Coastal Identity and Resiliency: The Case of the Upper Texas Gulf Coast

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The coastline of the Houston-Galveston region is low and flat. For roughly a hundred miles the land slopes toward the sea at a rate of about one foot per mile. This part of the Texas coastline is only weakly protected by a string of narrow barrier islands that rise just a few feet above seal level. The few high points along this coastline are on top of the rare salt domes where small, isolated promontories can rise up to thirty feet above adjacent wetlands. Offshore, the broad, shallow continental shelf extends far out to sea before dipping into deeper waters. Plied by legions of shrimp boats and sports fishermen, the continental shelf supports an abundance of marine life that is nurtured by the region's extensive lowlying marshes. It contains huge deposits of oil and natural gas as well. But for all of the benefits that the region's continental shelf and low-lying land areas provide they also present dangers that are unparalleled in other parts of North America.

Like Louisiana and Mississippi, Texas is regularly visited by hurricanes. Larger diameter storms that move slowly across the surface of the sea are particularly dangerous. Their long arms sweep up waves, pushing storm surge ahead of them. In deeper water, wind driven currents swirl downward before rising again. In the shallow waters above the continental shelf the water has nowhere to go but in the direction it is pushed. If hurricane winds push it landward, the surge piles up higher and higher on top of the land. Surge tides well in excess of twenty-five feet above sea level are not unheard of. Waves ride on top of hurricane surge tides, slamming into buildings and creating debris fields that batter normal construction into rubble, scraping the land clear of factories, homes and communities that are otherwise safe.

A category two storm, Hurricane Ike caused thirty billion dollars in damage to the Houston-Galveston region. It is estimated that if Ike had hit forty miles to the west of its ultimate landfall or if it had been a more powerful storm the damage to the Houston-Galveston region would have reached ninety billion dollars, not including long term damage to the economy and the environment from the destruction of unprotected chemical and refining plants along the Houston Ship Channel. If a larger and more powerful storm had hit forty miles to the west of Ike's landfall, the damage would have been an order greater again. Damage to the national economy from destruction of a large percentage of the nation's chemical and refining capacity would have been beyond calculation. Given the limited capacity of current evacuation routes and the fact that many people refuse to evacuate, casualties and deaths from a hurricane in the Houston-Galveston region could easily be in the tens of thousands.

This level of destruction is not unprecedented in Texas. Seven to ten thousand deaths were associated with the hurricane of 1900. This storm destroyed the City of Galveston and created the impetus for the development of the Houston Ship Channel and the Port of Houston. In 1900 relatively few people lived on Galveston Island and along the coastline around Galveston Bay. But times have changed. It is estimated that within the next twenty-five years well over a million people will live in local tidal surge zones. During this time, ever-larger refineries and toxic chemical storage facilities will continue to be built in these areas.

These risks are well known by government officials and yet there are no credible plans to deal with

the threat of hurricanes. There are no plans to increase the capacity of evacuation routes to keep up with the exploding population. There are no development restrictions to prevent construction in the most dangerous areas or to require chemical plants to be able to withstand surge tide flooding. Adequate building codes for ordinary construction are only eforced in urban areas but much of the regions growth is outside of municipal boundaries. In many locations the threat of inland flooding from tidal surge is not reflected by appropriate minimum slab elevations or requirements for infrastructure hardening. Worse yet, many people do not understand the danger and government officials appear to be unwilling to act. Sea level rise and the threat of increasingly severe and more frequent hurricanes makes the hazards faced by the Houston-Galveston region even more pressing.

Figure 1. City of Galveston destroyed by 1900 hurricane.

The first post-Ike proposal to deal with tidal surge was put forward by Dr. Earl Merrill of Texas A&M University at Galveston. Dr. Merrill revived a 1970's era Army Corps of Engineers proposal to build a single, massive levee along the entire Houston-Galveston coastline. This one levee was to protect the entire Galveston Bay system and coastal islands. This levee, which he named the Ike Dike, was to be provided with enormous gates to allow ocean going shipping to enter the Port of Houston.

Initially the Ike Dike received enthusiastic support but serious problems soon became apparent. The proposal's vast scale meant that construction costs would be prohibitive, especially in today's economic environment. Aside from cost, the barrier islands upon which it was to be built are subject to severe erosion and migration. In some areas these islands move up to several feet per year. Additionally, the levee itself would destroy much of what it was supposed to protect. If built on the beach, where it could wash away very quickly, it would ruin the beach, beach houses and beach views. If it were built behind coastal communities, these communities would be destroyed by the next storm. The levee could actually make tidal surge more destructive in these locations. Finally, during Hurricane Ike, it was water from Galveston Bay that flooded the City of Galveston and not water directly from the Gulf of Mexico. Tidal surge from water inside the bay would require additional levees around developed areas even if the Ike Dike were to be built.

Even as the Ike Dike proposal was being proposed, a multi-disciplinary team of researchers was coming together to examine the issue of coastal resilience in the upper Gulf Coast. In 2007 the Center for Severe Storm Prediction, Education and Evacuation From Disasters was formed. Since its establishment, the SSPEED Center has developed a detailed, scientifically validated understanding of weather related threats that face the Houston-Galveston region. It has also developed plans to deal with these threats. The team includes civil and environmental engineers, environmental lawyers, computer and surge tide scientists, coastal and environmental scientists, oceanographers, transportation planners, meteorologists, and regional design and planning specialists. This diverse team has worked with various government agencies and non-profit organizations to develop a full menu of possible responses and implementation strategies. Among the alternatives that were examined three sorts of proposals quickly rise to the top: structural and non-structural design responses and informational programs.

STRUCTURAL RESPONSES

Areas where major economic, social, and cultural resources are concentrated must be protected. These protections can take various forms depending on the exact nature of the threat and specific local conditions. The most significant form of structural protections include levees and sea walls. Levees or sea walls can be built to resist storm surge and wave action. In order to do this it is necessary to anticipate maximum surge heights, sea level rise and where applicable, subsidence and erosion. Levees should

be designed to not only protect but also to enhance the coastlines that they protect. Shown below are a series of alternative levee alignments that have been proposed to meet the needs and opportunities presented by local circumstances. Levee heights are being established using the latest LIDAR surveying and super-computer based ADCIRC technologies. The effects of the various levee alignments on potential surge tide heights in adjacent areas is being evaluated, as are local environmental and community impacts. Economic, social and cultural impacts are being analyzed using the newly available census figures and GIS databases.

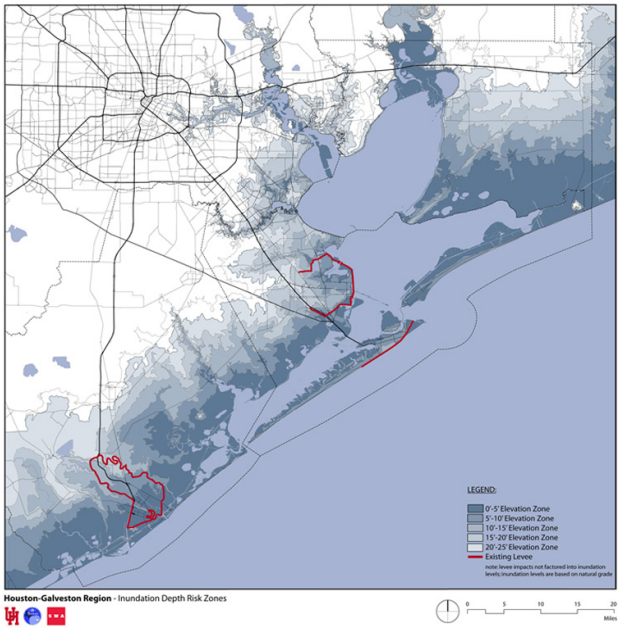

Figure 2. Potential inundation to 25'-0" in 5'0" increments, existing levees (in red) and roadway system.

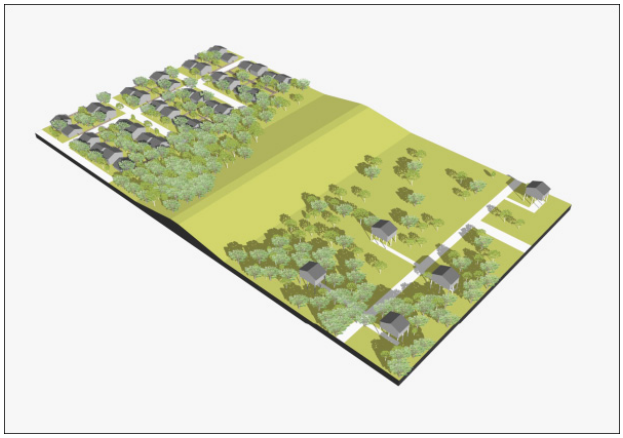

Figure 3. Typical neighborhood-levee design study.

Figure 4. West Galveston Bay, SH 146 alignment proposal shown. Other levees under consideration include protecting the Houston Ship Channel and completing the levee system around the east end of Galveston.

Where levees are not possible and risks of tidal surge and wave action are not so great, buildings

can be raised and hardened to resist hurricane winds and flooding. The technology for this kind of construction is generally understood. Except in the most exposed locations, construction standards based on appropriate wind speeds and local flooding conditions merely need to be enforced. However, some issues do require further study. The destruction of unprotected public infrastructure makes resettlement after extreme weather events an unnecessarily slow and extremely expensive process. Long delays in resettlement can threaten economic redevelopment and the very existence of communities. For all of these reasons, where scour and wave action have repeatedly destroyed bridges, roadbeds, sewer, gas, and water lines, septic systems and electrical distribution lines, new sorts of design solutions are required.

Raising base flood elevations also presents a number of urban design and planning challenges. Beach houses have long been raised to protect them from rising waters and wave action. During Ike, widespread destruction in older neighborhoods has demonstrated that realistic base flood elevations must be imposed in inland areas as well. In these locations, where slab elevations fifteen to twenty feet above adjacent grade are required it is not clear how neighborhood communities can be preserved, or how accessibility for the infirm and the elderly

Figure 5. Previously flooded home raised to new BFE in Galveston.

can be maintained. While some precedents for elevated larger scale residential developments can be found, particularly in the work of Ursula Emery McClure and Michael McClure at LSU, the investigation of elevated neighborhoods remains unexplored.

NON-STRUCTURAL RESPONSES

Where the structural responses described above are not possible and physical danger is extreme, a conventional governmental response would be to restrict new construction and curtail infrastructure investments. Even if the right of private property owners to build inthe most dangerous areas were to remain fully protected, subsidies of wind and flood insurance might reasonably be withdrawn. However, none of this is likely to be possible in the current political climate. In this circumstance a solution is required that is entirely voluntary and that will create economic opportunities for local landowners and local government. Such a solution may be found in the form of a National Recreation Area.

National Recreation Areas are not like National Parks or National Seashores. Their primary purpose is recreation rather than conservation. They allow a much more liberal use of land and a broader range of activities than is possible in National Parks. More importantly, today many NRA's are administered through creatively designed network governance agreements. Under the terms of these agreements, landowners, local business people, local and state government representatives, nongovernmental organizations and the National Park Service come together to form a governing board. The board is responsible for the administration of the NRA. Participation in the NRA and in the board is entirely voluntary.

Fortunately, although pressure to develop the coastline is growing, most low-lying areas long the Houston-Galveston coastline are as yet undeveloped. Most areas below five to ten feet in elevation are marshlands, a substantial percentage of which are already protected as wildlife sanctuary, parklands, and hunting leases. Existing conditions along the coastline would seem to be amenable to the development of an NRA, particularly in areas where the danger of storm surge is extreme. The challenge is to create economic opportunity in a risky landscape. Most local communities in the region are dependent on tourism, much of which is eco-

tourism related. Bird watching, fishing, kayaking, hunting and beach activities are extremely popular activities. The development of an NRA could create a national identity for an important but little known wilderness resource. It could create opportunities for coordinated marketing of eco-tourist and other recreational and cultural resources and activities. An NRA could start with available lands and later expand the area of protection as funding becomes available and as the economic benefits of participation become apparent. Local farming in some areas and carbon sequestration in saltwater marshlands can also spur participation in the partnership but local municipalities must also be involved.

Several areas along the region's coastline are already protected from storm surge. If an NRA is created, these communities would benefit from concentrated growth and from an increase in tourism. High Island to the east is at the center of one of the most important bird migratory routes in North America. It is on top of a major salt dome and safe from surge waters. To the west, Freeport, Texas is surrounded by ecological and historical attractions and protected by a local levee. The City of Galveston is already an important tourist destination. It is partially protected by a sea wall and many structures are already built to resist flooding. These areas would become anchors of the National Recreation Area. Gateway communities on major thoroughfares leading to the NRA would also benefit from increased tourist trade. An additional constituency for the development on an NRA is found in the community of people who are concerned for the protection of irreplaceable ecosystems including wetlands that support marine life, feeding grounds for migratory birds, oyster reefs, and endangered species. Improving appreciation of and access to these extraordinary resources is a fundamental premise of the proposal.

INFORMATIONAL PROGRAMS

One of the most important reasons that people move into surge tide threatened areas is that they do not understand the risks associated with moving there. People from other parts of the United States, people from other parts of Texas and even local peoplesimply do not understand that their homes could be submerged under a twenty five foot surge tide with waves crashing on top. There is no mandatory disclosure requirement for this when purchasing a property and there are few ways for the average resident to find out exactly what the threat to their homes and places of business is.

Figure 6. Gateway communities, and protected 'anchor' communities to benefit from proposed NRA.

A recent experimental program of placing tidal surge markers or bollards in at risk subdivisions was promising. Each bollard showed potential surge height above ground at a particular location depending on the category of hurricane. But homeowners and business people objected. They felt that these bollards would ruin their land values at a time when home prices are already soft. The signs have been taken down.

Even if surge tide gauges are unacceptable, information for residents of low-lying areas can still be provided. This information could be provided at web sites that provide real time and anticipated flooding locations and depths, and optimum real time evacuation routes from any location. The same web sites could reveal the location of local "refuges of last resort", or storm proof facilities where residents who have not evacuated can hunker down for the duration of a storm without worrying about rising floodwaters or falling trees. Such a web site would access the latest storm monitoring radars and forecasting technologies, providing up to date surge tide and rainwater flooding predictions related to local topography and traffic conditions.

A variety of other proposals for educational and risk awareness programs have been developed, including a proposal to require surge tide risk disclosure at real estate sales and inclusion of address-specific warnings in utility bills. The common thread that links all of these educational and risk awarenessproposals is the assumption that local residents must be provided with information that is required to make informed decisions about where to live and, in the event of a hurricane, how to evacuate flood prone areas.

IMPLEMENTATION

The SSPEED Center is based at Rice University and its researchers include senior faculty from a half dozen other universities, but its goals are not entirely academic. Its researchers are interested in developing proposals for implementation. Working with private landowners, non-profit organizations, local and state government agencies we hope to implement the following hurricane protection strategies for the Houston-Galveston region:

1. Where it is necessary and affordable, levees should be built to protect densely populated existing communities and major employment centers. When constructed, levees must be absolutely reliable and they should enhance quality of the physical environment and local ecosystems.
2. Where levees are not practical but the threat of surge tides exists, buildings and infrastructure should be made to resist surge tides, wave action and high winds. Appropriate Base Flood Elevations should be enforced. Critical infrastructure must be particularly resistant to hurricane force winds and surge tides. Local "refuges of last resort" should be made available in every neighborhood.
3. Where extreme risk exists, construction should be deincentivized. In order to accomplish this and at the same time build local employment, support economic development, and protect invaluable ecosystems, a National Recreation Area should be established.
4. In all at risk areas, local residents should be informed of the dangers associated with their property. Residents should also be provided with adequate real-time flood warnings and real-time evacuation routing information.

While these proposals are still a long way from implementation, the response from political leaders, NGO's and community groups is encouraging. As we move into more detailed analysis and design work the SSPEED Center will be working with local communities and government agencies to prepare detailed proposals for local districts. An important part of this process involves identifying and developing those design studies that are necessary to securing and improving the Houston-Galveston coastline. These studies represent an important opportunity for architects to help shape local identities to address the global challenges of population growth, extreme weather events and climate change in coastal areas.