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THE EYE OF THE STORM

GIS and the Hurricane Business

Abstract: From April through November of every year, the state of Florida keeps a close eye on the Atlantic and Caribbean Oceans, and the Gulf of Mexico - an eight month hurricane watch. The nature and extent of the threat posed by one of these storms varies, based on storm strength, population distribution, coastal topography, and a number of other issues. This paper looks at the hurricane event, and how it can impact a coastal locale. Using the Hillsborough County GIS as the frame of reference, it also considers how GIS/LIS technology might contribute to the planning and management of activities in response to the approach and passage of such a storm. Finally, this paper will attempt to detail how consideration of such issues may influence GIS/LIS design and development parameters.

INTRODUCTION

"Men pushed and poled upriver as far as she would go, but Storter River - that's what us old-timers call it - rose ten or twelve feet before midnight, till that barge tore loose and carried farther up into the trees. Tide turned before dawn, and barrels, boxes, cows, and all Creation drifted by, and the next thing you know, along come the new schoolhouse...the heavy gray of land and sea during the rains, the knowing that all you hoed and built, so much hard work and discouragement for years and years, could be washed away by storm in a single night - all that dread wore them out."

Peter Mathiessen's novel Killing Mister Watson weaves a tale of the early people of Florida's Everglades islands. A central event in the lives of this story is the 1910 hurricane that struck the lower west coast of Florida. And though our knowledge and understanding of these great tropical cyclones has changed much since that time, some part of the dread and anxiety remain - as well they should. For other than the tornado, whose swath of damage is generally much more restrictive (though perhaps more severe), no single weather phenomenon threatens the people of Florida so consistently, or so menacingly as the "West Indian Hurricane."

Classically defined as intense cyclonic low pressure areas having sustained winds of at least 74 miles per hour, hurricanes are born of the interchange between the tropical sea and the atmosphere. But hurricanes may grow strong far beyond the 74 mile per hour birthline. Witness the Saffir-Simpson "Hurricane Disaster-Potential Scale":

Category....	Wind Speed Range Range (mph).....	Relative Damage Scale
1	74 - 95	Minor; some coastal flooding
2	96 - 110	Moderate damage
3	111 - 130	Extensive damage and flooding
4	131 - 155	Extreme
5	155 - up	Catastrophic

"From Marco Island all the way north to Punta Rassa, a small boat could mostly stay inside the barrier islands, but my dad didn't like the way them clouds was churning down that sky, ugly purple and yellow, like the firmament itself was torn and battered." (Killing Mister Watson)

While in the past one hundred years, only four Category 5 storms have either struck or threatened the American coast (an unnamed storm that struck the Florida Keys Labor Day, 1935, Camille in 1969, Frederick in 1980, and Gilbert in 1990), it is estimated that "storms of extreme violence strike land perhaps ten times per century at irregular intervals" (Herbert Riehl). Moreover, wind damage is only one of the components of a hurricane's passing. Other threats include: heavy rains, tornadoes, flooding, and tidal storm surges.

As if this were not in itself enough, consider that the coastal population of the southern United States has had a very high growth rate over the past thirty years, with states such as Florida and Texas leading the way. In Florida alone, an average of nearly 1,000 new residents a day moved into this state, and many of them have been attracted by the beauty and richness of the state's coastline. In the early part of this century, less than 10 percent of the people lived in proximity to the Florida coast, while today nearly 35 percent do!

To make matters worse, this increase is occurring in a state where there has been a recent lull in hurricane activity. The sixties, seventies and eighties have been largely characterized by major hurricanes in the Gulf of Mexico. During the decade of the fifties, on the other hand, major hurricanes moved up the east coast of the United States, while the twenties, thirties, and forties featured bad storms in Florida. Will we see a return of the great storms to Florida? And if we do, what is the hurricane experience level of our coastal residents?

The Tampa Bay area is considered particularly vulnerable to the hurricane threat. Almost two million people now live in this area, with more than 75,000 living on offshore islands whose elevation is between four and six feet. Over 90 percent of these people have never experienced a major hurricane. The last large storm in this area was Donna in 1960, but the lesson learned from that storm should never be forgotten: had Donna followed strictly the forecast track (she veered more easterly than predicted), more than 150 miles of the Florida West Coast from Fort Myers to Clearwater would have been inundated by a storm surge in excess of ten feet, and in Tampa Bay the wall of water would have been even higher - perhaps fifteen to twenty feet! The devastation would have been awesome, and the potential for loss of life very, very high.

"The lull reached Belle Glade about 8:30 p.m. The storm tide, which reached 11 feet, 6 inches at the lake shore two miles away had not yet rolled into town." (Nixon Smiley, "The Night the Lake Became an Ocean")

Until 1955, when Hurricanes Connie and Diane struck the eastern American coast, no large-scale hurricane studies had been attempted. But after that year, the National Hurricane Center was established in Coral Gables, to begin tracking and trying to understand these storms. The Center and its allies have used a number of tools to deal with hurricanes: reports from passing ships, "hurricane-hunter" aircraft, radio, television, land-based radar, and finally satellites. All of this has helped us to figure out simply what these monsters are really like, and where we think they're going, but the impact of knowing just that much has been tremendous.

Out of this gain in knowledge has come a turnabout in the effect of hurricanes on American life and property. There has been a steady increase in the dollar damage from hurricanes since the turn of the century. This should come as no surprise, since we continue to build on the waterfront. Yet, at the same time, there has been a steady decrease in hurricane related deaths over the same time period. Though doubtless there is a complex of reasons for this, a good portion of it can certainly be attributed to better warning systems.

The problem is that improvements in the warning services have not kept pace with demands imposed by the increasing coastal population. Officials fear that in the near future a disaster will occur that may equal, or even surpass, the Galveston tragedy of 1900,in which 6,000 people died. To help prevent that possibility, public service officials in "Hurricane Alley" will employ all the weapons at their disposal.

The most important of these is information - getting and spreading it. What to do, when to do it, where to go in case of an emergency, who do you call, when can you come back - each of these constitutes an important part of the overall information resource. Following them should lessen the emotional and physical trauma brought on by the event - and one might just save a life.

"Lost Man's Key was awash in a tide so high that the river looked a mile across, and the sea and the river were jumbled up together, thick chop and wind roil of a dead lead-gray, like all life color had been bled away." (Killing Mister Watson)

Many in the GIS community are fond of pronouncing that 75-85% of the information maintained by a government has a geographic base. If this is the case, would it not seem safe to say that a GIS probably contains much of the information that "hurricane fighters" are looking for? Is it time for GIS to get involved? One response has been to argue that GIS projects are meant to address tasks such as tax mapping, infrastructure inventories, or land management. Can systems so typically oriented towards the planning and monitoring of everyday life contribute in the loosely structured panic of hurricane response? In the last analysis, how will a GIS really help a locale to deal with a hurricane?

It turns out that there are several ways. A GIS can provide significant resources to assist in the three major functions: hurricane response planning, on-site information for emergency services and damage control, and first-rate storm damage assessment data.

HURRICANE RESPONSE PLANNING

"From the first of September a hurricane of small intensity had been observed in the eastern Caribbean. It crossed the central provinces of Cuba and curving normally west-northwest moved along south of Florida and in the Gulf of Mexico reformed with increased intensity toward the Texas coast." (Marjory Stoneman Douglas; Hurricane)

As most local governments officials in Florida are keenly aware, Hurricane Response Planning may be defined as hurricane evacuation management. This function is subdivided into three parts: (1) response need definition, (2) geographic extent measurement, and (3) response timing.

Defining the need to respond means determining that a hurricane is actually going to impact an area. While efforts in this area have improved significantly, it remains a difficult task. Hurricanes have a way of turning seemingly willy-nilly, driven by an ocean-atmosphere relationship still too complex to easily model - as the path of the 1985 Labor Day storm, Elena, clearly demonstrated.

Geography helps to tell the story of a hurricane's potential impact on the land and populace (geographic extent). Where is flooding likely to occur? Can we predict the severity? Under such conditions, what bridges are likely to be stressed or fail? When we know that landfall is very likely, who needs to evacuate first? When they go, by what routes are these people supposed to get out? The answers to this set of questions may determine whether 10,000 or 510,000 people have to leave their homes.

Ultimately, timing is the critical variable in the three-part equation, and the one most resistant to automation. Timing decisions must remain the purview of human beings. Because of the length of time required to fully evacuate large numbers of people, deciding when to go may require action well in advance of confident landfall predictions. As a rule, this can lead to unnecessary evacuations. However, the alternatives - under-evacuating, or issuing the order too late - are blueprints for possible disaster.

By virtue of rapidly emerging skills in intelligent mapping and database analysis, GIS technology is poised to make a positive contribution to the work effort in this area. It should be possible for GIS to support a broad range of functions from storm modeling to infrastructure management. Delivering such benefits, however, means that the "points of integration" must be determined, and inter-agency relationships resolved. These decisions will, no doubt, generate their own set of challenges, and these must be dealt with early on.

Merging localized GIS technology with hurricane planning is largely a matter of ascertaining how the GIS should handle storm characteristics and meteorological data. Hurricane modeling programs work with geographic bases whose size gives new meaning to a number of the traditional GIS issues such as map scale, relative accuracy, and attribute content. Moreover, it is likely that the need to work closely with other governmental agencies will require some serious planning and management to develop a smooth information and decision-making transfer between participants whose objectives and priorities vary radically from one to another.

EMERGENCY SERVICES AND DAMAGE CONTROL: ON SITE KNOWLEDGE

"All the telegraph wires were down but one, over which Joseph Cline sent the last message that the disaster was upon them. Two bridges to the mainland were down and a causeway was covered with rising water. The city was cut off." (Marjory Stoneman Douglas, Hurricane)

Once a hurricane has made landfall, the time for precautions has passed. Critical decisions have been made, and evacuations must be complete. It has become a matter of "riding out the storm", of surviving. In the local emergency operations center (EOC) itself, close attention will be given to monitoring remaining operational communications systems to update storm data, and to coordinate the handling of distress calls as they are received by the various agencies.

In many communities, GIS projects will ultimately serve as the repositors of infrastructure inventory data, particularly those relating to transportation, water and sewer, and stormwater networks. This should include the condition and operating characteristics of the individual elements of such networks. Under the demands of "live" hurricane response, the information has a very high value. If system performance issues are properly addressed, real-time availability of the data would be a major plus for both the system and response staff.

Transportation maps could be developed that contained primary, secondary, and tertiary emergency routes as layers. These could be designed into a high-performance window or menu-driven system wholly contained within the EOC, perhaps using a microcomputer-based subset of a larger GIS (generally maintained outside the EOC). With a matching database created specifically for this purpose, these "pictures" could give EOC personnel high-speed options to consider, in the event unforseen situations interrupt standard response strategies.

Databases could also be developed to handle such specialized information as medical facilities, sites of special concern, and key response resources. Having this information on-line during a storm may not, by itself, mean the difference between life and death, but it might help the crisis management process. Typically, much of this data is stored in disconnected databases maintained by independent departments, or developed onto manually completed panels and boards within local EOCs.

Handling this role might require some special planning and programming on the GIS side itself - including innovative systems development that suspends some of the normative assumptions of the system. It may even be that the product(s) finally developed can nót be considered as "children" of a parent GIS project. The point is that current technological development paths offer possibilities that have brought such considerations closer to realty.

DAMAGE ASSESSMENT

"From the upper porch of Tedder's hotel the misty light of a reluctant dawn revealed a panorama of indescribable desolation. Dark, ragged clouds drooped low. Water, knee deep, covered all the land. Projecting dismally above the flood were fragments of roofs and floors, bed posts and trunks, uprooted custard apple trees, wrecked automobiles...The eye searched in vain for familiar buildings. Instead it was confused by strange houses, leaning crazily, where none had been before." (Lawrence Will, Okeechobee Hurricane)

For the human community, the aftermath of a hurricane begins in bewilderment and shock, and ends in hard, often muddy work. Hurricanes seem to bring their own version of the night, and the morning after may be the most difficult time of all. Those who were able to stay put will begin to emerge; those who had to leave will want to come back. Electricity may be out, and there may be no functioning water or sewer. Streets likely will be littered with debris from the night of rampage, and flood waters could still be high, isolating some residents. Civil control must be maintained, and the clean up has to somehow begin.

Ascertaining the extent of damage - beyond such indefinable terms as extensive or catastrophic - becomes the major task of hurricane response managers not involved directly in the reconstruction management process. How many homes were lost or damaged? How many lives, if any, were lost? Such information serves two purposes, one immediate, and one longer-term. The first is to assist in disaster recovery. The faster an assessment of damage can be developed, the faster the federal government is likely to declare a disaster area. In turn, with better assessment turn-around, federal disaster assistance should be forthcoming more quickly - a direct benefit to the residents.

Second, the information aids in refining future planning processes. Looking at patterns of damage caused by a particular storm may help to update models used in developing predictions. If so, both the models and the skills of response personnel will be enhanced.

In these two functions, GIS technology offers substantial resources. The results of site-by-site damage assessments can be entered into a system linked to basic cadastral data developed for the central GIS project. Through access to GIS graphic display and analysis resources, officials will be able to quickly develop both analytical and summary representations of the overall damage situation. Substantiating information for disaster area declaration can be provided on request, and long-term effects of reconstruction assistance monitored against the historical record of a particular storm.

Once assessments are completed, these can be matched against assumptions used in evacuation strategies. Were the suppositions correct? Were the right people evacuated? Or, was another area, not identified in the planning stage, impacted? Comparative studies of projected and actual storm damage will greatly aid in updating models and plans.

A STORMY SCENARIO: HILLSBOROUGH COUNTY

"As the land began to rebound, people did also. There was talk of rebuilding the houses on Alligator Point that had been washed into the sea, this time on stilts, this time behind the dunes instead of in front of them. The sea had taught only respect. She had chosen not to teach fear and terror this time." (Jack Rudloe, The Living Dock at Panacea)

Moving from the general to the particular, how could ideas discussed above be accomplished at the local level? Using an existing GIS project, and the neighboring Emergency Operation Center as models, what needs to be done to bring about the maximum reasonable set of services and benefits?

The Hillsborough County Geographic Information System was implemented, over the past four years, from a Florida State Plane Coordinate-rectified aerial photographic base. This base, done at a 1:200 scale, covers 1,038 square miles, and includes some 210,000 land parcels. Using GENAMAP GIS software and an ORACLE RDBMS operating on a network of Hewlett-Packard HP9000 UNIX systems, the system documents a centerline transportation network, wetlands and open water features, high-resolution coastline definition, jurisdictional limits, and land parcel boundaries. Appropriate attribute tags are implemented for all these elements. Cadastral information was manually converted from the Property Appraiser's database.

In addition, projects relative to other governmental applications such as water, sewer, recovered water, and stormwater infrastructures, land use, environmental data, zoning, and population distributions are now underway. Finally, as part of a Commissioner Reapportionment project scheduled for completion in August, 1991, an effort to merge U.S. Census PL94-171 and Post-Census TIGER data with the County's base map has been initiated.

Meanwhile, working with data provided by the regional water management authority, Southwest Florida Water Management District (SWFWMD), pilot projects have been undertaken to determine the feasibility of importing such diverse data as soils maps, 1-foot and 5-foot topographical contour lines, and riverine basin boundaries and features, all from an ARC-INFO system. These projects bear mentioning due to the usage by SWFWMD of USGS Quad Sheets as a map base. Initial reports from these projects have been very encouraging. Though not perfect, our ability to successfully translate from one software approach, as well as one geography set, to another has worked better than expected. Ultimately, the ability to utilize USGS-based data will prove critical to the intentions of developing the broadest possible spectrum of GIS applications in this County.

As it now stands, the completed base map already provides much information useful to EOC personnel in the event of a hurricane. Specifically, land ownership attributes (parcel identifiers and street addresses) are fundamental to the damage assessment task described earlier. A 286/386 PC-based program, using Clarion database management software has been developed and implemented to support this particular objective.

Parcel identification and address tags were downloaded from the HP9000 ORACLE attribute database to the Clarion program. They were then combined with additional fields pertinent to damage measurement and documentation. When the damage data is filled out after an actual storm, the Clarion software will produce summary statistics and reports for emergency management agencies. If desired, data can also be uploaded to the HP9000, and used to plot storm damage maps.

Providing data support to hurricane forecasting and evacuation planning is another matter. The National Hurricane Center has developed a very sophisticated hurricane modeling application, for the purposes of forecasting storm surge threats. Known as SLOSH (Sea, Lake, and Overland Surge from Hurricanes), this model produces an atlas of projected heights of storm surge and extents of flood inundations. The atlas forms the basis for the evacuation zone maps developed and published by the EOC.

SLOSH works with various combinations of hurricane strength, forward tracking speed, and direction of storm motion. Strength is modeled by use of the central pressure and storm eye size using the five categories of storm intensity. Ten storm-track headings were selected as being representative of storm behavior in this region on the basis of observations at the National Hurricane Center.

SLOSH utilizes a "Tampa Bay Basin" grid. The grid is a telescoping elliptical coordinate system, reflecting a compromise between conflicting needs. The objective was that the model domain include a large geographic area (hurricanes may affect up to 500 miles in all directions at any one time), but also that small, detailed topography be addressed. As a result, over land, which is the area of greatest interest, the small spatial resolution facilitates relation to land features. At the same time, larger grid squares over the ocean diminish the model's limitations on storm dynamics, better emulating actual conditions. To surmount the difficulty that this elliptical grid might cause when working with map projections, storm surge results have been reanalyzed into a conventional map projection, one based on USGS Quads. This allows National Hurricane Center staff to develop coordinate (latitude and longitude) information for grid cell corners, and to reproduce cell boundaries onto standard map displays, using a CAD-based graphics product.

From Hillsborough County's perspective, two things need to be done at this point: (1) Complete the topographic contour maps for the County, and (2) Create a layer for SLOSH grid cell boundaries. For hurricane management purposes, these two accomplishments would enable direct entry of SLOSH atlas data onto the GIS base. EOC personnel would then be able to display storm surge projections directly overlaid onto the transportation network, which is considerably more up-to-date than that of the USGS Quads for this area. It would also enhance local verification of SLOSH data, which may be difficult to analyze visually, given the uneven quality of the map base used, when plotted at an acceptable working scale. Ultimately, the products should be improved evacuation zone maps.

Once completed, zone maps will prove directly beneficial in the publication and distribution of a public service tabloid. This document, which is available at no charge through a wide variety of wholesale and retail outlets, contains both generic and specific hurricane warning information. The generic data provides basic guidelines as to what to do in case of a hurricane, while the specific information concerns evacuation zones and shelter locations. This publication is currently produced by a third-party vendor utilizing AUTOCAD. Automating the development of baseline zone maps should improve the process, all the while utilizing the central GIS database.

A program to accomplish these objectives is currently under design, and is scheduled for start-up this summer. Contour maps will be obtained from SWFWMD, imported into GENAMAP, and verified by Stormwater Management staff. At the same time, GIS and EOC personnel will be working very closely with both the Regional Planning Council (which functions as a clearinghouse on SLOSH data) and National Hurricane Center itself, as well as other GIS managers and staff in the Tampa Bay area to research and develop means to more tightly couple SLOSH and GIS. Given that some of the detailed goals of this effort have not yet been fully stated, it is anticipated that it will take one to one-and-a-half years to complete, test and implement this project to the satisfaction of EOC administration.

The other major area of endeavor will be the development of On-Site Knowledge applications. Work in this area is currently impacted by two factors: first, EOC staff are heavily involved in the development of current evacuation zone boundaries, for publication in the public service tabloid. Second, EOC and GIS staff have spent much of the recent past working on other projects, and have not yet defined specifically which On-Site Knowledge applications on which to focus.

GIS staff has begun consulting with EOC personnel to develop initial specifications for these projects. The timing of this effort may actually be fortuitous. Given that exact parameters have not yet been defined, and that new developments are taking place in the interfacing environment, particularly with regard to the use of windows in application design, the project team will have the opportunity to research very carefully hardware performance issues. One of the policies of the County's GIS has been to plan and design within an "Open" architecture philosophy - for both hardware and software issues; such flexibility maximizes the ability to respond to specific needs on several levels. On-Site Knowledge work will likely put that policy to a serious test.

As part of the work in this area, GIS and EOC staff will also seek the direct participation of infrastructure agencies. It is critical that these bodies be involved in the hurricane management thought process. If nothing else, their involvement will educate them as to the value of the effort, to potential linkages between various systems, and to impacts that such links might have on their respective information support programs.

The goal for completing projects identified out of this process is to have at least the first such application operational prior to the end of the 1991 hurricane season. For testing graphic applications, pilot projects will be run against a MAPINFO license held by the Fire Department (which participates in the EOC). If successful, EOC administration may be encouraged to acquire PC-based GIS software and hardware as necessary. In addition, a number of secondary projects could be completed, at least in beta form, prior to the onset of the 1992 season. Obviously, each will have to be tested out in hurricane simulations, prior to acceptance by the EOC.

"To one who has not been exposed to the fury of this, one of the most intense of recorded storms, its stupendous power can scarcely be realized. It has been estimated that the energy developed by this hurricane in one hour, would furnish the whole United States with electric power and lights for an entire year...This was the instrument of destruction. (Lawrence Will, Okeechobee Hurricane)

It should be clear that the interplay between hurricanes and GIS technology is a fertile ground for research and development. Hillsborough County hopes to focus a good deal of the energies in both GIS and EOC in this direction. The objective is to bring the two together to as great a degree as possible. Such a work effort provides an opportunity to develop challenging and innovative applications. At the same time, the real reward is that, in working with the emergency management teams, considerable benefit - to the point of possibly avoiding loss of life - will come to the County's residents.

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