Learning the Lessons of Hurricane Ike

A Synopsis of Ongoing SSPEED Center Research Funded by the Houston Endowment

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SSPEED

RICE

MAY 2010

EXECUTIVE SUMMARY

The Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center located at Rice University is dedicated to scholarly research and education on severe storms that impact the Gulf Coast. SSPEED is comprised of world-class researchers from around the state of Texas with a common concern about the seriousness of the risks the Houston/Galveston region faces every hurricane season and the urgency with which critical and creative thinking is needed to avoid calamity.

In 2009, the Houston Endowment awarded SSPEED a grant to research the problems caused by Hurricane Ike in the Houston/Galveston area and to identify management practices that have the potential to provide input to future storm mitigation strategies. The results of this study will help us better understand the complex and interconnected nature of severe storms and how we should go about preventing damage from occurring in future storms. Although research is continuing and the final results are not due until summer 2011, several interesting findings are emerging.

1. A hurricane's storm surge is a significant and destructive force that has not been fully appreciated or integrated into the long-term planning of the Houston-Galveston region.
2. Hurricane surge and wave elevations are seriously underrepresented in engineering literature.
3. The convergence of hurricane storm surges and rainfall-related stream flooding represents a new and under-examined flooding phenomenon that could worsen damages due to surge flooding alone.
4. Over 65% of the water-crossing bridges in the Galveston Bay area require further investigation of their damage potential. It is these water-crossing bridges that have exhibited vulnerability in past hurricanes events. Damage to these structures could pose a threat to emergency response and recovery.
5. The mass movement of the estimated one million people that live in the evacuation zones is a challenge for existing emergency evacuation corridors. Furthermore, it does not appear that future transportation projects will be able to adequately support the current population nor the projected population growth of 500,000 people.
6. Refineries and chemical plants along the Houston Ship Channel are typically protected to the mapped flood plain elevation of approximately 14-15 feet, an elevation only a few feet higher than that experienced in Hurricane Ike and ten feet lower than a reasonable worst case surge of about 25 feet from a Carla-type storm.
7. A number of structural and non-structural alternatives exist that offer varying levels of protection to the Houston/Galveston region from hurricane surge flooding, rainfall and wind. A thorough examination and comparison of the economic costs, environmental impacts, social hazards and overall reliability and effectiveness of these alternatives should be completed before any final selections.
8. Researchers have identified 14 zones in the Galveston Bay region where different structural and non-structural alternatives could be used. Additionally, certain aspects of the proposed Ike Dike were evaluated.
9. In studies conducted in Florida and Texas, non-structural alternatives have been found to be consistently more effective in reducing flood damage than structural control measures. As such, they are being evaluated as an alternative to traditional structural options.
10. The ultimate solution(s) chosen to address the vulnerability of the Houston-Galveston area to hurricanes will dictate the social, economic and environmental future of the upper Texas coast.

In the wake of Tropical Storm Allison (2001), Hurricane Rita (2005) and Hurricane Ike (2008), the ever present worry of another severe storm hitting the Galveston/Houston Area motivated the Houston Endowment to fund the Severe Storm Prediction, Education and Evacuation from Disasters Center (SSPEED) to research how Hurricane Ike has impacted the region and what lessons may be learned from it. Under the direction of Dr. Phil Bedient and environmental attorney Jim Blackburn, SSPEED has assembled a team of academic experts from Texas and around the nation. The research effort has been on going since July 2009 and is expected to be completed by summer 2011.

Hurricane Ike struck the Texas Gulf Coast on September 13, 2008. It was one of the most destructive hurricanes to hit the United States. The storm surge devastated portions of the Galveston/Houston coastal area causing over $30 billion in damage and dozens of deaths. In Galveston, the impact was so serious that an estimated 10,000 residents have not returned. Yet with all this destruction, the Galveston/Houston region is fortunate. If Hurricane Ike had hit 30 to 50 miles down the coast, the devastation would have been remarkable; the cost could easily have exceeded $100 billion and hundreds might have died, as was the case with Katrina. The SSPEED team is concerned that the threat represented by the storm surge has not been fully appreciated or incorporated into our thinking about settlement patterns around Galveston Bay.

Hurricane Ike is a difficult storm to categorize. It struck land as a strong Category 2 storm[1]. However, the destructive storm surge generated by Hurricane Ike was both deep and wide, covering most of Texas east of Galveston Bay with at least a fifteen foot surge. As can be seen in Figure 1, the surge tide extended from the east side of Galveston Bay into Louisiana, causing significant flooding of over 200 miles of coastline.

The actual inundation area was extensive on the east side of Galveston Bay and less so on the west side. Nevertheless, all low-lying coastal areas were flooded. Waves came across Follets Island in Brazoria County, Galveston Island beyond the sea wall and the Bolivar Peninsula. The City of Galveston behind the sea wall was flooded from the bay-side rather than the Gulf-side. Parts of Bolivar Peninsula and the community of Gilchrist were leveled, along with much of Crystal Beach and many of the beach-front houses. On the west side, the major damage was caused by "back-side" winds that generated large waves down the length of Trinity and Galveston Bay. The "back-side" winds and large waves pounded communities such as San Leon, Bacliff and Kemah in Galveston County and Seabrook and Shoreacres in Harris County. Massive flooding shut down the City of Galveston for weeks after the passage of Ike.

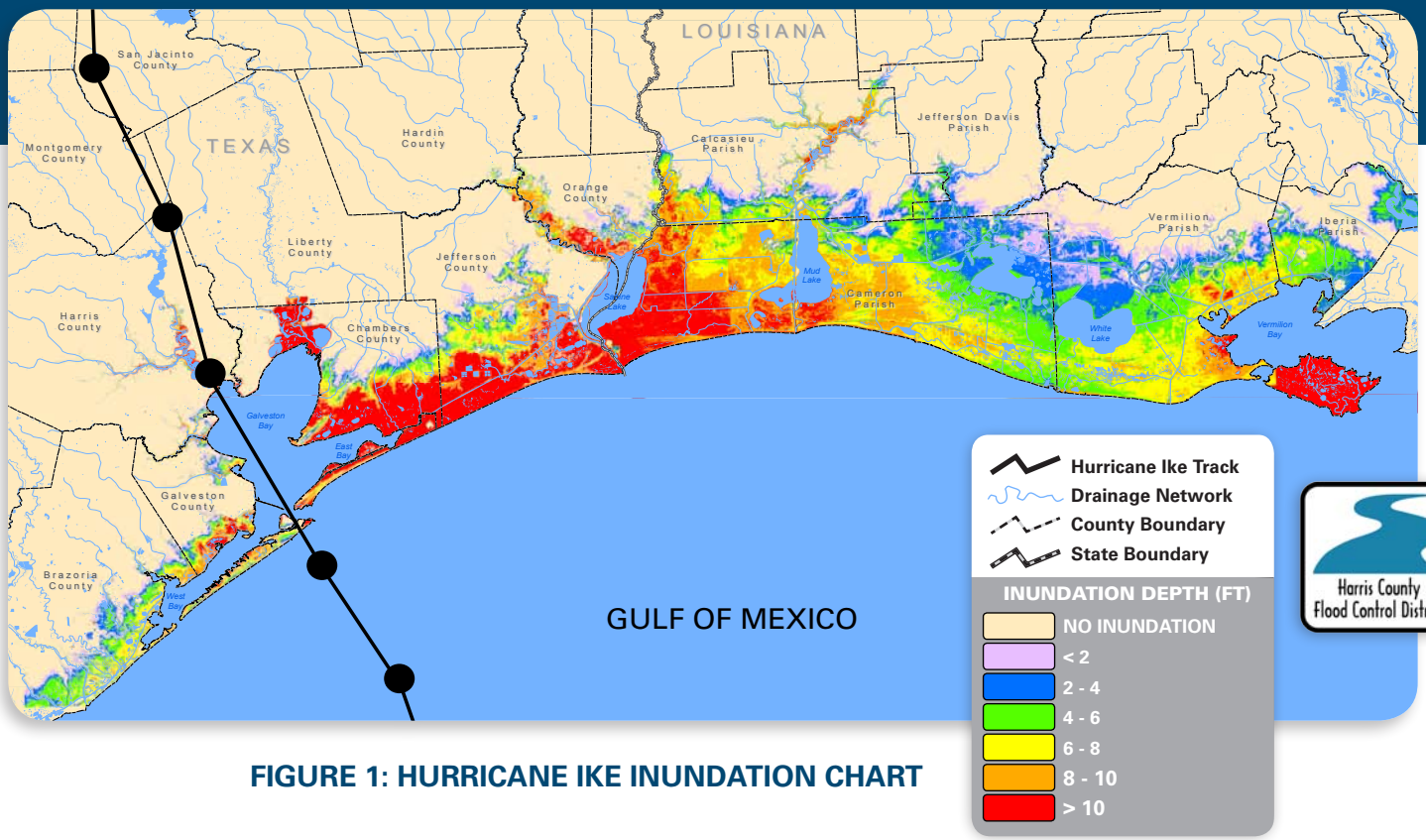


FIGURE 1: HURRICANE IKE INUNDATION CHART

RESEARCH PROJECTS
IMPACT OF FUTURE HURRICANES ON INFRASTRUCTURE

The threat posed by a major hurricane in the Houston/ Galveston area continues to be high for the region and nation. A reasonable worst case storm scenario (such as Hurricane Carla) could generate a 25-foot surge tide in the upper portions of Galveston Bay, have wind speeds of 150 miles per hour and drop 12 inches or more of rainfall within a few hours. While we have yet to see such a storm in the region, there is no doubt that significant amounts of industrial, residential, commercial and transportation infrastructures are extremely vulnerable.

In order to assess this vulnerability, the SSPEED Center is studying the overall area subject to surge flooding, finding the relationship between surge flooding and rainfall-generated inland flooding, evaluating surge impact in the Houston Ship Channel complex, assessing the regional bridge infrastructure, analyzing non-structural and structural control methods, and quantifying hurricane evacuation capacity.

The surge before the storm swamps Galveston Island, Texas, and a fire destroys homes along the beach as Hurricane Ike approaches Friday, Sept. 12, 2008. (AP Photo/David J. Phillip)

Houston Ship Channel - Dr. Hanadi Rifai and her group at the University of Houston are evaluating the vulnerability of the Houston Ship Channel (HSC) industries to a hurricane (see Figure 2). The HSC is one of the busiest waterways in the United States and is home to the nation's largest petrochemical complex. Within the HSC is the Port of Houston, the largest foreign tonnage port in the U.S. The Port provides $118 billion in annual economic benefit to the state of Texas. The Coast Guard estimates that a one-month closure of a major port like Houston would cost our national economy $60 billion. The HSC is so strategically important that the Department of Homeland Security has identified it as one of the most important areas in the country to protect against terrorism.

Environmental regulations for hazardous waste, oil spill contingency planning and wastewater plants require protection to the elevation of the one-hundred year flood plain as set out in Federal Emergency Management Agency's (FEMA) flood plain maps. Along the Houston Ship Channel, typical flood plain elevations range from 14 to 15 feet above sea level. This is significantly lower than what is needed to protect the projected 20 to 25 foot surge tide in a 100 year event. The role of Dr.'s Rifai's work is to understand the extent of the risk posed to major industrial facilities and their hazardous products and waste by hurricane surge. As of the spring 2010, various hurricane scenarios are being run and are being overlaid on the industrial data base.

photo: Bryan Carlile, Beck Geodetix

FIGURE 2: HOUSTON SHIP CHANNEL

Surface elevations along a section of the Houston Ship Channel used for hurricane surge risk analysis of industrial facilities. Highest risk elevations (low lying areas) presented.

Elevation data taken from airborne LiDAR collected in 2003. Resolution is 52 feet.

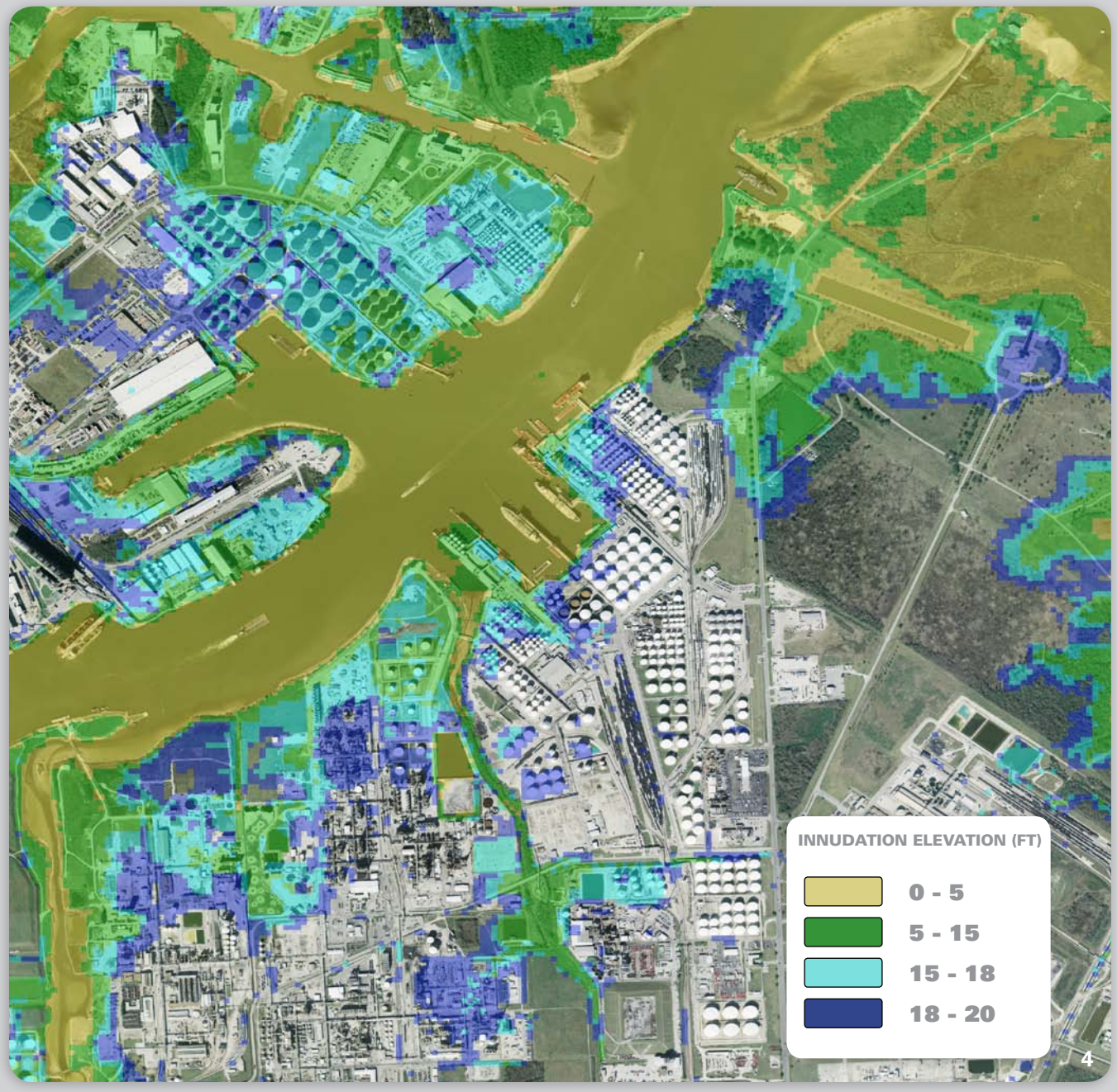
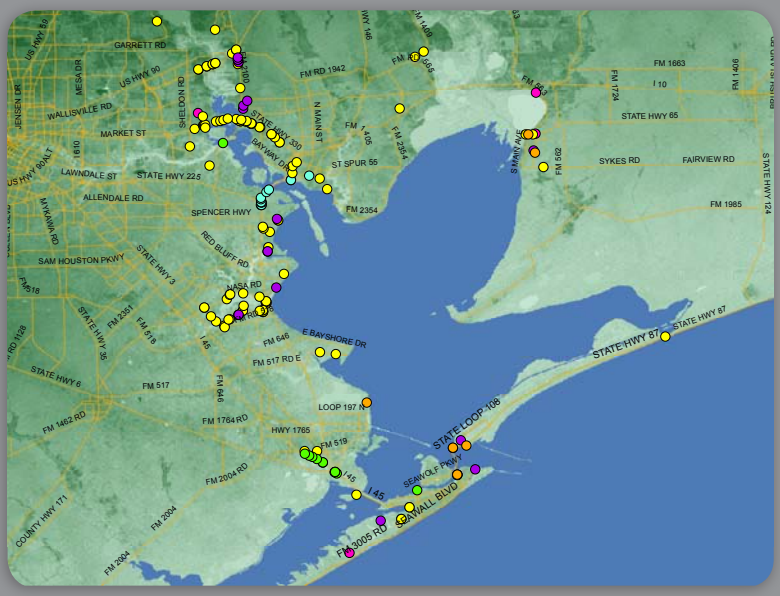


photo: Colin Hill

Bridge Structures - Dr. Jamie Padgett of Rice University is completing an inventory of bridge structures adjacent to Galveston Bay. The primary goal of Dr. Padgett's work is to compile a database regarding bridge elevation, bridge construction date, and construction material and plans in order to better understand which of these bridges are the most vulnerable to severe storms and need attention (see Figures 3 & 4). Additionally, various storm scenarios will be conducted to determine the extent of inundation possible, the potential for major structural damage, and likely post-hurricane availability of routes for emergency response and recovery.

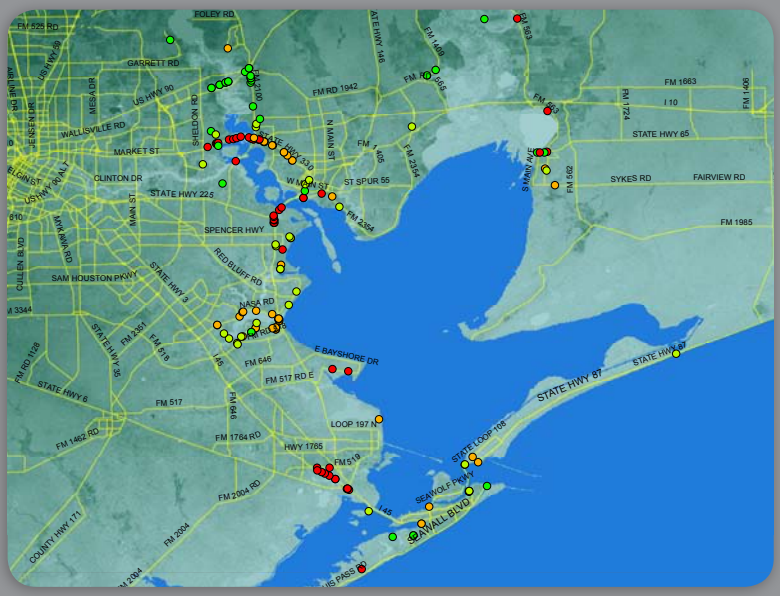
Dr. Padgett's Hurricane Ike reconnaissance and data collection indicates that over 45 bridges in the greater Galveston area were documented as suffering some form of damage from the event. Their findings indicate that over 65% of the water crossing bridges in the Galveston Bay region have simple supported concrete spans. Depending upon other details, these bridges may be the most susceptible to structural damage as indicated in past hurricane events such as Katrina and Ivan.

FIGURE 3: CLASSIFICATION OF BAY AREA BRIDGES



MSC CONCRETE
MSC STEEL
MSSS CONCRETE
MSSS STEEL
OTHER
SS CONCRETE

FIGURE 4: AGE OF BAY AREA BRIDGES



1910 - 1956
1957 - 1970
1971 - 1984
1985 - 2005

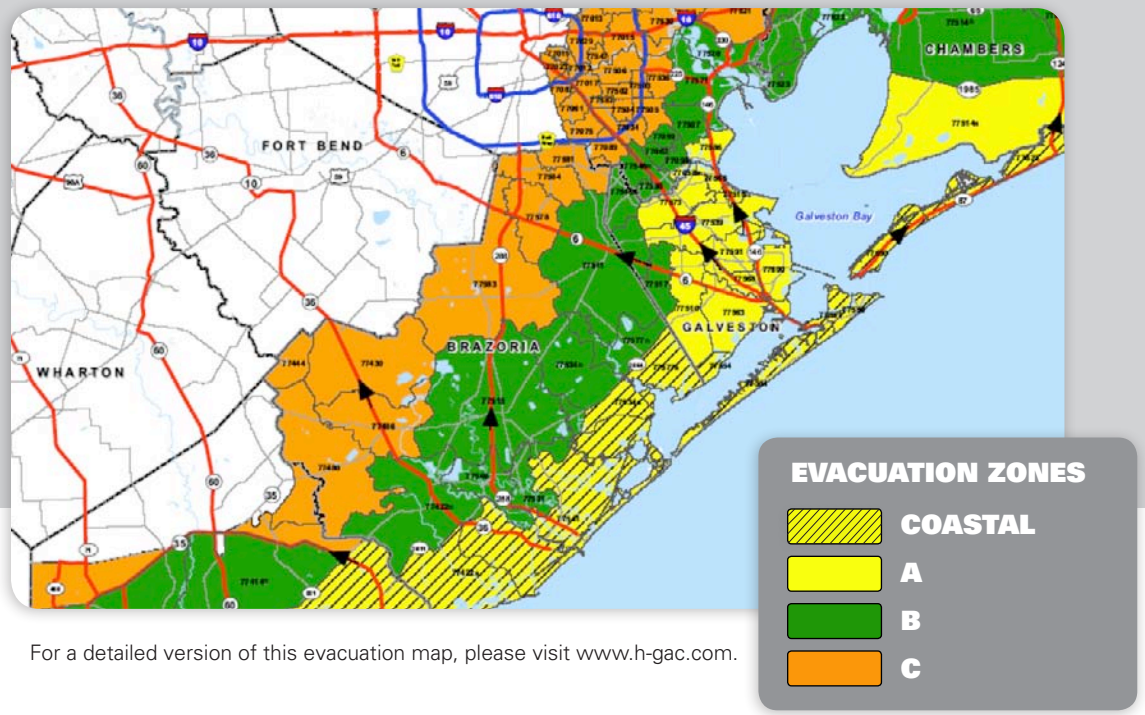
Hurricane Surge Flooding And Rainfall-Related Overlap - Dr. Bedient of Rice University is developing computer models of the geographic overlap between hurricane surge flooding and rainfall-related stream flooding. In particular, this research is most concerned about timing issues in the arrival of the peak hurricane surge and peak rainfall runoff surge. If these two peaks significantly overlap, as they did during Ike, then the extent of flooding could be much greater than predicted by either surge modeling or rainfall modeling.

To date, Dr. Bedient has successfully modeled Horsepen Bayou in the Clear Lake area with replications of the surge and rainfall peaks using non-steady state modeling techniques. The next step is to apply these techniques to the Buffalo Bayou/Houston Ship Channel area to determine the overlap of surge and rainfall peaks. This would help us evaluate the feasibility of the construction of flood control gates where the Houston Ship Channel enters Galveston Bay.

Roadway Capacity for Evacuation - Hurricane evacuation is a complex set of issues dependent upon voluntary actions of a population to a perceived threat. The surge zones are plotted on maps and determined based on zip codes and level of inundation. The current evacuation strategy is to voluntarily vacate the lower lying areas sequentially starting with Zone A followed by Zones B and C (see Figure 5). In 2005, Houston-Galveston Area Council reports, an estimated one million people lived in the three evacuation zones. Population growth projections anticipate to increase by another 500,000 persons by the year 2035, leading to a total population of 1.5 million.

According to transportation expert and SPEED Center member, Dr. Carol Lewis of Texas Southern University, it will be virtually impossible for existing roadway capacity to provide for their safe evacuation. According to Dr. Lewis, our current roadway infrastructure does not have adequate capacity to evacuate existing populations much less to add another 500,000 to that list. Dr. Lewis will be advising the project team on the role of new transportation projects such as the Galveston/Houston rail line to aid our evacuation preparedness.

FIGURE 5: VOLUNTARY EVACUATION ZONES



For a detailed version of this evacuation map, please visit www.h-gac.com.

BEST MANAGEMENT PRACTICES
FOR SEVERE STORM ABATEMENT AND CONTROL

The Houston/Galveston region has always been vulnerable to hurricanes. Population trends demonstrate an increasing number of people, houses, industries and commercial structures would be harmed by a major hurricane. The social and financial costs for dealing with the consequences of our land-use choices are enormous. Information in the form of natural/social scientific research and public debate need to address some fundamental and critical issues before any management approach could be considered equitable and rational. For example:


photo: Bert Flores

What structural and non-structural options exist that will mitigate the damage, destruction and death that accompany severe storms? How do they compare with one another?

As we calculate the value of living and working in flood prone areas such as the coast, what are the financial, health and safety risks? What public policies will reduce risk?

What are the best land management methods available to mitigate risk?

There is no doubt that the question of which alternative(s) to select and implement is incredibly difficult and our choices will determine the long-term future of the upper Texas coast. No solution is without serious economic, social and environmental consequences. Moreover, no issue facing this region has the potential to affect the physical features and social structure of the Upper Coast as does the choice of how to best manage the health, safety and quality of life needs of Texans.

Recently, Dr. William Merrell of Texas A&M Galveston put forward his concept of the Ike Dike, a levee structure that initially was proposed to extend from High Island to Brazoria County along the Gulf Shoreline and utilized large gates to provide entry and exit through the Houston Ship Channel at Bolivar Roads and across San Luis Pass. In addition to large gates across the ship channel, the crossing at Bolivar Roads will require some type of levee in the water between the shore and ship channel. There are many details that need to be developed regarding this alternative including the storm size, the proposed levee height, the amount of sea level rise, the amount of wave run-up, etc... In turn, the answer to these issues will dictate the amount of land required for construction as well as the cost of construction.

This concept along with other alternatives will be considered in detail by the Gulf Coast Community and Recovery District, a local governmental corporation that has been formed by Orange, Jefferson, Chambers, Galveston, Harris and Brazoria Counties to study approaches to abate storm surge flooding.


photo: Bryan Carlile, Beck Geodetix


photo: Bryan Carlile, Beck Geodetix


photo: Jeff Nouis

Super Computer Modeling of Surge Using the ADCIRC Model - Computer models can be used in forecast/nowcast mode to predict coastal inundation due to surge for the purposes of evacuation and emergency management, and in hindcast mode to study the effects of proposed surge mitigation systems, coastal development and restoration, and long-term coastal resiliency. Dr. Clint Dawson at The University of Texas at Austin, in collaboration with groups at The University of Notre Dame and The University of North Carolina at Chapel Hill, has developed the Advanced Circulation (ADCIRC) model, which is a high-resolution simulator for modeling coastal ocean flows. The ADCIRC model has been used extensively to study Hurricane Ike, both as a forecast model and currently in hindcast mode. As part of the SSPEED center activities, we are studying "what-if" scenarios regarding proposed future mitigation strategies for the upper Texas coast. For example, an initial run of a hurricane Ike scale surge with and without the presence of the so-called Ike-Dike is shown in Figures 8 and 9.

FIGURE 8: HURRICANE IKE FLOODING

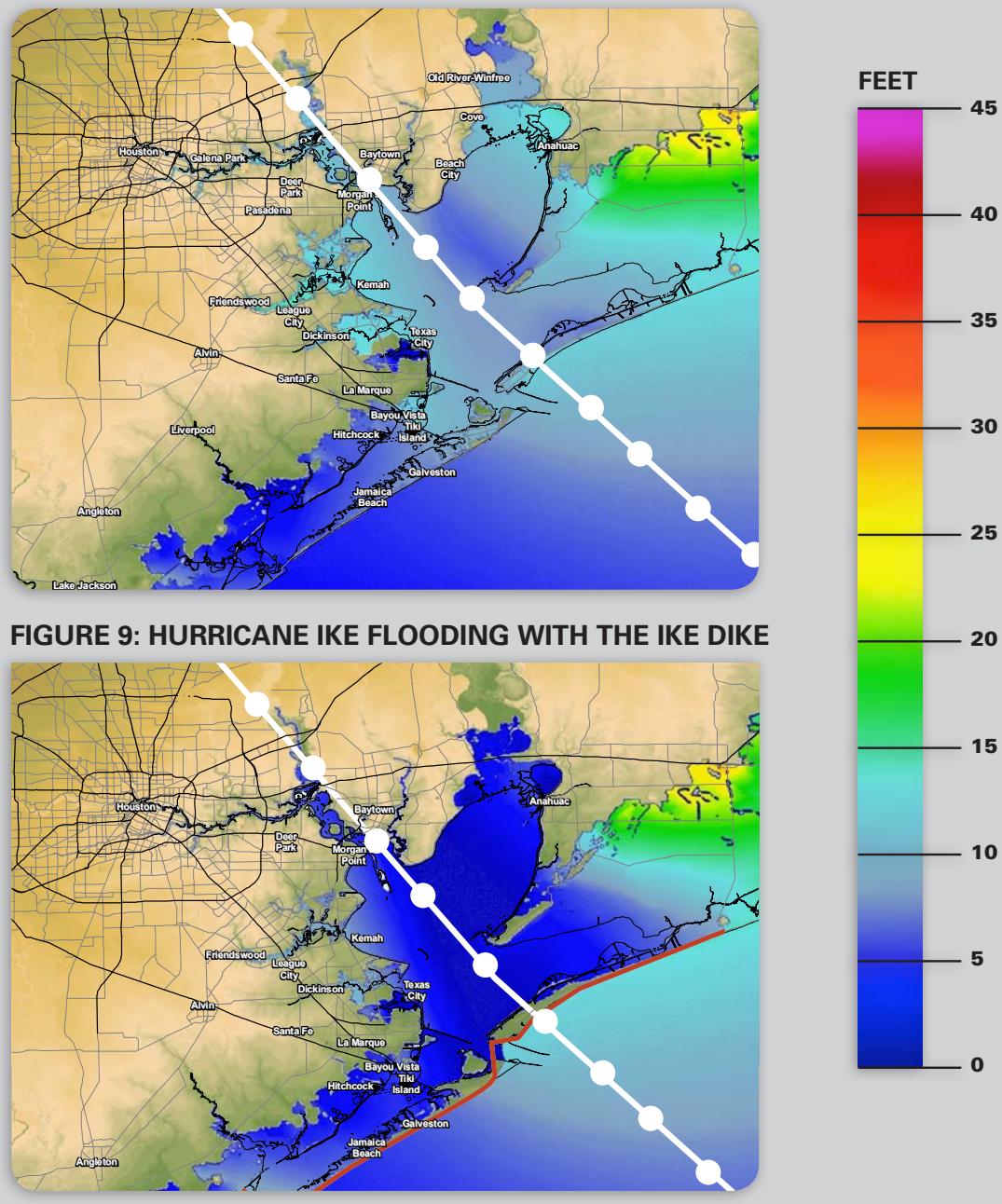


FIGURE 9: HURRICANE IKE FLOODING WITH THE IKE DIKE

As can be seen, there is still flooding around Galveston Bay although the extent of the inundation is reduced. The code could also be used to study non-structural mitigation techniques, such as restored or manufactured wetlands, raised dunes and barrier islands. In addition, Dawson's group collaborates with Dr. Gordon Wells at the Center for Space Research and the Texas Division of Emergency Management in using the ADCIRC model as a surge forecasting system for the Texas coast.

Other Structural Options - As part of the work undertaken by the SSPEED Center, a wide range of both structural and mixed structural/non-structural options are being developed along with purely non-structural alternatives. Two members of the research team - Mr. Thomas Colbert of the University of Houston School of Architecture and Kevin Shanley, President of SWA Group – have taken the lead in creating a conceptual approach for developing alternatives around the Galveston Bay system. Mr. Colbert and Mr. Shanley have divided the land areas surrounding Galveston Bay area into several different zones that have differing physical and social structures.

This "zone-specific solution" is a customized approach based on the notion that each zone is geographically unique and as a result must be taken into consideration when designing a landscape. An example is shown in Figure 10 where Mr. Colbert and Mr. Shanley have divided the land area surrounding the Galveston Bay complex into 14 areas with individual solutions proposed for different zones.

In this diagram, a flood control gate is proposed across the Houston Ship Channel (area 10) and a levee is proposed along Highway 146 protecting most of the Clear Lake area (area 9) and connecting with the existing levee protecting Texas City (area 8). Alternatives to this levee include a levee running along the shoreline of Galveston Bay and a number of smaller levees protecting individual facilities such as NASA and/or various industrial facilities in the Bayport complex. This map also proposes a levee surrounding the City of Galveston (area 6) while noting the existing levee around Freeport (area 1). On the other hand, no structural protection is shown in the diagram for several areas, including the West End of Galveston Island (area 5), Folletts Island (area 3), Surfside (area 2), Brazoria County adjacent to West Bay (area 4), Galveston County adjacent to West Bay (area 7), the Bolivar Peninsula (area 13), Jefferson County adjacent to the Gulf (area 14), Chambers County adjacent to East Bay (area 12) or Chambers County adjacent to Trinity Bay (area 11). For areas that will not have protective structures, Mr. Colbert and Mr. Shanley suggest that they would rely on non-structural approaches.

FIGURE 10: "ZONE SPECIFIC SOLUTION" APPROACH

1. **Freeport**
2. **Surfside Beach**
3. **Follett's Island**
4. **Brazoria County bottomlands**
5. **West end of Galveston Island**
6. **East end of Galveston Island**
7. **Galveston County bottomlands**
8. **Texas City and adjacent communities**
9. **West Bayshore**
10. **San Jacinto, Upper Bay, and the Houston Ship Channel**
11. **East Bayshore at Trinity Bay**
12. **Chambers County bottomlands**
13. **Bolivar Peninsula**
14. **Jefferson County bottomlands**

Ship Channel Gate

Levee Systems

Non-Structural Options - Efficacy of Land Use Management - Non-structural mitigation strategies are those that do not necessarily require the construction of structures such as levees, dikes or other physical impediments to flood waters. Instead, non-structural alternatives rely on planning strategies such as land acquisition, buffer zones, building elevation, building codes and other local regulations. As a starting point, the project team wanted to know how effective structural and non-structural alternatives have been in the past. This research task was addressed by Dr. Sam Brody of Texas A&M at Galveston. Here, Dr. Brody evaluated the effectiveness in reducing flood damage of both structural and non-structural alternatives, including land-use controls.

Based on research involving multiple local communities in Florida and Texas[2], Dr. Brody determined that non-structural measures were consistently more effective than structural measures were in preventing flood damage across the study area. Examining the relationship between specific mitigation techniques and insured flood losses helps identify which approaches may be most useful for local policy makers to adopt. After conducting statistical correlations, it became apparent that none of the structural approaches significantly reduced insured residential property damage from floods. However, stormwater retention or detention ponds were the most effective structural options of the mix. In contrast, almost half of the non-structural strategies evaluated in the 2005 survey were found to be significantly related to reduced National Flood Insurance Programs reported losses from flood events. Having a flood-specific policy within a local comprehensive or development management plan was found to have the strongest statistical correlation with damage reduction. This result indicates the effectiveness of comprehensive planning, which often is a spatial blueprint for future development patterns. Protected areas and setbacks from flood-prone areas were also local mitigation strategies significantly associated with reduced flood loss.

In association with other members examining non-structural solutions, Mr. Colbert and Mr. Shanley will develop and evaluate a number of scenarios informed by the work of Dr. Brody as well as that of Ms. Mary Kelly of the Environmental Defense Fund and Ms. Lynn Scarlett, visiting scholar at Resource for the Future. Ms. Kelly has compiled and summarized a number of existing plans developed by local governmental entities, including the plans of Galveston County for the recovery of Bolivar peninsula , the City of Galveston as well as Houston Wilderness's *A Strategy for Realizing the Economic Value of the Ecological Capital of the Greater Houston Region.* Ms. Kelly also has worked extensively in the Louisiana effort to structure a post-Katrina plan of action and will assist in coordination efforts. Ms. Scarlett is reviewing the policies and regulations of FEMA, it's National Flood Insurance Program, and related flood insurance issues. She is also reviewing policies, tools, and financial resources of the federal government, including the Department of the Interior, and evalutating institutions and options for partnerships.

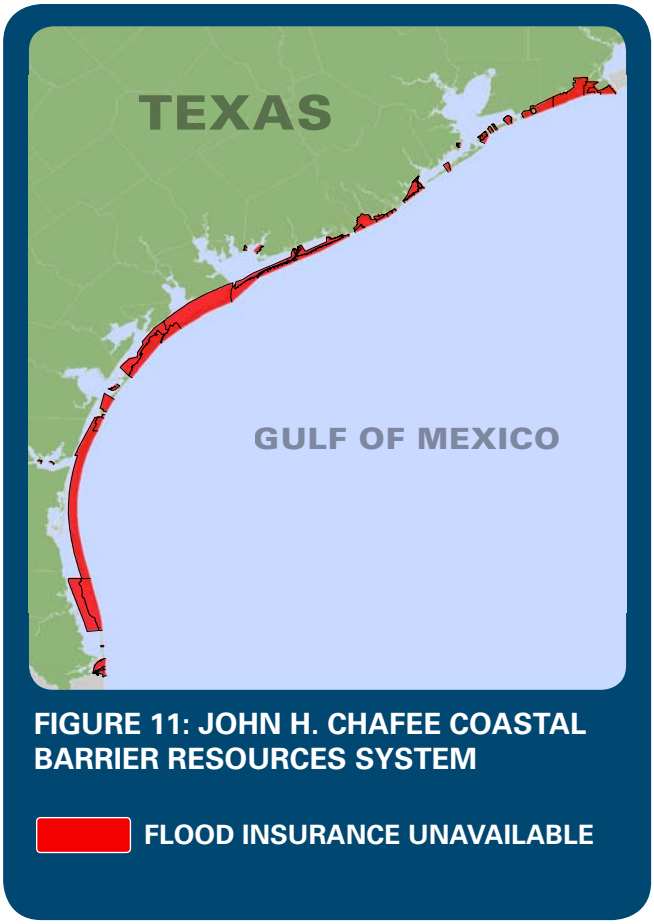
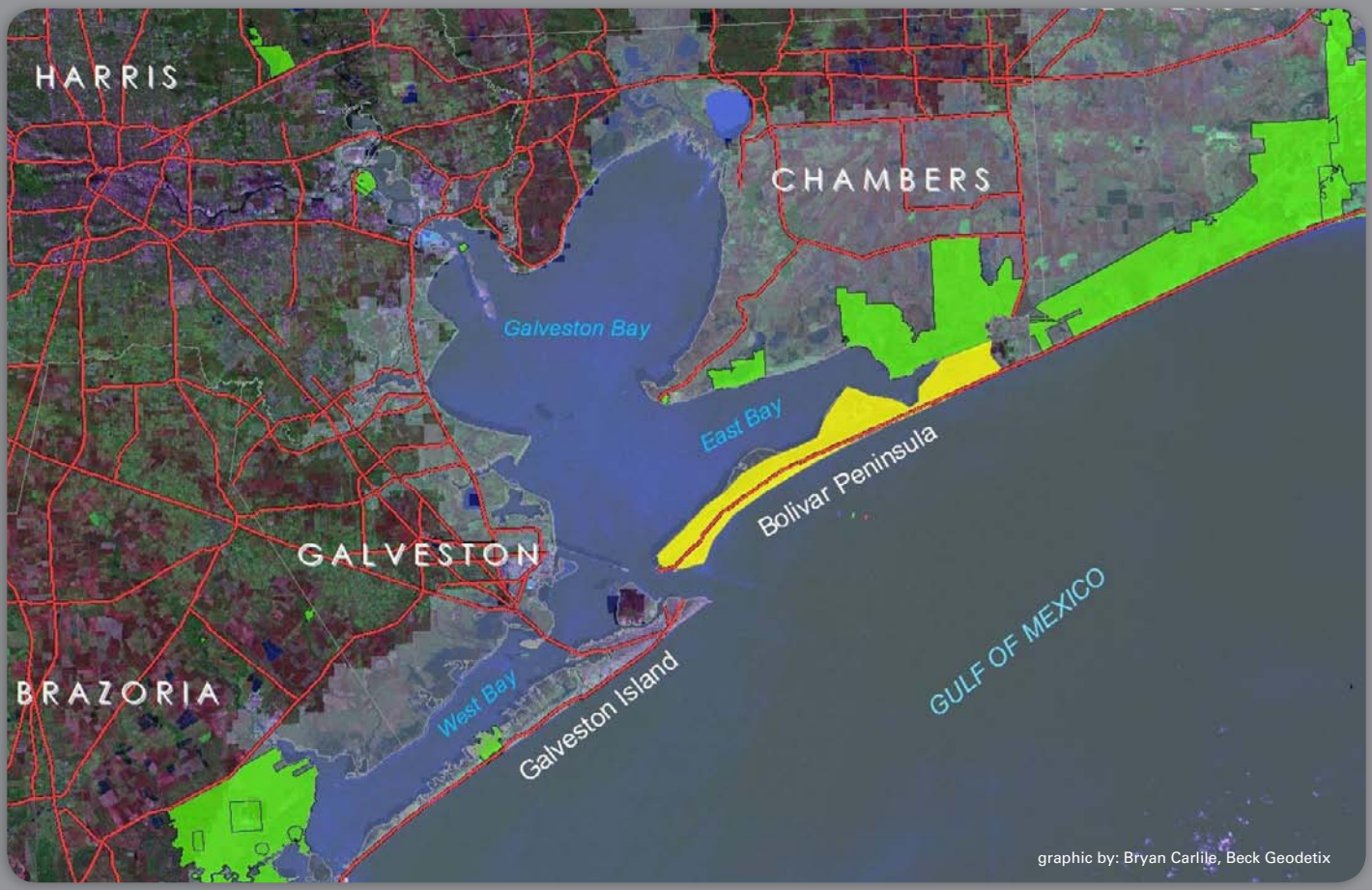


FIGURE 11: JOHN H. CHAFEE COASTAL BARRIER RESOURCES SYSTEM

One of the key regulatory issues is the role of FEMA flood insurance program, both in informing new development of flood hazard risks and in possibly enabling expensive new development in high hurricane hazard areas. Among the early findings are the fact that there is a major disconnect between projected hurricane surge tide flood levels and mapped one hundred year flood elevations. The highest 100 year flood elevation contained on FEMA flood maps in the Clear Lake area is 15 feet, yet a hurricane surge of about 22 feet would be anticipated in this area from a Category 4 storm such as Carla that hit the middle Texas coast in 1961. Additionally, FEMA flood insurance availability and its role in development is being seriously considered. In Figure 11, the areas subject to the Coastal Barrier Resources Act (CBRA) that make flood insurance unavailable are displayed. Among other issues are questions about whether this CBRA zone should be enlarged to include additional areas on the Texas coast. In such cases, one approach might be to allow coverage until the next major claim, then offer buy-out or the opportunity to rebuild without federal insurance. In this manner, taxpayers would no longer be subsidizing expensive development in high risk zones.

FIGURE 12: BOLIVAR PENINSULA (yellow) ALONG WITH NATIONAL WILDLIFE REFUGES AND STATE PARKS (green)



Other Non-Structural Approaches - In addition to regulatory approaches, there is a major role for either fee simple or easement acquisition to capture the natural value of ecological systems. Photos taken days after Hurricane Ike came ashore show water continuing to flow back into the Gulf of Mexico across the chenier plain in Jefferson County at the McFaddin National Wildlife Refuge. This demonstrates the massive amounts of water stored on the coastal prairie and wetlands. As part of an investigation of non-structural flood abatement alternatives, the potential for natural areas to store flood waters is being explored. Jim Blackburn, Professor of the Practice at Rice University and environmental lawyer, is leading this investigation. Mr. Blackburn will examine the legal and technical issues associated with using natural areas for flood water storage along with other non-structural alternatives.

Dr. John Jacob of Texas A&M Sea Grant College Program is working on identifying the areas where there are significant remnant wetlands that can be managed for flood storage. Additionally, researchers are examining the added benefit of utilizing this land for other uses such as carbon sequestration and wildlife value.

Dr. Ron Sass of Rice University is developing strategies for maximizing the amount of carbon dioxide (CO_2) that can be sequestered in restored wetlands and prairies. This adds to the concept of realizing natural values from a strategy of setting aside and preserving natural landscapes in low-lying coastal areas. Ultimately, the existence of multiple natural functions – flood storage, fish and wildlife habitat, and carbon sequestration – make setting these lands aside very attractive from an economic standpoint.

Together, these concepts may be considered when thinking of expanding existing national wildlife refuges along the coast, including McFaddin in Jefferson County, Anahuac and Moody in Chambers County and Brazoria in Brazoria County. Over time, sea level rise will necessitate the conversion of certain brackish wetlands to salt marsh and brackish wetlands will move further into the adjacent prairies. It is reasonable to anticipate this natural response and to allow this progression to occur over time on lands that have been preserved for their natural functions of flood abatement and storage as well as fish and wildlife enhancement and carbon sequestration. An image of this concept can be seen in Figure 12.

photo: Bryan Carlile, Beck Geodetix

Public/Private Partnerships for Bolivar Peninsula and Follets Island - The coastal barrier islands present one of the most difficult challenges. The Bolivar Peninsula was essentially destroyed by Hurricane Ike. There is a need for a creative and imaginative alternative to address this barrier peninsula as well as Follets Island that connects Surfside to San Luis Pass. In this regard, the project team is exploring the concept of a public/private joint venture to develop innovative concepts for the future of these two fragile coastal barriers. Here, it may be possible to develop a partnership between the federal and local governments to create a high quality recreational area. This area will be a major regional amenity and that will also be a high quality natural resource destination.

Consider the Bolivar Peninsula, it is connected to Galveston Island by ferry. Bolivar is home to two of the best bird-watching destinations in the United States – the Bolivar Flats and High Island, both managed by the Houston Audubon Society. Bolivar has excellent marshes, a connection to East Bay and has a developed but heavily damaged beachfront on the Gulf of Mexico. One possible solution is for a governmental partnership to purchase and develop approximately 25% of the existing lots damaged by Ike into a world-class recreational area on Bolivar and Follets Island. This recreational development could be augmented by redevelopment of the sand dune system that was virtually flattened. Another member of the research team – Dr. John Anderson, a coastal geologist – has identified a source of high quality sand that could be used to redevelop the dune system on both Bolivar and Follets Island. In this manner, a natural flood barrier could be constructed while improving recreational value. This concept is being fully developed by the team, including a land use concept by Mr. Colbert and Mr. Shanley.

CONCLUSION

Hurricane Ike was a destructive storm that adversely impacted the lives of millions of people in the Houston/Galveston area. The Houston Endowment awarded the Severe Storm Prediction, Education and Evacuation from Disasters Center (SSPEED) at Rice University a grant to research the problems caused by Hurricane Ike and to identify management practices that have the potential to inform future mitigation strategies.

SSPEED Center's investigation of Ike's impact on the region is nearing the midway point. Several interesting findings are being revealed. It is clear that the choices we make in the next several years will have a direct and significant impact on the physical form of Upper Texas coast – the location and style of land development, the extent of natural areas, and the extent of recreational resources. At the least, these decisions should be made with full information about alternative approaches and relative economic, environmental and social costs of those alternatives. It is to this end that the work of the SSPEED Center is directed.

Over the next year, the SSPEED research team intends to develop methods that are capable of providing better storm surge predictions for various sized storms and pathways.

1. We intend to continue our evaluation regarding the effectiveness of structural and non-structural mitigation strategies for controlling surge flooding.
2. We will explore the vulnerability of the refineries and chemical plants along the channel to various surge tides and conduct a modeling analysis of flood control gates across the outlet of the Houston Ship Channel into Galveston Bay.
3. We will propose concepts for risk disclosure in hurricane evacuation zones.
4. We will propose alternative solutions for various high risk areas adjacent to the Galveston Bay system.
5. We will create conceptual diagrams of future development of the Bolivar Peninsula.
6. We will explore in greater detail the role of the FEMA flood insurance maps and policies in mitigating flood-related damages.
7. We will identify institutional and funding concepts to implement various alternatives.

The SSPEED Center through its conferences, meetings, web sites and publications will host a well informed and vigorous debate about alternative concepts and futures for this region. Only in this manner can optimal, informed decisions be made.

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Acknowledgements

On behalf of the research team, the authors would like to thank the Houston Endowment for their financial support. It is only through their leadership that we have been able to bring together such a world-class team of researchers.

Footnotes

[1]The Saffir–Simpson Hurricane Scale is a classification used for some Western Hemisphere hurricanes where sustained winds exceed a minimum of 74 mph. The highest classification in the scale, Category 5, is reserved for storms with winds exceeding 155 mph. Hurricane Ike has caused a reevaluation of the way hurricanes are classified so they are more inclusive of other damaging factors such as rainfall and storm surge.

[2]Brody, Samuel D., S. P. Bernhardt, S. Zahran and J. E. Kang "Evaluating Local Flood Mitigation Strategies in Texas and Florida," Built Environment, VOL 35. NO 4. 2009. 492-515.

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