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EFFECTIVENESS OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) APPLICATIONS IN FLOOD MANAGEMENT DURING AND AFTER HURRICANE FRAN

Ute J. Dymon
Department of Geography
Kent State University
Kent, Ohio 44242-0001

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ABSTRACT

Geographic Information Systems (GIS) are powerful tools for eliminating guesswork when it comes to decision making processes during and after a disaster. This research addresses the GIS support for mapping and graphic aids for decision makers after Hurricane Fran in North Carolina. Before the storm, GIS models were applied to calculate the size of the potential storm surge for several categories of hurricanes, particularly the storm surge heights expected according to the speed of the storm. Emergency managers used these models to make decisions about potential flooding and identified which portions of the population needed to evacuate given areas. Other GIS applications verified the legitimacy of insurance claims submitted by those enrolled in the National Flood Insurance Program (NFIP). Differing degrees of GIS implementation existed in the local, state and federal operations. Data sharing commonly occurred between all levels of government. Heretofore, the implementation of GIS support during major disasters has proceeded slowly. During and after Fran, at both the federal and

state levels, especially, an organized effort made immediate implementation of GIS possible. Hurricane Fran established the major advantages GIS has to offer in a disaster management operation.

INTRODUCTION

On September 5, 1996, Hurricane Fran swept across North Carolina leaving behind a swath of destruction throughout most of the state. The Hurricane made landfall near Cape Fear, and the eye of the hurricane moved directly over the coastal city of Wilmington and continued on to Raleigh, the capital of North Carolina. Fran strengthened to a category 3 (major) hurricane by the Saffir-Simpson hurricane scale. Hurricane Fran was the sixth named storm of the 1996 hurricane season. For eleven hours the storm thrashed the state with winds clocked at 115 mph on the coast and up to 79 mph at Raleigh, located in the center of the state. As dawn broke, it became evident that Hurricane Fran was one of the worst storms to hit North Carolina in decades. The storm surge caused severe coastal flooding and continuous rainfall added to the problem. More than 10 inches of rain fell in less than 12 hours. The storm was slow moving, and the intense rainfall quickly flooded the coastal areas. Lowlands were saturated, and rivers swelled which eventually severely flooded inland areas as well.

Hurricane Fran claimed twenty-two lives in North Carolina. More than 1 million people were without power and other utilities. President Clinton declared 51 out of 100 counties as federal disaster areas. Tens of thousands of buildings were damaged, and the economy of the state was left in disarray. Property losses, agricultural, business and tourist industry losses will add Hurricane Fran to the list of recent mega-disasters in the United States. The Property Claims Service Division of the American Insurance Services Group reports that Fran caused an estimated $1.6 billion in insured property damage to the United States, which includes $1.275 billion in the state of North Carolina alone, (NCDC, Internet, June 12, 1997). Estimates are still being revised

upward, but Fran will likely top 4 billion dollars when all costs are identified.

The rising concerns over the losses from natural disasters and especially losses from hurricanes, the increasing volume of funds required for relief of victims, and the limited success of communities in managing their flood-prone areas require a shift in future efforts which now focus more on understanding the social and economic ramifications and encourages more adaptive human responses (White and Haas, 1975; Foster, 1986). Adaptive responses require knowledge of the existing physical and social spatial conditions of the geographical area impacted. Geographical Information Systems (GIS) are the ideal tools to apply in disaster situations to capture and present existing conditions. However, research after Hurricane Andrew demonstrated that application of GIS was still not accepted by many emergency managers (Dymon, 1993). Nearly four years have passed since Hurricane Andrew, and GIS technology has advanced to be a household name in many government agencies. This research focused on: 1) the use of GIS after Hurricane Fran, 2) applications of GIS in the pre- and post-disaster management of the storm, 3) how data was shared among different agencies, and 4) the role FEMAOs NFIP maps played in the response and recovery stages.

ARRIVAL IN NORTH CAROLINA

My graduate assistant, Deborah Scheeler, and I drove to North Carolina on September 23, 1996. We experienced a major traffic jam on Rt. 70 delaying us for nearly four hours. Later, we learned that we had been driving along the route to the designated debris dump site for this disaster. Trucks carrying debris from the Hurricane had the right of away all along the route causing our delay. Like most field researchers after a disaster, we had to drive a considerable distance to find a hotel room (within our budget) for the night. Federal agents and relief workers had pre-booked available hotels in the region.

INFORMATION GAINED FROM STATE AND FEDERAL WORKERS

North Carolina Center for Geographic Information and Analysis (CGIA)

Through executive order by the Governor of North Carolina, the North Carolina Geographic Information Coordination Council (GICC) was established in 1994. The task was to coordinate a statewide data initiative. As a result, the State of North Carolina Center for Geographic Information and Analysis (CGIA) was staffed to support the Council in its efforts to compile and maintain a corporate geographical database. Numerous public and private organizations participated in this effort. Federal content standards or digital geospatial metadata were applied to assure quality when data was provided from different sources. The CGIA serves as a clearinghouse for this data. Currently, the CGIA maintains about 60 data layers, including: USGS basemap files, municipal and county boundaries, census boundaries, population files, water quality, air quality, coastal area management act information, land use and land cover, soils, topography, hydrology/hydrography, hazardous waste facilities, Hurricane Storm Surge Inundation Areas, National Wetland Inventory, transportation, water supply and historical sites (North Carolina Geographic Data Catalog, 1996).

Application of GIS Before, During and After Fran

Before Hurricane FranOs arrival in North Carolina on September 5th and 6th in 1996, the North Carolina Center for Geographic Information and Analysis prepared Hurricane Storm Surge Inundation Area maps. These maps showed the historic extent of hurricane storm surge inundation for four southeastern coastal counties in North Carolina. The application of a computer program called the Sea, Lake and Overland Surges from Hurricane (SLOSH) Model was used to produce maps to show the potential flooding for both fast and slow velocity hurricanes.

The maps showed land susceptible to flood inundation according to the severity of different hurricane categories. The inundation information was overlaid on a 1:24,000 United States Geological Survey, 7.5 minute Series Quadrangle. This provided basic information about the areas such as roads and topography and basic land use. These maps proved to be very useful and were the basis for the preparation of evacuation maps. With the use of the SLOSH model, Hurricane Evacuation Restudy maps were prepared. These maps showed storm surge heights in feet above National Geodetic Vertical Datum. They were prepared for slow and fast moving hurricanes of categories 2, 3 and 5 since the same evacuation maps are used for category 4 and 5 hurricanes. These Hurricane Evacuation Restudy maps were applied to analyze the risk for flooding. Emergency managers employed the maps to guide the evacuation of residents in the stateOs coastal and lowland areas. The Federal Emergency Management Agency (FEMA) quickly identified the valuable data layers available at North Carolina's CGIA. Before Hurricane Fran even arrived, FEMA requested data on hurricane storm surge inundation areas, state-owned complexes, historical sites and districts, and natural heritage element occurrence sites and sought county road maps with municipal boundaries. FEMA worked closely with the CGIA in preparation for this storm. All computer files gathered for GIS applications were carefully backed up before the storm arrived. The Division of Forest Resources requested maps of forest damage. These maps were created by overlaying various forest cover layers with the hurricane storm surge inundation data. A map of the declared disaster counties and the path of the storm was requested by the Geographic Information Coordination Council, and this map was prepared after the storm by the CGIA (Figure 1). County-wide basemaps were requested for various agencies, including the Department of Environment, the American Red Cross, Health and Natural Resources. The latter used the maps for the planning of mosquito spraying. Data were provided in ARC/INFO, ArcView, MapInfo and Atlas GIS formats in order for federal agencies to work with the data immediately (State of North Carolina, 1996).

North Carol

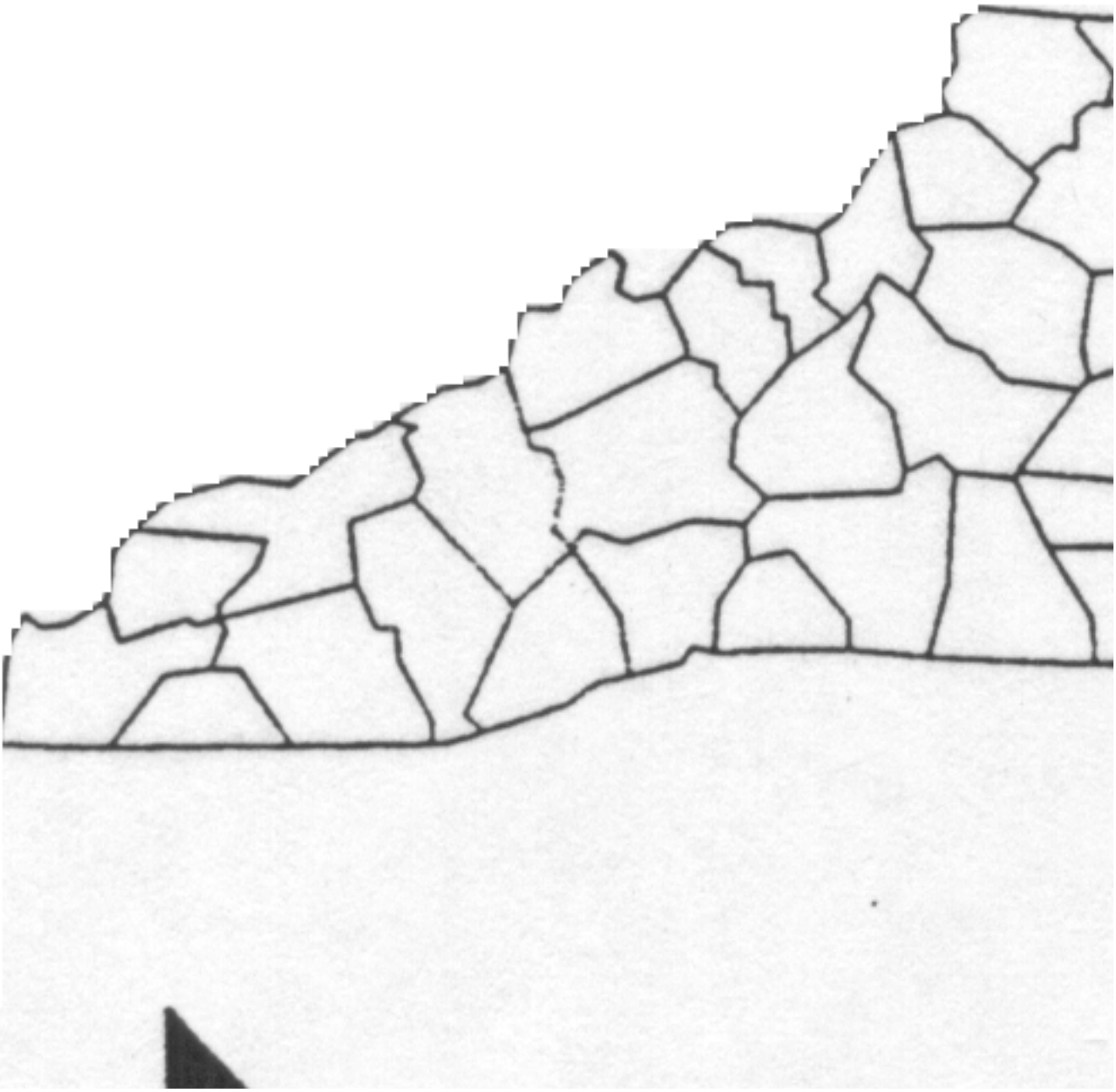

Figure 1: Location Map

GIS Technology in the Disaster Field Office

In contrast to previous hurricanes, such as Hurricane Andrew, most federal agencies brought their own GIS to operate in the Disaster Field Office in Raleigh or were directly connected through the World Wide Web (WWW) or through the Internet with their home offices. Situation reports were released daily over the WWW to keep politicians, such as the Governor and cabinet members as well as emergency managers, abreast of the changing situation in the field (FEMA WWW, September 1996).

Weather conditions, the physical conditions, such as debris removal, social impacts, and cultural impacts, were monitored, and reports on these subjects were sent out over the WWW. In addition, requests for supplies, equipment, and volunteers were broadcast over the WWW to the population at large. Field data were available within a few hours, not only to emergency responders on the ground, but also to the emergency community at large on the Internet. This was a decided contrast compared to information flow after previous natural disasters such as Hurricanes Hugo and Andrew. FEMA had also greatly speeded up its process of identifying those who qualified for disaster assistance. Within just a week, some victims received checks for repairs needed to their properties. Clearly, information technology has found its way into disaster management operations and has taken much guesswork out of the response process for emergency decision makers.

The National Flood Insurance Program (NFIP)

Congress passed the National Flood Insurance Act of 1968 and established the National Flood Insurance Program (NFIP) in response to mounting flood losses and disaster relief costs. The public could purchase insurance from the fund if their own local governments implemented and enforced measures to reduce flooding risk in new construction (FEMA, 1995). To set appropriate premium rates, Congress

authorized the systematic identification of flood-risk areas across the nation. FEMA's Mitigation Directorate is in charge of creating and updating flood maps which are called Flood Insurance Rate Maps (FIRMs). These maps identify a variety of information, including common physical features, such as major highways, secondary roads, railroads, lakes, streams and other waterways. In addition, the risk factor of flooding in local communities is mapped (FEMA, 1995). The most significant risk factors are flood zone and elevation differences such as 100- and 500-year flood hazard areas. In recent years these maps have been made available in digital format becoming Digital Flood Insurance Rate Maps (DFIRMs).

The purpose of these maps is to identify special flood hazard areas, identify the location of specific properties located within these flood hazard areas, identify the base 100- or 500- year flood elevation at a specific site, locate regular floodways and identify the potential magnitude of a given flood. After Hurricane Fran, these maps were used to match addresses with flood insurance policies.

As Fran pounded the state, there were about 67,331 National Flood Insurance policies in place in North Carolina, mostly along the coast, representing $7.5 billion in coverage. FEMA awards disaster grants to the States for subgranting to individuals and to local governments. The task is to match the DFIRMs to the addresses of people requesting funding for repairs to determine the eligibility of those applying for NFIP funds. FEMA hired consulting firms to deal with this matching task. These private firms developed a database of georeferenced addresses for application in GIS; communities can now purchase this database for their own use. Over $100.9 million has been paid by the NFIP in North Carolina as a result of Hurricane Fran (FEMA, Internet March 5, 1997).

INTERVIEWS WITH VICTIMS

Upon our return to Kent State University, we interviewed eleven victims

by phone. Each person interviewed owned a home or trailer. The victims came from three locations, Topsail Island, Surf City and Kure Beach. Victims were eager to share their experiences with us. An overwhelming majority of these victims were natives of North Carolina. All of the victims we talked to took the National Weather Service warnings about the approaching hurricane seriously and had evacuated before the storm made landfall. Most of the victims stayed with friends or relative within a 50 mile radius of their homes. However, four persons stayed in shelters in Wilmington, N.C. Each of the victims experienced severe property damage. Two lost their homes, and two lost trailers. The rest of the interviewees experienced major property damage. Three persons had previously experienced property damage after Hurricane Bertha made landfall on the eve of July 12, 1996. When Fran made landfall, none of the three had their Bertha damages completely repaired yet. All except two of the eleven victims participated in the NFIP. This small sample of NFIP participants helps characterize somewhat the incidence of repetitive losses in the hurricane-prone lands of North Carolina.

THE INFORMATION AGE ENCOMPASSES FRAN

Through this research an attempt was made to try to identify the extent to which GIS were applied before, during and after Hurricane Fran by emergency managers. On the local level, GIS was not, or was only scarcely, applied at the early stages of response. Local communities were so hard hit physically that they were without power, in some cases for several weeks. Local offices were closed or had to respond to more urgent problems after the storm.

At the state level, the data layers provided by North Carolina's CGIA were without question of major importance in the management of this disaster and will be especially valuable in the future for mitigation decisions. This availability of detailed data gathered before the extreme event occurred constituted a major difference between disaster

information flow after Hurricane Andrew in 1992 (Winter, 1997) and Hurricane Fran in 1996.

It was clear that, in the four years since Hurricane Andrew, all federal agencies identified in this investigation of Hurricane FranOs effects had reached the Information Age. With GIS available, they took an active role in fast and efficient dissemination of field information. This speedy information flow was the most outstanding characteristic of the management of disaster conditions after Hurricane Fran.

THE NEED TO APPLY GIS IN FUTURE DISASTERS

Many federal employees predicted that Fran will provide the impetus for additional GIS applications within their agencies. With the dramatic rise in disaster costs, all possible forms of technological advances must be explored on a continuing basis at all three levels of government in order for disaster response to become as efficient as possible.

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hazctr@colorado.edu