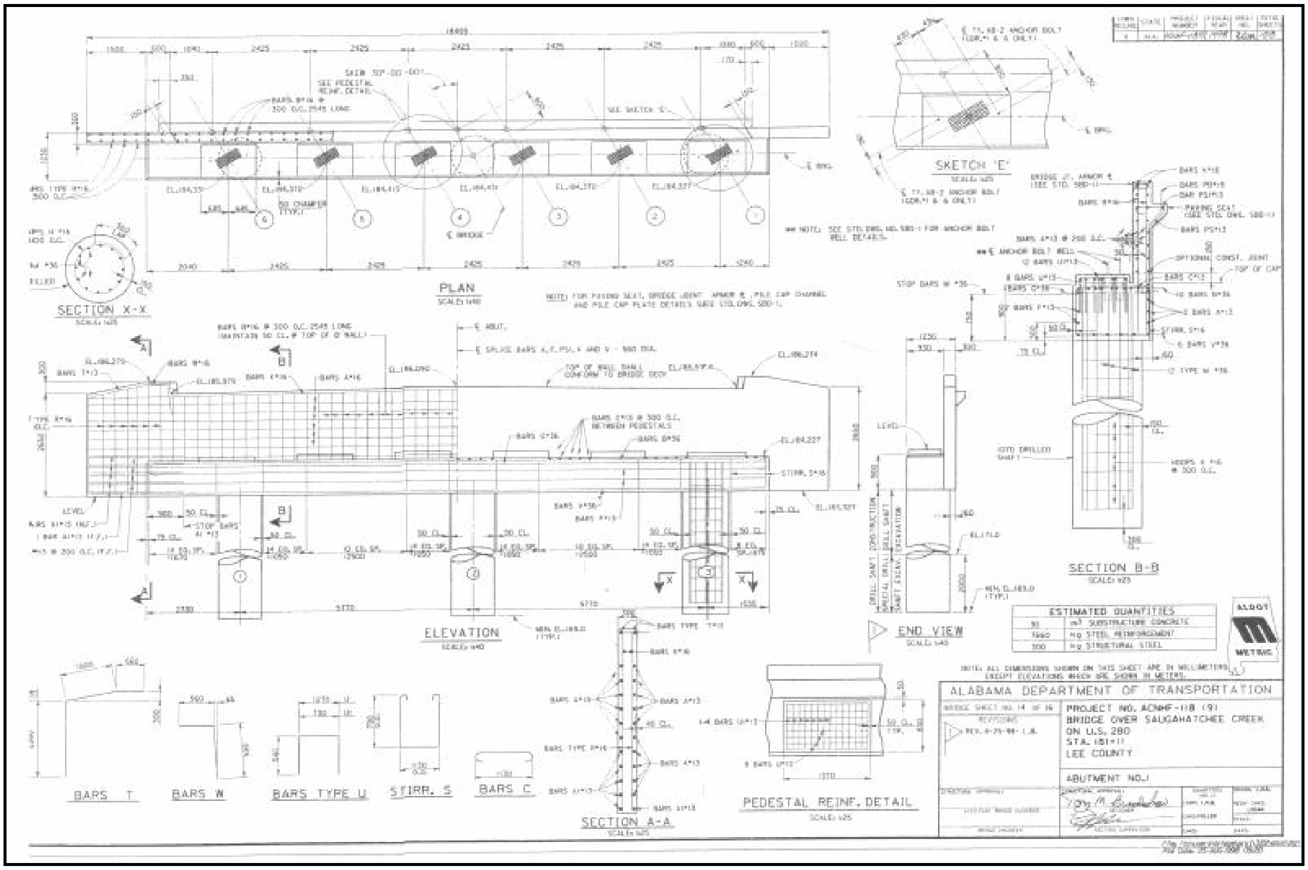

Figure 2-7. Plan sheet for Project No. NHF-118(9) in Lee County

The developed Geo-GIS database was made available on two platforms: desktop/laptop (ArcGIS 8.2) and web-based (ArcIMS 4.0). UA performed the research and developed the Geo-GIS system on a desktop computer. TGS scanned physical documents, maintained a server and software, and developed a secured URL address so that ALDOT personnel could use the GIS system.

Section 3.0
Go-Forward Strategy

Introduction

This section of the report reviews and summarizes the level of effort and the file storage requirements for extending the scope of this project to more than 18,000 bridges statewide. Guidelines and recommendations are outlined to assist researchers and ALDOT personnel on future activities related to electronic data storage and retrieval of geotechnical information. The proposed "go-forward" strategy is for an agency-wide geospatial database of geotechnical data. This strategy is divided into seven elements: who, what, where, when, why, how, and how much.

Who

Although it is possible that extending the Geo-GIS for statewide implementation could be performed internally at ALDOT or externally with an outside consultant, a combination of both groups would be beneficial. Internally, ALDOT has extensive knowledge related to the type and location of geotechnical data. Externally, UA and TGS have extensive knowledge of GIS, database systems, scanning, and server applications. A combination of ALDOT, UA, and TGS provides the best team to proceed with this project. In a combined effort, ADLOT can identify and label geotechnical data, while an outside source can scan, digitize, and store the data. Then ALDOT can use the data.

What

Out of the four layers in the pilot Geo-GIS, foundation information was duplicated in both the foundation layer and the bridge layer. Scanned foundation data can be accessed strictly through construction data associated with a bridge. Hence, it is proposed to remove the redundant foundation layer and enhance the use of scanning data over the labor intensive task of keying-in attribute data.

The pilot project found that accurately locating features by all methods (ABIMS latitude and longitude, digitizing based on screen features, or digitizing from scanned sheets) was an inefficient process. It is recommended that future location information (latitude and longitude) for bridges and soil borings be collected as accurately as possible to improve feature location in the GIS. This will most likely be accomplished through the use of the Global Positioning System (GPS). Low-cost handheld units that incorporate the Wide-Area Augmentation System (WAAS) provide suitable accuracy (less than 3 m) for the Geo-GIS cataloging effort.

Where

ALDOT and external vendors have specific skills that are important to the successful implementation of the statewide Geo-GIS. Table 3-1 shows tasks recommended for ALDOT and for a vendor to ensure ease of data compilation, use, and accuracy.

Table 3-1. Tasks at ALDOT and vendor

ALDOT	Vendor
Label geotechnical data Collect location data Verify accuracy of loaded data Provide authorized users with login ID's	Scan and load data Digitize location Key in attribute data Verify accuracy of loaded data Upload data onto a secured server

Data for the Geo-GIS, in the form of paper documents or digital drawings, should be captured when a project is "active." This project may be active because of work being performed by ALDOT or a consultant for ALDOT. Only documents collected for the active project will included into the Geo-GIS; thereby reducing the effort required to populate the database. Due to the complexity of geotechnical data, the task of labeling the geotechnical documents should be supervised by a geotechnical professional. It is anticipated that labeling will consist of a simple system such as color coded stickers for each type of geotechnical document, such as soil boring sheet, PDA reports, geo-hyrdo report, etc. Once documents are coded any scanning service can be utilized to scan in the documents and place them in the appropriate directories.

The software and server on which the Geo-GIS resides can be maintained either internally (ALDOT) or externally (consultant). It is recommended that the server be securely maintained by introducing authorized logins which could be handled by the network administrator who deals with the ALDOT computer network.

When

One of the primary concerns in developing a statewide database is the availability of data. It should be noted that the current pilot-scale database has missing data due to the missing paper documents. It is recommended to collect and enter project data into the Geo-GIS when a project is "active." For maintenance or retrofitting of an existing bridge, paper data should be collected, organized, labeled, and copied. While the data is "pulled" and available, it should be digitally captured (scanned and keyed-in) and placed in the Geo-GIS. Additional ALDOT data, such as geohydro reports, pile driving analysis reports, etc., that was not required for the maintenance work should be located and scanned into the Geo-GIS to complete that digital record.

For new projects and bridges, it is recommended that contractors supply:

- latitude and longitude for projects, bridges, and soil borings
- PDF format for reports and documents
- JPG format for plans and other construction drawings
- standardized ALDOT soil boring sheet

Why

The scope of this project is vast and includes geotechnical data for more than 18,000 bridges in the state of Alabama. The goal is to develop a data storage and retrieval system that is easy to load, easy to maintain, easy to update, and above all easy to use. This pilot study was the first step in achieving that goal.

How

As discussed previously, the developed Geo-GIS can be physically located on a server at ALDOT or a secure website from where ALDOT personnel can electronically retrieve data. At this stage, it is not recommended that ALDOT set up an internal geotechnical server with software. It is important to understand that the Geo-GIS is still in the development and testing phase and therefore is expected to evolve and change. Investments at this stage should focus on development and not on hardware, software, and personal training. Instead, it is recommended that an outside vendor maintain the Geo-GIS server and software, while at the same time scanning and loading new geotechnical data for the next phase of this project. For full-scale statewide implementation of the Geo-GIS, it is recommended that ALDOT invest in a server, software, and trained personnel.

How Much

The cost of implementing a statewide Geo-GIS can be divided into two categories, equipment and data entry. Equipment consists of a server, scanners, and software. Data entry includes digitizing, keying in data, and scanning. As stated previously, it is recommended that the Geo-GIS be maintained off site at the present time. This eliminates the upfront cost of equipment. Estimates of equipment costs continually drop due to improvements in hardware. Therefore hardware costs beyond the cost of data storage are not estimated herein.

For the pilot project, two graduate students digitized the project, bridge, soil boring and foundation points, keyed in attribute data, and organized scanned information into folders. On average, each bridge took approximately two to three hours for the digitizing of soil borings and foundation points. It should be noted that labeling and organizing the scanned images into appropriate directories also required a significant amount of time. In addition to digitizing and keying-in data, the scanning sheets and reports for the 18 pilot bridges took place. Table 3-2 details the cost of scanning documents and presents the cost to convert scanned pages into single PDF reports. The table is organized by page size and color or grayscale scans. Hourly operator costs are also presented in Table 3-2 (TGS).

Table 3-2. Scanning and PDF Conversion Costs

Document Type	Scan rate (pages/hr)	PDF Conversion rate (pages/hr)	Operator Cost, $ (per hour)	SCAN COST, $ (per page)	PDF COST, $ (per page)	TOTAL, $ (per page)
Index Card						
Grayscale	800	400	35	0.04	0.09	**0.13**
Color	400	400	35	0.09	0.09	**0.18**
US Letter/A4						
Grayscale	400	400	35	0.09	0.09	**0.18**
Color	200	400	35	0.18	0.09	**0.26**
US Legal						
Grayscale	300	300	35	0.12	0.12	**0.23**
Color	150	300	35	0.23	0.12	**0.35**
ANSI B						
Grayscale	30	60	50	1.67	0.83	**2.50**
Color	15	60	50	3.33	0.83	**4.17**
ANSI D						
Grayscale	10	30	50	5.00	1.67	**6.67**
Color	5	30	50	10.00	1.67	**11.67**
ANSI E						
Grayscale	10	20	50	5.00	2.50	**7.50**
Color	5	20	50	10.00	2.50	**12.50**

For the pilot project, TGS scanned plans, drawing sheets, and reports related to various projects and converted the scans into JPG and PDF format. In addition, TGS uploaded the geotechnical data entered by UA to a secure website using ArcIMS technology.

Estimates of the time, size, and costs of the pilot project and for the 18,000 bridges for statewide implementation are shown in Table 3-3. The cost associated with each entry in the table is provided in italics. These are initial estimates and these estimates are expected to drop as volume and expertise increases. One potential cost savings is the use of available scanned ALDOT data. In the pilot project, the data from ALDOT project I-10-1(17) was scanned by a vendor associated with a different ALDOT project. This data was easily added to the Geo-GIS at a minimal cost. The only effort required was locating the appropriate data and setting the path with in the GIS.

Table 3-3. Cost estimation for statewide Geo-GIS

Details	**No. of Bridges**	**Time in hours [*Cost in $*]**		**Scanning details [*Cost in $*]**			**Total Cost**
		To Digitize	**To Key-in Attributes**	**Letter Sheets (8.5 ×11)**	**Plan Sheets (ANSI B + ANSI E)**	**Storage (megabytes)**	
Pilot Study	1	2 hr [*$20*]	2 hr [*$20*]	30 pages [*$5.4*]	4 [*$10*] + 1 [*$7.5*]	29.6 Meg [*$0.59*]	$63.49
	18	36 hr [*$360*]	36 hr [*$360*]	533 pages [*$95.94*]	67 [*$167.5*] + 20 [*$150*]	532.6 Meg [*$10.6*]	$1144
Statewide	18000	36,000 hr [*$360,000*]	36,000 hr [*$360,000*]	540,000 pages [*$95,940*]	67,000 [*$167,500*] + 20,000 [*$150,000*]	532,600 Meg [*$10,600*]	$1.15 million

Guidelines for Go-Forward Strategy

Guidelines for the next phase of the Geo-GIS include (i) creation of enhanced data search and retrieval mechanisms; (ii) development of a flexible and user-friendly data entry system; and (iii) design of a catalog system for electronic documents. Although each element addresses different aspect of the database, their implementation can be performed concurrently. A description of each enhancement is provided in the remainder of this section.

Enhanced Data Search and Retrieval

The current Geo-GIS includes the ability to search across different data sets to find information defined by keywords. It is recommended that the search functionality be enhanced to provide an expanded data set that details additional, related information to that selection.

In this system, each item in the search results would include links to other information related by project number, bridge ID, or geographic proximity. For example, if a search for pile-driving records returned information from several different bridges, each pile-driving record would have an attached reference to related data, such as bridge plans, boring logs, as-built drawings, etc., so the user could click on the reference and view that related data. In this fashion, users could "drill down" through a data set and retrieve all information relevant to their needs, even if that information were not returned in the initial search.

Data Entry System

The key to a valuable database is ease-of-update. It is suggested that data entry templates be developed for each type of information to be stored in the Geo-GIS database and that a metadata server be constructed to facilitate description and retrieval of data sets. Where raw geotechnical data is to be collected and stored (blow counts, soil properties, etc.), data entry will be allowed in two ways: direct entry of values through a user-friendly interface, or import of data files with a semi-automated import engine that helps identify correspondence between the source data fields and those in the database. Inclusion of non-text or non-numeric data (e.g., scanned images, photographs, drawings, etc.) is discussed in the Catalog System description below.

A metadata server will store "data about data," that is, descriptive information about each data element in the Geo-GIS database. There are several standards for metadata, but each includes basic information such as the date, author, database location, and keywords pertaining to specific data. The current cross-data set search functionality in the Geo-GIS already incorporates metadata in its operation, but a standards-compliant metadata server greatly increases the availability of data to users through a more efficient and complete search of all described data sets.

Catalog System

To expedite storage and retrieval of electronic information stored outside of a traditional database, it is recommended that a hierarchical catalog system be developed to name and organize these files. A logical and consistent storage system has fewer misfiled documents and more rapid retrieval. Such a catalog also facilitates user entry of new information, resulting in a more complete catalog over time. This catalog system should also include reference to the physical location of non-electronic data, such as paper reports, legacy drawings, samples, etc. A bar-code system is highly recommended for library-type storage, but may be unnecessary for more scattered information.

Section 4.0
Conclusions and Recommendations

This final section of the report presents recommendations for the next phase of work on this project, as well as recommendations for the entire project. Based on the observations made from this pilot project, the following research experiences, conclusions, and recommendations are outlined:

1. This research successfully used GIS to develop a pilot-scale geotechnical database system for managing geotechnical and subsurface structural information associated with 18 bridges from seven ALDOT divisions from across the state.
2. The Geo-GIS developed during this pilot study efficiently stored and retrieved data associated with 18 bridges and seven projects in the state of Alabama.
3. Delays were encountered in collecting data as some of the projects were old and retrieval of information from the divisions was difficult.
4. Latitude-longitude coordinates for bridge locations were not available for some projects, which made it difficult to identify the exact location on the GIS map. In such cases, written descriptions of bridge locations were used for digitizing.
5. Each project and bridge had several scanned documents and reports; therefore a user-friendly hyperlink in a HTML format was created to access multiple scanned records.
6. Multiple project numbers may be associated with one location; therefore, the project number used during construction was employed as the primary ID and preliminary project numbers were associated to the primary ID.
7. A second phase of research is recommended before the Geo-GIS is implemented statewide.