
by Jerrell R. Ballard, Jr., Margaret Rose Kress

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Flood Impact Support Tool (FIST)  
User's Manual  
and  
Technical Documentation

by  Jerrell R. Ballard, Jr., Margaret Rose Kress

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Preface

The work described herein was conducted by personnel of the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, from September 1994 to January 1996. The study was funded by the U.S. Army Engineer District, Vicksburg. Technical Monitor was Mr. Rayford Wilbanks, Economist, Planning Division, Vicksburg District.

The report was prepared by Mr. Jerrell R. Ballard, Jr., and Dr. Margaret Rose Kress of the Environmental Characterization Branch (ECB), Natural Resources Division (NRD), Environmental Laboratory (EL), WES. Mr. Scott Bourne, ECB, contributed to data analysis and software debugging.

The study was conducted under the general supervision of Drs. John Harrison and John W. Keeley, Director and Assistant Director, EL, respectively, and Dr. Robert M. Engler, Chief, NRD, and under the direct supervision of Mr. Harold W. West, Chief, ECB.

At the time of publication of this report, Commander of WES was COL Robin R. Cababa, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>acres</td>
<td>4,046.873</td>
<td>square meters</td>
</tr>
<tr>
<td>feet</td>
<td>0.3048</td>
<td>meters</td>
</tr>
<tr>
<td>inches</td>
<td>2.54</td>
<td>centimeters</td>
</tr>
<tr>
<td>miles (U.S. statute)</td>
<td>1.609347</td>
<td>kilometers</td>
</tr>
</tbody>
</table>
1 Introduction

Existing methods for estimating economic damage from floods in the Lower Mississippi River Valley (LMV) provide limited decision-support products for managers. The current methods rely on the utilization of hydraulic and existing data that in many cases must be modified and updated to correspond to the flood conditions. Current damage-estimation methods are limited and have no graphic or map-based products.

This guide describes a new approach to determining flood damages that overcomes many of the limitations of the existing methods. The Flood Impact Support Tool (FIST) is a prototype that uses a geospatial-based (GIS-assisted) flood damage estimation methodology.

The primary objective for the development of FIST was to improve decision-support products related to flood impacts. Other objectives were (a) to increase the flexibility and life cycle of economic data; (b) to provide full data update and analysis capabilities; and (c) to demonstrate the integration of dynamic, spatially referenced databases with flood damage modeling.

The LMV floodplain is divided into Water Resource Units (WRU) for flood control and flood damage assessment purposes. Figure 1 illustrates the complex pattern of the WRUs. FIST is designed to determine flood damages for individual WRUs under specified flood conditions. Flood conditions are defined by river stages (measured or predicted). Four of the WRUs in Figure 1 were used during development of the prototype FIST. Spatial and economic databases were developed for two WRUs in the Vicksburg District (VXD031 and VXD046) and two WRUs in the New Orleans District (NOD038 and NOD053).

The FIST was developed by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, for the Lower Mississippi Valley Division Support Element for Flood Impact Assessment. This Support Element, housed at the Vicksburg District, provides decision support for flood impacts in the St. Louis, Memphis, Vicksburg, and New Orleans Districts.
Figure 1. Four WRUs used during development of prototype FIST
This guide contains an overview of FIST, information about software and hardware requirements; installation, operation, and user input requirements; and examples of output products.
2 Components of FIST

FIST utilizes a combination of spatial analysis techniques and high-resolution geospatial data to estimate economic damage under specified flood conditions. There are four main components to FIST:

a. Fully functional commercial off-the-shelf (COTS) geographic information system (GIS).

b. High-resolution geospatial databases.

c. Flood damage model.

d. Custom-designed user interface.

Each of these are briefly described below.

GIS

The GIS serves as the database manager, provides access to a complete range of spatial analysis capabilities, and establishes the graphic display environment. ARC/INFO from Environmental Systems Research Institute (ESRI) is the GIS used for FIST. The operational concepts and flood damage modeling approach used for FIST could be implemented in other COTS GIS products as well.

Databases

The high-resolution databases describe the physical terrain, man-made structures, and land-cover conditions in each WRU included in the study. The database for each WRU has two primary parts. The first is the three-dimensional digital topographic elevation model of the WRU. The second is the spatially referenced structure database containing the location, elevation, and value of residential and commercial structures in the WRU. Complete documentation of FIST database requirements and development is given in Chapter 5.
Flood Damage Model

FIST includes a flood damage model designed to run in conjunction with and utilize the capabilities of ARC/INFO. It includes programs written in the C programming language and routines written in the ARC/INFO Advanced Macro Language (AML). FIST automates the flood damage calculation process, executes the flood extent calculation, determines and stores the economic damage estimates, and generates output products.

User Interface

The FIST user interface is written using the ARC/INFO menu language. The interface guides the user through WRU selection and establishing input parameters. It also displays results and assists the user in obtaining hard copy output.
3 FIST Algorithms

Unique algorithms for generating a flood surface and calculating damage were developed specifically for use with the FIST. A detailed description of these algorithms is provided for the generation of the flood surface and calculation of structure, crop, and road damage.

Derivation of Flood Surface

The flood surface is derived using three data sources. These data sources are the river stages, river miles (or interpolated points for water flow), and the digital topographic elevation model of the ground surface within the WRU represented as a regularly spaced data grid.

Using the locations of two gauges and their respective water levels, the relative change in water elevation is first calculated. Then the distance is determined by calculating the total length between the gauges through the river miles or water flow interpolation points. From the relative change in water elevation and distance, the water slope is determined with the assumption that the water slope remains uniform between the gauges. From the water slope, water elevation is calculated at each river mile by using the point-slope form equation.

A preliminary water surface for the WRU is generated for a widely spaced grid file where the water level for each x-y grid point is determined by its closest distance to the water flow interpolation points. This preliminary water level surface is compared with the digital elevation model. If the elevation of the water surface
is greater than or equal to the terrain surface, then that particular point is determined to be flooded. Otherwise, that point is assumed to be not flooded. This method effectively marks all the positions on the land that are below the water level, but does not consider the effects of man-made or natural levees that protect low lands.

To account for the effects of levees on the flood surface, the flow path of the water across the digital elevation model to the main channel is modeled. This is accomplished in the ARC/INFO Grid software by using the function path-distance(). The function pathdistance() calculates the path-cost distance over a surface to a set of source points. The set of source points used were the main channel points. The results of pathdistance() is a surface where true flooded areas are labeled as zero, and areas protected by levees are labeled with values greater than 1,000. The resulting grid file from pathdistance() is compared with the flooded surface, and only the true flooded areas are extracted into the final flooded surface grid.

**Calculation of Economic Damage to Structures**

Damage estimates to structures are derived using four data sources. These data sources are point data and attributes for the structures, the flood surface elevation, depth-damage curve table for structure content damage, and the depth-damage curve table for the structure damage. The depth-damage tables describe the percent damage of the contents in the structure as well as the damage to the physical structure related to the depth of the water in the structure for several types of structures.

For every structure in the WRU area, the level of the floodwater relative to the first floor of the structure is computed using the floodwater surface elevation at the location of the structure and the first floor elevation. If this relative difference is less than the minimum water level as depicted by the damage tables, the structure is considered to have no damage. Otherwise, the depth of the water in the structure and the type of the structure are used as indices in the damage tables, and the percent damage is determined from the structural damage and contents damage data.

**Calculation of Damage to Crops**

Damage estimates to crops are derived using the water surface elevation, land-cover grid file, and the crop distribution and damage table. The flood surface elevation is compared against the land cover file, and the flooded cleared land (agricultural) acres are determined and tabulated. For each individual crop type listed in the crop distribution and damage table, the percent flooded of that type is calculated as the percent cover of the crop in cleared land multiplied by the amount of cleared land acres. The area (i.e., acres of crop type flooded) is
multiplied by the per acre damage for that crop type to arrive at the total crop
damage value. The total crop damage is calculated similarly for all crop types.
The noncrop damage is calculated by applying a per acre damage factor to the
flooded cleared land.

Calculation of Damage to Roads

Damage estimates to roads are derived using the digitized road data, flood
surface elevation, and per mile road damage table. The digitized road data are
compared with the water surface elevation data to determine which sections of the
roads are inundated by the floodwater. The length of the section, labeled either
paved or unpaved, is tabulated into total length in miles of paved and unpaved
roads. The total length of the flooded sections is multiplied by the road damage
and is reported as the estimated road damage.
FIST requires specialized computer hardware and software for proper system operation. The generation of flood surfaces used for estimating structure and crop damages is computationally intensive and requires a workstation type of system for optimum performance. To achieve this level of performance, the minimum hardware requirements are a UNIX workstation with an 8-bit, 20-in.\textsuperscript{1} color graphics monitor, CD-ROM drive, and 1 gigabyte of hard disk space. A Sun Microsystems Sparcstation 20 with 64 megabytes of RAM will satisfy these requirements.

The GIS used in FIST is ESRI ARC/INFO. It allows the complex interactions between the gridded flood surface and point data. ESRI ARC/INFO AML code was utilized for the algorithms in FIST. Because of this, the minimum software requirements are ESRI ARC/INFO 7.0.4, ESRI ArcGrid 7.0.4, and ESRI ArcTin 7.0.4.

The FIST system output requires a high-resolution color graphics printer to adequately depict the calculated flood surface. The suggested requirements for this is a color electrostatic or color laser graphics printer capable of printing on 8.5- by 11.0-in. size paper with a minimum of 200 dots per inch.

\footnote{\textsuperscript{1} A table of factors for converting non-SI units of measurement to SI units is presented on page vi.}
The databases delivered with FIST include all the geospatial and nonspatial data required to run FIST. A brief description of each type of data used by FIST is given here.

FIST is designed to use data contained in the GIS database, several look-up tables, and user-supplied parameters. All FIST GIS databases are provided with complete Federal Geographic Data Committee compliant metadata. These metadata are integrated with the ARC/INFO files and are provided as separate text files on the CD-ROMs. The metadata for the residential structure data file in WRU VX031 are reproduced in Appendix A. The metadata contain complete descriptions of the content and characteristics of each data file.

**Elevation**

The "elevation" file is a gridded file containing the digital elevation model (DEM). The DEM for each WRU was developed using contours, benchmarks, and surface drainage features digitized from 1:24,000 U.S. Geological Survey (USGS) topographic maps and supplemental field-surveyed elevations. The ARC/INFO routine TOPOGRID was used to interpolate a continuous elevation surface from the contours and point elevations. TOPOGRID uses the information on surface hydrographic features during interpolation to ensure that drainage features are properly represented in the DEM.

The DEM was developed at a spatial resolution of 20 by 20 m. The interpolated elevations were stored as meters above mean sea level. This file is used directly by FIST during the flood surface and economic damage calculations.

**Landcover**

The "landcover" file is a grid file containing information on cleared, wooded, and urban areas in the WRU. Information on land cover was developed for each WRU by digitizing wooded (forested) and nonwooded areas from 1:24,000 USGS...
topographic maps. All green-tinted areas on the USGS maps were manually digitized and coded as wooded. FIST recognizes four land-cover classes. These are cleared, wooded, urban, and other. This file is used directly by FIST in calculation of crop damage.

**Residential**

The "residential" file contains data on structure location (geographic coordinates) ground and first floor (sill) elevations, description (type), and value of residential structures in each WRU. Structures were surveyed and characterized using several field methods. The value of each structure was estimated using Marshall and Swift Residential Evaluation software. Inputs required by Marshall and Swift (M&S) were recorded during the field survey and are included in the database.

**Commercial**

The "commercial" file contains data on structure location (geographic coordinates) ground and first floor (sill) elevation, description (type), and value of commercial structures in each WRU. Structures were surveyed and characterized using several field methods. The value of each structure was estimated using Marshall and Swift Commercial Evaluation software. Inputs required by M&S were recorded during the field survey and are included in the database.

**Border**

The "border" file contains the geographic boundary of the WRU. The WRU boundaries were defined by the Vicksburg District and digitized from 1:24,000 USGS topographic maps. This file is used for graphic display by FIST.

**Boundary**

The "boundary" file is a grid file indicating the geographic extent of the WRU by the integer value one (1). Locations outside the WRU have a value of zero (0). This file is used directly by FIST when interpolating the flood surface.

---

Rivermiles

The “rivermiles” file is a point coverage containing the location of a series of interpolation points between the upstream and downstream gauges. The points were defined mathematically and are used by FIST during calculation of the flood surface.

Rivermiles.dat

The “rivermiles.dat” file is an ASCII text file containing the x,y coordinates of the interpolation points in “rivermiles.” This file is used by FIST during calculation of the flood surface.

Other Files

The ARC/INFO databases delivered with FIST include additional data that were required during database development of software testing. They are not used directly by FIST, but may be useful for additional analysis or other applications. A brief description of these files is given below.

Contours. The “contours” file is a vector line coverage containing elevation contours manually digitized from 1:24,000 USGS topographic maps. These data were used in development of the DEM. They are not used directly by FIST.

Benchmarks. The “benchmarks” file is a vector point coverage containing benchmarks manually digitized from 1:24,000 USGS topographic maps. These data were used in development of the DEM. They are not used directly by FIST.

Streams. The “streams” file is a vector polygon/line coverage containing surface hydrographic features digitized from USGS 1:24,000 topographic maps. These data were used in development of the DEM. They are not used directly by FIST.

Gauges. The “gauges” file is a point coverage containing the geographic coordinates, elevation, name, and ID number of the stream gauges used by FIST for the WRU. This file is not used directly by FIST.

Levees. The “levees” file is a line coverage containing the locations of man-made levees in the WRU. This file was used during development of the DEM. It is not used directly by FIST.

Roads. The “roads” file is a line coverage containing paved and unpaved roads in the WRU. Roads were manually digitized from USGS 1:24,000
topographic maps and updated with field observations. This file is not used directly by FIST.

Shoreline. WRU NOD053 has a “shoreline” file. The file is a line coverage containing the banklines of the Atchafalaya River. This file is unique to this WRU and is not used directly by FIST.
Installation of Software and Data

Installation of FIST using the CD-ROM is described below. A typewriter font is used for commands as follows:

```
is /cdrom/cdrom0
```

**FIST Software Installation**

The first step is to decide where the FIST software will reside on the computer system hard disk drive. There are no special requirements for the location of the software, except that the software will need at least 2.3 MB of disk space on the computer system. To determine how much free space is available on the computer disk system type the following:

```
df -k
```

Next, set up a directory for the FIST software on the desired disk by using the `mkdir` command. For example, to set up a directory named `/data2/fist`, type the following:

```
mkdir /data2/fist
```

Next, copy the FIST software from the CD-ROM using the `cp -r` command as follows:

```
cp -r /cdrom/cdrom0/fist/* /data2/fist
```

FIST uses a computer system environment variable named `$FISTDIR` to determine the location of the FIST software. This variable may be set to the location of the code on the computer disk by typing

```
setenv FISTDIR (FIST directory)
```
or as in the example

```
setenv FISTDIR /data2/fist
```

The FIST system has the following directory structure that contains the program used during execution.

<table>
<thead>
<tr>
<th>Directory Name</th>
<th>Description and Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>/amls</td>
<td>ARC/INFO AMLs used for damage calculations</td>
</tr>
<tr>
<td>/bin</td>
<td>Executable programs</td>
</tr>
<tr>
<td>/menus</td>
<td>ARC/INFO menus</td>
</tr>
<tr>
<td>/misc</td>
<td>ARC/INFO fonts and shadesets for FIST</td>
</tr>
<tr>
<td>/src</td>
<td>C language source code for flood surface generation</td>
</tr>
<tr>
<td>/tables</td>
<td>Default depth damage tables</td>
</tr>
<tr>
<td>/templates</td>
<td>Map templates used for FIST output</td>
</tr>
</tbody>
</table>

After the environment variable has been set, the file will need to be edited by typing the command:

```
cd $FISTDIR/bin
```

and editing the file named 'fist'. A text editor such as vi or nedit can be used to edit this file. In this file, the assignment statement needs to be changed in lines 11 and 12. On line 11, the assignment statement for the FISTDIR environment variable should be modified to reflect the location of the FIST software. On line 12, the assignment statement for the DBASEDIR environment variable should be modified to reflect the location of the ARC/INFO data coverages of the WRUs. These two lines should look somewhat like the following:

```
setenv FISTDIR /cdrom/cdrom0/fist
setenv DBASEDIR /dta3/fdes
```

Appropriate changes can be made using the editor. This file called 'fist' will be the executable code that initiates the FIST software.

To complete the installation, the UNIX path variable should be modified to check in the FIST executable directory by typing the following:

```
set path = ( $path $FISTDIR/bin )
```

or as in the example:

```
set path = ( $path /data2/fist/bin )
```
The .cshrc file in the user's home directory should be modified to include the above command.

**Data Installation**

FIST is designed to generate damage calculations using the WRU data residing on the computer disk or from the data provided on the CD-ROM media. The WRU data must be placed on the users hard disk. This can be accomplished by changing the following line in the program as follows $FISTDIR/bin/fist:

```
setenv DBASEDIR /location_of_wru_directories
```

where `location_of_wru_directories` is a directory name, or if the WRU data are on the CDROM media:

```
setenv DBASEDIR /cdrom/cdrom0
```

This variable indicates where the ARC/INFO work spaces for the WRU data are located. If it is necessary to copy the WRU data from the CD-ROM, use the following:

```
mkdir /location_of_wru_directories/wru_name
cd /location_of_wru_directories/wru_name
cp -r /cdrom/cdrom0/wru_name
```

where `wru_name` is the name of the WRU.