

USING GIS FOR HAZARDS VULNERABILITY ANALYSIS

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ABSTRACT

South Florida is considered one of the most hurricane prone areas in the nation and warrants a comprehensive and well-maintained hazards vulnerability analysis. As part of an effort to develop a long-range post-disaster redevelopment plan, an initial hazards vulnerability analysis was completed for Palm Beach County, Florida using a Geographic Information System (GIS). This paper provides a discussion of this experience. Hazards vulnerability analysis is the process of determining the degree to which population, property, environment and social and economic activity are at risk. It is recognized that a high level of prediction accuracy about time, place and magnitude of potential disasters is not likely to happen. A number of techniques are available for identifying and locating the extent of storm hazards. Those discussed include:

1. SLOSH (Sea, Lake and Overland Surge from Hurricanes) Model;
2. Flood Hazard Mapping;

3. Composite Hazard Maps and
4. Wind Damage Estimates

The justification for using GIS, it's strengths and shortcomings, data base requirements, limitations and examples of final products and their use are among the principal topics considered. As GIS becomes available to more local governments, emergency managers and town planners will be able to enhance their efforts to understand the magnitude and mitigate the potential damage of natural and man-made disasters.

NATURAL HAZARDS IDENTIFIED

A number of hazards were identified for Palm Beach County. Those to be discussed include hurricanes and floods.

Hurricanes

The County is located on the Southeast coast of Florida. The Atlantic Ocean is contiguous to forty four miles of its eastern border. SLOSH Models have been conducted and used to define specific coastal areas which are considered vulnerable to storm surge. The entire 2,024 square miles within the County's boundaries are subject to the destructive forces created by hurricane velocity winds.

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Floods

The terrain of Palm Beach County is relatively level. The eastern shores are at mean sea level and the mean elevation of the County is fifteen feet. Drainage problems are created by long periods of unusually heavy rainfall, after which the operation of locks and lift stations are insufficient to prevent floods in certain areas. All areas within the proximity of inland bodies of water and those areas below ten feet of elevation are subject to flash flooding or the pooling of water as a result of extensive rainfall.

METHODOLOGY

A number of existing techniques and data bases are available for identifying and locating the extent of storm hazards. These are discussed below.

SLOSH (Sea, Lake and Overland Surge from Hurricanes) Model

The National Weather Service has developed sophisticated computer models to estimate the predicted wind and surge effects of potential hurricanes. One of these that has already been applied to Palm Beach County is the SLOSH Model (Sea, Lake, Overland Surge, and Hurricane). The SLOSH Model differs from the models used to delineate flood zones under the National Flood Insurance Program (NFIP) in that it is non-probabilistic and does not assume a specified return frequency based on historical data (i.e., the 100-year flood zone).

Several steps are involved in applying the SLOSH Model to any coastline. First of all, the model must be "fitted" to the coastline under study. This means that it must be tailored to take into consideration the numerous specific natural and manmade

features of the coastline which have some effect on surge penetration onto land. To do this, data are aggregated into grid areas overlaid onto the study area. The computer model is run for the area which results in a large number of scenario simulations based on different hurricane tracks, forward speeds, size and intensities. The Model produces output including (1) surface envelope of the highest surges above mean sea level; (2) time histories of surges at selected grid points; (3) computed windspeeds at selected grid points; and (4) computed wind directions at selected grid points.

Some of the most useful output for pre-disaster and recovery planning using GIS techniques are maps that indicate areas of maximum surge penetration under different intensity assumptions. Using different intensity and storm path projections, the SLOSH model generates generalized maximum water depth estimations. These estimations are used to produce inundation maps depicting the identification of areas particularly vulnerable to hurricane storm surge. Once this information can be digitally produced and entered into a GIS, spatial overlay analysis can estimate potential risks to different structure types.

Among the information items included on the SLOSH maps for Palm Beach County are:

- .Category 1 inundation area
- .Category 3 inundation area
- .Category 5 inundation area
- .Spot depth estimations for surge tide
- .Planimetric information such as roadways and hydrography

FLOOD HAZARDS

The National Flood Insurance Act, established by Congress in 1968, created the National Flood Insurance Program (NFIP) which provides property owners in

floodplains with federally subsidized flood insurance in those areas which implement ordinances to reduce future flood losses.

Later, in 1973, Congress passed the Flood Disaster Protection Act making the purchase of flood insurance mandatory in special areas. The Federal Emergency Management Agency, who administers the NFIP, bases its studies on a definition of a 100-year flood event as a flood having a one per cent probability of being equalled or exceeded in any given year.

Local governments must agree to regulate new development in floodplain areas in a way which minimizes future flood losses. Flood Insurance Rate Maps (FIRM) are prepared by FEMA for this purpose. They show the one percent chance flood and detailed base flood elevation information. These maps become the basis for establishing insurance rates for floodplain property owners. They are an excellent source for flood hazard analysis once they are digitized. However, they are difficult to automate due to numerous map sheets produced at different scales, with different publication dates and out of date planimetric features.

COMPOSITE HAZARD MAPS AND DATA

Composite maps permit policy makers to view the cumulative effects of different elements of the hurricanes, coastal storm hazards and flood events, and to identify particularly hazardous locations. The polygon overlay and network capabilities of Geographic Information Systems (GIS) technology were very useful to develop the composite maps and associated attribute data.

Palm Beach County's Planning, Zoning and Building Department's GIS project was implemented in September of 1991 using ESRI's ARC/INFO and

Intergraph's MGE/MGA software. As with all maturing GIS, a common problem is not having reliable digitized maps for detail site specific analysis. Due to timely procurement of a new SLOSH model with digital final products and a FEMA pilot project for digital flood zone maps, GIS coverages were available to start the analysis.

The only problem was the lack of parcel specific data or maps. To bypass this problem, aggregate data were used to estimate potential risk. By using aggregated unit counts from the Property Appraiser's records to run the overlay analysis, composite hazard maps were produced. Based on section/township/range summaries, the unit counts were linked to the SLOSH generated coverages by using the original survey section square mile grid. A similar approach was used to calculate the risk to 100-year flood events. Other useful coverages that were overlaid include critical facilities, current and future land uses and the transportation network.

Also, using GIS, tables were easily created containing the following information:

Section/Grid I.D.
(Range/Township/Section)
Total Single Family Units
Total Multi-family Units
Total Mobile Home Units
Total Subdivided Units
Residential Units
Grand Total Residential Units
Total Wind Damaged Units
Economic Code of Unit (Land Use)
Description
Count of Non-residential Units
Total Gross Floor Area
Total Value of Non-residential Units

Graphic information stored in the GIS includes:

Municipal Boundaries
Water Features

Vacant Land Areas
 Section Boundaries
 Critical Facilities
 Planned Industrial Land Use
 Planned Commercial Land Use
 Categories 3 and 5 Hurricane
 Storm Surge Boundaries
 100-Flood Event Boundary

The general strategy used for calculating the percent of a section under the threat of a storm surge and flooding was as follows: First, GIS methods were used to calculate the percent of the storm surge area in each survey section. Second, the amount of the section devoted to municipal areas and water features was deleted. Due to the scope of work for the project, only the unincorporated areas were used in the calculations. The calculated result was the land area within each section under a hypothetical storm surge. Next, the section grid was linked to the aggregated unit count data bases to estimate the units at risk from the storm surge and flooding.

A series of maps and tables were prepared to show the vulnerability of Palm Beach County to storm surge and flooding. These maps should not be used to identify specific detailed geographic areas. They are prepared to provide County officials with a general order of magnitude of vulnerability based on an overall storm threat, not predictions of future events. In the future, the risk based on a hypothetical storm could be generated if specific factors of each individual type storm were modeled and more detailed mapping was available.

GIS was used to produce estimated residential structures and non-residential units at risk from a storm surge Category 5 hurricane and for a 100-year flood event in eastern Palm Beach County. The data is graphically shown by the township/range/section breakout. Approximately 29,600 units

could be impacted by a storm surge and over 64,000 units in a flood event.

The composite maps indicate that the major concern from storm surge is in the northeastern corner of the County, around the City of Jupiter. This is due to the extensive area of land affected by the storm surge that flows up the Loxahatchee River and the amount of unincorporated land in north Palm Beach County.

A number of maps and tables have been produced to complete the Hazards Vulnerability Analysis for Palm Beach County. Among them are:

Maps

- Residential units impacted by a 100-Year Flood
- Critical facilities threatened by a storm surge
- Commercial land impacted by a storm surge
- Industrial land impacted by a storm surge
- Index map of Range, Township and Section Numbers

Tables

- Residential structures at risk from a Category 5 hurricane and a 100-year flood event
- Number of structures damaged as a result of 140 m.p.h. winds
- Number of non-residential units and gross square feet affected by a 140 m.p.h. wind speed by Section
- Summary of agricultural acreage and values by type of crop affected by wind speeds of 140 m.p.h.

Map A.1.1, is shown as an example of the GIS output. It depicts a portion of the residential units at risk from a

Category 5 hurricane. Shadings indicate the impact area and severity of damage in percentage terms for sections.

One task that GIS analysis could not model was potential wind damage. Due to very specific sets of variables (i.e. storm track, wind field strength, wind direction, damage caused by projectiles, etc.) that effect wind damage by hurricane storm events, this task was meaningless for a pre-event analysis. During the time this project was being developed, the post-Andrew damage assessment results verified the difficulty in predicting wind damage.

In the future, more specific vulnerability analysis map products will be needed. Parcel specific mapping will be required to pinpoint special populations that will need help in evacuation procedures. Using network analysis techniques, the carrying capacities of roads can be used to model different evacuation scenarios. Temporary storm trash disposal sites can be planned, using GIS capabilities to lessen impact to well field zones and to the environmental sensitive lands. With detailed topographic information, roads and causeways that will be impacted by rising flood water can be identified and used in evacuation modeling. Also, what-if projections can be run to estimate impact from catastrophic events such as dike failures during a storm.

Reference

Palm Beach County, Appendix A Hazards Vulnerability Analysis, *Draft Palm Beach County Post-Disaster Redevelopment Plan*, Published by Palm Beach County, 1993, pgs. A.1 i - A.1 viii.






MAP A.1.1
RESIDENTIAL UNITS AT RISK FROM A CATEGORY 5 HURRICANE'S STORM SURGE
 Map is for Emergency Plan Demonstration Only

Illustr. 1

Scale: 1" = .57 Miles

Estimated # of
 Units Affected by
 Section, labeled in Black

(Unincorporated Areas Only)
 Source for Surge Tide Data
 from FEMA Mapping

-  Surge Tide Impact Area
-  100-75% Units Affected
-  75-50% Units Affected
-  50-25% Units Affected
-  25-0% Units Affected



PHYSIOGRAPHICS
 DEPT.

