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EVACUATION DECISION MAKING AND PUBLIC RESPONSE IN HURRICANE HUGO

Summary

Although the worst of Hugo affected one of the more sparsely populated reaches of the South Carolina coast, it was necessary for residents in a much larger area to assess and respond to the threat. Forecast information provided by the National Hurricane Center was good during most of the crucial response period, making decision making much easier than might have been the case. Inundation maps and evacuation clearance time calculations produced in pre-storm studies proved useful and generally accurate. Computerized and graphical decision aids were utilized extensively and contributed an impression of "high-tech" performance and credibility to elected officials, but some users had dangerous misconceptions about the tools' functions and capabilities. There was very little clear-cut incorporation of forecast uncertainties into response decisions. Evacuations went well, evidenced in part by the low loss of life from flooding. In many surge-prone areas, however, evacuation was not as complete as is widely believed, and had the maximum force of Hugo struck any of the major population centers of South Carolina, many homes would have been flooded with occupants still in them.

Forecasts and Warnings

After Hugo left the Caribbean, forecasts indicated that the storm would follow a northwesterly course. From Monday, September 18 through Tuesday the 19th, long-range forecasts had the storm approaching various locations along Florida's east coast.

On Wednesday, September 20 the 6 am forecast moved the forecast track farther north, anticipating landfall between Beaufort and Charleston in approximately 60 hours. Charleston's probability of being affected by Hugo was put at 12%.

During the day Wednesday the forecast track was altered slightly, taking Hugo northwesterly, then more northerly just before landfall, which in the 6 pm advisory was anticipated at Beaufort in less

than 36 hours. A hurricane watch was issued for the area from St. Augustine, Florida to Cape Hatteras, North Carolina at that time, indicating that landfall was expected in 36 hours or less.

Throughout Wednesday communities on Florida's east coast and in Georgia and South Carolina monitored the storm, watching for a more westerly track or an increase in forward speed. No significant response actions were implemented, although in some locations such as Beaufort officials suggested as a precautionary measure that residents go to friends and relatives farther inland if they would feel more comfortable doing so.

Wednesday evening officials in Charleston county recommended that residents evacuate. It was considered a marginal call, but officials felt the 11 pm news programs would be their last opportunity to reach residents via the mass media until the following morning.

The next morning at 6 am the center of Hugo was forecast to reach Beaufort in 24 hours, and the National Hurricane Center issued a warning from Fernandina Beach, Florida to Cape Lookout, North Carolina. The watch remained in effect south to St. Augustine and north to Cape Hatteras. Charleston's landfall probability was 30%, and Hugo's sustained winds were reported as 109 mph, just 2 mph short of being a category 3 storm.

The Governor of South Carolina ordered evacuation of barrier islands, beaches, and peninsulas, except for the city of Charleston. Officials in Charleston county changed their recommendation to an order. Local governments disseminated the order, assisted by the National Guard. Most if not all locations in South Carolina evacuated for a category 3 hurricane. Coastal Georgia also began to evacuate in response to the warning, as did parts of North Carolina.

At noon on Thursday Hugo was upgraded to a category 3 storm, with winds reported and forecast to remain at 115 mph. The track moved slightly north, taking the center over Charleston.

At 3 pm Thursday a special advisory was issued to report that Hugo's winds had unexpectedly increased to 126 mph and that the forward speed had increased (from 17 mph to 23 mph). The hurricane warning area was extended to Oregon Inlet, North Carolina, and the watch was extended to Cape Henlopen, Delaware. The track was shifted a bit farther north (with landfall predicted near

Georgetown, South Carolina), and the areal extent of the wind field was expanded. The intensification prompted evacuees in at least one Myrtle Beach shelter to be relocated farther inland.

At 6 pm Hugo was reported having intensified to 138 mph sustained winds, making it a category 4 hurricane (133 mph the threshold). Forward speed decreased slightly to 20 mph. The evacuation was nearly complete by that time, however, and few preparations were altered.

Decision Making

Public officials face a tremendously difficult responsibility in deciding whether and when to recommend or compel their citizens to evacuate during a hurricane threat. Unnecessary evacuations are expensive, disruptive, and unpopular, but waiting too late to leave can be disastrous. In Hugo decisions were made much easier due to the consistency and validity of the forecasts provided by the National Hurricane Center.

Near 1983 Federal agencies began studies which provided the foundation of hurricane evacuation plans in South Carolina. The National Hurricane Center simulated numerous hurricane scenarios to indicate the areas that would be inundated by storm surges. The Corps of Engineers and its contractors calculated the number of people who would need to evacuate, the length of time necessary to evacuate, and the public shelter space needed in different storm categories. The state of South Carolina mapped the surge-prone areas of each county, and FEMA paid for much of the information to be computerized.

In making response decisions, officials consider the strength of the storm which might affect their location and look up the length of time necessary to evacuate for that storm category. They then consider the length of time remaining before the storm is expected to arrive and compare the two times to determine when evacuation must begin in order to provide sufficient time for evacuees to reach safety. All the coastal counties in Georgia, South Carolina, and North Carolina had graphical devices provided by the Corps of Engineers and/or computer software made available by FEMA or a private firm to facilitate the necessary computations. Officials appeared to employ the aids with varying proficiency, but at least some used them effectively.

Those computations, however, are not the difficult part of decision making. The difficult part is anticipating how strong the storm will be, whether it will "hit" a particular location, when it will reach a location, and how large the storm will be. Each of those parameters is forecast by the National Hurricane Center, but each is subject to error. Accounting for the forecast uncertainty and incorporating it into the decision process is the difficult part of decision making.

The National Hurricane Center since 1983 has included probabilities with its advisories to indicate the likelihood of a storm passing within 65 miles of certain locations during various time periods. These probabilities account for uncertainty in the direction and forward speed of forecasts. Commercial software in use by some of the counties in the threatened area provided a graphical depiction of the position forecast uncertainty and calculated intensity uncertainties.

Few officials exhibited evidence of systematically employing uncertainty information, particularly NHC probabilities, in responding to Hugo. Discussions of the decision process always centered upon the forecast itself and on clearance times, with only a general concern that the forecast or the clearance time calculations could be in error.

In South Carolina coastal officials relied very heavily upon the Charleston office of the National Weather Service for advice and judgment, and that interaction was more influential than any other input. The Charleston office interpreted NHC forecasts for local officials and in some instances offered second opinions. Fax connections to local governments and conference call capabilities would have facilitated the NWS office's ability to interact with local officials. Computer software available to counties in South Carolina included a module originally developed by the Charleston NWS staff indicating appropriate response actions, based upon the NWS staff's judgments about acceptable risk and other factors. When Hguo was believed to have increased to a category 4 storm at 6 pm on Thursday the Charleston NWS was influential in the decision to not attempt to evacuate a larger area. The Governor's office in South Carolina worked more closely with the Columbia NWS office.

Decisions, in retrospect, appeared "correct" largely because the information being assumed (forecasts and clearance times) proved accurate. But had Hugo increased forward speed earlier, for example, the retrospective might have been different. It should also be noted that the worst of Hugo

did not hit the populated locations of Beaufort, Charleston, or Myrtle Beach. If such had been the case, 20% to 30% of the homes in the inundated areas of those locations would have flooded with occupants still in them. Although evacuation notices were timely they were disseminated successfully only in the most hazardous beachfront and island locations.

A claim following Hugo that the relatively low loss of life in such a severe storm was attributable to the improved planning conducted since 1983 is not supported by fact, except perhaps that the studies provide a better indication of the areas needing evacuation. Most locations didn't evacuate in Hugo until the National Hurricane Center issued a warning, which has been the norm for at least two decades. Luck -- the fact that the right side of the eyewall crossed the coast in one of the least populated reaches of South Carolina's coast -- was probably the greatest factor resulting in so few deaths. On average, however, the improved studies and plans will result in lower deaths over time.

The evacuation proceeded as smoothly as could be expected, and the public evaluated the warning and evacuation performance by public officials very favorably (Baker, 1990a). Traffic tie-ups on Interstate 26 leading west from Charleston prompted officials to devise a scheme to employ all lanes for westbound traffic. By the time the plan was completed, however, traffic was moving more smoothly and the idea was not implemented.

A public school used as a public shelter in McClellanville in Charleston county flooded to a depth of approximately six feet with several hundred evacuees inside during the height of the storm, but there were no fatalities. Building drawings provided by the school board listed the elevation of the ground floor of the building as approximately 20 feet, whereas the actual elevation was closer to 10 feet. No ground survey was conducted as part of the hurricane evacuation studies to verify the actual ground elevation of the building. The greater planning failure, however, was that during the study's review and local involvement process no one questioned the 20 foot elevation in a location clearly shown as flood-prone on study-generated surge maps and on flood insurance maps. With hindsight locals in the McClellanville area felt it was "obvious" that the school site was not 20 feet high.

Use and Evaluation of Evacuation Study Products

Surge Maps

The single most extensively utilized technical product generated in evacuation studies in the areas threatened by Hugo were surge inundation maps. The surge heights predicted by SLOSH when the program was run after Hugo's landfall, using parameters determined afterward, matched observed surge heights at the coast very closely. SLOSH maps generated earlier and used for evacuation planning were composites of different storm scenarios, and officials seemed satisfied with their validity in Hugo, although we have seen no specific verification data. Users in several locations felt the surge zones should be mapped at a larger scale to show greater detail.

Clearance Times

Another heavily employed planning product was clearance time calculations, which were generated by a consultant for the Charleston district of the Corps. These, in conjunction with storm forecasts, provide the basis for timing of response actions such as evacuation. They are based upon assumptions about road and street networks and public response patterns.

In the Charleston area, as Hugo threatened, the NWS office suggested to the county emergency preparedness director that the clearance times calculated for the evacuation study were unrealistically pessimistic. After polling municipal officials in the county, the director was unable to find a consensus regarding the any sort of perceived bias in the times, so the study-generated times were employed. Clearance times observed in Hugo appeared very close to the calculated times, although the analysis was cursory.

Decision Aids

The response decision making process was discussed earlier, and it was noted that NHC forecasts were used in conjunction with planning study clearance times. Graphical tools and computer software were employed in some locations to facilitate the computations. None of the tools appeared to have been used very effectively in most locations to assess forecast uncertainties, however, and some

users had gross misconceptions about the tasks performed by the aids. At least two local preparedness officials credited the aids with making accurate **predictions** of when the storm would arrive. None of the tools made predictions; they simply facilitated computations based upon assumptions which were input. The tools appeared to be accurate simply because in Hugo the NHC forecasts and study-generated clearance times were accurate. Users were generally pleased with the computer software available to them, but in many locations it was more a device for impressing elected officials and the media than for sophisticated decision making.

Public Response

Approximately three months following Hugo's landfall in South Carolina, telephone interviews were conducted with residents in Myrtle Beach, the Charleston area, and Beaufort. Parts of each sample were composed of households which had been interviewed in previous studies in the area regarding hypothetical hurricane threats. In Myrtle Beach some respondents had also been previously interviewed to document their response in Diana. Not all earlier respondents could be contacted, however, and in each area the sample was supplemented with newly selected households. In Myrtle Beach and Beaufort a total of 150 post-Hugo interviews were completed, and in Charleston, on the peninsula and west of the Ashley, 200 households were interviewed. Included in the Beaufort sample were 27 respondents on St. Helena island who had been interviewed in an earlier study. In addition, a combined 100 interviews were completed in Mt. Pleasant, Sullivan's Island, and Isle of Palms, where no hypothetical response data had been gathered previously.

The supplemental households weren't selected using the same criteria as those originally employed, but they are generally comparable. The great majority of respondents in all areas were in category 1, 2, or 3 surge zones. No supplemental respondents were outside category 4 zones. The old and new Beaufort samples are different in part because the new sample included no St. Helena respondents. In both the Charleston and Myrtle Beach supplemental samples, a greater portion of respondents lived within a mile of water (beach, harbor, river, etc.) than in the original samples.

Evacuation Rates

In none of the primary sample locations was evacuation complete. In Beaufort 72% left, in Charleston 62%, Mt. Pleasant/Sullivan's 81%, and Myrtle Beach, 79%. There were, however, variations within these areas. From Sullivan's Island and Isle of Palms 96% left, and there were probably comparable successes in other high-risk barrier islands.

It would be inaccurate to say that everyone in the sample should have evacuated or that officials indicated that they should. A small minority in fact lived outside areas advised or ordered to leave. Nevertheless, Hugo generated a category 4 type storm surge, and evacuees and officials had no assurance until shortly before landfall that it would not cause such effects in their locations. Taking just the category 1, 2, and 3 surge areas, it is unlikely than more than 75% to 80% evacuated from most areas other than barrier islands and beachfronts.

Most but not all respondents believed they had been told by officials to leave (71% in Beaufort, 64% in Charleston, 72% in Mt. Pleasant/Sullivan's, and 73% in Myrtle Beach). Very few respondents interpreted the evacuation notices as being mandatory. Of the total sample only 30% in Beaufort and Myrtle Beach and 15% to 20% in Charleston said they heard an order to evacuate.

If more had heard officials say they should leave and if more had interpreted the notices as orders, more would have left. Overall 89% of those who said they heard an order evacuated, compared to 70% who said they only heard a recommendation. Surprisingly, 61% saying they heard neither evacuated. This is relatively high for people not hearing official evacuation notices. Many did, however, hear from other sources that they should leave and were aware that neighbors were leaving.

Those saying they lived within a block of most types of water bodies were most likely to evacuate (84%). Of the respondents saying they lived more than a block but less than a mile from water, 73% left, compared to 65% who said they lived more than a mile from water. The exception to this trend were respondents living within a block of rivers, of whom only 67% left.

Respondents were asked whether they thought their homes would have flooded if Hugo had struck their location directly. If they believed their homes would have flooded, 83% left, compared to 65% of those who felt their homes would not have flooded.

Evacuation Timing

When a watch was issued Wednesday at 6 PM fewer than 10% of the eventual evacuees from most areas had left. The percentage was slightly higher in Beaufort (17%) where officials indicated they had suggested to residents earlier in the day that a visit to friends or relatives in safer locations might be prudent.

By midnight, following the earlier voluntary evacuation notice in the Charleston area and statements by the Governor, additional evacuees had left, between 10% and 20% of the eventual totals.

When the warning was issued at 6 AM Thursday morning, and the governor ordered evacuation from the most vulnerable coastal areas, 50% of the evacuees from Sullivan's Island and the Isle of Palms said they had already left. In Charleston 30% of the evacuees said they had gone when the warning was issued, followed by 25% from Mt. Pleasant, 22% from Beaufort, and 10% from Myrtle Beach, farther to the north and away from the storm.

Throughout Thursday morning most evacuees departed, and by noon between 75% and 90% had left from all the survey areas except Myrtle Beach, from which only 35% had gone. By 4 PM almost everyone who left had already done so except in Myrtle Beach where departures continued until 7 PM. Almost two-thirds of the Myrtle Beach evacuees said they left between noon and 7 PM.

Type of Refuge

Very few evacuees went to public shelters (9% in Beaufort, 7% in Charleston, 2% in Mt. Pleasant/Sullivan's, and 13% in Myrtle Beach). Across the four sites more people went to motels than shelters, ranging from 15% in Myrtle Beach to 26% in Mt. Pleasant/Sullivan's. More than half the evacuees from all areas (56% to 66%) went to the homes of friends or relatives.

Shelter use is usually associated with income, and such was the case in Hugo. In households reporting annual incomes below $10,000, 25% used public shelters. In no other income group did more than 8% go to shelters.

Non-whites -- primarily blacks -- were much more likely to use public shelters than whites (31% vs. 5%). There was a difference even within most income groups 39% vs. 9% for incomes less than $10,000/year, 27% vs. 3% for incomes between $10,000 and $25,000/year, and 22% vs. 3% for incomes from $25,000 to $40,000/year.

Respondents living in mobile homes were slightly more likely to use public shelters than other residents (14% vs. 8%). Evacuees living within a mile of water bodies other than rivers were less likely than other groups to use public shelters. Of the evacuees staying in their own county 25% went to public shelters, compared to only 2% of those going out-of-county. Breakdowns by county for in-county evacuees going to public shelters are unreliable due to the small sample sizes involved.

Evacuation Destinations

In all primary sample locations between 64% and 78% of the evacuees went to out-of-county destinations. Roughly a fifth of all evacuees reached their destinations in less than 30 minutes, indicating very short trips. Between 28% (Mt. Pleasant/Sullivan's) and 49% (Myrtle Beach) took an hour or less. Beaufort (16%), Charleston (20%), and Mt. Pleasant/Sullivan's (29%) all had substantially more evacuees requiring over five hours to reach their destinations than Myrtle Beach (3%).

Number of Vehicles

The number of evacuating vehicles per household ranged from 1.1 in Charleston to 1.4 in Beaufort and Mt. Pleasant/Sullivan's. This represented 59% of all available vehicles in Charleston to 71% in Beaufort.

Comparison of Public Response to Behavioral Assumptions Derived Before Hugo

Evacuation Rates

In hypothetical response surveys conducted before Hugo very few people said they would refuse to evacuate even if ordered (1% to 4%). The behavioral analysis indicated that *without disseminating evacuation orders door-to-door* 35% would not leave from Beaufort, 35% from Charleston west of the Ashley River, 20% from the Charleston peninsula, 20% from moderate-risk areas in Myrtle Beach, and less than 10% from high-risk islands and beachfronts.

Evacuation rates in Hugo were extremely close to those indicated in the behavioral analysis. Exact comparisons aren't possible without further disaggregating the Charleston sample east and west of the Ashley and without more precise determination of respondents' evacuation zones. It is clear, however, that in areas other than high-risk barrier islands and beaches, the evacuation was not extensive enough to be called a complete success, primarily because too many people did not believe they were being ordered by officials to evacuate. The limited usefulness of the hypothetical response data is also apparent.

Evacuation Timing

In responses to hypothetical hurricane scenarios, 40% to 50% of those interviewed before Hugo said they would evacuate when a watch was posted, *before* officials indicated they should leave. The behavioral analyses indicated that a variety of response curves were plausible, depending upon various warning scenarios, but suggested that no more than 10% to 15% of the evacuees were likely to leave before evacuation notices were issued by officials. In Hugo officials in different locations said various things at certain times, but overall the behavioral analysis figures were very close to the mark. If anything there was slightly more early response in Hugo than behavioral analysis guidelines suggested.

Type of Refuge

In hypothetical response surveys 37% in Beaufort, 40% in Charleston west of the Ashley, 49% on the Charleston peninsula, and 35% in Myrtle Beach said they would go to public shelters if they evacuated. The behavioral analyses cautioned that hypothetical shelter use is normally twice actual. Shelter use assumptions in the behavioral analysis labelled "cautious" (i.e., attempting not to underestimate demand in normal circumstances) were 15% for Beaufort, 15% for Charleston west of the Ashley, 30% for the Charleston peninsula, 20% for moderate-risk areas of Myrtle Beach, and 5% to 10% for high-risk barrier island and beaches. (The exception to the last case was St. Helena island, a socially close-knit, predominantly black community, where shelter use was projected at 40%, compared to 62% who said they would use shelters.) Shelter use in Hugo was generally lower than the numbers cited in the behavioral analyses, particularly in moderate-risk to low-risk predominantly white areas. The behavioral analyses did, however, point out that in early evacuations for severe storms more evacuees would leave the local area, causing shelter use to be lower, and that if officials took actions to discourage shelter use, it would be lower. Both conditions appeared to pertain in most locations during Hugo, especially in Charleston and Beaufort where shelter use was lowest and deviated most from the norms cited in the behavioral analysis. In Myrtle Beach 18% of the original hypothetical response interviewees used public shelters, almost exactly the figure indicated by the behavioral analysis. Behavioral analyses should provide a numerical adjustment for special circumstances affecting shelter use rather than simply a directional adjustment, and more situational guidelines rather than place-specific estimates should be provided in the analyses. Those practices are in fact the norm in most contemporary behavioral analyses, the process having evolved since the South Carolina studies were completed. Behavioral analyses should also project demand for in-county and out-of-county public shelter separately. The bulk of public shelter demand was assumed in the behavioral analyses to be in-county, but a numerical distintion was not made in the report. (In that sense, the behavioral analysis model actually projected demand more accurately than the overall comparison cited above indicated.) The issue of non-white demand for shelters being greater than white demand across income groups is a factor that needs further consideration.

South Carolina officials have estimated that 256,000 people evacuated in the state during the Hugo threat, and Red Cross records indicated that 94,000 were registered in public shelters, almost half in inland shelters. Those figures seem to imply that 37% of South Carolina's evacuees went to public shelters, which is almost certainly not the case. The figures also appear to conflict with the survey data indication that only 2% of the evacuees who went out-of-county went to public shelters. It is possible that there were substantially more than 256,000 evacuees, including many from low-risk areas not included in the sample survey, or that there were fewer than 94,000 people in public shelters seeking refuge from the storm. It is also possible that those in shelters include people seeking refuge *after* the storm.

Destinations

In hypothetical response surveys 45% from Beaufort, 50% from Charleston, and 50% from Myrtle Beach said they would go to out-of-town destinations when evacuating. The behavioral analyses indicated that 40% from Beaufort, 45% from Charleston west of the Ashley, 35% from the Charleston peninsula, and 60% to 70% in Myrtle Beach (the latter for a severe storm with a timely evacuation) would leave the local area. The behavioral assumptions were very close in Myrtle Beach, but low for the other areas. Here too the analyses indicated that early evacuations would see more people going inland, but no numerical guidelines were given except for Myrtle Beach. The effect of actions by public officials, which was largely responsible for the large out-of-town evacuation in Hugo, was not addressed explicitly in the behavioral analyses as it was in the discussion of shelter demands. Again, the norm in contemporary behavioral analyses is to provide explicit numerical guidelines for such scenarios.

Vehicle Use

Hypothetical response data indicated that about 65% of all available vehicles would be used in evacuating households, and the behavioral analyses recommended using that figure for Charleston and Beaufort and using 70% to 75% for Myrtle Beach. Actual use was within five percentage points.

Response Outside South Carolina

Officials' perceptions of public response, especially quantitative estimates thereof, are not as reliable as scientifically designed and administered sample surveys. No such surveys were conducted in North Carolina or Georgia, therefore no firm conclusions are possible for public response in those states. The evacuation in most of North Carolina appears to have been only partially implemented, making comparison between actual response and that projected in behavioral analyses for that area meaningless. A full-scale evacuation was implemented in coastal Georgia, and officials estimated that there were 175,000 evacuees, 6,000 of whom went to public shelters. If both figures are even close to actual response, the public shelter demand figures projected in the Georgia behavioral analysis were grossly exaggerated (15% for barrier islands and up to 65% for other areas). The Georgia behavioral analysis appears to have relied far too heavily on hypothetical response data. Although official estimates of other responses in Georgia aren't available, the Georgia behavioral analysis projections for early evacuation (during a watch, prior to recommendations or orders) also appear flawed.

Conclusions

Public response to the Hugo threat was extremely good and demonstrated once again the impact public officials can have on evacuation behavior. Over 90% of the respondents felt that officials had handled the evacuation well. More people probably should have evacuated than did, and more would have but did not believe that officials had ordered them to do so. Relatively few evacuees left prior to explicit recommendations or orders from public officials, but in some locations a substantial portion of the eventual evacuees had already left when the warning was posted Thursday morning. Public shelter use and local refuge demand were relieved considerably by officials' urging evacuees to seek other alternatives. Behavioral analyses upon which evacuation studies were based for South Carolina were quite accurate for most locations and most behaviors but would have been more useful had they provided numerical guidelines for planning for a greater variety of scenarios.