Computerized Data Base Management and Analysis System for Field-Collected Scour Data

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The scouring of the piers supporting highway bridges has come to be recognized as a major problem facing the highway engineer. It is becoming increasingly obvious that bridges that face possible scour situations must be monitored during their lifetimes. Much data will be collected during the monitoring phase. A computerized system for the storage, organization, analysis, and display of field-collected scour data is described. The system accepts input from the user, and on the basis of user specification, allows the data to be organized and viewed in a variety of formats. These formats include cross sections from scour measurements at selected locations upstream or downstream of the bridge, longitudinal profiles through a selected pier, and the temporal history of maximum scour activity within a specified area near the bridge. The data may be viewed in tabular as well as graphical formats. In addition, the available scour data were analyzed and used to develop regression equations that related long-term trends in channel degradation to flow and geometric variables. These equations were incorporated into the computer system so that the user could determine if observed trends in channel degradation were likely to continue.

The safety of highway bridges can be seriously impaired because of the undermining of the supporting piers by scour. The threat that potential bridge scour poses to the integrity of the highway system is becoming increasingly obvious. Recent failures in New York and Tennessee demonstrate the risk faced by many bridge structures. Potential scour must be taken into account during the design phase of bridge construction. However, it is also important that bridges that face possible scour situations be monitored during their lifetimes. Much data will be collected during the monitoring phase. These data must be organized and analyzed in the most efficient manner possible. The organization and analysis of field-collected scour data are the topics with which this paper is concerned.

Presently, the Louisiana Department of Transportation and Development (LADOTD) is monitoring about 80 bridges to detect possible danger of failure caused by pier scour. The scour surveys are done after flood events, or at specified time intervals during low water by fathometer and are reported on scour survey sheets that contain channel bottom elevations (NGVD) at selected locations upstream and downstream of the bridge piers. A schematic of a typical survey layout is shown in Figure 1. There are not sufficient data for either a full longitudinal profile or a full channel cross section to be plotted. In addition, no sediment data or discharge data are currently taken by LADOTD. Presently, the hydrographic survey data are plotted manually and then inspected visually and compared to past surveys to subjectively determine the relative severity of the scour situation at the particular location. This analysis can sometimes be very time consuming.

The monitoring program has been ongoing for about the past 12 years. A great deal of data (scour surveys) have been collected in that time period. A computerized system was created to store, organize, display, and analyze this historical survey data. This system, called the Louisiana Scour Analysis Management System (LASAMS), is capable of sorting and displaying the data base in a variety of formats as well as analyzing the data for the presence of trends in the observed data and relating these trends to bridge geometry and streamflow variables where possible.

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LASAMS

The scour analysis management system consists of three subsystems:

- A data entry and editor facility,
- A query facility that allows the data base to be sorted and viewed in a variety of tabular and graphical formats, and
- A scour analysis facility (performed through a query).

The system has been implemented on the Intergraph Interpro 32 workstation. The selection of Intergraph was based on the mutual availability of that system at both Louisiana State University (LSU) and LADOTD and the availability of software for data base and graphics manipulation. The Intergraph system also provided facilities for their integration. The choice of Intergraph for this project does not necessarily imply an endorsement of this product by the authors or LADOTD but merely that it was already available and possessed some of the necessary general capabilities. However, the system-provided software was not sufficient to perform the specific tasks required for this project. It does not possess the capability for a user-friendly interactive analysis of the data and the type of graphics necessary to meet the needs of this project. Therefore, a great deal of original programming (10,000 lines) in Fortran and Host Operations Language (HOL) was necessary. Thus, the final system is a composite of packages supplied by Intergraph and programs written for this project.

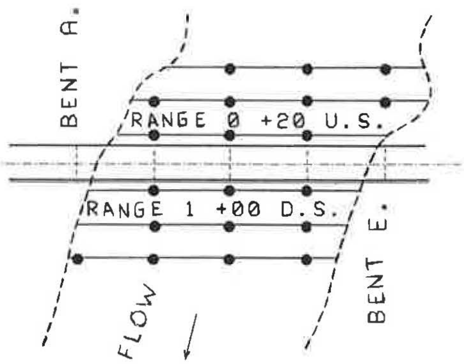

FIGURE 1 Typical scour survey layout.

LASAMS operates interactively in all three subsystems. The scour data base is constructed by entering data through the system-supplied editor, DMRS Worksheet Editor (DWE). This facility provides a spreadsheet-like interface to the data base. The specific attributes of the LASAMS data base and query facilities have been described by Narasimhan et al. (*1*) and in greater detail by Cruise and Argialas (*2*). The data base consists of eight entities that describe the bridge structure, channel conditions, and hydrographic survey. These entities and their descriptions are as follows:

- BRIDGE. This entity contains static information about bridges. The attributes of this entity include Name, ID Number, Route, etc.
- SOUNDING. This entity contains the actual sounding data. The attributes of this entity are
  —Bridge number,
  —Pier/bent number,
  —Distance (from bridge),
  —Position (upstream or downstream),
  —Bottom elevation,
  —Date of survey, and
  —Comment.
- PIER. This entity contains information about the location of the piers of a bridge, their type, and their bottom elevations. This information has to be entered before the CROSS SECTION or HISTORY query can be made. The reference point for measuring the distances can be arbitrarily fixed as the left-most pier of the bridge (looking upstream).
- CROSS SECTION. This entity contains the cross section of a river near a bridge. These data must be obtained external to the scour surveys and are used for calculating the cross-sectional area, velocity, etc., required for scour analysis.
- BRIDGE NOTES. This entity contains comments about a bridge made by a survey team.
- PARISH CODE. This entity contains a list of parishes and their two-digit codes. This information is used only at the time of data entry for reference.
- PIER CODE. This entity contains information about the type of the pier and its corresponding code.
- STRUCTURE CODE. This entity contains the type of structure and its corresponding code.

Of course, the scour data base is continuously updated as new data become available.

LASAMS ARCHITECTURE—QUERY SUBSYSTEM

The objective of LASAMS is to provide access to the archived scour data base and display scour data in tabular as well as graphical formats. In the Intergraph system, graphic data are stored and manipulated in a graphic design file. LASAMS therefore needs to access two resources: the scour data base and the scour graphics file. The scour data base can be accessed and manipulated programmatically. Although it is possible to create graphic elements programmatically, the display of graphics is possible only with the help of an interactive Intergraph program called Intergraph Command Environment (ICE). This necessitated the existence of two processes, ICE and Query, running concurrently.

The main function of ICE in LASAMS is to interact with the user and display the scour graphics file. The function of the Query program is to access the scour data base, and give the results of the queries made by the user. The Query program is also responsible for making graphical output of the query and plotting them on the scour graphics file. A scour trend analysis request is passed on to the scour analysis subsystem for processing. The system architecture is shown schematically in Figure 2. In reading the following description of Query architecture, it is helpful to refer to this figure.

The Intergraph system provides the facility to design sophisticated graphical interaction with the user by means of graphic menus, which are driven by graphic menu drivers. In the LASAMS system, the user specifies the criteria for query for filling up a form (the graphic menu). The criteria are checked for errors and compiled. The Query process is then spawned that waits for requests to serve. Once an error-free query is obtained, the menu driver transmits it to the Query process through a mailbox. The Query process now accesses the data base and gets the result of the query. The result is transmitted back to the menu driver through the mail box. The menu driver formats the result in the form of a table and displays

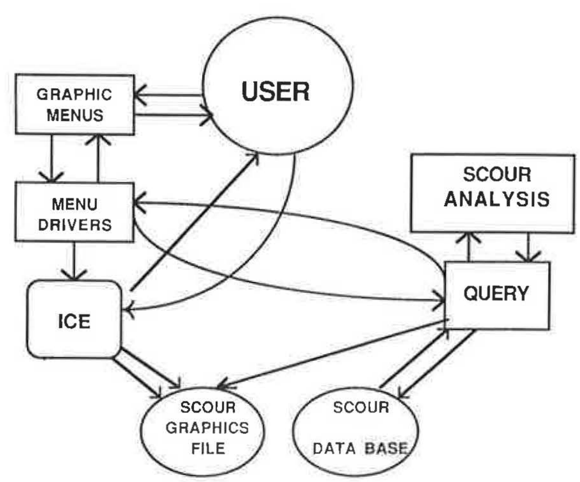

FIGURE 2 LASAMS architecture.

it to the user. If the user requests a graphical presentation of the results, this request is transmitted to the Query process. The Query process temporarily wrests control of the scour graphics file from the ICE process, creates graphic elements from the results of the query, and plots them on the graphics file. After plotting the graphics, control of the scour graphics file is returned to the ICE process, along with a completion message to the menu driver. The menu driver then displays the graphic results to the user with the help of ICE. Requests for scour analysis are also received by the Query process, but are passed on to the scour analysis system. The results of the analysis are received by the Query process and then transmitted to the menu driver. The architecture of LASAMS is such that it also facilitates direct interaction between the user and the powerful ICE program. This interaction allows a seasoned user of the Intergraph system to manipulate the scour graphics file using the full functionality of the ICE program, while still inside the LASAMS system.

The following sections describe each graphics menu available to the LASAMS user. These menus are grouped under the Query subsystem of the program.

Main Menu QUERY

The user normally activates the main menu when logging on to the system. The available options are the following:

- REVIEW BRIDGES,
- SURVEY SHEET & PLAN,
- CROSS SECTION,
- LONGITUDINAL SECTION,

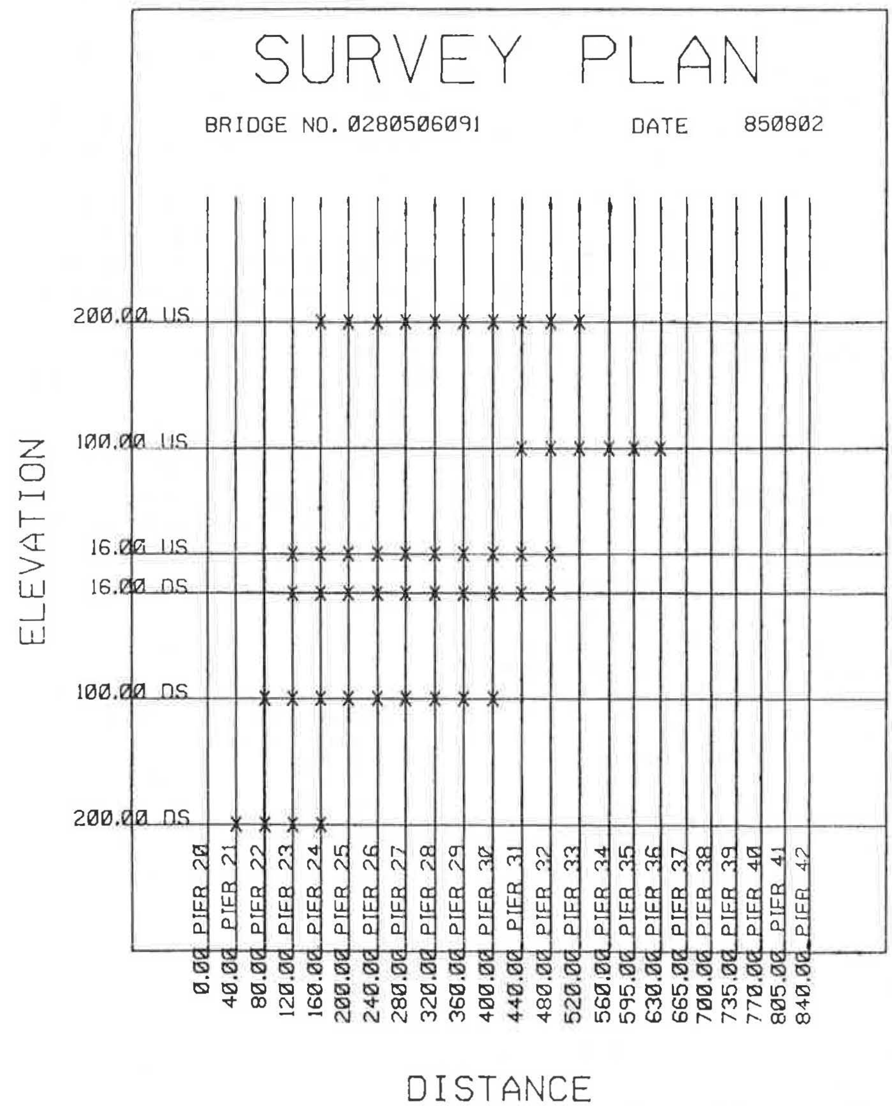

FIGURE 3 Typical survey plan.

- HISTORY & SCOUR PREDICTION, and
- END.

Menu REVIEW BRIDGES

This menu provides the user with information about bridges, such as the name of the bridge, number, route, structure, and frequency of survey. The specifications for this query are as follows:

- Bridge number,
- Parish,
- Route,
- District,
- Structure type, and
- Survey frequency (months).

The user can omit any or all of the specifications by just typing RETURN at the corresponding key entry fields.

Menu SURVEY SHEET & PLAN

Using this menu, the user can obtain the scour survey sheet and a plan of the survey for a bridge on a given date. This is the actual data reported by the survey crew. The specifications for this query are as follows:

- BRIDGE NUMBER and
- DATE OF SURVEY (in YYMMDD format).

If a graphical presentation of the survey plan is desired, the user selects the SURVEY PLAN option on the menu. A sample survey plan is shown in Figure 3.

Menu CROSS SECTION

Using this menu, the user can obtain the cross section of the scour data on a given date at a specified distance from the bridge. The specifications for this query are as follows:

- Bridge number;
- Distance from bridge (ft);

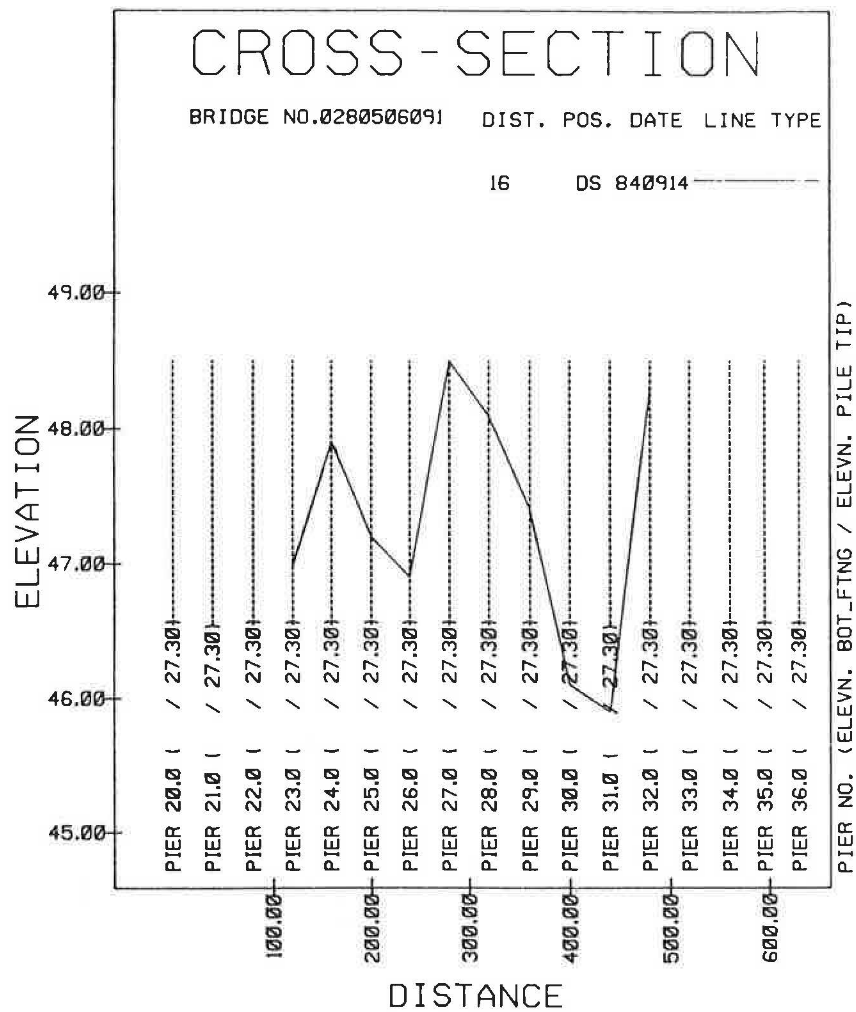

FIGURE 4 Typical scour cross section.

- Position (upstream US, centerline CL, or downstream DS); and
- Date of survey (in YYMMDD format).

A graphical presentation of the cross section is shown in Figure 4. Note that the cross sections corresponding to different survey dates can be overlayed on the screen for direct comparison.

Menu LONGITUDINAL SECTION

Using this menu, the user can obtain the longitudinal section of the scour data on a given date along a given pier. The specifications for this query are as follows:

- Bridge number,
- Pier/bent number, and
- Date of survey (in YYMMDD format).

The longitudinal section is shown graphically in Figure 5. As in the case of cross sections, overlays of longitudinal sections can also be done for comparisons.

Menu HISTORY AND SCOUR ANALYSIS

Using this menu, the user can obtain the variation of the maximum scour depth in a given area over a period of time and also get an estimate of the degradation trend likely to occur for a given flow history for some bridges. The specifications for the history query are as follows:

- Bridge number
- Upstream bound for area of interest
  —Distance from bridge (ft)
  —Position (upstream US, centerline CL, or downstream DS)

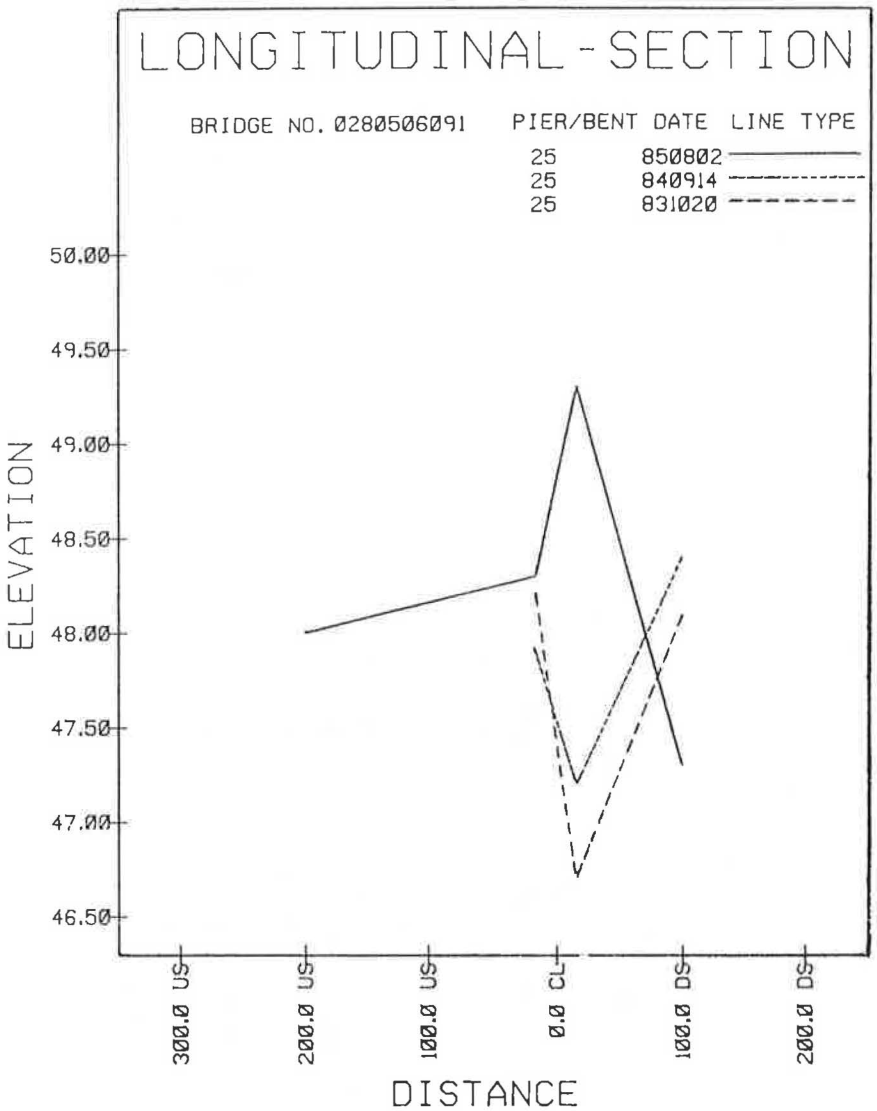

FIGURE 5 Typical scour longitudinal section.

- Downstream bound for area of interest
  - —Distance from bridge (ft)
  - —Position (upstream US, centerline CL, or downstream DS)
- Left bound, pier/bent number
- Right bound, pier/bent number
- Dates of interest (in YYMMDD format)
  - —Initial date
  - —Last date
- Bridge number
- Flood flow (in ft^3/sec)
- Stage (ft)

Under this option, the system scans the survey data within the specified bounds and chooses the maximum value for each survey. These values are then plotted versus the survey date as shown in Figure 6. A graphical display of scour trend (Figure 6) can be obtained by overlaying the results of trend prediction on a plot of a history query.

End

Selection of this option causes the program to end. The user has to return to the QUERY menu in order to end the program.

TREND ANALYSIS

The observed scour data are presently interpreted by visually comparing the current survey with past surveys at the same location. It is difficult to predict the relative severity of any trends that might be visually identified unless information about the flow history that caused the observed channel degradation is known. Scour analysis might be improved if this information could be incorporated into the system. For this reason, regression analyses were performed to relate trends in observed scour profiles with flow variables.

It is important for the reader to keep in mind the function of the regression equations. These equations in no way repre-

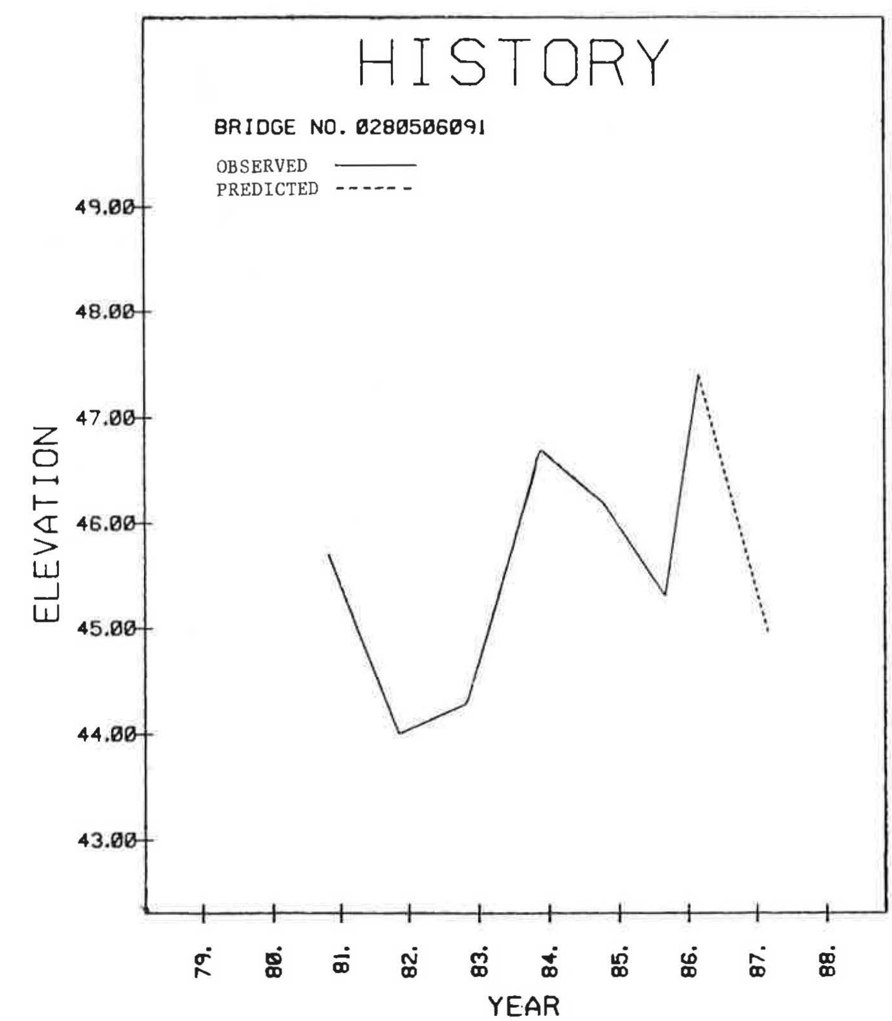

FIGURE 6 Typical scour history and trend prediction plot.

sent scour prediction equations. As stated previously, the scour surveys are normally done under low-water conditions. The stream velocities are usually negligible under these conditions and past studies have shown that there is little sediment movement in most Louisiana streams during low water. Thus, it is reasonable to assume that most bed degradation takes place during flood events. However, by the time the surveys are taken, much of the scour material has already been filled in during the receding flood waters. Therefore, the observed bed degradation is the residual or left over scour from the flood. There are no available data on maximum scour development during flood events for any of these streams. Therefore, it was not possible to develop equations to predict maximum scour or to check the validity of existing equations.

However, it is reasonable to assume that a relationship exists between the residual scour values and the flow variables that caused the original scour. The purpose in identifying this relationship is not to attempt to predict future maximum possible scour at any specific location, but to predict the future trend in channel degradation such that long term planning for bridge maintenance would be possible. For this reason, the equation must be site specific and incorporate the flow history of the specific stream under analysis. The U.S. Geological Survey maintains continuous stream gaging stations on 12 of the bridges in the current monitoring program. However, not all of these sites were suitable for analysis because of missing data or lack of channel control. Therefore, initial regression analyses were performed on four bridges. In all of these cases, it was found that a simple energy-based equation resulted in the best description of the observed channel degradation. This equation is

$$d_s = K_1 Y + K_2(V^2/2g)$$

where

d_s = observed residual channel degradation (ft),
V = average cross-sectional flow velocity (ft/sec),
Y = average depth of flow in approach section (ft),
g = acceleration of gravity (ft/sec^2), and
K_1, K_2 = site-specific regression coefficients.

In developing this equation, the flow variables for the most recent flood event preceding the scour survey were used. This formulation resulted in a better fit to observed data than did equations involving more variables including average discharge between surveys or maximum discharge between surveys. The average coefficient of determination (R^2) for the four bridges used in this analysis was 0.89. This equation has been incorporated into the scour history menu of the LASAMS program. It remains for LADOTD personnel to calibrate it for other bridges for which it will be applied. Calibration can be done using a regional flood study currently being completed for LADOTD (*3*) and the FHWA bridge backwater model.

CONCLUSIONS

A computerized system has been developed for the storage, display, and analysis of field scour data. The program is currently in the implementation stage at the LADOTD. Once fully implemented, the program will greatly enhance the ability of department engineers to efficiently analyze these data. The historic survey data for more than 80 bridges will be transferred from paper files to the computer system. This data base can easily be updated as new surveys are taken. The data can be sorted and visually compared on the screen in a variety of graphical formats. For bridges at which trend analyses are desired, a trend analysis formula has been developed to relate trends in the data to flow variables. This formula should greatly aid in the objective analysis of the scour trends. The LASAMS package should facilitate and enhance the scour monitoring program at LADOTD and help ensure the safety of Louisiana highway bridges from scour failures.

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