# DEVELOPMENT OF A BRIDGE MANAGEMENT SYSTEM IN ALABAMA

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**ABSTRACT**

This paper describes the development of Alabama's bridge management system (ABIMS) by the Alabama Department of Transportation (Department). Unique features of ABIMS development include its comprehensive committee structure and efficient software development procedure. Specific information is given regarding important ABIMS functions such as bridge resource tracking, needed and performed maintenance reporting, and scour monitoring. After hiring the University of Alabama as a consultant, the Department organized several committees to oversee, review, and develop ABIMS. The committees were composed of personnel from many branches and levels within the Department, the Federal Highway Administration (FHWA), and city and county representatives, which ensures ABIMS will interface as smoothly as possible with existing systems and will meet the needs of all users. Early, the Department decided to develop its own bridge management system (BMS) rather than use an off-the-shelf system. ABIMS was designed by pulling information and ideas from many sources and molding a BMS to custom-fit Alabama's needs. The detailed system design was performed by the bridge management engineer and the computer-program analyst assigned full-time to the project. Software development for ABIMS followed a three-phase procedure in which the function of every component was first fully-defined before proceeding with the actual computer programming. Several of ABIMS components or modules are up and running, including its unique scour module. This module displays stream-bottom profiles based on sounding data from biennial inspections. The graphical display allows bridge inspectors and maintenance engineers to spot developing scour problems.

## INTRODUCTION

In today's struggling economy, all transportation agencies are faced with the same difficulty of striving to maximize the use of available dollars to handle the immense needs of our aging highway system. The old cliché of "the hurrieder I go, the behinder I get" applies here. Therein lies the need for bridge management. And, as one of our colleagues would say, "We have to do the best we can with what we've got"; this is exactly the purpose of bridge management. The Department strives to be proactive, rather than stand by and wait. We want to participate in the group that makes things happen. The Department recognizes the need to preserve the taxpayers' investment in the existing bridge system in Alabama. Toward this end, the Department began development of a bridge management system in 1989. Called the Alabama Bridge Information Management System (ABIMS), the system will provide ready access to a wealth of information concerning Alabama's bridges. When complete, ABIMS will go beyond information management. Instilled with the Department's level of service goals, maintenance policies, and replacement criteria, ABIMS will help the Department develop cost-effective bridge maintenance, rehabilitation, and replacement policies.

This paper presents an overview of the development of ABIMS. It describes how the project began with the hiring of an outside consultant and the organizing of supervisory, user, and working committees within the Department. Through combined efforts of the consultant and the Department, time was spent reviewing the existing FHWA guidelines on BMSs, surveying available literature and visiting states that had BMSs in place.

## PROJECT ORGANIZATION

The first commitment made by the Department was to hire the University of Alabama (University) to help with the design and development of the system. Second, the Department established three committees to monitor and give direction in the development efforts of ABIMS. The composition of each committee is outlined in Figure 1. The Steering Committee is the highest in authority and consists of five representatives. This committee has the authority to allocate special funds, hire additional personnel, purchase special equipment to support the system, or make policy or procedural changes in the Department. One of the Steering Committee's first actions upon receiving the University's first interim report was to appoint a Bridge Management

| | |
|---|---|
| **Steering Committee** | |
| 1 | Administrator |
| 2 | Bureau Chiefs (Maintenance & Computer Services) |
| 1 | University of Alabama Representative |
| | Bridge Management Engineer |
| **User Committee** | |
| 7 | Bureau Chiefs (Accounting, Bridge, Construction, Design, Maintenance, Secondary Roads, State Planning) |
| 4 | Division Representatives |
| 2 | County Representatives |
| 1 | City Representative |
| 2 | University of Alabama Representatives |
| 1 | FHWA Representative |
| | Bridge Management Engineer |
| **Project Committee** | |
| 7 | Bureau Representatives (Maintenance, Bridge, Computer Services, Secondary Roads) |
| 1 | County Representative |
| 2 | University of Alabama Representatives |
| 1 | FHWA Representative |
| | Bridge Management Engineer |

FIGURE 1 Composition of supervisory and working committees.

Engineer. The User Committee is second in authority and consists of eighteen representatives from several bureaus in the Department, from the FHWA and from a county and a city. This committee reviews what has been planned and proposed for the system and ensures that ABIMS will meet the needs of all users and will interface smoothly with other bureaus and agencies. The Project Committee is the working committee and is composed of twelve people from the most-affected Department bureaus and includes an FHWA representative and a county representative. These people brainstorm ideas and work on the logistics of the system. The User and Steering Committees must review and approve the proposals of the Project Committee before proceeding with software development. Occasionally, the Project Committee had to make many decisions within a very short time. When this occurred, several task committees were named from the Project Committee members and from other Department employees who have the necessary expertise to help with the technical issues. By delegating specific tasks to subcommittees the progress of the system development was expedited.

This plan of development has worked very well for Alabama. It allows people to be directly involved with the hands-on development of ABIMS without demanding so much of their time. It also prevents any one group from dominating the design of the system. For example, since ABIMS will be housed in the Maintenance Bureau, it would be easy for maintenance personnel to tailor the system to accommodate only their needs and desires at the expense of others' needs.

## DESIGN PROCEDURE

After receiving the contract in 1989, the University conducted a literature review and presented several seminars to brief the Department on the state-of-the-art in BMSs. Most helpful was an overview of BMSs by FHWA (*1*) and several publications describing the North Carolina BMS (*2,3*). Key concepts explained during the seminars included level of service, user costs, deterioration prediction, and system optimization.

The Project Committee visited the highway agencies of three other states to learn firsthand how these states ran their BMSs. Much useful information was exchanged during the visits to Pennsylvania, North Carolina and Virginia. During the visits, Department personnel often paired-up with their counterparts from the other state and shared specific information about bridge management and other pertinent topics. The Project Committee returned home and discussed the strengths and limitations of each state's BMS.

### Preliminary Design

Before designing Alabama's BMS, ABIMS team members met to outline the needs and desires of the Department. Suggestions were solicited from all members of the Steering, User and Project Committees. After identifying the basic tasks for ABIMS, the Project Committee defined individual components or modules to perform the tasks. Figure 2 is a schematic layout developed by the University which shows conceptually some tasks to be performed by the software.

The University conducted a significant amount of research in the preliminary design stages and completed several interim reports (*4,5,6,7,8*) to document their efforts and findings. In Interim Report No. 1, it was recommended to the Department administrative staff that approval be granted for the preliminary design. The administrators readily approved the recommendations and detailed development began.

In the early stages of the detailed development, approximately fifteen programs or modules were identified for ABIMS. As the Project Committee

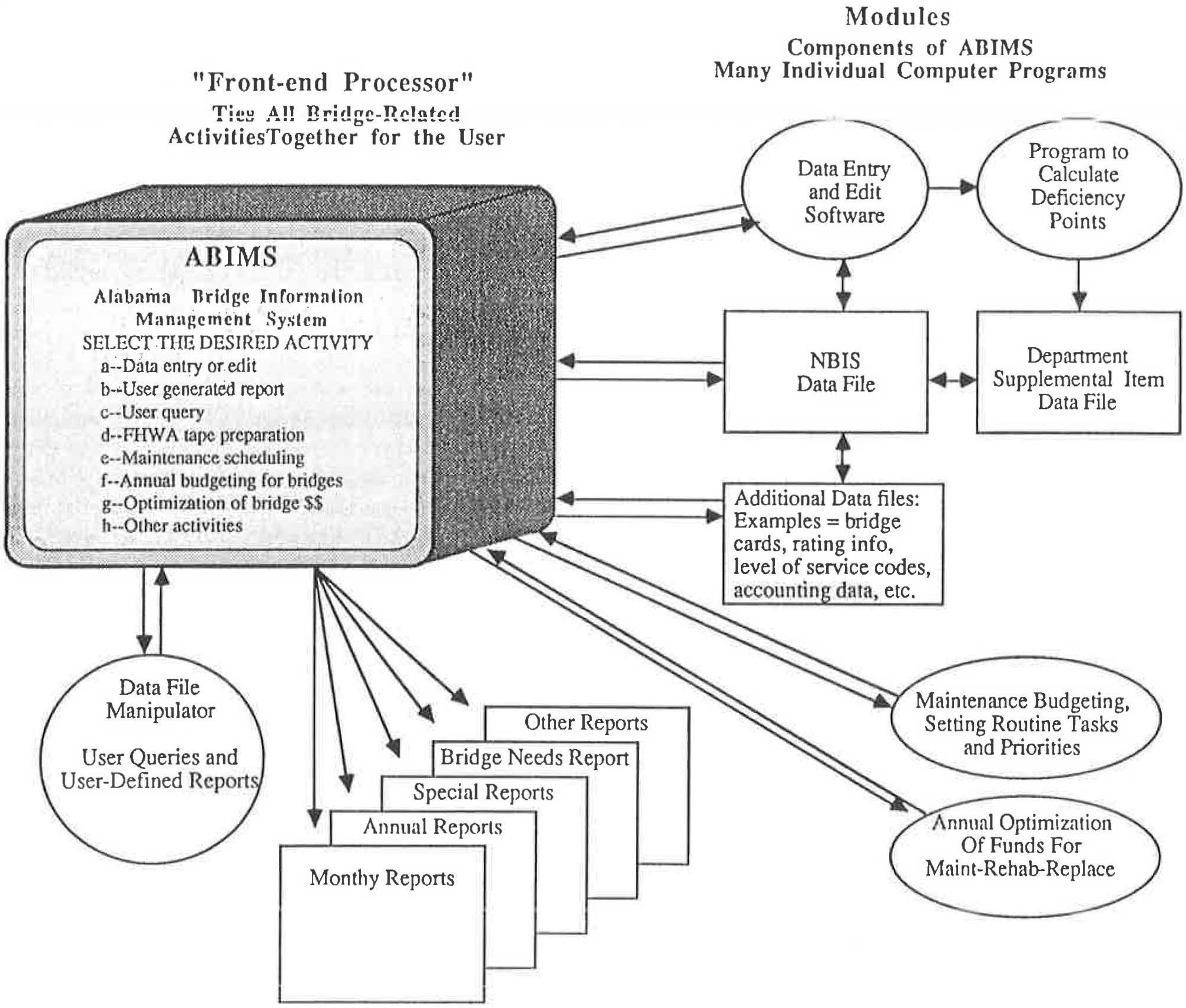



**FIGURE 2** Preliminary schematic diagram for Alabama's bridge management system.

worked through what was expected from the system and how these expectations would be met, additional modules were identified and ultimately twenty-two modules were defined for ABIMS. In Figure 3, a list is provided with the modules grouped by their primary function.

Early, the Department made the decision to develop its own BMS, customized to fit its unique needs and programmed by its own computer services personnel. Once this decision was made, one programmer/analyst was named the ABIMS representative. This person was to be responsible for the software development of the system and would coordinate the programming of all modules of the system to cause it to be implemented most productively within the total plan. In the Department's Computer Services Bureau, there were approximately 10 programmers available to work on the ABIMS. Thus far, approximately eight of these programmers have been involved in writing software for the system.

**Software Development Procedure**

The strategy adopted for software development was recommended by the Computer Services Bureau. Based on the success in the development of another complex computer program, it was agreed to work through a three-phase development procedure.

*Functional Specifications*

The first development phase was the writing of the functional specifications. Functional specifications simply consist of a brief paragraph for each module in the

system. This paragraph includes the purpose of the module, the type of information necessary to drive the module and what type of output is expected. In the functional specifications, the committee clearly established the type of modules to be included in the system, the amount of data to be collected, and the type of data manipulation required to obtain the desired results.

*General System Specifications*

The second phase of software development was to write general system specifications for each program module. These specifications were much more specific and included information such as which data items were required for input, where these data came from, what types of calculations and formulas were necessary, which modules interfaced with this module, and what type of output was required (for example reports or electronic storage).

*Detailed System Specifications*

The final phase of software development before actual coding of the program was to write the detailed system specifications. These specifications are detailed in nature and specify such things as size of data in bytes and whether data are alpha or numeric. Occasionally, modules with redundant tasks were removed and new modules were added to do mundane but necessary tasks such as recovery and security. Once the plan was completed and approved by the committees, any changes to the original plan were reviewed and approved by the committees. The functional specifications were written by delegating the modules to different task committees. This allowed parallel development of many of ABIMS's modules, shortening development time. The modules were implemented on a staggered schedule, allowing users to become familiar with each part of the system separately. This caused the users to be more receptive to the system without being overwhelmed by the amount of data required and the amount of data generated by the system.

## STATUS OF IMPLEMENTATION

The Department is now 100 percent complete with development of the functional specifications, about 60 to 65 percent complete with the general system specifications and about 25 to 30 percent complete with the detailed design specifications. An overview of the 22 modules in ABIMS is presented below, followed by short discussions of selected modules.

**Incidental Modules**
- Front End Program
- On-Line Help
- Security
- Training
- Recovery

**Data Capturing Modules**
- Conversion
- NBI File Maintenance
- Element Rating Entry
- Maintenance Needs Estimate
- Maintenance Reporting
- Supplemental Data
- Scour Profile Plotting/Hydrology
- Deficiency Points
- Data Access in Other Fields

**Data Analysis/Manipulation Modules**
- Bridge Status Display Screens
- FHWA Edit Program
- Resource Tracking
- Maintenance Budgeting & Prioritizing
- Deterioration Models
- Optimization Program
- User Query
- Standard Request & Reports

FIGURE 3 Alabama bridge information management system modules.

### Overview of Modules

Twenty-two modules have been identified for ABIMS. These modules are listed in Figure 3 where they are grouped according to function. Incidental modules do tasks necessary for any large program to be user friendly and reliable. Eight modules are devoted to data capture in ABIMS. Data enters ABIMS from many different sources such as bridge inspectors, maintenance crews, hydrologists, the project office, the National Bridge Inventory (NBI) file, the supplemental data file, and the accounting files. Data analysis and manipulation modules manipulate the massive bridge database and generate a multitude of display screens and reports for users at all levels.

### Supplemental Data Items

Preliminary research by the University showed some states were collecting over 400 data items per bridge. This was significantly more than the 128 data items collected in Alabama at the time. Project committee members became concerned about the significant expense of collecting and maintaining a large amount of

additional data, and the usefulness of the additional data. Reviewing data items collected by several other states, a task committee identified approximately 200 additional data items as necessary for the complete implementation of ABIMS. The definition of each item, the type of data (alpha or numeric), and the number of characters or digits in the data field were specified for each data item. An extensive set of codes was developed for many data items. For example, bearing type is entered as one of 21 possible codes with each code corresponds to a specific type of bearing. As development of other modules proceeds, additional data items are sometimes added to the supplemental data items. Data items are occasionally dropped when redundant data are discovered or the data item is no longer considered useful.

**Bridge Number**

One of the first tasks the Department faced was determining a method of uniquely identifying bridges that would be permanent for the life of the bridge. The current method for numbering state-owned structures is linked to the state route and the milepost distance from the county line. Both items can change over the life of the structure if a route realignment is completed or if structure ownership is transferred from one governing authority to another. Also, counties and cities in Alabama identify their structures by a different method. Because a unique bridge number was necessary for ABIMS as well as for the accounting reference systems and project management reference systems, a bridge identification number, or BIN, was established. This unique six-digit number bears no significance to the route or milepost and will not change for the life of the structure.

**Bridge Resource Tracking**

Currently under development, the bridge resource tracking module will collect data necessary for determining the expenditures on a specific structure at any point in time. The current eight bridge-related maintenance activities were expanded to 38 to provide more detailed data. Expenditures such as labor, equipment and materials will be tracked for individual structures by this module. Data from this module will be used to update the unit costs for labor and equipment. In the future, data from this module will be used to study the effect of maintenance activity on bridge deterioration. Much of the data to support this module is collected via the maintenance reporting module described below. Additionally, this module will collect and store data on the cost of construction of new bridges and the rehabilitation of existing bridges.

**Maintenance Needs Estimate and Maintenance Reporting**

FHWA wants state highway agencies to have a follow-up procedure for maintenance work reported as needed. Currently, once Alabama inspectors identify work to be done, they do not have a formal procedure for checking that the work is done. The maintenance needs and maintenance reporting modules will provide an automated procedure for identifying work needed on a bridge, tracking all maintenance activity on the bridge, and then documenting work accomplished for the bridge.

*Maintenance Needs Module*

The bridge inspectors are the primary source of data for the maintenance needs module. They will identify what type and how much maintenance the bridge needs by indicating one or more of the 38 possible maintenance activities and estimating the quantity (in appropriate units) associated with each needed activity. The inspector also will suggest a priority using one of four categories: emergency, urgent, priority or routine. The division maintenance engineer can adjust the suggested priority when considering the maintenance needs across the entire division. Information from the maintenance needs module can be used for several management activities. Once entered, ABIMS will assign information on needed maintenance to the appropriate bridges. A breakdown on the required maintenance for each bridge can be displayed on a computer screen. Anticipated costs will be displayed by ABIMS using unit costs calculated from the previous year's accounting data. An example of a bridge status display screen showing needed maintenance is shown in Figure 4.

*Maintenance Reporting Module*

The crew leader will record the data for the maintenance reporting module (crew leader may be the district engineer, a bridge inspector, a bridge repair crew supervisor, or similar personnel). The amount of labor, equipment, and materials used on each bridge and the activity accomplishment will be coded on the form. Information from the maintenance reporting module will be used to prepare payroll, material requisitions, and equipment usage reports. Also, the crew chief will check the box titled "Job Completed" to show the maintenance activity is complete. This is necessary to resolve discrepancies between the actual number of work units

**NEEDED MAINTENANCE**

B.I.N.: Bridge No.:

| ACT. CODE | DESCRIPTION | QUANTITY PLANNED | ACT UNITS | EST. COSTS | DATE ENTER | MAINT PRIORITY |
|---|---|---|---|---|---|---|
| B29 | Drift Removal | 300 | MH | $3,655 | 02 92 | U |
| B14 | Major Super Rpr--Steel | 3,000 | MH | $255,000 | 02 92 | R |
| B23 | Bridge Painting--Spot | 1,100 | SF | $485 | 01 92 | R |
| B02 | Curb/Rail/Fence Repair | 2,500 | LF | $37,500 | 12 91 | R* |
| B17 | Minor Sub Rpr--Steel | 1,800 | MH | $135,000 | 12 91 | R |
| B31 | Accident Repair | 144 | MH | $4,320 | 11 91 | U |
| B04 | Joint Repair--Sealed | 450 | LF | $13,500 | 10 91 | R* |
| | Total Estimated Costs = | | | $449,460 | | |

* Maintenance underway but not completed

FIGURE 4 Example display screen showing needed maintenance on a particular bridge.

**COMPLETED MAINTENANCE**

B.I.N : Bridge No:

| ACT. CODE | DESCRIPTION | QUANTITY COMPLETED | ACT. UNITS | ACTUAL COSTS | DATE COMPLT | MAINT BY |
|---|---|---|---|---|---|---|
| B08 | Major Deck Rpr--Steel | 3,200 | SF | $208,000 | 01 92 | C |
| B03 | Joint Repair--Open | 3,211 | LF | $212,000 | 09 91 | D |
| B31 | Accident Repair | 120 | MH | $4,000 | 04 91 | D |
| B24 | Bridge Painting--Partial | 200,000 | SF | $88,264 | 06 90 | D |
| B11 | Minor Super Rpr--Steel | 452 | MH | $22,600 | 09 88 | C |
| B30 | Slope/Shore Protect Rpr | 367 | MH | $5,505 | 08 87 | D |
| B28 | Light/Nav Light Repair | 93 | MH | $2,325 | 06 87 | D |
| B17 | Minor Sub Rpr--Steel | 2,400 | MH | $180,000 | 09 86 | C |
| B32 | Vandalism Repair | 150 | MH | $5,000 | 04 86 | D |
| B04 | Joint Repair--Sealed | 320 | LF | $9,600 | 02 85 | D |

30 OTHER MAINTENANCE JOBS FOR $ 11,516,288 COMPLETED SINCE 1961

LAST INSPECTION CYCLE MAINTENANCE COST = $ 512,264/yr
LAST INSPECTION CYCLE MAINTENANCE COST PER SQ FT = $ 65/yr
AVG INSP CYCLE MAINT COST, LAST TEN YEARS = $405,360/yr
AVG INSP CYCLE MAINT COST PER SQ FT, LAST TEN YEARS = $ 58/yr

FIGURE 5 Example display screen showing completed maintenance for a particular bridge.

and the estimated number of work units reported by the bridge inspector. An example of a bridge status display screen for completed maintenance is shown in Figure 5. This module also will include provisions for tracking maintenance work performed by both Department personnel and outside contractors. Maintenance not marked "Job Complete" will appear on a monthly report of remaining maintenance. If needed maintenance identified by the bridge inspector is not performed by the next inspection, the bridge inspector can clear the maintenance request and enter a new updated request if the bridge has further deteriorated.

**Bridge Element Condition Rating**

The bridge element rating module allows the entry, update, retrieval, and display of information from the bridge inspection report (Alabama's BI-5 Form). The BI-5 form is a detailed inspection sheet used by bridge inspectors for rating the condition of individual bridge elements. Adapted from a form distributed by FHWA in the early 70's, the BI-5 form contains approximately 75 data items for rating the condition of deck, superstructure, and substructure elements as well as culverts, channels and channel protection, and expansion joints. Other information includes traffic safety features, approach roadways, and the inspector's signature and certification number.

**Deficiency Point Module**

The deficiency point module will compare selected bridge characteristics against the appropriate level of service goals for each bridge in the database. The module will extract nine pieces of information from the NBI for each bridge (load rating, roadway width, vertical clearance, deck, superstructure, and substructure conditions, traffic volume, detour length and functional class). It also will use several supplemental data items and then compute a deficiency point number stored in the database for each bridge. The deficiency point equation was calibrated in Alabama by comparing lists of bridges picked by the deficiency point module against bridges selected by experienced maintenance engineers and bridge inspectors from several divisions and counties. After adjustment, the deficiency point algorithm showed excellent agreement with the engineers and bridge inspectors. The calibration procedure established the credibility of the deficiency point algorithm and established a uniform criterion for evaluating all bridges in the state. The algorithm can be adjusted in the future to reflect policy changes in the Department.

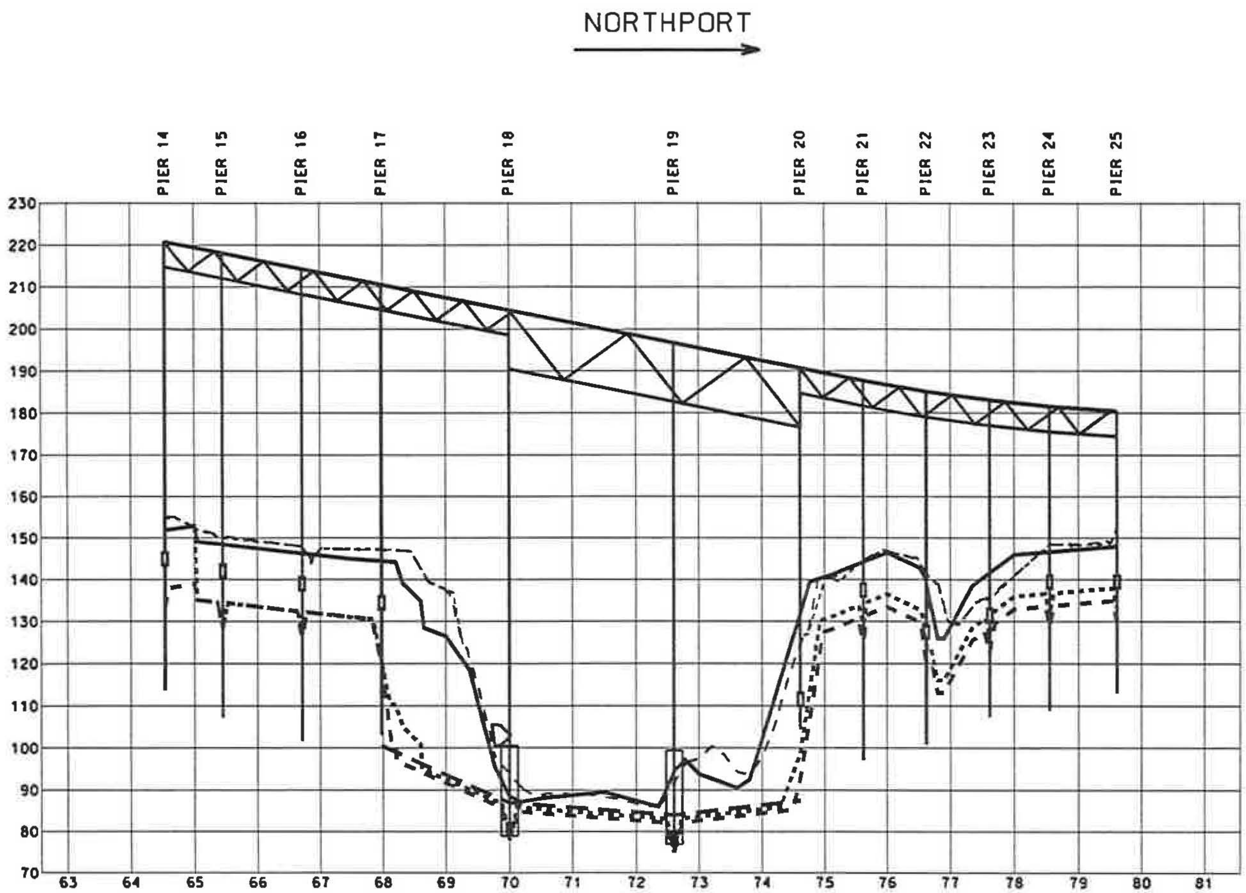
**Scour Module**

The scour module graphically displays foundation elevations and stream bed sounding data from several years. It was designed to detect changes in the stream bottom which may lead to undermining of the foundations. The scour module, the first completed module in ABIMS, was ranked high on the priority list once the FHWA began to schedule deadlines for the different phases of the states' scour programs. Because the Department chose not to classify any structure as low risk until an evaluation was complete, it faced a difficult deadline for completing the scour analyses on existing structures. The scour module provides a means for doing a visual evaluation of the stream bed and foundation elevation data and increases the user's confidence when classifying a structure as low risk.

The bridge inspectors are responsible for collecting the approximately 100 data items for this module. Data include bridge deck stations and elevations, stream bed soundings across the stream, superstructure thickness, and foundation types and elevations. The module displays an elevation view of the bridge showing the bridge deck, the bottom of the superstructure, the pier locations, and the bottom of the foundations. A typical plot generated by the scour module is shown in Figure 6. Information from soundings is displayed to show previous stream bed profiles and the current stream bed profile. The anticipated scour profile calculated by the hydraulics section also can be displayed for several flood frequencies. The scour module has been well received throughout the Department and highly praised for a 'job well done.' Besides the graphical presentation of the data, users can generate a report in tabular format listing the stations and elevations of the bridge, the original stream bed, the current stream bed, and the potential scour profile. The module uses graphics software (Intergraph's MicroStation) running on personal computers located in division and county offices throughout the state. The personal computers are linked (using File Transfer Protocol, NFS and Inter-link software) to the mainframe computer in the Department's central office.

**Optimization Module**

Currently under development, the optimization module will inform Department administrators about future budget requirements, support cost-effective allocation of current bridge funds, and provide other system-wide decision support. Because North Carolina served as the primary model for much of ABIMS design, (performed during 1990 and 1991), the Project Committee decided to adapt North Carolina's optimization program OPBRIDGE (*9*). The cooperation of Dr. David Johnston and the North Carolina DOT in sharing the program source code and example data files have been appreciated. The Project Committee is inserting Alabama's Level of Service goals, deterioration rates, accident rates, and other factors into the OpBridge program.




BIN: 10773. SN: 0000 0 069 63 016 5 0
DIVISION: 5. DISTRICT: 2
TUSCALOOSA
RIVER RD.MN AV.WARRIOR
TUSCALOOSA COUNTY
LEFT SIDE OF BRIDGE

1968 ORIGINAL GROUNDLINE
1993 CL Scour Evaluation 0100 Yr Flood
1993 CL Scour Evaluation 0500 Yr Flood
1993 CL Scour Evaluation ROCK LAYER
01'90 SOUNDINGS LEFT RAIL
09'92 SOUNDINGS LEFT RAIL

| ESTIMATED SCOUR | | | | | | | | | | | | 0100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PIER NUMBER | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| CONTRACTUAL SCOUR (FT) | 0 | 14 | 14 | 14 | 2 | 12 | 10 | 10 | 10 | 10 | 10 | 10 |
| PIER SCOUR | | | | | | | | | | | | |
| PIER SCOUR (FT) | 0 | 6 | 5 | 10 | 8 | 8 | 23 | 5 | 5 | 5 | 5 | 5 |
| TOTAL SCOUR (FT) | 0 | 20 | 19 | 24 | 10 | 20 | 33 | 15 | 15 | 15 | 15 | 15 |

| ESTIMATED SCOUR | | | | | | | | | | | | 0500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PIER NUMBER | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| CONTRACTUAL SCOUR (FT) | 14 | 14 | 14 | 14 | 3 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| PIER SCOUR | | | | | | | | | | | | |
| PIER SCOUR (FT) | 5 | 6 | 6 | 11 | 8 | 8 | 26 | 6 | 6 | 6 | 5 | 5 |
| TOTAL SCOUR (FT) | 19 | 20 | 20 | 25 | 11 | 21 | 39 | 19 | 19 | 19 | 18 | 18 |

NOTE: THE SOUNDINGS OF 1991 ARE NOT COMPLETE. THIS DRAWING ONLY INCLUDES THE TWO OVERBANK AREAS.

FIGURE 6 Typical plot from ABIMS scour module showing bridge elevation view and stream profiles.

**Other Modules**

The Standard Request/Reports module is being developed as other modules are implemented. This module generates standard reports for other modules. Other incidental modules are being developed concurrently with the major ABIMS modules. The Front End module, the Security module, the Training module and the Recovery module all perform important tasks to make ABIMS user-friendly and to safeguard the data in ABIMS.

## CLOSING

Though ABIMS is far from the finish line, portions are already on line. Several reports and graphical output files can be generated to support decision-making efforts. Many output reports which will be implemented soon aim to make work efforts more efficient and productive. Considering the expanse of inspection and maintenance work facing the Department, improved efficiency will be much appreciated. In the short time that the scour module has been operational, many requests have been submitted for recommended changes and enhancements to the program. As the users become more familiar with the ABIMS scour module, they realize the potential and begin to suggest ways to make it better. We hope users will embrace the other ABIMS modules with the same enthusiasm. Finally, metric conversion is another hurdle for ABIMS. Much effort has already been expended within the Department on this topic, however, and no significant problems are anticipated in making ABIMS metric compatible.

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