AUTOMATION OF FLOOD HAZARD MAPPING BY THE FEDERAL EMERGENCY MANAGEMENT AGENCY

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ABSTRACT

Flood hazard maps are currently produced by the Federal Emergency Management Agency (FEMA) with conventional cartographic methods. These maps, which depict areas that would be inundated by a flood having a one-percent probability of being equaled or exceeded in any given year (100-year flood), are produced to support the National Flood Insurance Program. FEMA is now evaluating techniques that can be used to automate the flood hazard mapping process, with the potential for developing an entirely computer-based system for the collection, analysis, and dissemination of flood hazard data. This paper presents the results of FEMA's initial efforts to automate topographic data collection and flood hazard map preparation.

INTRODUCTION

The Federal Emergency Management Agency (FEMA), an independent agency within the Executive Branch of the Federal Government, is tasked with administration of the National Flood Insurance Program (NFIP). Flood hazard mapping produced by FEMA provides the basis for NFIP community floodplain management, as well as flood insurance rate structuring. Since the inception of the NFIP in 1968, flood hazard areas have been mapped in 18,600 communities nationwide (Mrazik, 1986). Flood hazard maps depict areas that would be inundated by a flood having a one-percent probability of being equaled or exceeded in any given year (100-year floodplain), the 500-year floodplain, floodways, coastal high hazard areas, 100-year flood elevations, and insurance risk zones. Standard hydrologic, hydraulic, and modeling techniques are used to assess flood risks, and the resulting mapping is prepared through conventional methods. Paper map products are distributed by FEMA to NFIP communities, insurance agents, state agencies, and upon request, to any other interested party. During Fiscal Year 1986, the number of flood hazard map panels distributed by FEMA exceeded ten million.

The integration of developing technology in the fields of remote sensing and automated cartography into the NFIP can provide both economic and administrative benefits to FEMA and flood-prone communities. The collection of data required for risk assessment, particularly topographic data, is costly and time consuming. Paper maps, although functional, cannot provide the flexibility and analytical power of digital data incorporated into a Geographic Information System (GIS). Recognizing this, FEMA has developed a concept for automated flood study production (Mrazik, 1984). The purpose of this paper is to describe the Agency's initial progress toward fully automated flood hazard mapping (see Figure 1).

CONCEPT

Flood hazard studies are performed for FEMA by Study Contractors (SCs). The SCs may be private or public organizations with expertise in hydrologic and hydraulic analyses. The data required to support a flood hazard study include land cover, topography, hydrography, stream gage records, and cultural data. The results of SC analyses are displayed on maps at scales of 1:4,800 to 1:24,000. In a fully automated system, all data would be collected in digital format, integrated with existing digital base mapping, and analyzed through a GIS to produce flood hazard maps.

Initially, FEMA has identified two areas for experimentation as steps towards automating flood study production. These areas are the collection of topographic data (which represents, on the average, 35 percent of study production costs) and the feasibility of producing flood hazard maps with automated cartographic technology.

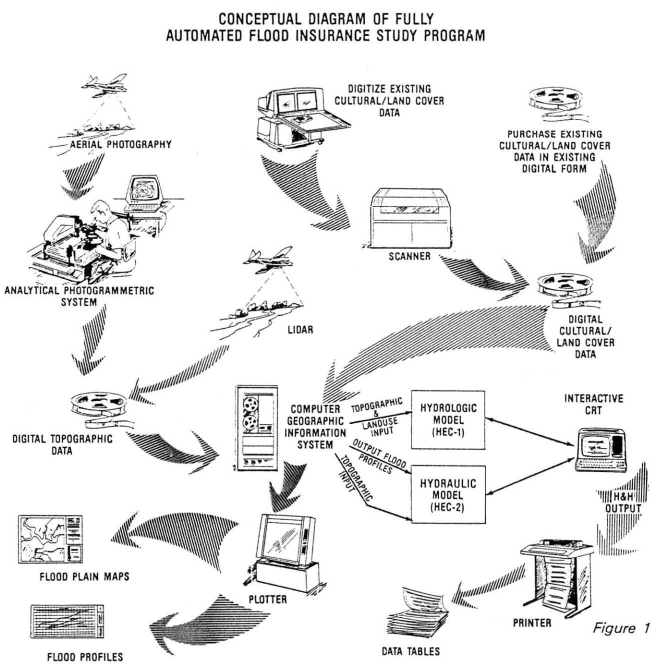

Figure 1

AUTOMATED TOPOGRAPHIC DATA COLLECTION

Conventional photogrammetric methods are employed by FEMA in collecting much of the topographic data used for flood studies. In the past, photogrammetry has clearly been the most efficient means of acquiring these data. However, developing laser mapping holds promise for extremely rapid data collection regardless of leaf bloom, sun angle, or overcast conditions.

FEMA is currently participating with the Corps of Engineers in an operational field test of airborne LIDAR (Light Detection and Ranging Technology) (see Figure 2). The data collection portion of this test was conducted as part of FEMA's Hays County, Texas, flood hazard study. The test included comparison of LIDAR data with ground survey and photogrammetric data.

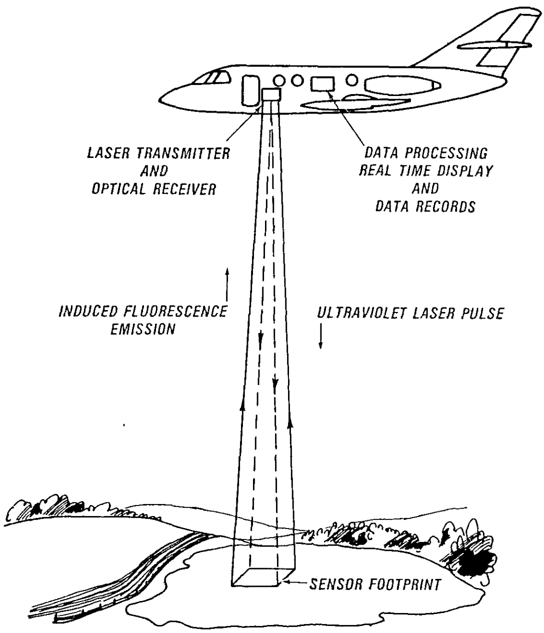

Figure 2

A full evaluation of the LIDAR system's accuracy, including the creation of a digital elevation model (DEM) has yet to be completed (Stole, 1986). Initial results indicated that a vertical accuracy of ±1.5 feet can be achieved with LIDAR. This accuracy is well within FEMA's requirement for four foot contour interval topographic mapping for flood hazard area identification.

AUTOMATION OF FLOOD HAZARD MAP PRODUCTION

At present, final flood hazard maps are prepared for publication by FEMA Technical Evaluation Contractors (TECs). These final products are based on work maps submitted by the SCs. After review of SC hydrologic and hydraulic analyses, the TEC transfers the flood hazard information to an appropriate base map. Conventional scribing, screening, masking, and photographic processes are used to prepare a final negative for printing.

The present format of flood hazard maps requires that two separate maps be prepared for studied areas. One map, the Flood Insurance Rate Map, or FIRM, portrays 100-year flood elevations, also referred to as Base Flood Elevations (BFEs), and insurance risk zones, while the second map, the Flood Boundary and Floodway Map, or FBFM, portrays the floodway (the portion of a floodplain set aside to convey the 100-year flood discharge without raising BFEs by more than 1.0 foot). As a result of a recent review (FEMA, 1985) of the FIRMs and FBFMs, FEMA has combined these two maps into a single map, which will display all flood hazard information in a simplified format. This review also called for the addition of horizontal control to flood hazard maps.

The addition of horizontal control is a significant step toward the creation of digital flood hazard mapping. Maps now published by FEMA lack horizontal control and are therefore difficult to digitize in correct spatial relation to the earth's surface. However, before flood hazard maps can be published with horizontal control, FEMA must establish a workable method to control these maps to a reasonable accuracy without a great cost to the mapping program.

During 1986, FEMA experimented with several methods of establishing horizontal control. The most effective method was found to be the transfer of horizontal control, in the form of geocoordinates, from U.S. Geological Survey (USGS) 7.5 minute topographic quadrangle maps to flood hazard map panels. An initial test program, using AUTOGIS*, showed that, in most cases, horizontal control can be transferred from the USGS quadrangle maps to flood hazard maps with an accuracy of about 0.1 arc second (FEMA, 1986).

Based on those results, FEMA is now engaged in a pilot project to determine whether this method of adding horizontal control to flood hazard maps is practical and cost effective for use in a production environment. Also of concern will be verification of the quality of the horizontal control. The pilot project will include independent checks of control points and internal map points to ensure that the maps are published with correct spatial relations relative to the earth's graticule.

Aside from determining a procedure for providing horizontal control, a digital data standard for flood hazard maps is required to facilitate automated mapping endeavors. A digital data standard for flood hazard maps must be acceptable to a wide variety of users, be well documented, and specify annotation codes as well as fonts. Further, the standard must be flexible so that unique flood hazard data can be incorporated with the attribute code specifications (see Figure 3).

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* AUTOGIS is a flexible body of software packages, including AMS (Analytical Mapping System) and MOSS (Map Overlay Statistical System), for the analysis of spatial data developed by the Fish and Wildlife Service of the Department of Interior.

After reviewing existing standards, FEMA elected to adopt the USGS (DLG) format (USGS, 1985). The wide use of DLG and the design of USGS DLG feature codes to allow inclusion of non-standard map features, such as flood hazard data, were primary reasons for this selection. Figure 3 shows unique flood map symbols, and the USGS DLG codes for these symbols devised by FEMA. Other attributes, such as the base map transportation network and hydrography, are digitized and annotated according to appropriate USGS DLG standards.

The selection of USGS DLG, as amended to include the flood hazard map features shown in Figure 3, as a digital data standard is an important result of FEMA's initial efforts toward an automated mapping program. The Agency encourages users of FIRMs and FBFMs to apply these standards whenever flood hazard data are to be digitized for inclusion within a GIS.

TULSA, OKLAHOMA PILOT PROJECT

FEMA performed a pilot project during 1986 to test the process of digitizing flood maps, and to estimate costs associated with digital flood hazard map production, and to identify and resolve problems with the automation of flood hazard map production by contractors. For the pilot project, the existing flood hazard maps for Tulsa, Oklahoma, were selected (see Figure 4). These maps, originally published in 1971, presented a number of problems that would not normally be encountered in the digitizing process. Problems with these flood hazard maps included FIRMs and FBFMs at different scales, with different base map sources, and with different panelization schemes; lack of flood profiles or original flood insurance study text; poor readability of the FBFM (see Figure 4); and a lack of horizontal control.

SELECTED FEATURES, SYMBOLOGY, AND DLG CODING
UNIQUE TO DIGITAL FLOOD HAZARD MAPS

FEATURE	SYMBOL	DLG CODE MAJOR CODE	MINOR CODE
Base Flood Elevations (with lines to be annotated with BFE)		400	0001
Cross Section (Cross sections to be annotated by letter)		400	0002
Floodway		400	0003
Approximate A Zone (100-year flood) boundary		400	0004
100-year Flood Boundaries		400	0007
500-year Flood Boundaries		400	0008
Zone D		400	0005
Gutters (zone boundary lines)	white lines	400	0006

Figure 3

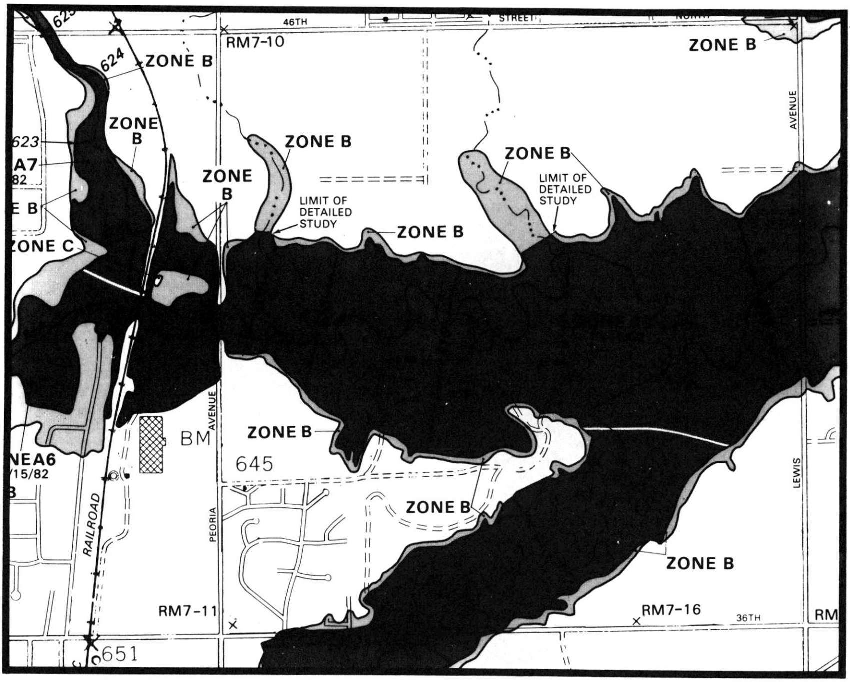


Figure 4

EXAMPLE OF PUBLISHED FIRM FOR THE CITY OF TULSA

In assessing the problems with the data set, several key tasks were identified for completion at the predigital stage. The primary problem, requiring considerable manual effort, was preparation of mylar overlays of data contained on the FBFM. These mylar overlays were keyed to the FIRM panels for digitizing. This step, which would not normally be necessary in digitizing flood hazard maps, was required because of the poor readability of the FBFM (see Figure 5).

Digitizing was performed using a manual system (Intergraph). Data were initially recorded as a continuous string, with data being captured by thematic topics. Quality control of the digitized data was achieved by comparison of an intermediate map output, or "check plot" of digitized data with the original map. Correction averaged 10 to 30 percent of the entire digital data set per map. The error level varied depending on the operators' experience and the complexity of the original geometry digitized. Quality control and edit were found to require between two and four times the amount of time required to simply digitize data.

The digitized data were converted to USGS-Digital Line Graphics Level 3 (DLG-3) through the creation of nodes and attribute coding of the digital data set. Software available on Intergraph allowed much, but not all, of this task to be automated. Intergraph DLGIN/DLGOUT software was used to create and convert files from Intergraph format to DLG and vice versa. Some difficulties were encountered in this procedure resulting from limits formerly inherent in Intergraph software relating to the number of points, nodes, and areas that can be identified in a given data set, and the expansion of the DLG-3 codes to include flood data.

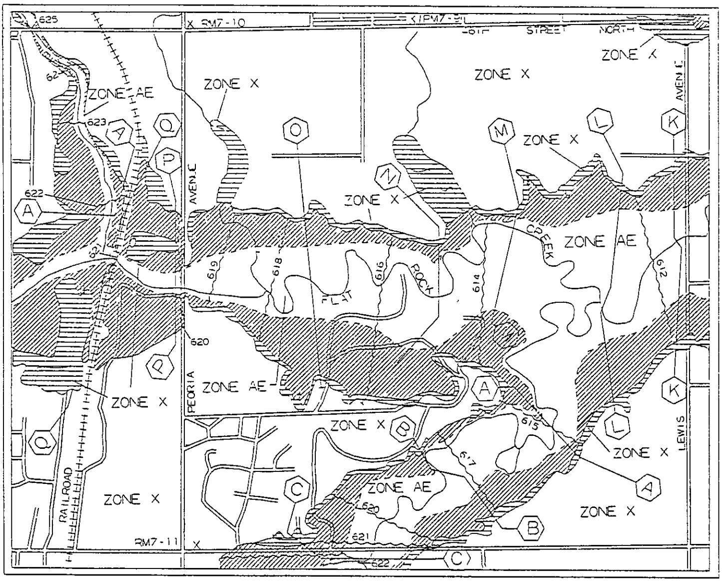
Figure 5

EXAMPLE OF PUBLISHED FBFM FOR THE CITY OF TULSA

The resulting digital data set for Tulsa is a data file in a topological format, designed to be integrated with GISs. The data were captured in relation to geocoordinates. The DLG-3 output tape is in USGS Standard Distribution Format, a direct charter representation (ASCII) of the binary file translated from the Intergraph system.

Graphics output using the digital data set and various plotting devices was generally found to be comparable with conventional flood hazard map graphics (see Figure 6). However, three areas require further research:

1) text placement;
2) removal of road casings at intersections ("cleanout"); and
3) duplication of the screen used for the 100- and 500-year floodplains.



EXAMPLE OF COMPUTER-GENERATED
FIRM FOR THE CITY OF TULSA

Figure 6

TIME AND COST ANALYSIS

In evaluating the time required to apply automated cartographic techniques to produce flood maps, compared with that to produce flood maps through conventional procedures, it was estimated that the time required to produce flood hazard maps in an automated mode could increase production time requirements by a factor of four; and the cost to produce flood hazard maps would increase by a factor of two if automated cartographic technologies were applied.

Some of this unfavorable comparison of computer vs. conventional mapping is the result of selecting a worst-case map set for the pilot project. Considerable pre-digital manual effort was expended that would not normally be required. However, even given that this resulted in a high time-and-cost figure for automated map production, it is not likely that a simple case would provide a much more favorable comparison. In part, this is because the Agency relies heavily on USGS 7.5 minute quadrangle map separates for base map material. Manual flood hazard map production requires only that these existing base map data be photographically modified to the correct scale and the flood hazard data be overlain. The automated process requires the time consuming and costly creation of a digital data set containing the base map information.

A more viable option would be that only the data related to flood hazards be digitized by FEMA in the USGS DLG format, and that no base map information be recorded. The cost of pursuing this option is an increase in FEMA flood hazard map production costs of about 40 percent above those currently experienced. This relates to a cost of about 800 dollars to produce digital flood data for a single FEMA flood hazard map panel. Acceptance and use of such a data set would be dependent, to a large extent, upon the existence of digital base map data and the willingness of users to create their own digital base map information.

CONCLUSIONS

As a result of this project, two conclusions are clear:

1) It is technically possible to produce high quality flood hazard maps from digital data; and
2) The increase in flood hazard map production costs that would result from a conversion to automated flood hazard map production is unacceptable to FEMA unless benefits to the tax payer can be identified outside map production that will justify the increased cost.

A third conclusion must also be drawn from this project: Given the versatility of GIS technology, FEMA should perform a benefit analysis to determine if sufficient value can be assigned to the use of digital flood hazard data by other Federal agencies, as well as state, local, and private organizations to justify the creation of a digital flood hazard data base by the Agency.

FUTURE DIRECTION

In the future, FEMA expects to continue the assessment of LIDAR technology, and to incorporate this technology into some flood insurance study data collection efforts. Developing technology in the field of remote sensing, particularly as it applies to topographic data collection, will be monitored by FEMA for its applicability to NFIP requirements.

FEMA has also developed a GIS that can provide on-line capabilities for the analysis of spatial data. This system, the Integrated Emergency Management Information System (IEMIS), is intended to provide low cost access to digital data, planning models, information management, and networking capabilities. IEMIS data are structured in a digital line graph format, and the system has the ability to read in data structured according to USGS DLG specifications. Further information on IEMIS can be obtained by writing to: Federal Emergency Management Agency, State and Local Programs Directorate, Technological Hazards Division, Washington, DC 20472.

IEMIS will be a cornerstone of the assessment of benefits that would result from the creation of a digital flood hazard data base. The Agency will base the benefit analysis on the following assumptions:

1) Only flood hazard data produced by FEMA will be digitized by the Agency;
2) USGS 1:100,000 scale maps, now being digitized by the Bureau of Census, can serve as adequate base maps for digital flood hazard data;
3) Both the digital flood hazard data and the digital USGS 1:100,000 scale data can be made available to users through FEMA's IEMIS, which will also provide on-line GIS capabilities to users; and
4) Digital flood data will only be generated for communities with significant populations and properties at risk from flood hazards and a significant demand for data in digital form.

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