Witness List -- August 24, 2010

I

Bill Order / Bill Format

S/C on Flooding & Evacuations
August 24, 2010 - 10:00 AM

Charge 2 -- 9-1-1 & Emergency Notification Services

ON:

De La Cruz, Pete Director, 9-1-1 Emergency Network (Southeast Texas Regional Planning Cmsn.), Beaumont, TX
Heffernan, Stan Chief Technical Officer (Greater Harris County 9-1-1 Emergency Network), Houston, TX
Kidd, Nim Chief (Texas Division of Emergency Management), Austin, TX
Mallett, Paul Executive Director (Commission on State Emergency Communications), Austin, TX
Schwender, Lavergne Executive Director (Greater Harris County 9-1-1 Emergency Network), Houston, TX
Wilkins, Jack Operations Manager (Galveston County Emergency Communication District), Dickinson, TX

Charge 2 -- Emergency Alert System & Mass Communication

ON:

Arnold, Ann Executive Director (Texas Association of Broadcasters), Austin, TX
Kidd, Nim Chief (Texas Division of Emergency Management), Austin, TX

Charge 4 -- Overview of Bills Passed from 81st Session

ON:

Allen, Joe B. (Self; Allen Boone Humphries Robinson), Houston, TX
Brookins, Linda Director, Water Supply Division (Texas Commission on Environmental Quality), Austin, TX
Garibay, Chuck President (Association of Water Board Directors), Spring, TX

Public Testimony -- Charge 2

ON:

Downs, Ben (Self; Bryan Broadcasting), Bryan, TX
Ley, Susan Director of Sales (Tech Radium), Sugarland, TX
Miller, Jeff (Self; Advocacy Incorporated), Austin, TX

Witness List -- October 18, 2010

Bill Order / Bill Format

S/C on Flooding & Evacuations
October 18, 2010 - 2:00 PM

Interim Charge #1 -- Regionalized Drainage Planning

ON:

Eckels, Robert Former Harris County Judge (Self)
Guerra, Aurelio County Judge (Willacy County), Raymondville, TX
Jones, Ken Executive Director (Lower Rio Grande Valley Development Council), McAllen, TX
Kidd, Nim Chief (Texas Division of Emergency Management), Austin, TX
Lambert, Sonia General Manager (Cameron County Drainage District #3), San Benito, TX
Oliver, David General Counsel (Allen Boone Humphries Robinson) (Fort Bend Flood Mgmt. Assoc.), Houston, TX
Ramirez, Rene County Judge (Hidalgo County), Edinburg, TX
Scott, Suzanne General Manager (San Antonio River Authority), San Antonio, TX
Sesin, Raul Planning Administrator (Hidalgo County), Edinburg, TX
Tamayo, Edna County Commissioner (Cameron County), Harlingen, TX
Wells, Gordon Dr. (UT-Austin, Center for Space Research), Austin, TX

Interim Charge #3 -- Evacuation & Hurricane Engineering

ON:

Kidd, Nim Chief (Texas Division of Emergency Management), Austin, TX
Ramirez, Rene County Judge (Hidalgo County), Edinburg, TX
Tanner, Larry J. Research Engineer (Texas Tech Wind Science Engineering Ctr.), Lubbock, TX
Wood, Sharon Dr. (UT-Austin, Dept. Chair Architectural Engineering), Austin, TX

Public Testimony

ON:

Hazen, Vincent Lone Star Logos & Signs (Self), Austin, TX

Public Testimony -- Charge #3

ON:

Garcia, Claudia (La Union del Pueblo Entero), Mission, TX
Martinez, Francisco (U.F.W. La Union Pueblo), Mission, TX
Soto, Eva (A Resource In Serving Equality (ARISE)), Alamo, TX
Torres, John-Michael (La Union Pueblo Entero), Mission, TX

Written Testimony: Dr. Gordon Wells

TESTIMONY BY GORDON WELLS

Center for Space Research, The University of Texas at Austin

October 18, 2010

Mr. Chairman and members of the committee:

Thank you for inviting me to join your discussion today.

My name is Gordon Wells, and I manage the real-time satellite Earth observation program at the University of Texas at Austin's Center for Space Research. For several years, I have served as a member of the Governor's Emergency Management Council and as science advisor to the Texas Division of Emergency Management. When a disaster threatens Texas, my team and I work with other scientists, such as the forecasters and modelers at the National Hurricane Center and West Gulf River Forecast Center, with first responders in the field, such as Texas Task Force 1, and with the emergency managers and public officials who guide the State's response to changing events during a crisis. Our primary mission is to interpret the information from numerical forecast models generated by supercomputers that we and other groups create as an early warning of an impending disaster. We then determine the geographic extent and magnitude of the damages that have occurred from a disaster based on satellite and aerial observations and impact modeling.

My testimony deals primarily with the Lower Rio Grande Valley and the threat of catastrophic flooding to Starr, Hidalgo, Cameron and Willacy counties. I want to address three questions:

1) In what ways does flooding impact the Lower Rio Grande Valley?

2) How did the region's flood control infrastructure perform following Hurricane Alex?

3) What challenges arise from the shared responsibility with Mexico to protect our populations from regional floods?

First, the Lower Rio Grande Valley represents a special case for coastal flooding in Texas. The region is located in the center of a large, naturally subsiding fan of sediments comprising the Rio Grande Delta. The main river channel and parts of the distributary system that were active in the recent geological past occupy the high ground with subsiding basins lying in between. Most of the population lives in the naturally subsiding basins. Circumstances are often made worse by networks of canals and transportation corridors that cross the terrain. In the Lower Rio Grande Valley, canal structures can represent the highest topographic features on the landscape and, therefore, create divides and obstructions to natural drainage. Fifty years ago, a sheet flood covering this landscape would have impacted agricultural fields, but suburban development (with accompanying impervious cover) places many residences and high-value commercial properties at high risk. Expanding development also adds to the complexity of modeling the region's vulnerability to future floods.

Topographic conditions conspire to expose the region to three different kinds of flooding. An illustration (Exhibit 1) included in my written testimony shows the surfaces subject to inundation according to historical experience and recent numerical modeling. The Lower Rio Grande Valley can be impacted by coastal storm surge from hurricane landfall, local sheet flooding from torrential rainfall and river flooding from the main stem of the Rio Grande and from combinations of all three kinds of flooding. Hurricane Beulah in September 1967 created the most damaging example of the combined impacts.

The greatest flood risk arises from river flooding that triggers the diversion of Rio Grande floodwaters into the interior floodway system of the bi-national Lower Rio Grande Flood Control Project of control structures and earthen levees. River flooding in the aftermath of Hurricane Beulah reached 220,000 cubic feet per second (cfs) at Rio Grande City and completely overwhelmed the original Lower Rio Grande Flood Control Project destroying thousands of Valley residences from Mission to Harlingen. In the 1970s, the project was reconstructed and fortified to accommodate floods of the magnitude created by Hurricane Beulah. Over the past twenty years, potential design flaws detected by modeling studies and confirmation of the deterioration of earthen levees by the collection of extremely accurate elevation surveys using aerial laser terrain mapping techniques have demonstrated that components of the Lower Rio Grande Flood Control Project are functioning at levels well below their original design capacity.

Since 2006, the International Boundary and Water Commission has taken initial steps to identify and begin repairs on the sections of the levee system most in need of rehabilitation. This effort encompasses both the primary levee bounding the main river channel and the levees along the interior floodway in Hidalgo, Cameron and Willacy counties. A significant portion of the early costs of levee repairs was borne by local jurisdictions in the Valley to accelerate the levee improvements before the next large-scale flood event. As an addendum to my written testimony, I have included a time line for the development of flood control infrastructure in the region that provides further details.

You might ask how well the flood control system fared in the aftermath of Hurricane Alex which made landfall last June 29.

Hurricane Alex was a very large storm that produced the second lowest surface pressure for a June storm in the history of the Atlantic-Gulf Basin. Very little rain from Alex fell directly over the Lower Rio Grande Valley. Instead, the dissipation of Hurricane Alex produced three separate flood waves from exceptionally high rainfall over areas in northern Mexico and the Big Bend Region in Texas. Flooding occurred immediately to produce a massive flood wave along the Rio San Juan and its tributaries in Nuevo Leon and Tamaulipas. Upstream from Laredo to the Big Bend above Amistad Reservoir, a second flood wave originated. And in the interior of Coahuila along the Rio Salado and its tributaries, truly extraordinary rainfall events created a third flood wave that did not reach the main stem of the Rio Grande for over a week after Alex's landfall. The three flood waves converged on the Lower Rio Grande Valley.

The magnitude of the flood waves prompted the emergency release of floodwater from Mexican dams in Nuevo Leon, Tamaulipas and Coahuila and from the International Falcon Reservoir, which reached its highest pool elevation in history on July 17. For the first time since Hurricane

Gilbert in September 1988, floodwaters were diverted into the interior floodways of the Lower Rio Grande Flood Control Project beginning on July 8, a process that has continued even as recently as the past week. The discharge of the Rio Grande at Rio Grande City reached a maximum of approximately 102,000 cfs, less than one-half of the flow that occurred following Hurricane Beulah in 1967, but sufficient to test many segments of the interior floodway system. Fortunately, as a consequence of the efforts of the local jurisdictions to fund recent repairs made to the most vulnerable levee sections, serious flooding was averted. I have included an illustration (Exhibit 2) of one of the critical repairs made to the levee along the Main Floodway located north of the City of Hidalgo.

Some local flooding did impact areas near the primary river levee at Havana, La Joya and Penitas, but major breaches did not occur. The Rio Grande at Rio Grande City stood above major flood stage for 26 consecutive days (July 9 - August 3). So much water entered the Rio Grande floodplain that unusual backflow conditions developed. These conditions were unanticipated and little understood by local officials. For instance, at Rio Grande City, the initial river crest of nearly 58 feet occurred after floodwater from the Rio San Juan entered the dry Rio Grande floodplain. The river rose quickly to major flood level, but did not threaten structures. Several days later following the emergency releases from Falcon Dam, the floodwaters had completely inundated Rio Grande floodplain, and a nearly equivalent river stage of over 57 feet at Rio Grande City resulting from backflow conditions produced widespread flooding across the entire floodplain near the town. County and municipal officials were puzzled why the same river stage would result in such different impacts. This highlights a problem with the standard practice of issuing flood alerts based upon river stage forecasts of the type developed by the West Gulf River Forecast Center. Operationally, the use of river stages in flood forecasts complicates and sometimes obscures the information that local officials need to take appropriate actions. A better warning system would employ advanced hydrodynamic modeling to issue inundation forecasts that specify the geographic area that will be covered by floodwater, its depth and duration. I have included a graphic (Exhibit 3) that we produced during the event to provide guidance to the public officials in Starr County and Rio Grande City.

Another issue that is raised in discussions about the Lower Rio Grande Valley is whether "pass-through flooding" is a problem. "Pass-through flooding" in the classic sense of the construction of upstream structures that magnify the impacts of flooding downstream do not exist in the region. While local development practices, including the construction of canals, causeways, highway ramps, etc., may serve to obstruct flows there is no organized attempt to "pass" floodwaters downstream or downslope to unprotected neighboring areas. There are some prevalent opinions in the Valley concerning what occurred following Hurricane Beulah in 1967 that might lead one to believe that floodwaters were deliberately diverted at the expense of downstream communities, but a careful inspection of engineering reports indicates that only unintentional structural failures occurred, and that the most famous of these at the Mercedes diversion from the Main Floodway to the Arroyo Colorado likely reduced the total impact of flooding downstream.

I would like to conclude my testimony today by considering the challenges presented by our shared responsibility for regional flood control with the nation of Mexico.

Hurricane Alex offers a great example of the problems associated with bi-national management of water resources particularly with regard to the observation and reporting of regional flooding. The vast majority of water entering the Rio Grande originates from sources in the mountains and interior basins of Mexico. With few exceptions, these inflows are unobserved or "under-observed" until they reach the main stem of the Rio Grande.

Even in the case of the most important reports issued from the major Mexican dams in Nuevo Leon, Tamaulipas and Coahuila, many hours of delay can occur between the time a measurement is made in Mexico and the information is relayed through the International Boundary and Water Commission in El Paso to the modelers at the West Gulf River Forecast Center in Fort Worth. I have included an illustration (Exhibit 4) of such a time delay in data from dam releases that occurred during a critical phase of the flooding affecting the Rio San Juan on July 1-3. When information of this kind is missing, flood forecast models can yield results that do not have an upper limit. We cannot determine if Texas will be dealing with a flood of 100,000 cfs, 200,000 cfs or a greater deluge in the Lower Rio Grande Valley. It becomes impossible to issue guidance about the level of impending threat.

In an age of near-instantaneous communications with satellite phones available, we should never experience delays in the delivery of such important reports about dam releases in Mexico.

Moreover, basic hydrographic conditions within the major Mexican tributary basins are currently not quantified. Over a week after the landfall of Hurricane Alex, the lower reach of the Rio Salado became inundated after choke flow conditions resulted in the formation of a temporary "lake" with a surface area comparable to the size of Falcon Reservoir that flooded the city of Anahuac more than 50 miles upstream from the constriction. I have included satellite images (Exhibits 5 & 6) of the new lake on the Rio Salado. The existence of this hydraulic impoundment was completely unknown in Mexico or the United States before Hurricane Alex because Mexican data for topographic elevations and river channel geometry are so poor. In this instance, the unknown and never modeled conditions happened to work to our benefit by delaying the arrival of the flood wave entering Falcon Reservoir from the Rio Salado. We may not be so fortunate during future floods in the region, when our ignorance of hydrodynamic conditions in Mexico may cause us to make an inaccurate forecast of the threat to the Lower Rio Grande Valley.

In essence, we are not going to be able to anticipate and plan for the threats posed by future floods along the Rio Grande until we have a uniform baseline of topographic and hydrographic information from which to model the entire contributing basin.

In conclusion, I hope the committee would urge the exploration of better modeling and simulation techniques to identify the full range of flood threats that could possibly impact the region. Plans for flood control infrastructure need to be based on supercomputing methodologies that represent hundreds of different flooding scenarios. I would also ask that the committee encourage the near real-time transmission of critical information from observations occurring in Mexico, preferably from data gathered by a more widespread reporting network of stream gauges along the major Mexican tributaries.

ADDENDUM TO TESTIMONY BY GORDON WELLS (UT-AUSTIN)

CHRONOLOGY OF FLOOD CONTROL LEVEE CONSTRUCTION AND INTERIOR FLOODWAY DEVELOPMENT IN THE LOWER RIO GRANDE VALLEY

1922 A near-record flood along the Rio Grande breaches the local levee at Mission leading to widespread property loss.

1924 The first local bond is passed to fund construction of a flood control levee along the Rio Grande from Donna to Brownsville.

1932 Under an agreement negotiated through the International Boundary Commission, the United States and Mexico agree to pursue mutual flood control projects on the Lower Rio Grande that would contain a design storm flood of 187,000 cfs measured at Rio Grande City. The system that includes river levees constructed along the Rio Grande and the development of interior floodways in Texas and Mexico becomes known as the Lower Rio Grande Flood Control Project.

1933 Following serious river flooding after a hurricane, the federal government begins to fund projects leading to a comprehensive flood control system in the Lower Rio Grande Valley of Texas. A series of WPA and military projects improves levees from Rio Grande City to Brownsville.

1944 Under the Water Treaty governing the Utilization of Waters of the Colorado and Tijuana Rivers and the Rio Grande, the International Boundary and Water Commission assumes responsibility for the construction and coordination of flood control measures in the United States and Mexico.

1951 Work is completed on the Lower Rio Grande Flood Control Project as conceived in 1932. The Mission Inlet is designed to divert water from the Rio Grande into the Interior Floodway in Hidalgo County.

1953 Construction of the International Falcon Reservoir is completed, providing storage capacity for 3.1 million acre-feet of water and offering flood protection from storm events affecting the main stem of the Rio Grande and its major Mexican tributary, the Rio Salado.

1967 Catastrophic river flooding following Hurricane Beulah overwhelms the levees along the Mission Inlet of the Interior Floodway causing widespread damage in Hidalgo County. The control structure at Mercedes regulating the flow of floodwater between the North Floodway and Arroyo Colorado fails causing extensive damage in the Harlingen area of Cameron County. The river discharge at Rio Grande City reaches 220,000 cfs exceeding the engineering design of the 1932-51 Lower Rio Grande Flood Control Project.

1969 Construction of the International Amistad Reservoir is completed, providing storage capacity for 5 million acre-feet of water and offering additional flood protection for events along the main stem of the Rio Grande and its major Mexican tributary, the Rio Conchos.

1970 The United States and Mexico agree to improve the infrastructure of Lower Rio Grande Flood Control Project to accommodate a design storm flood of 250,000 cfs measured at Rio Grande City. The IBWC supervises the design and construction of the Retamal Dam diversion in Tamaulipas and the Anzalduas Dam diversion in Hidalgo County. The Mission Inlet is abandoned. Construction occurs along the Main Floodway and North Floodway in Hidalgo and Cameron counties.

1988 Following the landfall of Hurricane Gilbert, floodwaters from the Rio San Juan cause the Rio Grande discharge at Rio Grande City to rise to 51,000 cfs. The Interior Floodway system is used for the first time since Hurricane Beulah. No failures occur in the system.

1992 The first modern hydraulic modeling study conducted by the U.S. Army Corps of Engineers concludes that the Lower Rio Grande Flood Control Project fails to meet its design criteria, and that levees are inadequate over 35 miles of the 274 total miles of levees in the system.

2004 A comprehensive hydraulic modeling study by the U.S. Army Corps of Engineers concludes that the Lower Rio Grande Flood Control Project would be overtopped along 38 miles of levees primarily upstream from Anzalduas along the Rio Grande and two miles of levee along the U.S. Interior Floodway. LiDAR elevation survey data collected by the University of Texas indicates additional areas where levee crests fail to meet their design height.

2006 The International Boundary and Water Commission releases the Rio Grande Flood Control System Rehabilitation Plan that identifies $125 million in levee construction projects in the Lower Rio Grande Valley. The report uses data from LiDAR elevation surveys to designate the sections most in need of repair.

2009 Congress appropriates $224 million to repair levees in the Lower Rio Grande Flood Control Project and build additional flood control infrastructure.

2010 Floodwaters from the dissipation of Hurricane Alex cause the Rio Grande discharge to rise to 102,000 cfs at Rio Grande City. Floodwater is diverted into the Interior Floodway system for the first time since Hurricane Gilbert.

Summary

The large-scale flood control system in the Lower Rio Grande Valley has developed in three phases: **1)** The 1932-51 design and construction of the original Lower Rio Grande Flood Control Project believed to be capable of containing a flood of 187,000 cfs measured at Rio Grande City. This system failed catastrophically in the aftermath of Hurricane Beulah in 1967. **2)** The redesign and construction of new flood control infrastructure beginning in 1970 to accommodate a flood of 250,000 cfs. The new system diverted floodwater to the Interior Floodway in 1988 following Hurricane Gilbert, when river discharge at Rio Grande City reached approximately one-fifth of the new design criteria. **3)** The identification of design flaws and physical limitations of the modern flood control system using hydraulic modeling techniques beginning in 1992 and aerial LiDAR elevation surveys in 2004. Further modeling has identified the levee sections most in need of rehabilitation.

During the development of the flood control system, metropolitan populations in the Lower Rio Grande Valley have increased by factors of 6-10 (1930 population: Brownsville 22,021; McAllen 9,074; 2000 population: Brownsville 139,722; McAllen 106,414). The flood control system originally protecting farmland now must protect large suburban populations.

Written Testimony: Dr. Sharon Wood

Texas Senate Subcommittee on Flooding and Evacuations
18 October 2010

Testimony Regarding Design and Retrofit of Commercial/Public Structures for Hurricane Evacuation Shelters

Sharon L. Wood, P.E.

Mr. Chairman and Committee Members, thank you for inviting me to speak to you today. Recent hurricanes along the Gulf Coast have highlighted the need and importance of hurricane evacuation shelters. Several national standards have been adopted over the past ten years that govern to the design of hurricane evacuation shelters. I would like to discuss these design standards briefly today and provide an indication of the costs of designing or retrofitting commercial and public structures to meet these standards.

The American Red Cross was among the first organizations to develop guidelines for selecting hurricane evacuation shelters [1]. These guidelines address acceptable locations for shelters, structural design criteria, risks due to hazardous materials, and space recommendations for each shelter resident. These guidelines alone are not sufficient to design or retrofit a hurricane shelter, but they summarize the lessons learned during Hurricane Andrew in Florida in 1992. For example, many large public or commercial buildings in the immediate hurricane impact area are not viable emergency shelters because they are located within the storm surge inundation zone for a Category 4 hurricane, located within the 100-yr floodplain, located on a barrier island, constructed before modern structural design codes were adopted in the community, or constructed from unreinforced masonry or other structural material that is susceptible to wind damage during extreme storms.

Shortly after Hurricane Andrew, the State of Florida began a program to increase the number of hurricane evacuation shelters throughout the state [2]. In addition to adopting higher design wind speeds than the national standards [3] in several high-risk areas, the 2007 Florida Building Code [4] includes provisions that portions of new public school buildings must be designed as enhanced hurricane protection areas. These enhanced hurricane protection areas provide at least 20 ft^2 for each evacuee and are designed to provide emergency shelter and protection for up to 8 hours. Specific design requirements for enhanced hurricane protection areas include:

- The minimum floor elevation must be above the maximum storm surge inundation elevation associated with a Category 4 hurricane.
- Wind design loads are 15% higher than those for buildings with regular occupancy. (The enhanced hurricane protection areas must be designed as essential facilities in accordance with national design standards [3].)
- All door, window, and roof openings must be designed for impact caused by wind-borne debris.
- All roof systems must be rain resistant and anchored against wind uplift.
- Emergency overflow scuppers on the roof must be sized for 6 hours of rainfall associated with the design hurricane.

- At least one emergency vehicle access route must be above the 100-yr floodplain.
- Parking for evacuees must be at least 50 ft from the building to reduce the risk of rollover hazards.
- Landscaping around the building must not represent a laydown or impact hazard for the building envelope.
- A standby emergency electrical power system must be provided.

In addition to the design guidelines, special inspection of the enhanced hurricane protection areas is also required:

- Inspection of the building and emergency electrical systems is required during construction.
- All shutter systems, roofs, overflow scuppers, structural systems, and emergency power systems must be inspected before the hurricane season begins each year and after each major hurricane.
- All structural systems must be inspected and recertified for compliance every five years by a professional engineer.

The Florida Division of Emergency Management develops an annual report to document their progress toward increasing the number of hurricane evacuation shelters. The 2007 report [5] notes that buildings designed and constructed before the mid-1980s rarely meet the structural criteria in the American Red Cross guidelines [1] and typically require major structural renovations to serve as hurricane evacuation shelters. In most cases, renovation of these older buildings was not considered to be cost-effective.

Using the Florida Building Code, buildings constructed in accordance with the modern, national standards for wind loads [3] (buildings constructed since the late 1980s) can often be retrofit by installing window protection or reinforced doors [6] to address shelter requirements for debris impact. The average cost of retrofitting buildings in this category was approximately $150 per evacuee space (in 2007 dollars) [5]. The cost of complying with the Florida Building Code provisions for enhanced hurricane protection areas for new construction was estimated as increasing the cost of constructing a new school building by 3 to 6% [5].

In spite of the design standards for enhanced hurricane protection areas, significant structural damage (Figure 1) was observed at a modern, hurricane evacuation center in Arcadia, Florida during Hurricane Charley in 2004 [7, 8]. Approximately 1,400 evacuees were housed in the building at the time of that the roof and exterior walls began to collapse. After the hurricane, it was determined that the building had not yet been evaluated for compliance with the enhanced hurricane protection areas design requirements [7], raising the possibility that this shelter had not been designed in accordance with the Florida provisions. Wind damage to roofs, cladding, and gutters led to rainwater intrusion was observed in several other shelters, however [7, 9].

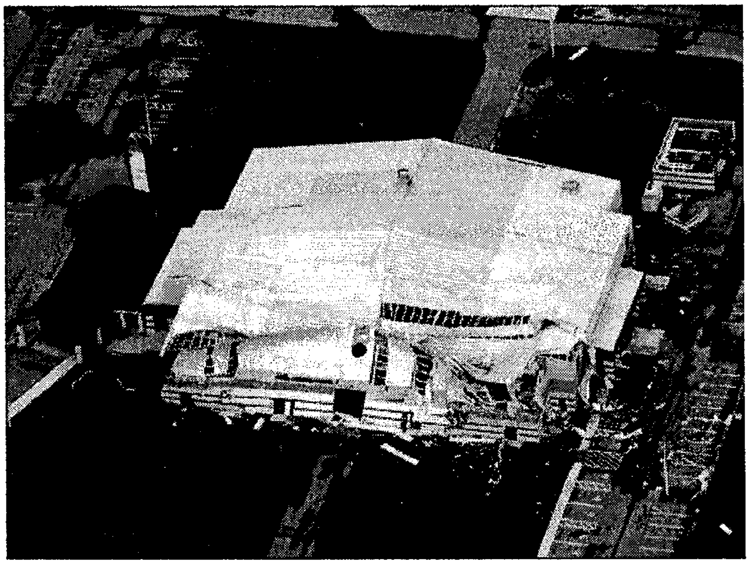

Figure 1: Turner Agri-Civic Center Damage Caused by Hurricane Charley [7]

More recently, two national standards have been developed that specifically address the design of hurricane and tornado shelters. The ICC 500 [10] provisions for community hurricane shelters are more stringent than the Florida Building Code [4] provisions for enhanced hurricane protection areas. For example, the design wind speeds are higher, design loads corresponding to debris missiles are considerably higher, and the minimum floor elevation must be above both the 500-yr floodplain and the maximum storm surge inundation elevation associated with a Category 5 hurricane.

The FEMA 361 provisions [11] for safe rooms are even more conservative than those in ICC 500 and are intended to provide "near-absolute protection" to the occupants. Because most residents are able to evacuate the immediate impact area before a hurricane, the FEMA 361 provisions are intended only for first responders and individuals who are physically unable to leave the immediate impact area [11].

The recent development of ICC 500 [10] and FEMA 361 [11] provides specific guidance regarding the design and construction of hurricane shelters and safe rooms. The 2009 edition of the International Building Code [12] adopts ICC 500 by reference. Therefore, these provisions will govern the design of hurricane shelters once communities in Texas adopt the 2009 IBC.

FEMA 361 [11] provides cost data from recent community safe room projects. Assuming a basic wind speed from the model building code of 140 mph, the incremental cost of hardening a portion of a new building to create a safe room with a 250-mph design wind speed is estimated to be 5 to 7% [11], based on the area of the safe room. The basic wind speed along the Texas Gulf Coast ranges from 130 to 140 mph [3]; therefore, these costs are considered to be representative of new construction in Texas, and are similar to the reported costs in Florida [5].

It is important to note, however, that observed damage during hurricanes is often attributed to minor changes from the original design [13]. Therefore, it is important that if Texas adopts a policy of constructing hurricane evacuation shelters, the requirements for periodic inspection of be adopted as well.

1. American Red Cross, *Standards for Hurricane Evacuation Shelter Selection*, ARC 4496, rev. January 2002. http://www.floridadisaster.org/Response/engineers/documents/newarc4496.pdf
2. http://www.floridadisaster.org/Response/engineers/library.htm
3. American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*, ASCE 7, 2005.
4. International Code Council, *Florida Building Code*, 2007, http://www2.iccsafe.org/states/florida_codes/
5. Florida Division of Emergency Management, *2007 Shelter Retrofit Report*, http://www.floridadisaster.org/Response/engineers/2007ShelterRetrofitReport.htm
6. State of Florida, Division of Emergency Management, "Issue Brief on the FEMA 361 Standard 'Design and Construction Guidance for Community Shelters' " 2008. http://www.davidopreyatt.com/wp-content/uploads/2009/05/fema361whitepaperfinal.pdf
7. Federal Emergency Management Agency, Mitigation Assessment Team Report, *Hurricane Charley in Florida: Observations, Recommendations, and Technical Guidance*, FEMA 488, 2005. http://www.fema.gov/library/viewRecord.do?id=1444
8. *Engineering News Record*, "New Florida Codes Bring Mixed Success," 2004. http://enr.construction.com/news/buildings/archives/040823-2.asp
9. Kilcollins, D., Reinhold, T., and Tezak, S., "Performance Standards and Expectations of Hurricane Shelters," presentation at Governor's Hurricane Conference, 2006, http://www.floridadisaster.org/Response/engineers/documents/06_GHC-PerfStds-of-Shelters.pdf
10. International Code Council/National Storm Shelter Association, *Standard for the Design and Construction of Storm Shelters*, ICC 500, 2008. http://www.iccsafe.org/Store/Pages/Product.aspx?id=8850P08_PD-X-SS-P-2008-000001#longdesc
11. Federal Emergency Management Agency, *Design and Construction Guidance for Community Safe Rooms*, FEMA 361, Second Edition, 2008. http://www.fema.gov/library/viewRecord.do?id=1657
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13. Federal Emergency Management Agency, Mitigation Assessment Team Report, *Hurricane Ike in Texas and Louisiana: Observations, Recommendations, and Technical Guidance*, FEMA 757, 2009. www.fema.gov/library/viewRecord.do?id=3577
14. Federal Emergency Management Agency, *FY 2011 Hazard Mitigation Assistance Unified Guidance: Hazard Mitigation Grant Program, Pre-Disaster Mitigation Program, Floor Mitigation Assistance Program, Repetitive Flood Claims Program, Severe Repetitive Loss Program*, 2010. http://www.fema.gov/library/viewRecord.do?id=4225

Written Testimony: Larry J. Tanner

Testimony to the

State of Texas

Texas Senate Subcommittee on Flooding and Evacuations

At the

Capitol Building,
Austin, Texas
October 18, 2010

Testimony Regarding

Mitigating Damage to Residential Structures from Hurricanes & Coastal Windstorms

Testimony of

Larry J. Tanner, P.E.
Wind Science and Engineering Research Center
Texas Tech University
Lubbock, Texas

Texas Senate Subcommittee on Flooding and Evacuations
Testimony Regarding

Mitigating Damage to Residential Structures from Hurricanes & Coastal Windstorms
by Larry J. Tanner, P.E.

Introduction

Thank you Mr. Chairman and committee members.

My name is Larry Tanner. I am an engineering researcher with the Wind Science and Engineering Research Center at Texas Tech University. I have documented 12 storms, tornadoes and hurricanes, in the last ten years, including the devastating Oklahoma/Kansas Outbreak of 1999, Hurricane Katrina in 2005, and Hurricane Ike in 2008. I was also a member of the FEMA Mitigation Assessment Teams for those storms. My CV is appended to this testimony.

Subcommittee Charge:

1. **Methods of mitigating hurricane damage to existing residential structures.**
2. **Methods of mitigating hurricane damage to new residential structures.**
3. **Comparable costs of these methods.**
4. **Recommendations relating to cost effective options to either retrofit or require new building structures to be built as shelters for use during evacuations.**

Background

According to the U.S. Census Bureau, as of July 1, 2007, 35.3 million people lived in areas of the United States most threatened by Hurricanes.[1] These areas are defined as the coastal portions of Texas through North Carolina and represent approximately 12% of the U.S. population.[2] Disaster losses paint a compelling picture of our economic and societal vulnerability to windstorms. From 1987 to 2006 the inflation-adjusted, insured losses break down as follows:[3]

$297.3 billion -	Total Disaster Losses
$137.7 billion (46.3%)	Tropical Cyclone Losses
$77.3 billion (26%)	Tornadoes
$19.1 billion (6.4%)	Earthquakes

Vulnerability will continue to increase due to a variety of economic and other factors, including the aging of our built environment, the percentage of the built environment constructed without use of model building codes, the increased cost of new construction, and the increase in coastal population.

Hurricane Hazards

The hazards of hurricanes and coastal storms include the following:

- Erosion of barrier sand dunes and foundation structures
- Coastal flooding, wave action, and storm surges
- High winds

Homes in Velocity Zones (National Flood Insurance Program - NFIP V Zones and Coastal A Zones) are vulnerable to wave action and storm surges if not elevated to or above the Base Flood Elevation (BFE) and properly constructed on an open and elevated foundation (piles), see **Figure 1**. The loss or alteration of the dune structures and vegetation can lead to erosion produced by wave and surge forces that can scour foundation piles and undermine the structure's stability. Although not subjected to wave and velocity surges, inland area homes in NFIP mapped Special Flood Hazard Areas (SFHA) should have appropriate foundation structures and their first floor elevated to or above the NFIP or jurisdictional Base Flood Elevation (BFE), shown in **Figure 2**.

Tropical storms and hurricanes produce winds far in excess of normal winds in inland and interior land areas. The wind forces will produce inward pressures on the windward face, outward pressures on the sides and leeward face, and depending upon the roof slope, outward pressures on the roof surfaces, see **Figures 1&2**. .

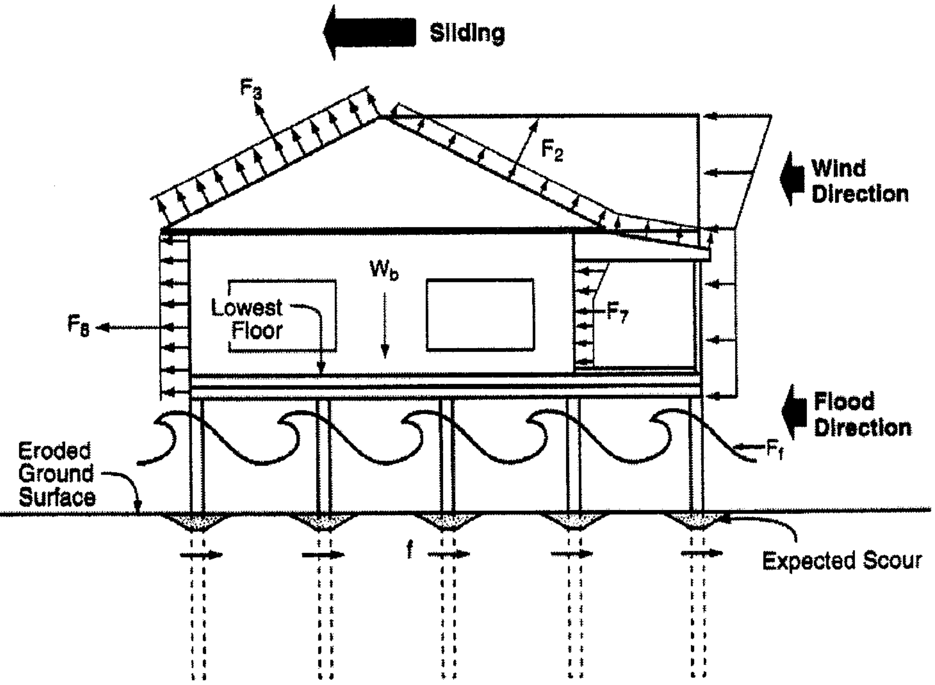
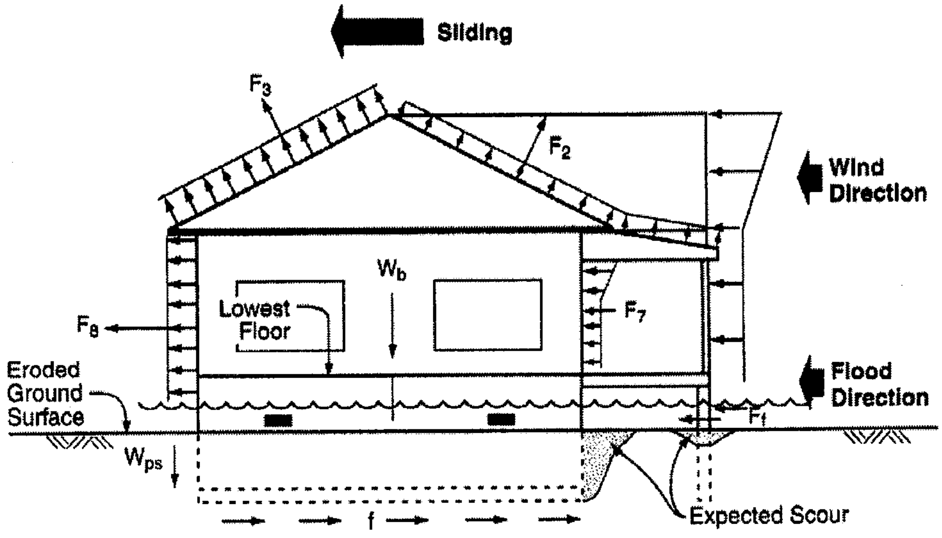


Figure 1



F = Wind Force
F_f = Flood Force
W_b = Building Weight (Including Foundation)
W_{ps} = Passive Soil Pressure
f = Frictional Resistance

Figure 2

Figures 1 & 2. Wind and water forces on coastal construction[4]

Construction Guidelines

Numerous surveys have been conducted over the years to determine the primary causes of building failures in hurricanes. Differences in building performance are routinely observed in adjacent structures. Initially, these differences were assumed to be the result of some anomaly in wind forces and water loads. However, post storm inspections and documentation routinely reveal this disparity to be the result of design and construction differences. In general, those homes that are better connected from roof top to foundation (load path) are more resistant to hurricane forces. **Figure 3** illustrates the concept of Load Path.

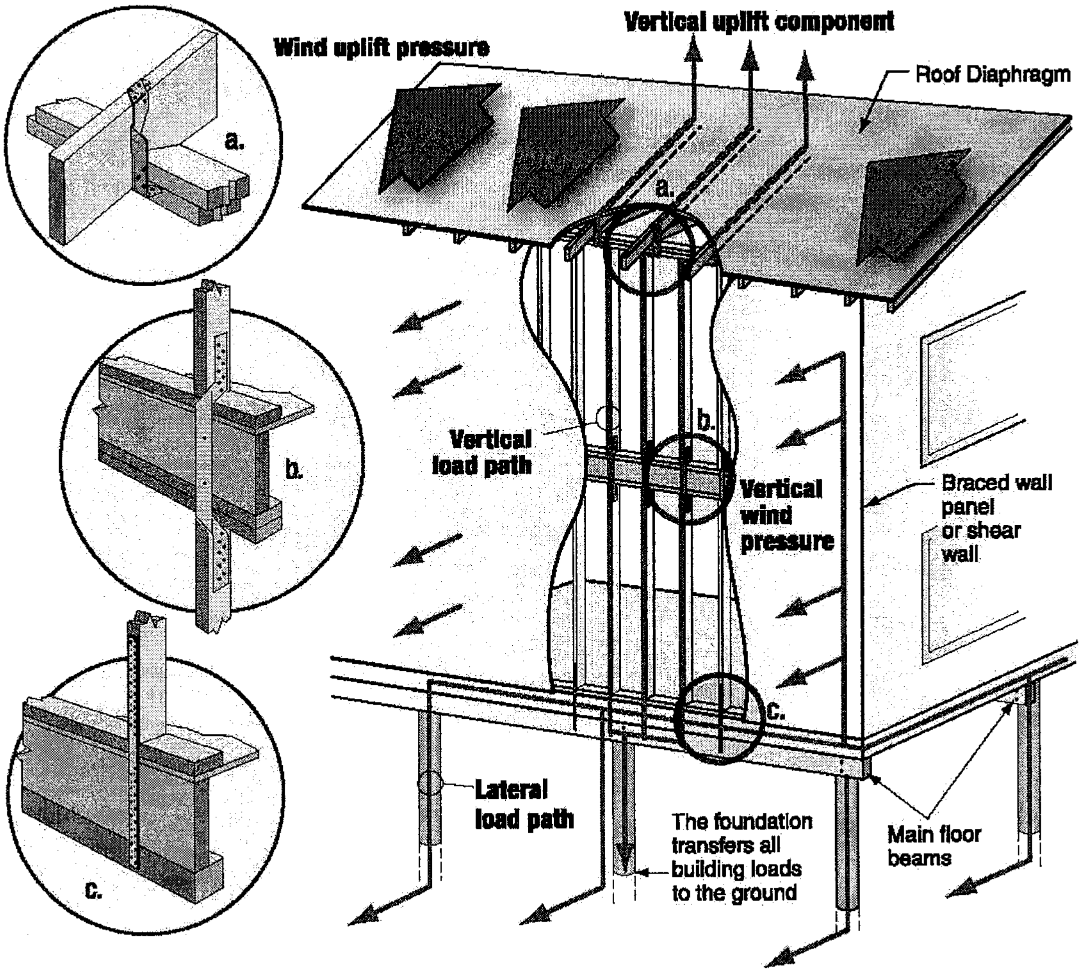


Figure 3. Building Load Path[5]

Building codes are written to provide a minimum design and construction standards, to diminish this divergence in building performance. Prominent building codes, standards and guidelines relevant to hurricane resistant construction include:

- *2006 International Building Code* [6]
- *2006 International Residential Code* [7]
- *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-05[8]
- *Flood Resistant Design and Construction,* ASCE 24-05[9]
- *Standard for Hurricane Resistant Residential Construction,* SBCCI SSTD 10-99[10]
- *Guidelines for Hurricane Resistant Residential Construction,* IBHS[11]
- *Coastal Construction Manual,* FEMA 55[4]
- *Florida Building Code*[12]
- The Texas Department of Insurance – Windstorm Program[13]

Retrofitting Existing Homes to Diminish Hurricane Damage

Hurricane Katrina, Hurrican Rita, and Hurricane Ike produced surge and flooding that exceeded the mapped the National Flood Insurance Program (NFIP) Base Flood Elevations (BFE). Thus, many homes were destroyed or severely damaged by these storms, including: 1) older homes constructed at or near grade; 2) homes constructed to the BFE; and 3) homes constructed outside the Special Flood Hazard Area (SFHA, shown on the Flood Insurance Rate MapsI and without regard to flood resistance. Short of moving or raising homes, very little can be done to improve the flood resistance of homes that are built at/or below the BFE, or just outside the SFHA.

Many recent hurricanes have resulted in significant amouts of wind damage to homes, despite having wind speeds below the Design Code speeds. Typical hurricane wind damage includes roof and siding damage, and wind propelled debris damage to doors and windows. Improper use of non-hurricane wind-zone materials, or the poor installation of rated materials, account for most of the observed wind damage. Unless a home has been gutted by a storm, the installation of "wind clips" and similar hidden metal connectors is virtually unreasonable:

Flood

1. For an elevated home with non-breakaway walls, install one 8"x16" flood vents per every 150 sf of enclosed space.
2. For an elevated home, remove and replace all visible corroded metal connectors and bolts.
3. Provide additional elevation of a home elevated at/or below the current BFEs. The lowest floor elevation should be equal to the Effective (i.e., shown on the currently adopted NIFP Map) BFE + 3-feet (Freeboard), see **Figure 6.** Homes in all flood hazard zones would qualify for a flood insurance premium reduction; however, unlike the case of new construction where freeboard costs are recovered quickly, the time to recover elevation costs through flood premium savings for existing homes (payback time) can be many years.

Wind

1. Improve and/or replace observable connections of elevated structures, overhangs, and porches.
2. Where gable ends are accessible from attics, provide wind bracing to prevent hinging of the gable end.
3. When re-roofing, the existing decking should be re-nailed to ensure a positive connection.
4. When re-roofing, the installed asphalt shingles should comply with ASTM D 7158, with Class G (120 mph) installed in Inland Zone I & II, and Class H (130 mph) installed in the Seaward Zone.

Hurricane Mitigation in New Residential Construction

New construction affords the builder/developer/owner to site, elevate, connect, and clad the home to be less affected by the hurricane forces of water, waves, and wind. Building location is a sustainable issue requiring extensive studies by affected communities and counties, as well as the State. Guidance on this issue is provided in the FEMA Mitigation Assessment Team Report, *Hurricane Ike in Texas and Louisiana, FEMA 757.*[14]. Resistance to water and erosion is a function of foundation depth and type (**Figure 4**), whereas wave resistance is a function of elevation (**Figure 5**). Resistance to hurricane wind forces is a function of good connections (**Load Path, Figure 3**), proper installation of hurricane rated roofing and cladding systems, and the protection of building openings with shutters or impact resistant glazing, see **Figures 4 & 5**.

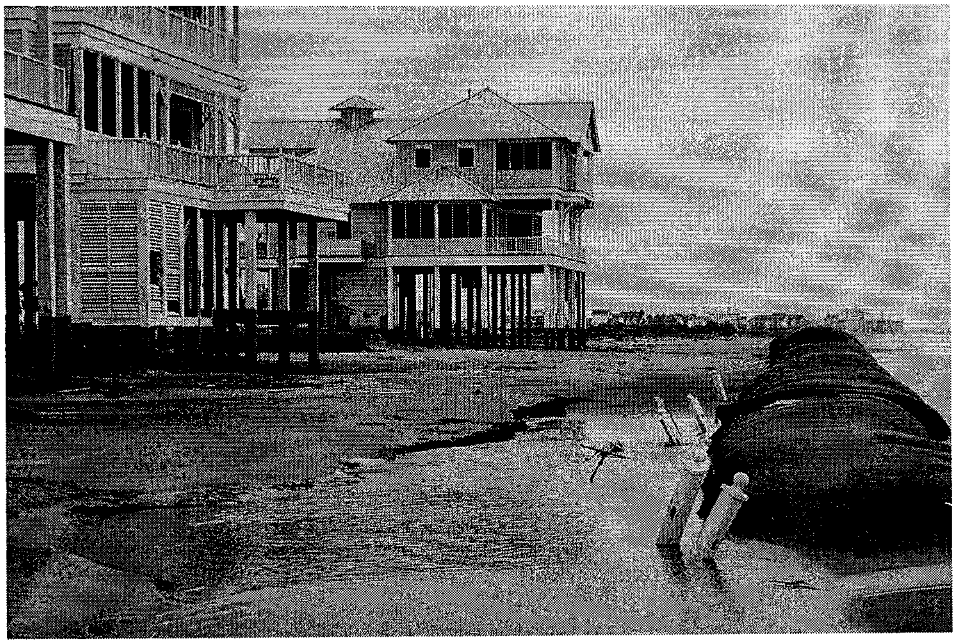


Figure 4. Erosion along the Galveston Island shoreline, west of the seawall (Oct. 17, 2008, photo C.P. Jones)

Figure 5. Bolivar Peninsula house on left sustained minor flood damage (to access stairs and below-BFE enclosures) during Ike, while the house on the right was severely damaged. The house on the left was constructed 5.5 ft above the BFE, the house on the right was estimated to be at the BFE (Oct. 18, 2008, photo C.P. Jones).

Flood

1. The only protection from waves and water is through sufficiently elevating the structure on a strong foundation. Many homes built to the current BFEs were damaged or destroyed by Ike. Until new Digital Flood Insurance Rate Maps (DFIRMs) are developed and adopted, a Freeboard of three feet should be added to the current Effective BFEs as shown in **Figure 6.** Though each foot of freeboard will cost more than the at-BFE construction cost, flood insurance premiums will be reduced. A V-Zone home should have a 1-3 year payback and an A-Zone home should have a payback period of approximately 6 years. [14]

2. Elevated homes frequently have parking slabs constructed below the home. Reinforced and stiffened concrete parking slabs should not be allowed under and around the residential structures, since they can become eroded and can transfer extreme wave and water loads onto the structure's foundation system. Parking slabs should be un-reinforced frangible slabs that will break-up under the water forces. Frangible slabs cost less than reinforced slabs.

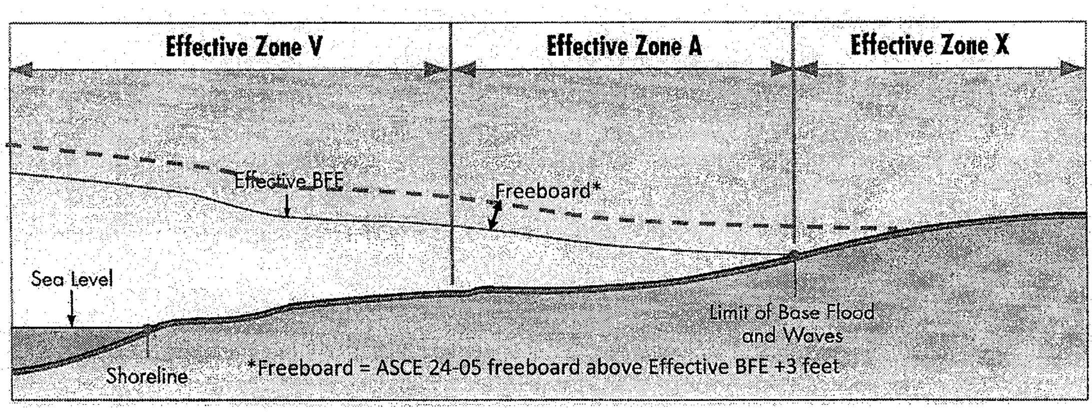


Figure 6. Comparison of Effective BFEs, flood hazard zones, and recommended Freeboard.

3. Below-BFE walls constructed of lattice or louvers are preferred over solid breakaway walls and will reduce flood insurance premiums by a couple of thousand dollars per year in V Zones.
4. Breakaway walls get taller as homes are elevated higher. Though breakaway walls normally perform as intended, they become large floating debris that produce damage to nearby structures. The installation of flood vents in solid breakaway walls can alleviate unbalanced water pressures, thereby delaying the damage and loss of breakaway walls, which are not covered by the standard flood insurance policy (repair or replacements costs must be borne by the owner)..
5. Tall breakaway wall sizes can be reduced by constructing breakaway joints at mid-height. This type of installation will reduce the size of floating debris and will reduce repair or replacement costs, should the upper section survive the storm.

Wind

1. Roof structures and roofing elements are particularly vulnerable to hurricane winds. Roof gable and shed roof ends must be braced to resist wind forces as recommended in the cited publications. Hip-style roofs are more wind resistant and normally perform better than other styles in hurricanes.
2. Asphalt roof shingles are the predominant roofing material found in coastal areas. The Texas Department of Insurance (TDI) currently allows Class F shingles, rated to 110 mph by the old ASTM D 3161 Standard, to be installed in all three Designated Catastrophe Areas (**Figure 7**). The Seaward Zone and the Inland I Zone are respectively 130 mph and 120 mph wind zones.

Products meeting the newer ASTM D 7158 Standard are available that meet the wind zone requirements. The Class F shingle should only be allowed in the Inland II, 110 mph Zone. The D 7158 shingle, though more expensive than the D 3161, Class F shingle, it is tested to meet the higher wind speeds in the Seaward Zone (Class H shingle) and in the Inland I Zone (Class G shingle).

3. Building felts are nailed to the roof decking to form a secondary moisture barrier below the shingles. Storm damage observations reveal that the building felts are routinely blown off the decking, along with the shingles. Taping of the joints formed by the overlapping felts had disappointing results in Hurricane Ike. It is therefore recommended that the secondary moisture barrier consist of either mopped felts or a self-adhesive membrane. Damage to home contents from water intrusion represents a large percentage of insurance claims.

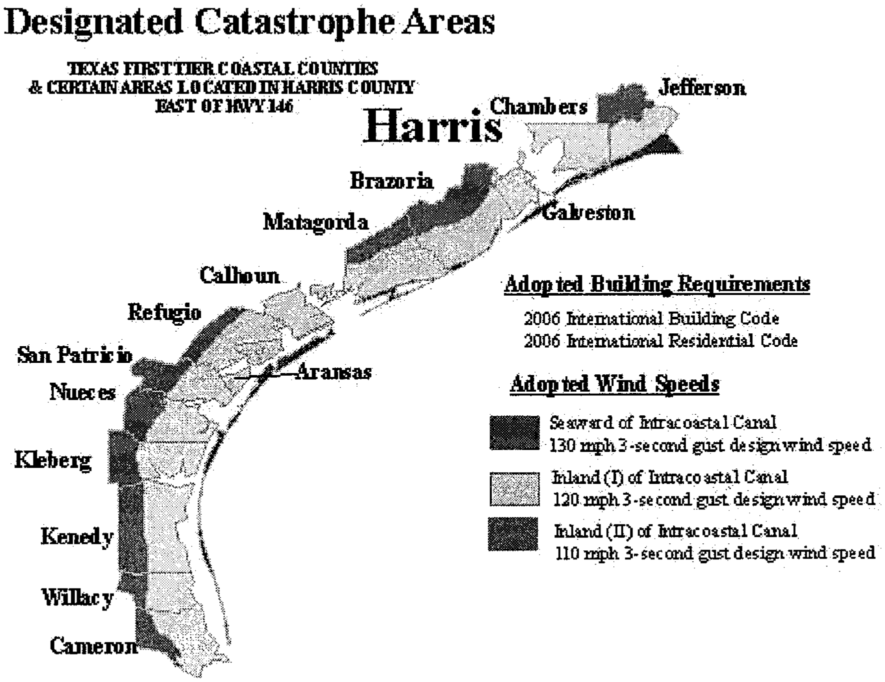


Figure 7. Texas Windstorm Designated Catastrophe Areas

4. Wall cladding materials are vulnerable to hurricane winds, and have been observed to fail when subject to less the "Code Design" winds. Cladding failure is normally associated with installation of "Non-High Wind Zone" products or with installation methods not consistent with manufacturer recommendations for high wind zones. This is a code compliance issue and not a cost issue.
5. Protection of openings is required by TDI in the Seaward and Inland I Zones. The opening protection of choice by most homeowners is plywood. Though

effective, it is difficult and dangerous to install over high windows and is frequently omitted on the non-seaward side of the dwelling. Plywood or shutters should be installed over all openings to protect the home from damage by wind pressures and rain. Though expensive, permanently mounted shutters could be installed over inaccessible or difficult to access openings. Costs for permanent shutters vary by quantity, size, and shutter selected. A less expensive alternative to shuttering inaccessible windows is to install windows with hurricane impact resistant glazing.

Summary of Mitigation Costs

NC	No Cost	MC	Moderate Cost
LC	Low Cost	HC	High Cost

Retrofitting Existing Homes		
1	Install flood vents in non-breakaway walls	LC
2	Install flood vents in solid breakaway walls	LC
3	Improve and replace observable metal connectors and connections	LC
4	Provide additional elevation to home (BFE + 3-ft. Freeboard)	HC**
5	Provide gable end bracing	MC
6	When re-roofing, re-nail decking	LC
7	When re-roofing, tape felt underlayment joints	LC
8	When re-roofing, additional cost for Class G shingles (120 mph)	MC*
9	When re-roofing, additional cost for Class H shingles (130 mph)	MC*
New Home Construction		
1	Elevate homes to BFE + 3-ft. Freeboard*	MC**
2	Install frangible parking slabs instead of reinforced concrete slabs	NC
3	Install flood vents in solid breakaway walls	LC
4	Construct tall breakaway wall in two horizontal breakaway sections	LC
5	Up charge to install Class G shingles (120 mph) over Class F (110 mph)	MC*
6	Up charge to install Class H shingles (130 mph) over Class F (110 mph)	MC*
7	Up charge to install substantial secondary roofing moisture barrier	MC*
8	Install hurricane windows in inaccessible locations	MC*

*Cost as compared to traditional construction or as indicated.
**Anticipated flood insurance premium reduction.

Hurricane Evacuation Shelters[15]

"The Texas coastal area population has grown more rapidly than the capacity of transportation facilities, resulting in congestion or even entrapment, thus creating hazards greater than the one prompting the evacuation. Evacuations are expensive for individuals and communities. Business interruptions are among the greatest of evacuation costs. Many options are available in safe rooms and in building design to improve safety and to reduce economic loss from extreme winds."[15]

The design of "Safer Areas of Refuge" and hardened safe rooms is contingent upon the perils anticipated. Tornadoes represent perils of extreme wind speeds, rain, and hail. Though hurricanes frequently spawn lower speed tornadoes, the greatest perils include high wind speeds, torrential rains, and flooding. Examples of building envelope hurricane resistance standards include those of TDI, Florida, and South Carolina. These standards address protection of building contents from extreme water intrusion, but do not address life safety. In 1997 the State of Florida enacted legislation requiring state university, college, and public school facilities be upgraded to serve as "Enhanced Protection Areas" for hurricane evacuees. The designated locations were selected based upon their perceived envelope resistance. The enhanced areas have generally performed well during recent hurricanes; however a few experienced problems that resulted in relocation of evacuees to other locations.

In 2000, FEMA published the first edition of *FEMA 361, Design and Construction Guidance for the Design of Community Safe Rooms.*[16] In 2008, the *ICC-500 Standard for the Design and Construction of Storm Shelters* was adopted for the *2009 International Building Code* to provide guidance for the construction of tornado and hurricane residential and community safe rooms.[17] Under this standard, community safe rooms were further identified as tornado, tornado/hurricane, or hurricane, and were based upon the differing wind speed and impact criteria. The FEMA 361 publication was updated in 2008 to specifically include hurricane safe rooms and identify parallels and comparisons between it and the ICC-500 Standard.[18] Both standards utilize the same wind speed criteria, but somewhat differ in impact criteria, with the FEMA 361 missile speed being slightly higher. Both standards provide sufficient hardening against wind forces and debris impacts specifically related to the intended peril to provide life safety protection.

Currently the State of Texas has a Hazard Mitigation Program funded by FEMA to provide grant assistance for safe room construction, most of which have been residential.[19] It is recommended that the State encourage the construction of FEMA/ICC-500 Hurricane Safe Rooms in the coastal areas when new schools and community structures are being planned. The incorporation of safe rooms in a host building, such as a school, represents approximately 6%-8% up-charge over traditional construction, whereas stand-alone community safe rooms can cost as much as $200-$300 per square foot. Although more costly to construct, stand-alone community safe rooms are frequently multi-use spaces, small gyms, community centers, etc.

Summary

Low cost to moderate cost measures can be implemented to improve existing home performance subjected to hurricane winds. However, little can be done to protect the home from water and waves if the home is built too low. For new construction, reasonable hurricane resistant construction codes, standards and guidelines currently exist and have proven to be effective. Constructing new homes to elevations that include freeboard, represent a modest increase over current coastal construction costs and provides the homeowner the benefit of a lower flood insurance premium.

It should be understood that codes and standards represent design/construction minimums and too often these minimums are compromised by poor construction practices and a lack of code enforcement. In essence, hurricane resistance is a function of better educated designers and constructors; and improved inspection. It should be also noted that new homes constructed outside of code enforcing jurisdictions are seldom inspected.

With the population growth of the Texas coastal areas, wholesale evacuation will soon not be an option. The lower Rio Grande Valley region is especially vulnerable to loss of life from hurricanes because large numbers of people are unable to evacuate due to personal limitations. The transportation infrastructure in this area is also inadequate to support such a massive evacuation. The State of Florida has already identified "Non-Evacuation Zones" outside of flood prone areas. Minimally and similarly to Florida, Texas should identify "Enhanced Protection Areas" to house those that must evacuate. However, given the life safety concerns for housing masses of people in non-hardened protection areas, it is recommended that the State encourage and support the construction of hardened community safe rooms that meet the FEMA/ICC-500 standards.

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Written Testimony: Dennis Quan

WITT
ASSOCIATES

October 21, 2010

Sean David Abbott, Committee Director
Office of Senator Mario Gallegos, Jr.
Committee Director/Senate Subcommittee on Flooding & Evacuations
PO Box 12068
Austin, TX 78711

Re: Comments to Texas Senate Subcommittee on Flooding & Evacuations

Dear Mr. Abbott,

Thank you for the opportunity to provide comments to the Subcommittee. You asked that I provide comments and recommendations related to the feasibility and cost-effectiveness of both the retrofit of existing facilities and possible new construction, which would be constructed as shelters or safe rooms, for use during future evacuations.

Specifically, you asked what can be done to retrofit existing structures, including:

- What sort of construction practices would be used in a new shelter or safe room building to make it habitable during a hurricane;
- The potential costs associated with retrofitting/new construction, specifically compared with traditional building costs.

You also asked for comments on the feasibility of retrofitting existing facilities versus constructing new facilities, specifically designed and constructed to meet the anticipated wind load for the area.

On behalf of Witt Associates I am pleased to provide comments to the Texas Senate Subcommittee on Flooding & Evacuations.

Founded in 2001, Witt Associates is a public safety and crisis management consulting firm based in Washington, D.C., with offices located throughout the country. We are committed to providing critical planning and consulting services to governments, businesses and non-profits, and implementing solutions to prepare for and recover from disasters and crisis. We continue that commitment today by offering these comments to the Texas Senate Subcommittee on Flooding and Evacuations.

Specifically, Witt Associates offers the Subcommittee the following observations and recommendations for hurricane construction and engineering, including recommendations relating to cost-effective options to either retrofit or require new structures to be built as shelters for use during evacuations.

I have framed my comments in the context of the many components that should be considered in conjunction with any effort to improve public safety during hurricanes. The factors that should be considered are not mutually exclusive, but represent individual elements of a holistic approach necessary to reduce loss of life, injury, and property damage. It should be noted that there is a direct correlation between reducing damage to property and reducing the risk and exposure public safety.

I will first discuss some factors that should be considered in determining if a facility can and should be retrofitted. Below are examples of steps that can help achieve this determination:

Dedicated Building Inspectors

Whenever any type of structure is being built or retrofitted, it is in the public's best interest to have dedicated and trained professional building inspectors involved in the process. Unfortunately, errors or omissions committed in the process of construction are a major contributing factor in building failure. Trained professional building inspectors assure compliance with local and state building codes and applicable industry standards, and help eliminate these errors and omissions.

In the aftermath of Hurricane Charley, which struck Florida in August 2004, forensic inspections were conducted of several hundred damaged buildings for causes of failure. In the course of the examinations, buildings that failed were compared to those in close proximity that had not failed. Buildings that did not fail consistently showed compliance to industry best practices and building codes, while the buildings that failed showed clear evidence of poor practices and non-compliance with building codes and construction standards. The examinations determined that some common building practices directly contributed to the structure failure. For example, in so-called "stick built" construction:

- Instead of toe nailing (nailing at an angle) 2 x 4 studs by using 4 ten penny nails to the bottom or top 2 x 4 "plates", just two smaller, less effective 8 penny nails were often used, or the stud was end nailed, i.e. a nail driven, through the top or bottom plate, into the stud. End nailing provides little resistance in keeping the stud from being separated from the plate by the force of high-velocity wind. Toe nailing is required by most major building codes. Unfortunately, there are many instances of carpenters, when not properly supervised or trained, using the end-nailing method in order to save time and materials.
- Roofing shingles that were often stapled instead of being nailed with the required full-headed roofing nail of sufficient length, having one inch of penetration into the roofing deck or the rafter, usually with three evenly spread nails placed 5 inches from bottom edge of the shingle. Of the roofing systems that failed, most were either stapled or poorly nailed. Failed roofing contributed heavily in failure of the building envelope. In most building codes, stapling is not allowed. Stapling is also contrary to most shingle manufacturer's specifications and instructions, and stapling does not meet industry best practices. I observed workers stapling new roofs, in house after house, just one month after Hurricane Charley hit in Punta Gorda. Clearly, this practice will not help reduce future losses and will likely contribute to repeat structure failure in future events.

In both of the above examples, the use of dedicated, trained, professional building inspectors would have helped in the enforcement of applicable codes and standards, and could have significantly reduced the occurrence of structure failure.

Witt Associates recommends the adoption of strong building codes by states and local jurisdictions as a means of building safe, strong, disaster resistant communities.

Witt Associates recommends the use of trained, dedicated, professional building inspectors for the purpose of enforcing building codes and industry standards.

Concrete Construction Practices

Concrete construction, when properly done to code and industry standards by trained professionals is, by far, the most economic method in achieving hurricane/disaster resistance. A few examples of concrete construction are:

- Structure Insulated Panel (SIP) method, which can be easily built to withstand wind velocity of 200 mph. Three buildings using SIP survived a direct hit from Hurricane Charley while many nearby structures were completely destroyed.
- Insulated concrete form (ICF) can be fashioned in any of the same architectural styles as stick-built, and can survive wind velocity of up to 200 mph. The only structure that survived a direct wave hit by Hurricane Katrina on the beach of Pass Christian, Mississippi was an ICF home.
- The thin-shell concrete monolithic domes are the strongest of all concrete styles. Walls typically withstand a force of 2,000 pounds per square foot. An F-5 tornado generates 404 pounds per square foot at 300 mph, or 5 times less then the tensile strength of the dome. The dome can withstand an impact from a runaway semi truck, a single engine Piper Cub, even a rifle bullet. Generally, damage, if any, is highly localized and superficial, and does not affect the structural integrity of the shell. This type of dome construction is often ideal for EOC's and as community shelters or safe rooms.

While it is not possible for me to provide you definitive information on building costs within these comments, I can provide you with some general comparisons. SIP and ICF methods are just slightly more expensive than traditional stick-built construction (wood). ICF methods can add as much 30% to the cost of conventional construction; SIP is generally about 5% more. Monolithic dome construction cost varies with the application and is generally much lower than tradition construction, depending on the use of the building and its interior finishes.

Most concrete construction methods are considered examples of green construction, using a fraction of the usual energy for heating and cooling, and the savings in energy can help recoup the cost of the structure in as little as 10 to 15 years.

Witt Associates recognizes that concrete construction methods offer sound mitigation opportunities for protection against a variety of hazards and recommends that the techniques be considered for construction in areas that are subject to hurricanes and other high-velocity wind events.

Shutters, Garage Doors and Protective Measures

A building engineered to survive high-velocity winds will perform adequately as long as the building envelope is not compromised or breached. As a rule of thumb, there should be no more than a one percentage opening, collectively, in the envelope including leaks around windows and doors. Once an opening is created, the additional pressurization may lead to catastrophic failure of the envelope.

One observation made after Hurricane Charley was that many buildings did not fail because the windows/doors/ or roofing elements were not compromised. It was observed that this was most often because of the use of shutters and other protective measures. The use of traditional wind retrofitting, such as shutters and high-performance roofing, is effective and often very cost effective.

Approximately 40% of all residential building failures as the result of high-velocity wind events are caused by collapsed garage doors. Even garage doors that meet the wind-load rating for a particular wind zone often do not provide adequate protection from hurricane-force winds. Some jurisdictions, like Florida's Miami-Dade County, require that garage doors be able to withstand a 150 mph wind load, be made with at least 24-gauge steel, and remain operable after being subjected to a high-velocity missile test.

An alternative is specially designed garage door braces. Door braces effectively allow the door to withstand a wind speed of up to 160 mph or more. The braces are manually installed just after the notification leading up to hurricane event. The braces will not always prevent the garage door from badly deforming, but will help prevent the door from blowing out. Door braces are also available also for large bay doors, such as those used at fire stations or public works garages.

Another solution that can be effective in protecting buildings is the use of fabric hurricane screens to cover the entire exterior of a building prior to a high-velocity wind event. For example, it is common for fire stations to be built as pre-engineered metal buildings (PEMB). Unless reinforced properly, PEMB's may fail in 80 or 90 mph winds. Many PEMB's, draped with hurricane fabric screens, survive very well during hurricanes. These screens are usually made from the same material used in backyard trampolines. Wind blowing through the screen at 100 mph, may be attenuated to about 6 mph.

Witt Associates recommends the use of properly installed hurricane shutters and other protective devices designed to assure the integrity of the building envelope during high-velocity wind events.

Retrofitting a Building to Survive High-Wind Loading

Some construction methods, available during new construction, are difficult to perform as a retrofit. For example, in order to put in a proper hurricane strap, one needs to remove the roof decking and soffit, to allow/install a full wrap around connectors. Installing a strap that only is nailed on the side of the rafter is insufficient, and will contribute to breaking the rafter from the nail stress loading. Putting in connectors between floors would require removal of siding, which can be very costly, and in the case of stucco or brick, this solution may not be technically feasible. Retrofitting is, in many cases, not a feasible alternative.

However, PEMB construction may be an exception to the retrofitting rule, as long as there is access the interior wall (no permanent interior wall covering). PEMB's can be retrofitted by upgrading wall and roof panels to higher-tensile steel (e.g. 80,000 psi), replacing fasteners with larger, corrosion resistance fasteners, increasing the number of fasteners, increasing the number of internal cross members (purlins and girts) to at least one every 2 to 3 feet apart, use of higher-strength cross members, installation of gussets underneath cap plate on top of columns, eave struts bolted to any masonry where applicable, additional cable or rod cross bracing, use of corrosion-resistant finished on all steel material, use of hurricane-rated doors and windows, and through the use of hurricane-rated coping, gutters and flashing. Using these techniques, it is possible to increase performance from 80-90 mph to 120 mph or more. High performance PEMB, built new, can be easily designed for 200 mph wind loading.

Another exception to the difficulties posed in building retrofitting is in cases of well-engineered concrete and steel buildings. In this type of construction retrofitting can often be achieved by protecting the roof, windows/doors and other openings from being compromised in a high-velocity wind event.

Witt Associates recommends retrofitting buildings to better withstand high-velocity wind events in cases where retrofitting is technically feasible.

Hurricane Rated Materials and the Miami-Dade Hurricane Compliance Code

It is recommended that all materials and protective devices such as shutters, screens, impact windows, doors, roofing, etc., used for protection from high-velocity wind events, achieve or exceed the standard established by Florida's Miami-Dade County Hurricane Compliance Code. These standards for construction practices, materials and products are among the strictest and strongest in the world. The Miami-Dade Approved Product control listing helps take the guess work out of knowing if a product is appropriate for the intended use in hurricane prone areas. Once a product is tested and certified, the product information is posted to the Miami-Dade's website, and a copy of the Notice of Acceptance is available to consumers. This service of Miami-Dade County helps builders and consumers better understand the products in the marketplace and helps eliminate false advertising or exaggerated product performance claims.

Shelters and Safe Rooms

While they have been used interchangeably in the past, the terms "shelter" and "safe room" have different meanings and connotations. While both types of facilities are designed for the protection of life during extreme-wind events, the facilities are designed to differing standards. Shelters are facilities that meet the criteria described in ICC-500, as published by the International Code Council. Safe Rooms, on the other hand, are facilities that are designed and constructed to meet FEMA publication 320 (for residential safe rooms) and 361 (for community safe rooms) standards. All safe rooms meet ICC-500 shelter standards; the reverse is not true.

Both design standards describe the criteria needed to meet the life-safety protection standards applicable to that design, for both new construction and retrofits. Both design standards also correctly note that it is often more cost-effective to implement safe room or shelter design criteria during new construction, rather than to retrofit these design elements into an existing facility.

It's worth noting that FEMA, the agency that funds the majority of mitigation retrofit and new construction projects, will not fund the retrofit or construction of a facility that is designed or constructed to less than FEMA 320 or 361 standards.

Residential Safe Rooms

Residential safe rooms, built to accepted standards, are hardened areas or rooms designed to withstand high-velocity winds that are characteristic of tornadoes, hurricanes and other extreme-wind events. They are considered a cost-effective method of protecting the inhabitants of dwellings from extreme wind events, and have proven to be a valuable life safety measure. In 1999, more than 900 safe rooms were built in private residences in Oklahoma City. When an F-5 tornado struck the city and destroyed homes in its path, all the occupants of dwellings with safe rooms were protected, even though their homes were taken by the winds.

Witt Associates recommends the construction of safe rooms as a cost-effective life safety measure in areas subject to high velocity wind events.

Community Safe Rooms

During Hurricanes Charley, Frances, Jeanne and Ivan in Florida, many shelters were utilized. These shelters were constructed in accordance with applicable safety criteria. Many of them suffered structural failures that forced the occupants to flee in the middle of extreme wind events. It became evident that the widely used safety standards to which the shelters were built were insufficient to offer the required degree of life safety and protection from high velocity wind events.

At a minimum, buildings that are considered for use as shelters or safe rooms in these types of events should be protected with approved hurricane shutters or impact windows, hurricane clips and braces that are appropriately and adequately tied to structural members, and hardened roofs. There should be minimal breaks in the building's envelope, to limit the possibility of failure or wind-entry. The use of buildings constructed of concrete or high tensile steel provides a better alternative. The best manner in which to obtain the highest degree of protection from significant wind events is the use of construction methods found in monolithic domes.

In conclusion, I would recommend the extreme-wind mitigation building practices be adopted and implemented in new construction wherever possible. While retrofitting is a viable option for some facilities, the best possible implementation of protection and mitigation comes during the building's initial design and construction. Retrofitting has inherent limitations that are simply not found in new construction.

Thank you for this wonderful opportunity to assist the State of Texas in encouraging sound construction techniques and appropriate mitigation measures as a means of building safer and stronger disaster resistant communities.

Sincerely,

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Attachments: Curriculum Vitae