



Mitigation Assessment Team Report

Hurricane Isaac in Louisiana

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-938 / March 2013

FEMA

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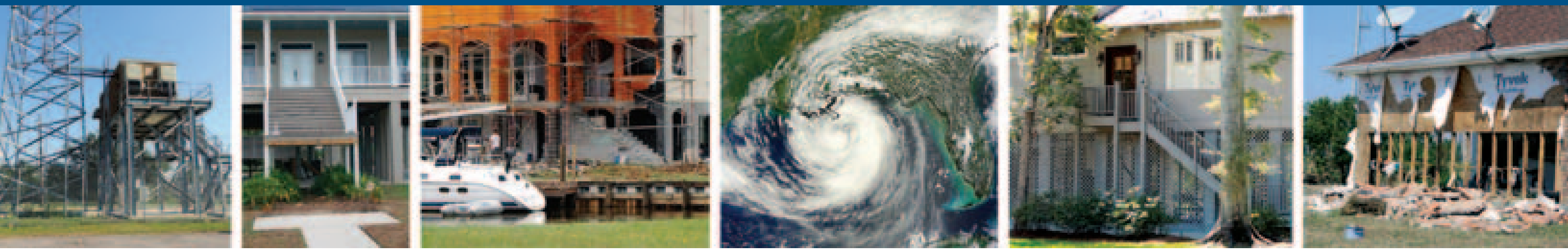
The Braithwaite Auditorium was rebuilt after it was damaged by Hurricane Katrina. The facility was built based on the preliminary Flood Insurance Rate Map base flood elevation (VE 21) and sustained minimal damage during Hurricane Isaac.

In response to Hurricane Isaac, the Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) to assess damage from the hurricane and provide observations, conclusions, and recommendations on the performance of buildings and other structures affected by wind and flood forces. The MAT included representatives from FEMA Headquarters and other Federal agencies, local government officials, academia, and experts from the design and construction industry. The conclusions and recommendations of this report are intended to provide decision makers with information and technical guidance that can be used to reduce future hurricane damage.

Photographs that appear across the top of the first page of each chapter (from left to right): Cellular tower equipment on elevated platform near Port Sulphur Community Center. The damage to this Mandeville, LA, elevated Zone V residence was limited to the loss of stairs. Residential building in Madisonville, LA, under construction with a partially enclosed ground-level area. NASA satellite image taken on August 28, 2012 as Hurricane Isaac approached the Louisiana coastline. Residential building in Mandeville, LA with electric meter installed adjacent to side entrance. Exterior damage to the garage of a non-elevated residence in Plaquemines Parish, LA.

MITIGATION ASSESSMENT TEAM REPORT



HURRICANE
ISAAC
IN LOUISIANA

Executive Summary

Hurricane Isaac made landfall twice along the coast of Louisiana: first on August 28, 2012, at the mouth of the Mississippi River in the southeastern portion of the State and again the next day near Port Fourchon, LA.

Hurricane Isaac was the ninth named storm during the 2012 hurricane season and the third to make landfall on the continental United States. It was significant not only for its impact on the Louisiana coast, but also because it made landfall almost exactly 7 years after Hurricane Katrina and affected many of the same locations.

When Hurricane Isaac first made landfall in Louisiana, it was a Category 1 hurricane with sustained winds of 80 miles per hour and a broad wind field encompassing nearly 200 miles. The broad wind field produced a storm surge higher than usually associated with a Category 1 storm. After the initial landfall, the eye of the hurricane moved westward along the coast, making a second landfall on August 29 west of Port Fourchon, LA. The storm then turned to the north and weakened; it was downgraded to a tropical storm by 1 p.m. on August 29 and then further downgraded to a tropical depression on August 30 at 3 p.m.

Despite weakening upon landfall, Isaac's slow movement resulted in prolonged exposure to storm conditions for affected areas. Isaac produced more than 19 inches of rain in New Orleans and more than 12 inches in areas around the Gulf Coast. The peak storm surge was reported as 12 to 14 feet in the Braithwaite community.

Damage caused by Hurricane Isaac resulted primarily from flooding in areas not protected by the Federal levee system, the 2012 greater New Orleans area 100-year Hurricane and Storm Damage Risk Reduction System, including but not limited to Slidell, Mandeville, Madisonville, LaPlace, and Lafitte. The storm surge pushed floodwater over a non-Federal levee in Plaquemines Parish, flooding a large area on the East Bank of the Mississippi River. Hurricane Isaac damaged nearly 59,000 homes in southeast Louisiana. In addition to housing damage, power loss contributed to the widespread impact of the storm and affected nearly 43 percent of the State's energy users.

Total economic losses from Hurricane Isaac are estimated to be in excess of $2 billion, with insured losses on land estimated at between $500 million and $1.5 billion by the claims forecasting company EQECAT (Sanburn 2012, Vanacore 2012). Losses of offshore assets are estimated at over $1 billion.

Mitigation Assessment Team

In response to a request for technical support from the Federal Emergency Management (FEMA) Joint Field Office in Baton Rouge, LA, FEMA's Mitigation Division deployed a Mitigation Assessment Team (MAT) composed of national and regional experts to affected areas in Louisiana on October 8, 2012.

The MAT was charged with evaluating damage from Hurricane Isaac, especially for buildings constructed or reconstructed after Hurricane Katrina, assessing the performance of Emergency Operations Centers and other critical facilities affected by the storm, evaluating the performance of electrical distribution and communication facilities, and investigating possible claims of wind damage in newly constructed buildings.

Assessment Observations

In general, Hurricane Isaac was below a design level wind event, with flood elevations that did not exceed the effective base flood elevation (BFE) in areas visited by the MAT (excluding areas in LaPlace and along the East Bank of the Mississippi River in Plaquemines Parish). The key recommendations of this MAT report, which are based on the team's observations while in the field, are summarized in the following section.

Recommendations

The recommendations presented in this report are made based on the MAT's field observations. They are directed toward designers, contractors, building officials, and coastal populations and recommend disaster-resistant practices for hurricane-prone regions.

Residential Construction

- **Elevation.** Build to the preliminary Flood Insurance Rate Maps or the best available data (i.e., Hurricane Katrina Advisory Base Flood Elevations). Incorporate freeboard requirements in accordance with the American Society of Civil Engineers *Flood Resistant Design and Construction* (ASCE 24) in addition to best available map data.

- **Slab-on-grade elevation projects.** For slab-on-grade elevation projects, obtain necessary information regarding the structural properties of the slab prior to design. In design, properly detail and design connections and load paths to resist flotation, impact loads, and uplift.

- **Stairs for building access.** Construct stairs used for access to elevated buildings with adequate connections to the structure and at the base. To improve performance, integrate partial openings in the risers. If this is not possible, construct stairs such that there are landings with supports that can resist flood forces, and construct risers parallel to wave action where possible.

- **Enclosed areas.** Enclosed areas below the BFE should be constructed of flood damage-resistant materials and should have walls designed to break away under flood loads.

- **Utilities and electrical service components.** Elevate all electrical service components to or above the BFE, and ensure that they are accessible. If this is not possible, elevate the electrical panel. Attach overhead service drop lines to the side of the residence rather than the roof if allowable by code.

- **Fire separation and flood damage-resistant materials.** For elevated buildings on open foundations with enclosed parking underneath, introduce fire separation on the exposed underside of the building. Fire separation should meet the guidelines of the 2012 International Residential Code Table R302.6 for habitable rooms above a garage, which requires not less than 5/8-inch Type X gypsum board or equivalent. Considerations should be made to ensure that this material is also flood damage resistant.

- **Raised floor system covering.** Proper fastener selection and attachment methods are recommended to reduce damage to raised floor system exterior covering on the underside of elevated buildings. Use materials that can withstand the wind loads expected on the structure.

Nonresidential Construction and Infrastructure

- **Siting of critical facilities, community centers, and schools.** Site new and replacement community centers, critical facilities, and schools outside the 500-year floodplain where possible; where not possible, elevate the critical facilities and all utility equipment above the 500-year elevation or the best available BFE information.

- **Infrastructure.** Where possible, site electrical substations, pump stations, and cellular towers outside the 500-year floodplain; where not possible, elevate facilities and electrical equipment above the 500-year elevation.

Outreach and National Flood Insurance Program Reform

- **Outreach efforts.** Continue ongoing statewide efforts focused on educating the public on new flood insurance program provisions contained in the Biggert-Waters Act (EDEN 2012). Place continued emphasis on the implications elevation has on an individual's long-term flood insurance premiums.

Best Practices

- **Mitigation Reconstruction Program.** Buildings constructed under the program were not damaged. Increase awareness of the pilot program, especially when older, non-compliant buildings are being considered for elevation projects.

Codes and Regulations

- State statutes that predate adoption of Act 12 should be evaluated to identify and resolve contradictions that could complicate enforcement and interpretation, and an explicit statement that buildings in flood hazard areas are also subject to local regulations should be included. Act 12 provides the authority for adoption of the Louisiana State Uniform Construction Code (LSUCC).

- National Flood Insurance Program (NFIP) communities should review local administrative and enforcement regulations to ensure their enforcement of the LSUCC provisions applicable in flood hazard areas are consistent with the NFIP.

- A clear statement that work on existing dwellings in flood hazard areas is subject to the flood requirements of the LSUCC would eliminate misinterpretation.

- The State should establish a freeboard requirement in areas with defined subsidence rates.

- Opportunities to improve the reach of training courses should be pursued, and floodplain management courses offered by the State and others should be considered for continuing education credits for code officials.

- Communities should evaluate the benefits of adopting requirements for additional freeboard in excess of what is required in the LSUCC.

- Local floodplain management regulations should be reviewed to resolve inconsistencies with the minimum requirements of the NFIP.

- Communities that have enforcement agreements with other governmental entities or with certified third parties should review those agreements to include local floodplain management requirements that are not already in the LSUCC.

- The State should distribute notices of the availability of FEMA's revised publication on manufactured homes to manufactured home installers and local officials.

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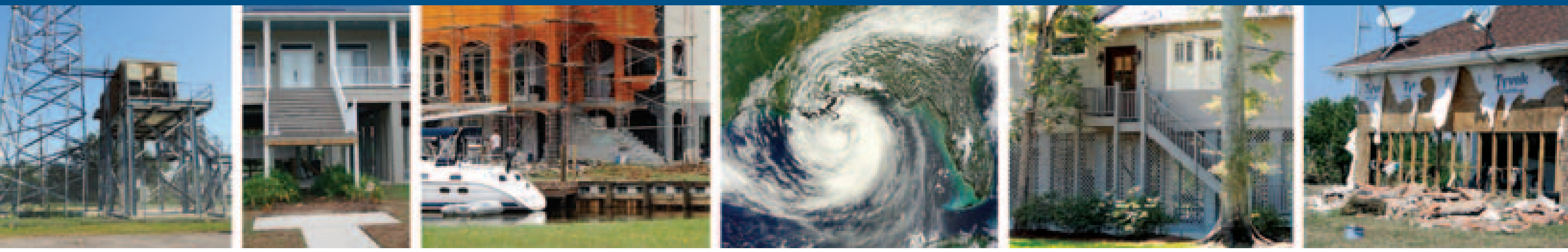

HURRICANE
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1 Introduction

On October 8, 2012, the Department of Homeland Security's Federal Emergency Management Agency (FEMA) Region VI Joint Field Office (JFO), in conjunction with the Mitigation Division of FEMA, deployed a Mitigation Assessment Team (MAT) to Louisiana to assess damage caused by Hurricane Isaac and document the successes of Post-Katrina reconstruction. This report presents the MAT's observations, conclusions, and recommendations as a result of those field investigations.

This chapter includes an introduction, a discussion of the event, historical information, and a description of the MAT process. Chapter 2 discusses the floodplain management regulations and the building codes and standards that affect construction in Louisiana. Chapter 3 contains a basic assessment and characterization of the observed flood and wind effects on residential construction. Chapter 4 details the performance of nonresidential structures and infrastructure. Chapter 5 presents an evaluation of elevation projects the MAT assessed. Chapter 6 presents the conclusions and recommendations, which are intended to help guide the reconstruction of hurricane-resistant communities in Louisiana and other hurricane-prone regions affected by future hurricanes. In addition, the following appendices are presented herein:

Appendix A: Acknowledgements
Appendix B: References
Appendix C: Acronyms and Glossary of Terms
Appendix D: FEMA Recovery Advisories for Hurricane Isaac
Appendix E: High Water Marks

1.1 Hurricane Isaac – The Event

Hurricane Isaac made landfall twice along the Louisiana coast as a Category 1 hurricane. The storm's first landfall was at the mouth of the Mississippi River in the southeastern portion of the State on August 28, 2012, at which point it moved west, making its second landfall near Port Fourchon, LA, the following day. The track of the storm in southeastern Louisiana is shown in Figure 1-1.

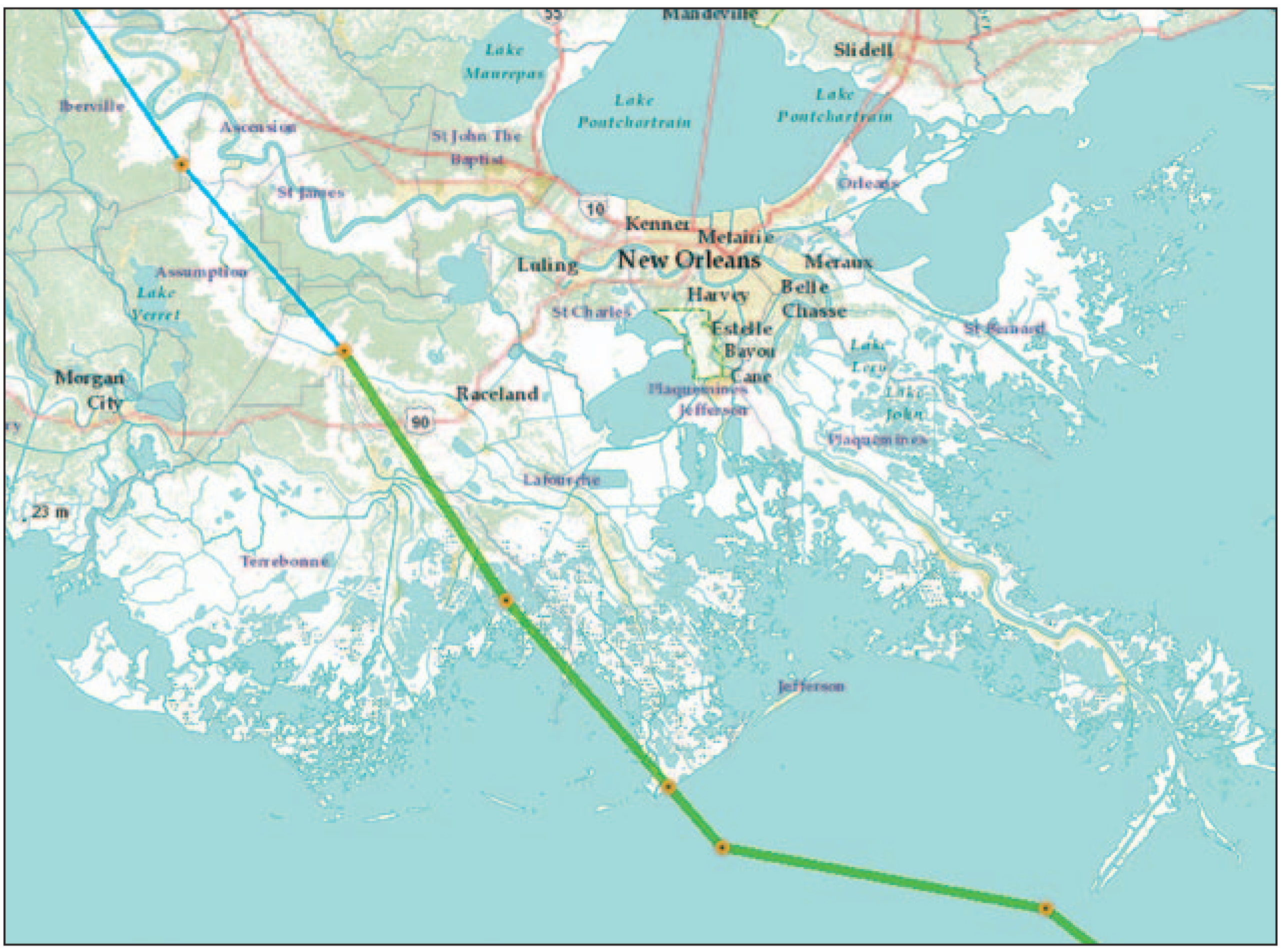


Figure 1-1: Hurricane Isaac's path through southeastern Louisiana

SOURCE: USGS ISAAC STORM TIDE MAPPER HTTP://WIM.USGS.GOV/ISAACSTORMTIDEMAPPER/STORMTIDEMAPPER.HTML

Hurricane Isaac was the ninth named storm during the 2012 hurricane season and the third to make landfall on the continental United States. It was significant not only for its impact on the Louisiana coast but also because it made landfall almost exactly 7 years after Hurricane Katrina and affected many of the same locations. This provided the MAT with a unique opportunity to evaluate post-Katrina mitigation measures in the New Orleans area for their performance in this storm.

1.1.1 Timeline

According to the National Hurricane Center, Hurricane Isaac originated as Tropical Depression 9, east of the Lesser Antilles on August 21, 2012, and was upgraded to Tropical Storm Isaac later that day. On August 28, the storm was upgraded to a Category 1 hurricane before making its first landfall over the Mississippi River Delta in extreme southeast Louisiana at 6 p.m. (Central Daylight Saving Time) (NOAA 2012b). Wind speeds at this time were 80 miles per hour (mph), and the wind field was broad, 200 miles at times. This breadth is significant because a broad wind field may produce higher levels of surge than a higher category storm with a smaller wind field. After the initial landfall in Louisiana, the eye of the hurricane moved west along the coast, making a second landfall on August 29 at 1:15 a.m. west of Port Fourchon, LA. The storm then turned to the north and weakened, though still producing large amounts of rain throughout the region. Hurricane Isaac was downgraded to a tropical storm by 1 p.m. on August 29 and then further downgraded to a tropical depression on August 30 at 3 p.m. Despite weakening upon landfall, Isaac's slow movement resulted in prolonged exposure to storm conditions for affected areas. Isaac produced more than 19 inches of rain in New Orleans and more than 12 inches in areas around the Gulf Coast. The peak storm surge was estimated at 12 to 14 feet in the Braithwaite, LA, area (USACE 2012). After its initial landfall and movement north, the storm traveled slowly north-northwest through Louisiana and then over Arkansas and southern Missouri.

Once Isaac made landfall, many areas that had ordered mandatory evacuations, as well as some that had not, experienced extreme flooding as a result of Isaac's storm surge and large volume of rain. In particular, the East Bank of the Mississippi River in Plaquemines Parish experienced high flood levels, and those who had ignored the mandatory evacuation orders had to be rescued from attics and rooftops.

1.1.2 Damage and Economic Loss

The damage from Hurricane Isaac primarily resulted from flooding. The levees constructed in the greater New Orleans area after Hurricane Katrina, the 2012 greater New Orleans area 100-year Hurricane and Storm Damage Risk Reduction System (HSDRRS), succeeded in holding back Isaac's floodwaters. However, flooding did occur in areas not protected by the Federal levee system. The storm surge pushed floodwaters over a non-Federal levee in Plaquemines Parish, flooding a large area on the East Bank of the Mississippi River from Braithwaite south, including White Ditch. This flooding forced many citizens in Plaquemines Parish to evacuate. To alleviate some of this flooding, a section of levee was removed in a low-lying area near the Braithwaite Park neighborhood.

In addition to Plaquemines Parish, other communities in the greater New Orleans area sustained damage, including Slidell, Mandeville, Madisonville, LaPlace, and Lafitte, among others. Based on FEMA damage assessments conducted after the storm, Hurricane Isaac damaged nearly 59,000 homes in southeast Louisiana (Associated Press 2012). This estimate includes nearly 47,000 owner-occupied houses and just over 12,000 rental units. Hurricane Isaac caused damage across 21 parishes, with Jefferson, Orleans, and St. John the Baptist Parishes having the highest numbers of damaged properties. Table 1-1 summarizes the number of owner-occupied housing and rental units damaged by Hurricane Isaac in Louisiana.

In addition to housing damage, power loss contributed to the widespread impact of the storm. At least 903,000 residences lost power, mainly in the New Orleans metropolitan area. This represents nearly 43 percent of the State's energy users (Louisiana Public Service Commission, media update August 31, 2012).

Total economic losses from Hurricane Isaac, as of September 4, 2012, are estimated by claims forecasting company EQECAT to be in excess of $2 billion, with insured losses on land estimated at between $500 million and $1.5 billion (Sanburn 2012, Vanacore 2012). This includes residential and commercial property, onshore energy production, and business interruption. Losses of offshore assets are estimated at over $1 billion.

Table 1-1: Housing Damage in Louisiana

Parish	Housing Damage (number of homes)
Ascension	1,112
Assumption	562
East Baton Rouge	1,114
East Feliciana	165
Iberville	515
Jefferson	12,912
Lafourche	2,103
Livingston	2,453
Orleans	9,777
Plaquemines	2,983
St. Bernard	2,257
St. Charles	1,368
St. Helena	482
St. James	953
St. John the Baptist	6,871
St. Mary	1,127
St. Tammany	4,572
Tangipahoa	4,584
Terrebonne	1,695
Washington	1,293
West Feliciana	54
TOTAL	58,952

1.2 Historic Hurricanes

The Louisiana coastline has experienced 59 hurricane strikes since 1851 (including Isaac), with Hurricane Katrina the most notable. Hurricane Katrina, which struck the U.S. coast on August 25, 2005, ranks as one of the most destructive hurricanes in U.S. history in terms of cost (No. 1), deaths (No. 3), and intensity (No. 3). Hurricane Isaac affected many of the same areas as Katrina (Figure 1-2), which provided an opportunity to study the performance of structures that were elevated after Hurricane Katrina.

Table 1-2 shows a comparison of Hurricanes Katrina and Isaac. All 55 of the parishes included in Isaac's Federal disaster declaration (and therefore eligible for either Individual or Public Assistance) were also included in Katrina's Federal disaster declaration (Table 1-2). Hurricane Isaac was a weaker wind event than Hurricane Katrina, with a maximum sustained wind speed of 65 mph, compared to Katrina's 127 mph maximum wind speed. Isaac's wind speeds did not equal or exceed the design level wind speeds for the affected areas. However, because Isaac was a slower moving storm and took a different path through Louisiana than Katrina, it produced higher and longer lasting storm surge conditions in areas not affected as severely by Katrina. Isaac's longer duration storm surge pushed more water into Lake Pontchartrain and Lake Maurepas (USACE 2012). In addition, some areas, including Braithwaite, LaPlace, and Lafitte, experienced higher storm surges during Isaac than during Katrina because of the slow movement and direction of the storm (USACE 2012).

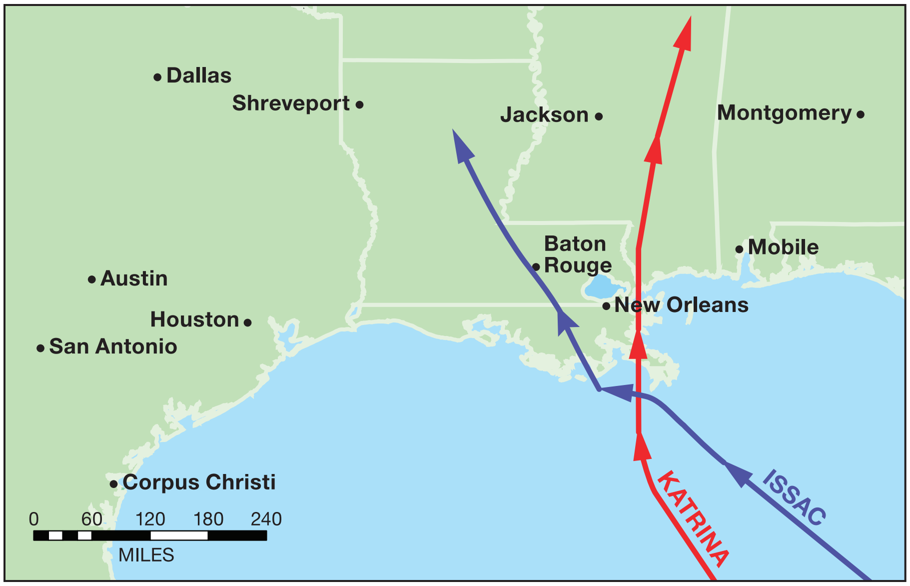


Figure 1-2: Storm tracks of Hurricanes Isaac and Katrina

Table 1-2: Comparison of Hurricanes Katrina and Isaac in Louisiana

Storm Feature	Katrina[1]	Isaac
Category at Landfall	3	1
Minimum Pressure at Landfall (millibars)	920	925
Maximum Sustained Wind Speed (mph)	127	65
Peak Storm Surge	10 to 20 feet above normal tide levels	10 to 15 feet above normal tide levels
Affected Parishes[2]	64	55
Number of Residential Buildings Damaged	283,838	59,000 (estimated)
Cost	$108 billion	$2 billion

mph = miles per hour

1 Source: FEMA 549, Hurricane Katrina in the Gulf Coast Mitigation Assessment Team Report, July 2006 (FEMA 2006a)

2 Includes parishes receiving Individual Assistance and/or Public Assistance (source: Katrina, http://www.fema.gov/disaster/1603/designated-areas; Isaac, http://www.fema.gov/disaster/4080/designated-areas)

1.3 Riverine and Coastal Flooding

The areas affected by Hurricane Isaac were primarily low-lying regions that are susceptible to flooding. Although the storm was only rated a Category 1 on the Saffir-Simpson scale, far lower than Hurricane Katrina, some areas still experienced significant flooding. Storm surge was exacerbated by intense and prolonged rainfall, affecting the coastline and traveling up the Mississippi River. These factors combined to produce higher flooding than Hurricane Katrina in some areas.

1.3.1 Storm Surge

The implementation of the HSDRRS system after Hurricane Katrina played a key role in protecting low-lying areas from storm surge in Hurricane Isaac. However, some areas experienced flood levels greater than those experienced during Hurricane Katrina. According to the U.S. Army Corps of Engineers (USACE), surge elevations generally ranged from 5 to 7 feet on the West Bank of the Mississippi River near Ama, LA, and from 12 to 14 feet on the East Bank of the Mississippi River near Braithwaite, LA. During Hurricane Isaac, southeastern Louisiana experienced sustained tropical-storm-force winds for as long as 45 hours from August 28 through August 30. These strong winds generated offshore waves of 5 to 15 feet. This storm surge, combined with the heavy rainfall, produced high water marks (HWMs) that, in some locations, exceeded levels for Hurricane Katrina.

1.3.2 High Water Marks

HWM data for Hurricane Isaac was provided to the MAT by the U.S. Geological Survey (USGS). Appendix E provides more detail of HWM data compared to the effective base flood elevation (BFE), the post-Katrina Advisory Base Flood Elevation (ABFE), and the preliminary BFE (as applicable) in the areas affected by Hurricane Isaac.

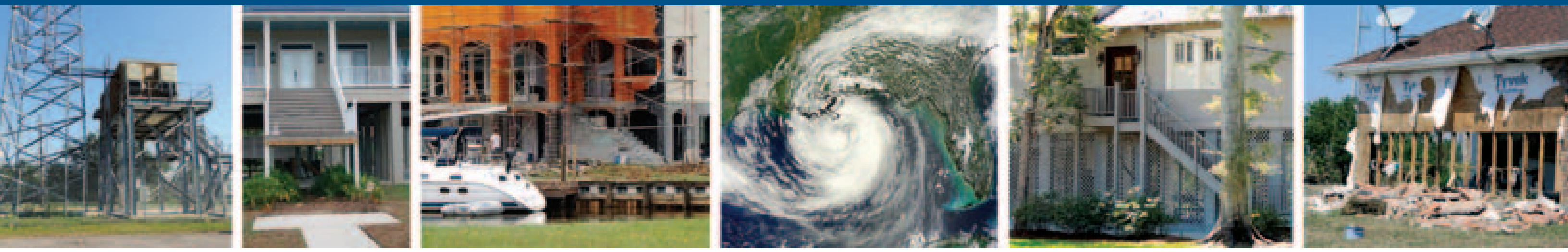
1.4 FEMA Mitigation Assessment Team

In response to a request for technical support from the FEMA JFO in Baton Rouge, LA, FEMA's Mitigation Division deployed a MAT composed of national and regional experts to affected areas in Louisiana on October 8, 2012. The MAT was charged with evaluating damage from Hurricane Isaac as well as post-Hurricane Katrina construction and reconstruction efforts, assessing the performance of critical facilities affected by the storm, evaluating the performance of electrical distribution and communication facilities, and investigating claims of wind damage in newer buildings.

Hurricane Isaac was below a design level wind event, which enabled the team to examine building elements that failed when they would not have been expected to fail. In addition, the MAT deployment provided a unique opportunity to visit a location that was previously studied by a MAT (Hurricane Katrina MAT) and to evaluate building performance of structures built since Hurricane Katrina.

Preliminary field investigations to assess damage in New Orleans and the surrounding areas were conducted between October 1 and October 4, 2012. These investigations involved identifying damaged areas for further observation. The data collected in the preliminary field investigations determined the area of focus for the full MAT. The full complement of MAT experts was deployed from October 8 through October 12 and conducted ground observations in Jefferson Parish, Orleans Parish, Plaquemines Parish, and St. Tammany Parish, observing sites in the City of New Orleans, as well as in the nearby communities of LaPlace, Port Sulphur, Mandeville, and Slidell. The team also visited affected rural areas in Plaquemines Parish.

Damage was observed to single- and multi-family buildings, manufactured housing, commercial properties, communications towers, and electrical substations. In addition, critical and essential facilities, such as fire stations, were evaluated to document building performance as well as loss of function from Hurricane Isaac. The MAT's observations are presented in this report. Photographs and figures are included to illustrate building performance in the wind field and surge areas produced by Hurricane Isaac. The conclusions and recommendations of the MAT as presented in this report are intended to assist in minimizing damage from future hurricanes.



HURRICANE **ISAAC** IN LOUISIANA

2 Regulations, Codes, and Standards

A combination of local floodplain management regulations and building codes determine the requirements that govern construction in flood-prone regions.

The floodplain management regulations of the National Flood Insurance Program (NFIP) and the flood provisions of the family of codes developed and maintained by the International Code Council, Inc. (ICC) are related. Since 1998, FEMA has participated in the code development process for the International Code Series (I-Codes). Every 3 years, the family of codes is modified through a formal, public consensus process.

THE I-CODES AND THE NFIP

FEMA prepared excerpts of the flood provisions of the 2009 and 2012 I-Codes, a checklist that compares the requirements of the NFIP to the flood provisions of the 2009 edition of the I-Codes and ASCE 24-05 (a standard referenced by the I-Codes), and *Highlights of ASCE 24* (FEMA 2010c). These resources are accessible online at http://www.fema.gov/building-science/building-code-resources.

The flood provisions in the 2009 and 2012 I-Codes are consistent with NFIP requirements for buildings and structures. Consequently, communities can rely on the I-Codes to fulfill some of the requirements they must meet to participate in the NFIP.

Unless constrained by State requirements, communities that enforce building codes with NFIP-consistent provisions have two primary tools to regulate development in flood hazard areas: (1) building codes that govern the design and construction of buildings and structures, and (2) either Appendix G of the International Building Code (IBC) or local floodplain management regulations. These tools are designed to work together to result in buildings, structures, and all other development, that are resistant to flood loads and flood damage.

This chapter begins with an overview of the NFIP and a summary of the program's minimum requirements for buildings and structures in Special Flood Hazard Areas (SFHAs). It then offers an overview of the Louisiana State Uniform Construction Code Council, highlights of the statutory provisions that are, in effect, State amendments to the I-Codes, and notes on local enforcement of the code and floodplain management regulations. The flood provisions of the Louisiana State Uniform Construction Code (LSUCC) are summarized, along with requirements for manufactured home installation.

The chapter concludes with a section that summarizes community-specific elements of floodplain management regulations and building codes for Plaquemine Parish and the Cities of Mandeville and Slidell, which were among the jurisdictions visited by the FEMA MAT.

2.1 National Flood Insurance Program

The authorizing legislation for the NFIP is the National Flood Insurance Act of 1968, as amended (42 U.S. Code 4001 et seq.). In that act, the U.S. Congress expressly found that "a program of flood insurance can promote the public interest by encouraging sound land use by minimizing exposure of property to flood losses."

The NFIP is based on the premise that the Federal government will make flood insurance available to communities that adopt and enforce floodplain management requirements that meet or exceed the minimum NFIP requirements.

The regulations of the NFIP are the basis for local floodplain management ordinances adopted to satisfy the requirements for participation in the NFIP. In addition, the NFIP minimum requirements are the basis for the flood-resistant design and construction requirements in model building codes and standards. When decisions result in development within flood hazard areas, application of NFIP criteria is intended to minimize exposure to floods and flood-related damage.

The most convincing evidence of the effectiveness of the NFIP minimum requirements is found in flood insurance claim payment statistics. Buildings that pre-date the NFIP requirements were generally not constructed to resist flood damage, while buildings that post-date the NFIP are designed to resist flood damage. The NFIP aggregate loss data indicate that buildings that meet the minimum requirements experience 80 percent less flood damage than buildings that pre-date the NFIP. Ample evidence suggests that buildings designed to higher standards that exceed the minimum requirements are even less likely to sustain damage.

At the Federal level, the NFIP is managed by FEMA and has three main elements:

- Hazard identification and mapping, in which engineering studies are conducted and flood maps and studies are prepared to delineate areas that are estimated to be subject to flooding under certain conditions.
- Floodplain management criteria, which establish the minimum requirements for communities to adopt and apply to development within mapped flood hazard areas; the expectation is that communities will recognize hazards throughout their entire land development process.
- Flood insurance, which provides some financial protection for property owners to cover flood-related damage to buildings and contents.

Performance requirements of the NFIP for development in SFHAs are set forth in Federal regulations at Title 44 of the Code of Federal Regulations (CFR) Parts 59 and 60. The requirements apply to all types of development proposed in SFHAs. The NFIP broadly defines the term “development,” and the requirements apply to new development as well as existing buildings and structures in SFHAs.

The NFIP provisions guide development to lower-risk areas by requiring compliance with performance measures to minimize exposure of new buildings and buildings that undergo major renovation or expansion (called “Substantial Improvement” or repair of “Substantial Damage”). Taken together, administration of NFIP-consistent requirements helps achieve the long-term objective of building disaster-resistant communities.

2.1.1 General Performance Requirements for Buildings

The NFIP’s broad performance requirements for new buildings and the Substantial Improvement or repair of Substantial Damage of existing buildings in SFHAs specify that:

HIGHER STANDARDS

FEMA encourages States and communities to adopt “higher standards” that provide a greater degree of protection than the NFIP minimum requirements. The most common higher standard that affects buildings is freeboard, a requirement to elevate buildings above the BFE. However, some States do not permit local amendments to building codes, which prevent communities from requiring freeboard and other higher standards.

DEVELOPMENT

Development means any manmade change to improved or unimproved real estate, including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations, or storage of equipment or materials (44 CFR 59.1).

SUBSTANTIAL DAMAGE AND SUBSTANTIAL IMPROVEMENT

Substantial Damage is damage of any origin for which the cost to restore a damaged building to its pre-damage condition equals or exceeds 50 percent of the building’s market value before the damage occurred.

Substantial Improvement is any reconstruction, rehabilitation, addition, or other improvement of a building, the cost of which equals or exceeds 50 percent of the building’s pre-improvement market value. When repairs and improvements are made simultaneously, all costs are totaled and used in the determination.

- Buildings shall be designed and adequately anchored to prevent flotation, collapse, or lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.
- Building materials shall be resistant to flood damage.
- Buildings shall be constructed by methods and practices that minimize flood damage.
- Buildings shall be constructed with electrical, heating, ventilation, plumbing, and air-conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components.

Beyond the general requirements, specific NFIP requirements for buildings are functions of the flood zone and flood characteristics that affect specific locations. Requirements for SFHAs that are designated Zone A (including AE, A, A1–30, AO, and AH) are summarized in Section 2.1.2, and requirements for coastal high hazard areas that are designated Zone V (including VE and V1–30) are summarized in Section 2.1.3.

2.1.2 Minimum Requirements for Buildings in Zone A

In addition to the general requirements summarized in Section 2.1.1, the NFIP minimum requirements for buildings and structures located in Zone A specify the level of protection (elevation) and limitations on enclosures below elevated buildings, including crawlspaces.

Building Elevation and Foundations (Zone A)

In Zone A, where FEMA designates BFEs, the NFIP requirements specify that the lowest floors of new and substantially improved buildings, including basements, are required to be elevated to or above the BFE. There are no limitations on the type of foundation used to elevate buildings. Buildings may be elevated on perimeter walls (crawlspace), filled stemwalls, columns, piers, pilings, or slabs on earthen fill. Nonresidential buildings may be elevated or protected by dry floodproofing that protects to or above the BFE.

Some SFHAs, referred to as "unnumbered A zones," are shown without BFEs. In these areas, BFE data from other sources are to be used if available. If no data are available, the BFE may be estimated using established methods, and communities are required to ensure that buildings are constructed using methods and practices that minimize flood damage. Once the elevation or height of the lowest floor above grade is established, the remaining requirements for Zone A apply.

LOWEST FLOOR

Lowest Floor means the lowest floor of the lowest enclosed area (including basement). An unfinished or flood-resistant enclosure, usable solely for parking of vehicles, building access, or storage in an area other than a basement area is not considered a building's lowest floor; provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirements of Section 60.3 (44 CFR 59.1).

The Zone AO designation is used where flooding is characterized by shallow depths (averaging 1 to 3 feet) and/or unpredictable flow paths. In these areas, lowest floors, including basements, are required to be at or above the highest grade adjacent to the building plus the depth number (in feet) shown on the Flood Insurance Rate Map (FIRM). For example, if the depth number is 3 feet, the top of the lowest floor must be at least 3 feet above the highest grade adjacent to the building. If no depth is shown, the minimum required height above the highest adjacent grade is 2 feet. Once the elevation or height of the lowest floor above grade is established, the remaining requirements for Zone A apply.

Enclosures Below Elevated Buildings (Zone A)

The NFIP requirements specify that areas below the lowest floors may be enclosed; however, the use of enclosures is restricted to vehicle parking, building access, or storage.

The walls of enclosures are required to have flood openings designed to allow the automatic entry and exit of floodwater so that interior and exterior hydrostatic pressures can equalize during flooding. Designs for openings must meet either a prescriptive requirement (1 square inch of net open area for every square foot of enclosed area) or a performance expectation (certified by a registered design professional). The following installation specifications apply to all flood openings: (1) a minimum of two openings for each enclosure, (2) the bottom of openings no higher than 1 foot above grade (exterior grade or interior floor/grade), and (3) screens, louvers, valves, or other coverings or devices, if any, permit the automatic entry and exit of floodwaters. See NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (FEMA 2008e).

2.1.3 Minimum Requirements for Buildings in Zone V

In addition to the general requirements summarized in Section 2.1.1, the NFIP minimum requirements for buildings and structures in Zone V specify the level of protection (elevation), type of foundation, and limitations on obstructions and enclosures below elevated buildings. Because of the greater hazard posed by breaking waves, structural designs and methods of construction are required to be developed, reviewed, and certified by a registered design professional as capable of resisting the effects of wind and flood loads acting simultaneously.

Building Elevation and Foundations (Zone V)

In Zone V, the NFIP requirements specify that the bottom of the lowest horizontal structural member (excluding vertical foundation members) of the lowest floors of new and substantially improved buildings are required to be at or above the BFE. Open foundations are required, including pilings and columns. The use of fill for structural support is not permitted. Concrete slabs, including patios, walkways, pool decks, and slabs used as the floor of enclosures, are required to be structurally independent or, if attached, building foundations are required to be designed to account for the added loads and effects of wave action.

Obstructions and Enclosures Below Elevated Buildings (Zone V)

The NFIP requirements specify that the area under elevated buildings must be free of obstructions that could interfere with the free passage of floodwater and debris underneath the buildings. The NFIP requirements specify that areas below the lowest floors may be enclosed; however, the use of enclosures is restricted to vehicle parking, building access, or storage.

Obstructions to be avoided—or minimized and constructed to meet the performance requirement—include stairs and ramps, decks and patios, equipment attached to foundation elements, foundation bracing, grade beams that extend above grade, shear walls, and slabs. Other site development that may create obstructions includes accessory structures, erosion control structures, fences and privacy walls, fill used for landscaping, septic systems, and swimming pools and spas. See NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements* (FEMA 2008c).

Walls of enclosures, if any, are required to be non-supporting breakaway walls, open wood latticework, or insect screening intended to collapse under wind and base flood or lesser conditions without causing structural collapse, displacement, or damage to the elevated building or supporting foundation. When walls collapse under specific lateral loads, floodwater can flow through column or pile foundations without obstruction. See NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings* (FEMA 2008a).

The NFIP regulations specify a design safe-loading resistance for breakaway walls of not less than 10 pounds per square foot and not more than 20 pounds per square foot (in almost all cases, water loads will significantly exceed the upper limit). Breakaway walls that do not meet those loading requirements may be used if a registered professional engineer or architect certifies that the walls will collapse under a water load less than that which would occur during the base flood and that the elevated portion of the building and supporting foundation system will not be subject to collapse, displacement, or other structural damage due to the effects of wind and water loads acting simultaneously on all building components.

2.1.4 NFIP Community Rating System

The NFIP's Community Rating System (CRS) is a voluntary incentive program that recognizes community floodplain management activities that exceed NFIP requirements. The CRS provides discounts on flood insurance premiums in communities that elect to undertake activities that support three goals: reduce flood damage to insurable property, strengthen and support the insurance aspects of the NFIP, and encourage a comprehensive approach to floodplain management.[1]

Communities apply to the CRS and are assigned a class based on the activities they undertake. Classes range from 1 to 10, with 1 representing the most active communities with the most flood hazard-resistant practices that, therefore, receive the largest possible discount. NFIP flood insurance premium rates are discounted in increments of 5 percent; i.e., a Class 1 community receives a 45 percent premium discount, while a Class 9 community receives a 5 percent discount (a Class 10 community receives no discount). The CRS classes are based on 18 creditable activities organized under four categories: (1) public information, (2) mapping and regulations, (3) flood damage reduction, and (4) flood preparedness.

COMMUNITY RATING SYSTEM

As of February 2013, 42 communities in Louisiana participate in the CRS.

Nationwide, more than 21,500 communities participate in the NFIP, of which more than 1,200 also participate in the CRS.

1 http://www.fema.gov/national-flood-insurance-program/community-rating-system.

2.2 Louisiana and Regulation of Construction

Shortly after Hurricane Katrina devastated much of coastal Louisiana, the State Legislature convened the 2005 First Extraordinary Session. A significant outcome was passage of Act 12, a statute to "provide for a state uniform construction code to govern new construction, reconstruction, additions to homes previously built to the International Residential Code, extensive alterations, and repair of buildings and other structures and the installation of mechanical devices and equipment therein."[2]

The public policy of Louisiana is to maintain reasonable standards of construction in buildings and other structures in the State consistent with the public health, safety, and welfare of its citizens. The State uniform construction code establishes uniform performance standards that provide reasonable safeguards for health, safety, welfare, comfort, and security, balanced with affordability. The code encourages the use of construction materials of the greatest durability, lowers long-term costs, and provides greater storm resistance.

As of early 2013, the LSUCC is based on the 2009 I-Codes. The Louisiana code includes identified parts of the 2009 editions of the IBC, International Existing Building Code (IEBC), International Residential Code for One- and Two-Family Dwellings (IRC), International Mechanical Code (IMC), International Fuel Gas Code (IFGC), the Louisiana One- and Two-Family Supplement to the 2006 IMC, and 2010 the National Electrical Code (NEC). State amendments to the codes identify parts that are not adopted. The Louisiana Plumbing Code was developed by the State Department of Health and Hospitals.

2.2.1 Louisiana State Uniform Construction Code Council

Act 12 authorized the Louisiana State Uniform Construction Code Council, consisting of 19 members appointed by the Governor. Members have various professional backgrounds, including construction, engineering, architecture, insurance, and local government. The primary functions of the Council are:

- To review and adopt the State uniform construction code, which is based on the I-Codes. The adoption process involves review committees that make recommendations and technical committees that evaluate the recommendations. The Council then acts on the recommendations and sends the resulting code and amendments to the legislature.

NEXT EDITION OF THE LSUCC

Codes based on the 2012 I-Codes are expected to be adopted after the spring 2013 legislative session and will be effective January 1, 2014.

- To provide training and education to code officials. The Council establishes the requirements and process for the certification and continuing education of code enforcement officers, code enforcement inspectors, third-party providers, and building officials.

- To accept all requests for amendments of the code (except the plumbing code). The Council determines whether amendments to the codes are justified. When the Council finds justification

2 http://lsuccc.dps.louisiana.gov/index.html.

for an amendment, it may adopt it after finding that the modification improves public health, safety, and welfare.

2.2.2 Louisiana Statutory Provisions

Louisiana statutes impose some limitations and requirements that are, in effect, State amendments to the I-Codes. The more significant provisions are described here.

Powers of parish governing authorities (Revised Statute [R.S.] 33:1236). Parishes are permitted to pass zoning ordinances, subdivision regulations, building codes, health regulations, and other applications and extensions of the normal police power to provide standards and effective enforcement provisions for the prudent use and occupancy of flood-prone and mudslide areas. Specifically, parishes may use such authorities to qualify for the NFIP.

Public contracts, works and improvements (R.S. 38:84). Parishes and municipalities are authorized to comply with the Federal flood insurance act by adoption of ordinances, rules, and regulations, including zoning and land use regulations, as necessary. NFIP participation is mandated "before construction of any project for local flood protection, or any project for hurricane or storm damage reduction which involves or receives federal assistance."

State buildings (R.S. 40:1722 and 40:1724). New construction, alteration, addition, or renovation of all State buildings must comply with the building code. Plans and specifications shall be approved by State authorities. The provision explicitly states that State-owned buildings shall not be subject to local permitting, review, or oversight, but shall be required to comply with the flood zone requirements of the NFIP.

LOUISIANA COMMUNITIES THAT PARTICIPATE IN THE NFIP

The Community Status Book for Louisiana, maintained by FEMA, indicates 312 communities participate in the NFIP, while 23 towns and villages that are identified as flood-prone elect not to participate (www.fema.gov/cis/LA.html, accessed February 26, 2013).

State Uniform Construction Code; "Act 12" enacted by the 2005 First Extraordinary Session (R.S. 40:1730.21–40).

- Requires all municipalities and parishes to enforce only the construction codes provided in the statute (no local amendments).
- Specifies enforcement of the code shall not conflict with R.S. 51:912.21 et seq. for the installation of manufactured homes.
- Requires homeowners of "new residential construction" to provide lenders with copies of certificates of occupancy, and requires lenders to file such copies in parish conveyance records.
- Requires parishes and municipalities to appoint certified building officials or, by agreement, contract with other governmental entities or private, certified third parties to issue permits and enforce the code.

- Adopts codes from the I-Codes (IBC, IEBC, IRC, IMC, IFGC); specifically, the code "shall be updated prior to the second regular legislative session after the release of the latest edition of the appropriate code."

- Does not adopt Chapter 1 of any codes but permits adoption of IBC appendices.

- For the IRC, limits enforcement "only for new construction, reconstruction, additions to homes previously built to the IRC, and extensive alterations" and defines those terms. Permits local enforcement of IRC Appendix J, Existing Buildings.

- Explicitly states that the code shall not apply to the construction or improvement of specifically listed industrial facilities that are "inside the restricted access area." The LSUCC and the fire code apply to any buildings, even if inside restricted access areas, if the buildings are accessible by the public.

- Defines "farm structure" and "residential accessory structure," and describes "private outdoor recreational structures" (such as hunting or fishing camps). The effect is that those structures are excluded from the code, except "for residential construction, the standards published by the Federal Emergency Management Agency for the National Flood Insurance Program shall apply."

LSUCC AND WIND SPEEDS

The Louisiana State Uniform Construction Code Council adopted an emergency rule to require the use of wind speeds in the 2012 IRC for any permit issued on or after January 1, 2013. Since adoption in 2005 of the first State code based on the I-Codes, the statute has required use of the 2003 IRC wind speeds for dwellings.

2.2.3 Local Enforcement of the LSUCC and Floodplain Management Regulations

All local jurisdictions are required to enforce the LSUCC, and local amendments are not permitted.

The statutes are explicit that parishes and municipalities may adopt regulations to qualify for the NFIP, and the statute that establishes the building code explicitly references "standards" published by FEMA for the NFIP. Therefore, the Council does not oppose communities that adopt, as part of the local floodplain management regulations, "higher standards" that affect the design and construction of buildings in SFHAs, especially when those higher standards are adopted by communities that participate in the NFIP CRS.

To date, the Council is unaware of situations where conflicts between the code requirements and local regulations have created problems. Should a problem arise, it would first be addressed by the local appeals board. Decisions of local appeals boards may be brought before the Council.

HIGHER STANDARDS ADOPTED BY CRS COMMUNITIES

As of May 2012, 42 of Louisiana's more than 300 NFIP communities also participate in the CRS, reducing NFIP flood insurance premiums by 5 to 20 percent. Communities receive credit for higher standards that affect buildings:

- 17 receive credit for freeboard
- 5 receive credit for foundation limits
- 7 receive credit for cumulative substantial improvement
- 2 receive credit for lower substantial improvement threshold
- 1 receives credit for enclosure limits

2.2.4 Post-Katrina Mitigation Grant to Build Code Enforcement Capacity

In 2005, very few local officials were certified as building professionals. With FEMA's encouragement, in early 2007, the Governor's Office of Homeland Security and Emergency Preparedness obtained a $10.5 million Federal hazard mitigation grant to help build State and local capacity to enforce building codes. The program, jointly administered by the Department of Public Safety and the Louisiana State Uniform Construction Code Council, supports training, education, the purchase of hardware and software for code implementation, and direct salary for regional code offices that work across a number of parishes.[3]

2.2.5 Flood Provisions of the Louisiana State Uniform Construction Code

The LSUCC that was in effect when Hurricane Isaac came onshore is based on the 2009 edition of the I-Codes. The flood provisions of the LSUCC are the same as the flood provisions of the I-Codes. According to FEMA, the flood provisions of the 2009 and 2012 I-Codes are consistent with the NFIP requirements for buildings and structures, and communities can rely on the I-Codes to fulfill some of the requirements for participation in the NFIP.[4]

The IBC achieves consistency with NFIP regulations in large measure through reference to American Society of Civil Engineers (ASCE) 24, *Flood Resistant Design and Construction*, while the IRC's consistency is based on the code's prescriptive provisions.

LSUCC, Building Code. The scope of the building code includes all buildings and structures except one- and two-family homes (covered by the residential code) and other buildings that are explicitly identified in the statute as not subject to the code (see Section 2.2.2). The code does not include any administrative provisions (Chapter 1 of the IBC).

The LSUCC references ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* for loads that must be accounted for in building design, including wind loads, snow loads, seismic loads, and flood loads. Flood loads include hydrostatic loads, hydrodynamic loads, wave loads, and debris impact loads.

The LSUCC includes flood provisions in several chapters, but most are in Section IBC 1612, Flood Loads, in Chapter 16, Structural Design, which references ASCE 24 for specific design and other requirements applicable in flood hazard areas:

- Section 1612.1 – General requirement that buildings, including buildings that are undergoing Substantial Improvement or repair of Substantial Damage, be designed and constructed to resist the effects of flood hazards and flood loads.
- Section 1612.2 – Definitions of terms used in the flood provisions of the code.
- Section 1612.3 – Flood hazard areas established by the adoption of flood hazard maps, which are, at a minimum, maps prepared by FEMA; requirements that apply if design flood elevations (DFEs)/BFEs are not included in the adopted map; and requirements for determining impacts in riverine flood hazard areas if DFEs/BFEs are specified but floodways are not delineated.

3 http://lsuccc.dps.louisiana.gov/grant.html.

4 FEMA prepared excerpts of the flood provisions of the I-Codes: http://www.fema.gov/building-science/building-code-resources.

- Section 1612.4 – Requirement to design and construct buildings and structures in flood hazard areas in accordance with ASCE 7 (loads) and ASCE 24 (all other requirements). Technical flood requirements are part of the IBC by reference to ASCE 24.

- Section 1612.5 – Documentation that must be prepared and sealed by registered design professionals.

Chapter 34 of the LSUCC includes requirements that apply to work on existing buildings. The NFIP requires local jurisdictions to evaluate work proposed for existing buildings, especially buildings that predate a community's participation in the NFIP. If the work on an existing building is determined to constitute Substantial Improvement or repair of Substantial Damage, the building must be brought into compliance with the requirements for new buildings in flood hazard areas. Chapter 34 includes provisions applicable to existing buildings in flood hazard areas. Separate sections contain flood requirements for additions, alterations, repairs, change of occupancy, and improvement of historic structures.

ASCE 24, *Flood Resistant Design and Construction*. ASCE 24 addresses topics pertinent to designing buildings in all flood hazard areas, including floodways, coastal high hazard areas, and other high-risk flood hazard areas such as alluvial fans, flash flood areas, mudslide areas, erosion-prone areas, and high-velocity areas. It covers the following topics: (1) scope, definitions, structure classification, basic requirements applicable in all flood hazard areas; (2) requirements for Zone A areas not identified as high-risk areas; (3) requirements for high-risk areas; (4) requirements for Zone V and Coastal A Zones; (5) materials; (6) dry floodproofing and wet floodproofing; (7) utilities; (8) building access; and (9) miscellaneous construction.

In some respects, ASCE 24 and the codes that reference ASCE 24 exceed or are more specific than the NFIP minimum requirements. ASCE 24-05 requirements are summarized in *Highlights of ASCE 24, Flood Resistant Design and Construction* (FEMA 2010c).[5]

LSUCC, Residential Code. The residential code of the LSUCC is applicable to one- and two-family dwellings and most townhomes. The code does not include any administrative provisions (Chapter 1 of the IBC). Flood provisions are included throughout the code, but most are in Section R322, which is specific to flood hazards.

- R322.1 includes requirements that apply in all flood hazard areas. The section includes the general performance statement that all buildings are designed, connected, and anchored to resist flotation, collapse, or permanent lateral movement due to structural loads and stresses from flooding equal to the design flood. This section also establishes the DFE, defines the lowest floor, specifies protection of equipment, specifies requirements for water supply and sanitary sewage systems, requires use of flood damage-resistant materials, and requires submission of as-built elevation documentation.

- R322.2 includes requirements for flood hazard areas other than coastal high hazard areas (Zone A). The section specifies that if the area subject to waves between 1½ and 3 feet is delineated, the area shall be designated a Coastal A Zone. Elevation requirements are specified, requiring the lowest floor to be at or above the DFE. If a Coastal A Zone is designated, the lowest floor

5 http://www.fema.gov/library/viewRecord.do?id=3515.

is required to be at least 1 foot above the BFE. Limitations on enclosures below the DFE are specified and, unless designed in accordance with the code requirements for foundations, masonry wall height limits are specified as a function of wall reinforcement and wall thickness.

- R322.3 includes requirements for coastal high hazard areas (Zone V). The section requires buildings to be landward of the reach of mean high tide and specifies that alteration of sand dunes and mangrove stands are not permitted unless engineering analyses demonstrate no increase in the potential for flood damage. Elevation requirements specify that the bottom of the lowest horizontal structural member, as a function of orientation with respect to the direction of wave approach, must be at or above the DFE. Limitations on enclosures and walls below the DFE are also specified, and scour and erosion must be considered in the design of foundations. The section also specifies that documentation of the design and methods of construction are to be prepared and sealed by a registered design professional.

The LSUCC Residential Code and ASCE 24. The residential code requires homes proposed to be located in floodways (where floodwaters tend to be deeper and flow faster) to be designed in accordance with ASCE 24. This requirement is intended to account for flood loads associated with flood depth and velocity in the foundation design instead of relying on the prescriptive requirements of the residential code. In addition, ASCE 24 is permitted as an alternative to the requirements in coastal high hazard areas (Zone V).

LSUCC, Existing Building Code. The scope of the existing building code includes repairs, alterations, additions, changes in occupancy, and relocated buildings. The code does not include any administrative provisions (Chapter 1 of the IBC). For work covered by this code, if the work constitutes Substantial Improvement (including repair of Substantial Damage), the proposed work and the existing building are to be brought into compliance with the flood-resistant design requirements for new construction. Certain historic buildings in flood hazard areas are not required to be brought into compliance if they retain their historic designation.

2.2.6 Manufactured Homes

Requirements for installation of new and used manufactured homes are specified in R.S. 51:912.21 through 31. Manufactured home installers are required to be licensed, and educational requirements are specified. The installation standards require compliance with manufacturer's installation instructions (or the State standards, if the original instructions are not available). Specific requirements are listed for steel piers, manufactured load-bearing supports, and concrete products. The following provisions are pertinent for installation in flood hazard areas:

- Compliance with "*Manufactured Home Installation in Flood Hazard Areas*, published by the Federal Emergency Management Agency"[6] is explicitly required for installation in flood-prone areas.
- Piers over 36 inches tall and corner supports over 24 inches in height are specified in detail, with concrete blocks used for the piers (without specifically saying they are permitted in SFHAs).
- All piers over 52 inches in height must be designed by an architect or engineer.

6 Although not explicit in the statutory citation, this refers to FEMA 85, which was published in 1985 and superseded by FEMA P-85, *Protecting Manufactured Homes from Floods and Other Hazards* (2009c).

The statute for the LSUCC specifically states that the building code does not apply to the installation of manufactured homes (R.S. 33:4775).

2.3 Local Floodplain Management Regulations and Building Codes

The MAT reviewed the floodplain management regulations and local regulations that pertain to enforcement of the building code adopted by Plaquemines Parish and the Cities of Mandeville and Slidell. This section shows the more significant observations based on the reviews.

Each community has adopted floodplain management regulations that contain provisions required for participation in the NFIP, including provisions that apply to buildings and structures within the scope of the LSUCC. Because the statute explicitly states that the LSUCC does not apply to several types of buildings, the State deems it important that communities retain complete floodplain management regulations that include all requirements, including those for buildings and structures. Any conflicts between the building code and local regulations are resolved by the building official and local floodplain administrator, typically with the more restrictive provision prevailing (e.g., locally adopted freeboard). This is considered appropriate because of the explicit statutory provision that references the standards of the NFIP (R.S. 40:1730.30). Appeals of those decisions may be made to local appeals boards; subsequent appeals can be made to the Council. Table 2-1 summarizes NFIP and CRS data for communities that the MAT visited.

Table 2-1: NFIP/CRS Data for Communities Visited by the MAT

Community Name (CID)	NFIP Entry Date	Current Effective FIRM	CRS Entry Date	Effective Date of Current CRS Class	Current CRS Class
Jefferson Parish (225199)	10/1/1971	3/23/1995	10/1/1992	5/1/2010	6
LaPlace (part of St. John the Baptist Parish, 220164)	7/16/1980	11/4/2010	10/1/1994	5/1/2010	8
Madisonville (220201)	12/2/1980	3/16/1983	Not in CRS	Not in CRS	Not in CRS
Mandeville (220202)	9/28/1979	5/16/2012	10/1/1992	10/1/2008	7
Plaquemines Parish (220139)	5/1/1985	9/30/1993	Not in CRS	Not in CRS	Not in CRS
Slidell (220204)	12/16/1980	4/21/1999	10/1/1992	10/1/2008	8

NFIP = National Flood Insurance Program

FIRM = Flood Insurance Rate Map

CRS = Community Rating System

SOURCE: NFIP COMMUNITY STATUS BOOK, HTTP://WWW.FEMA.GOV/CIS/LA.HTML; COMMUNITY RATING SYSTEM (CRS) COMMUNITIES AND THEIR CLASSES, HTTP://WWW.FEMA.GOV/LIBRARY/VIEWRECORD.DO?ID=3629

2.3.1 Jefferson Parish, LA

Jefferson Parish enforces both the LSUCC and floodplain management regulations (Zone A and Zone V) in the unincorporated areas of the parish. The floodplain management regulations contain the minimum requirements to conform to the NFIP requirements in 44 CFR Parts 59 and 60, but may have incomplete specifications for certain higher standards:

1) Floodplain Management Regulations:

   a. Require minimum NFIP elevation (see Table 2-2).

   b. Define but does not use "area of future conditions flood hazard" and "freeboard."

   c. Define "cumulative Substantial Damage" to be flood-related damage on two separate occasions, rolling 10-year period, for which the cost of repairing equals, on average, 25 percent of the market value of the structure before damage occurred. Specific provision at Sec. 14-5.5 simply "recognizes and accepts" the definition. There is no change to the definition "Substantial Damage," and thus no requirement to treat buildings that sustain "cumulative Substantial Damage" as Substantially Damaged.

   d. In definition of "lowest floor," references the "nonelevation design requirement of Section 60.3" rather than of the parish's regulation (i.e., enclosures).

   e. Use "first floor elevation" (not defined) where NFIP regulations use "lowest floor"; uses "livable areas."

   f. Define "repetitive loss" but does not include such structures in the definition for "Substantial Damage"; does not clearly require repetitive loss structures to comply with any requirement other than elevation (see Sec. 14-5.1 General standards).

   g. Define "severe repetitive loss," but uses the term only under the parish's responsibility to review construction to ensure compliance with "first floor elevation" requirements; does not clearly require compliance (see Sec. 14-4.3(e) and Sec. 14-5.1 General standards).

   h. Define "residential structure" to exclude "trailers, hotels, motels, and motor lodges," thus permitting buildings with those occupancies to be dry floodproofed.

   i. Require expansion of any existing use in coastal high hazard areas to be in accordance with the requirements.

   j. Limit placement of new manufactured homes in floodways and coastal high hazard areas to existing parks or subdivisions.

   k. Use but does not define "floodproofed" (it is described in certification requirements in Sec. 14-5.1(8)(c)).

   l. Adopt the "Preliminary Flood Insurance Study for Jefferson Parish" and the "Preliminary DFIRMs [digital Flood Insurance Rate Maps] for the East Bank of the Mississippi and ABFEs dated April 12, 2006, and revisions thereto," in addition to the "previous March 23, 1995 Official Flood Maps." Several other paragraphs describe maps; also see Sec. 14-5.6, Higher regulatory standards for specific designated areas.

2) Building Code:

   a. Adopts provisions for administration and enforcement of the LSUCC; specifically adopts the LSUCC, as amended (but identifies the 2006 editions of the I-Codes); and specifically adopts Part I-Administrative of the 2006 editions of the I-Codes.

   b. Does not adopt IBC Appendix G.

   c. Sec. 8-2-101.5.1 clearly establishes that every existing building must comply with the requirements for new construction "in its entirety" when repair, renovation, addition, or other improvement equals or exceeds 50 percent of market value. Specifies that "When a building is substantially damaged due to any origin, other than flooding, the building or structure shall meet the technical codes and requirements of this chapter for new construction." When damage is due to flooding, an exception requires "only the base flood elevation requirements for new construction shall be fully met." Omits compliance with all other flood requirements (e.g., foundation type, utilities, flood damage-resistant materials) and appears to not require full compliance with the rest of the code. Sec. 8-2.101.5.1.1 provides that except for regulations pertaining to floodplain management, the code official shall determine the extent of compliance.

d. Sec. 8-2-101.6 specifies that the code shall not be mandatory for existing buildings identified and classified as historic buildings, which may have the effect of superseding the requirements of IEBC.

e. Does not retain the IBC inspections in flood hazard areas.

f. Sec. 8-3-111.1.4, Slab foundation: (a) for residential use, requires the top of slab to be at or above BFE shown on the FIRM; (b) for nonresidential use, requires the same or, if below the BFE, permits floodproofing; and (c) in Zone V, requires construction to "conform to the FEMA regulations" and to be certified that "the structure is securely attached to adequately anchored pilings or columns."

g. Sec. 8-3-111.1.5, Piers or chain wall foundations, requires the "lowest portion of the structural members of the lowest floor (excluding the pilings, columns, or piers)" to be at or above the BFE established by FEMA and requires certification (without zone specified and without reference to same basis for establishing SFHAs as specified in the floodplain management regulations), that "the structure is securely attached to adequately anchored pilings, columns or piers."

h. Has parish-specific requirements related to soils, requirements for footings and foundation walls, and detailed specifications for piles.

Table 2-2: Jefferson Parish Elevation Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/Floodproofing: Zone A, Nonresidential	Bottom of LHSM of the Lowest Floor: Zone V
Floodplain Management Regulations	At or above the BFE	At or above the BFE	At or above the BFE
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: BFE + 1 foot for lowest floor/dry floodproofing (Categories II and III) IBC: BFE + 2 feet for lowest floor/dry floodproofing (Category IV)	IRC: • At/above BFE if LHSM is parallel • At/above BFE + 1 foot if LHSM is perpendicular IBC: same as IRC, except additional freeboard for Categories III and IV

LHSM = lowest horizontal structural member

BFE = base flood elevation

LSUCC = Louisiana State Uniform Construction Code

IRC = International Residential Code

IBC = International Building Code

2.3.2 LaPlace, LA (unincorporated St. John the Baptist Parish)

LaPlace is part of the unincorporated St. John the Baptist Parish, and development in LaPlace is subject to the requirements of the parish. The parish enforces both the LSUCC and floodplain management regulations (Zone A and Zone V) in the unincorporated areas of the parish. The floodplain management regulations appear to conform to the NFIP requirements in 44 CFR Parts 59 and 60:

1) Floodplain Management Regulations:
   a. Require minimum NFIP elevation (see Table 2-3).
   b. Have nonstandard definition of “elevated building”; the term is not used.
   c. Reference NFIP regulations rather than restating requirements (see definition “Lowest Floor,” appointment of Floodplain Administrator, and provisions for floodway encroachments.

2) Building Code: Adopts the Louisiana State Uniform Construction Code
   a. Has no technical amendments to the building codes.
   b. Does not adopt IBC Appendix G.
   c. Adopts IBC provision that authorizes the code official to grant modifications if “special circumstance makes the strict letter of this article impractical and the modification does not lessen health, accessibility, life and fire safety requirements.”
   d. Specifies content of applications and plans, including specific information for construction in flood hazard areas.
   e. Includes “floodplain inspection” upon placement of the lowest floor and prior to further vertical construction, and submission of elevation documentation.
   f. Requires businesses engaged in moving buildings to obtain a license from the parish engineer.

Table 2-3: St. John the Baptist Parish Elevation Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/ Floodproofing: Zone A, Nonresidential	Bottom of LHSM of the Lowest Floor: Zone V
Floodplain Management Regulations	At or above the BFE	At or above the BFE	At or above the BFE
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: BFE + 1 foot for lowest floor/dry floodproofing (Categories II and III) IBC: BFE + 2 feet for lowest floor/dry floodproofing (Category IV)	IRC: • At/above BFE if LHSM is parallel • At/above BFE + 1 foot if LHSM is perpendicular IBC: same as IRC, except additional freeboard for Categories III and IV

LHSM = lowest horizontal structural member
BFE = base flood elevation
LSUCC = Louisiana State Uniform Construction Code
IRC = International Residential Code
IBC = International Building Code

2.3.3 Madisonville, LA

The Town of Madisonville enforces both the LSUCC and floodplain management regulations (Zone A and Zone V). The Town's Web page makes available only the floodplain management regulations, and no other regulations. The floodplain management regulations do not fully conform to the NFIP requirements in 44 CFR Parts 59 and 60. The following are the most significant differences:

1) Floodplain Management Regulations:
   a. Require minimum NFIP elevation (see Table 2-4).
   b. Define but do not use "habitable floor" with a qualification that "a floor used for storage purposes only is not a 'habitable floor.'"
   c. Do not define "historic structure"; the Substantial Improvement exception does not use the term.
   d. Do not define or use "Substantial Damage."
   e. Do not include additions in the definition of Substantial Improvement.
   f. Specify the Floodplain Administrator by name.
   g. Have no provisions for manufactured homes in Zone V.

2) Building Code: not available online.

Table 2-4: Madisonville Elevation Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/ Floodproofing: Zone A, Nonresidential	Bottom of LHSM of the Lowest Floor: Zone V
Floodplain Management Regulations	At or above the BFE	At or above the BFE	At or above the BFE
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: BFE + 1 foot for lowest floor/ dry floodproofing (Categories II and III) IBC: BFE + 2 feet for lowest floor/ dry floodproofing (Category IV)	IRC: • At/above BFE if LHSM is parallel • At/above BFE + 1 foot if LHSM is perpendicular IBC: same as IRC, except additional freeboard for Categories III and IV

LHSM = lowest horizontal structural member
BFE = base flood elevation
LSUCC = Louisiana State Uniform Construction Code
IRC = International Residential Code
IBC = International Building Code

2.3.4 Mandeville, LA

The City of Mandeville enforces both the LSUCC and floodplain management regulations (Zone A and Zone V). The floodplain management regulations do not fully conform to the NFIP requirements in 44 CFR Parts 59 and 60. The following are the most significant differences:

1) Floodplain Management Regulations:
   a. Do not define or use "Substantial Damage"
   b. Do not include additions in the definition of Substantial Improvement ; specify costs "shall be cumulative, beginning from the date that the first alteration commenced")
   c. Have no provisions for manufactured homes in Zone V
   d. Specify elevation requirements:
      i. Freeboard of +12 inches in Zone A, residential only
      ii. No freeboard for nonresidential structures
      iii. No freeboard for Zone V
      iv. No freeboard for Zones AO/AH
   e. Prohibit manufactured homes in Zone A and Zone V but specify elevation and other requirements for manufactured homes in Zone A (and apparently the requirements apply to new installations, replacements, and Substantial Improvements). Require certain manufactured homes to meet full elevation requirements.

2) Building Code:
   a. Adopts the code mandated by the Louisiana State Uniform Construction Code Council, without specifying which codes or editions (and retains references to Southern Building Code Congress International [SBCCI]).
   b. Does not adopt IBC Appendix G.
   c. Specifies content of applications and plans, and requires submission of flood elevation certificate in flood hazard areas; also requires certificates "before authorization for the provision of permanent electrical service will be issued."
   d. Adopts a "grading supplement" (references SBCCI Standard Excavation and Grading Code), which specifies the finished floor elevation of attached and detached garages and accessory structures when fill is placed, and requires, among other things:
      i. The finished floor elevation of the living area of all habitable dwelling units shall not be less than 12 inches above the crown of a paved street, where the crown or center line of the street is elevation plus 11 feet or higher.
      ii. Where the crown of the street is below elevation 11 feet (above datum), the top of the finished floor of the living area of all habitable dwelling units shall be not less than elevation plus 12 feet or current applicable FEMA requirements.
   e. Makes no technical amendments to the building codes.

3) The State accepts higher standards adopted in local floodplain management regulations as prevailing over the LSUCC. The parish adopts a freeboard requirement for residential buildings that exceeds the elevation requirements of the LSUCC (Table 2-5).

Table 2-5: Mandeville Freeboard Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/ Floodproofing: Zone A, Nonresidential	Bottom of LHSM of the Lowest Floor: Zone V
Floodplain Management Regulations	BFE + 12 inches	To the BFE	To the BFE
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: BFE + 1 foot for lowest floor/ dry floodproofing (Categories II and III) IBC: BFE + 2 feet for lowest floor/ dry floodproofing (Category IV)	IRC: • At/above BFE if LHSM is parallel • At/above BFE + 1 foot if LHSM is perpendicular IBC: same as IRC, except additional freeboard for Categories III and IV

LHSM = lowest horizontal structural member

BFE = base flood elevation

LSUCC = Louisiana State Uniform Construction Code

IRC = International Residential Code

IBC = International Building Code

2.3.5 Plaquemines Parish, LA

Plaquemines Parish enforces both the LSUCC and floodplain management regulations (Zone A and Zone V) in the unincorporated areas of the parish. The floodplain management regulations do not fully conform to the NFIP requirements in 44 CFR Parts 59 and 60. The following are the most significant differences:

1) Floodplain Management Regulations:

   a. Permit detached “accessory structures not used or designed for human habitation” below the BFE, provided they are “limited to accessory uses permitted in conjunction with residences by the zoning ordinances.”

   b. Requirements for manufactured homes in Zone V point to the requirements for Zone A (thus not specifying elevation of the bottom of the lowest horizontal structural member).

   c. Essentially require elevation of residential structures on fill by stating that the use of other methods will be approved if the use of fill is demonstrated to be impractical based on lot size and similar factors, while also requiring permit applications to include information “necessary to determine the extent to which any proposed fill or other landscape alteration will result in displacement of flood waters.”

   d. Do not permit placement of manufactured homes and recreational vehicles in floodways except in existing parks and subdivisions. Manufactured home units used for offices, storage, or other nonresidential purpose are required to meet the same requirements as those used for residences.

e. Require subdivisions for residential use to either (1) provide building sites with an average elevation at or above the BFE, or (2) be subject to deed restrictions requiring elevation of structures to or above the BFE. Proposals for nonresidential structures are treated the same, except the deed restriction requires elevation or floodproofing.

2) Building Code:

a. Adopts the Louisiana State Uniform Construction Code as it may from time to time be amended and promulgated by the State and all applicable standards and appendices referenced in that code, including Appendix J (Existing Buildings) to the residential building code. Also adopts the administrative chapters "of the various building codes." The parish does not adopt IBC Appendix G.

b. No technical amendments to the building codes.

c. Does not adopt freeboard requirements that exceed the elevation requirements of the LSUCC (Table 2-6).

Table 2-6: Plaquemines Parish Freeboard Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/ Floodproofing: Zone A, Nonresidential	Bottom of LHSM of the Lowest Floor: Zone V
Floodplain Management Regulations	To or above the BFE	To or above the BFE	To or above the BFE
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: BFE + 1 foot for lowest floor/dry floodproofing (Categories II and III) IBC: BFE + 2 feet for lowest floor/dry floodproofing (Category IV)	IRC: • At/above BFE if LHSM is parallel • At/above BFE + 1 foot if LHSM is perpendicular IBC: same as IRC, except additional freeboard for Categories III and IV

LHSM = lowest horizontal structural member

BFE = base flood elevation

LSUCC = Louisiana State Uniform Construction Code

IRC = International Residential Code

IBC = International Building Code

2.3.6 Slidell, LA

The City of Slidell enforces both the LSUCC and floodplain management regulations (Zone A only). The floodplain management regulations do not fully conform to the NFIP requirements in 44 CFR Parts 59 and 60. The following are the more significant differences:

1) Floodplain Management Regulations:

a. Use but do not define "lowest floor."

b. Do not define "Substantial Damage."

c. Require survey of the “bottom of the lowest structural member of the lowest floor” (even though only Zone A).

d. “Adopt” 1 foot of freeboard “in the adoption of ABFEs,” but freeboard is not addressed in the requirements that specify elevations for buildings. How this requirement is administered and whether it results in buildings having their lowest floors elevated (or floodproofed, for nonresidential buildings) to the ABFE plus 1 foot is unclear.

e. Include specifications and limitations for fill; specifically identifies use of “enclosed retaining wall or other method not requiring the use of fill (such as pilings or pier construction)” if necessary.

2) Building Code:

a. Adopts the 2000 editions of IBC, IRC, IMC, and IFGC “and any subsequent amendments and revisions.” Does not adopt IBC Appendix G.

b. When private drainage facilities are proposed, the plans shall show the areas subject to inundation at flood stage and the “recommended floor elevation of residences to ensure safety in flood conditions and conformance with federal flood insurance regulations.”

c. No technical amendments to the building codes.

3) The State accepts higher standards adopted in local floodplain management regulations as prevailing over the LSUCC. The city’s regulations refer to the ABFE and require an additional foot of elevation, which may exceed the elevation requirements of the LSUCC (Table 2-7).

Table 2-7: Slidell Freeboard Comparison: Floodplain Management Regulations vs. LSUCC

	Lowest Floor: Zone A, Residential	Lowest Floor/Floodproofing: Zone A, Nonresidential
Floodplain Management Regulations	ABFE + 1 foot	ABFE + 1 foot
LSUCC	IRC: to or above the BFE (BFE + 1 foot where Coastal A Zone is delineated) IBC: BFE + 1 foot (Category II)	IBC: • BFE + 1 foot for lowest floor/dry floodproofing (Categories II and III) • BFE + 2 feet for lowest floor/dry floodproofing (Category IV)

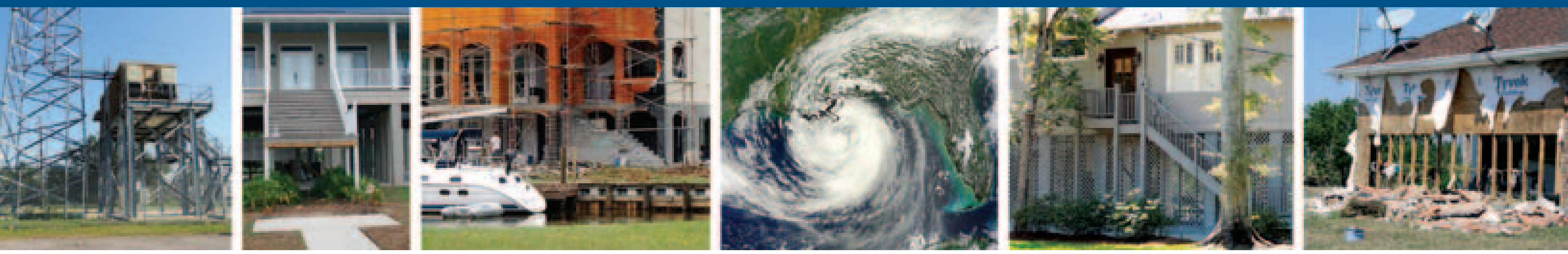
ABFE = Advisory Base Flood Elevation

LSUCC = Louisiana State Uniform Construction Code

BFE = base flood elevation

IRC = International Residential Code

IBC = International Building Code



HURRICANE ISAAC IN LOUISIANA

3 Residential Construction

During field investigations, one focus of the MAT was on the performance of residential buildings, particularly those repaired or reconstructed after Hurricane Katrina.

Assessing the structural and building envelope performance of residential buildings was one of the MAT's primary goals. In particular, buildings reconstructed after Hurricane Katrina that had experienced design flood conditions were of interest. The MAT used location-specific information that they gathered prior to and during the field investigations to identify which buildings were constructed post-Katrina. This prior knowledge of the hazard conditions that the buildings were exposed to during Hurricane Isaac was beneficial in the assessments.

Damage documented within this chapter was observed in the field or made available through information gathered from other public sources (local building departments, Substantial Damage inspection records, elevation certificates, etc.). Statements made herein are not intended to represent final judgments as to the cause of damage to individual buildings; the MAT recognizes that further investigation by others may refine or alter judgments made in this report. Nevertheless, general damage patterns and trends the MAT observed are the basis for the recommendations in this report for improving residential design and construction.

3.1 Residential Flood Damage

Isaac's flood elevations did not exceed effective BFEs in most of the areas visited by the MAT. Consequently, severe flood damage to one- and two-family residential buildings was not common throughout the study area. Damage to residential buildings was primarily a result of inundation by storm surge. The exceptions to these observations were in LaPlace, a community along Lake Pontchartrain, and in several areas along the East Bank of the Mississippi River in Plaquemines Parish. In these areas, flood levels did exceed the effective BFEs, and the MAT observed evidence of damage caused by waves, velocity flow, and flood-borne debris.

Most traditional one- and two-family residential buildings in the affected area were built on shallow foundations, such as slabs, stem walls, crawlspaces, or piers. In newly constructed buildings, pile or column foundations were more common. Masonry pier foundations were the most common foundations in areas designated Zone V and in Zone A near the shoreline, followed by timber pile foundations. When properly designed and constructed, all of these foundations were effective during Hurricane Isaac where waves and surge remained below the floor system. In areas that experienced damage, including LaPlace, Slidell, Mandeville, Orleans Parish, and Jefferson Parish, the damage was caused by slow rising water. Flood depths in residential buildings ranged from 2 to 4 feet above slab foundations. Typical damage to these buildings included interior finish; flooring; heating, ventilation, and air conditioning (HVAC); and contents damage. Very few homes on elevated foundations (piles/piers) in these areas visited by the MAT experienced flooding above the floor system; those that did experienced similar damage as homes on slab foundations. The one exception was buildings not properly anchored to piers that were displaced from their foundation.

The most extreme inundation was observed in Braithwaite along the East Bank in Plaquemines Parish, where floodwaters reached 8 to 10 feet above floor systems. In some areas along the East Bank, the MAT observed severe building damage in areas where levees were overtopped by rapidly rising, fast-moving water. This caused many buildings to be washed off their foundations.

At the Frenier Fishing Village, located east of LaPlace along the western shoreline of Lake Pontchartrain, some buildings were destroyed when surge and waves exceeded the floor elevation (see Figure 3-1). Age (ranged from 5 years to more than 30 years old) and elevation of construction were the primary damage indicators in this small community, with the older, non-elevated, pre-FIRM residences being destroyed and newer, elevated homes having less damage.

Most other areas visited by the MAT experienced damage caused by slow-rising water, where few indications of erosion and scour damage to foundations were observed. Typical flood damage in these areas is shown in Figures 3-2 through 3-4.

New construction and post-Katrina elevation projects consistently had minimal, if any, damage compared to adjacent non-elevated properties (see Figure 3-5). No flood damage was observed for the residential buildings the MAT visited that were constructed under the FEMA Hazard Mitigation Grant Program (HMGP) Pilot Mitigation Reconstruction Program.

Figure 3-1:
Wave and surge damage to a residential building. The house is located in Zone V along Lake Pontchartrain's western shoreline (Saint John the Baptist Parish, LA).

Figure 3-2: Damage was observed in most at-grade slab foundation residences, while minimal damage was observed in adjacent elevated properties (Barataria, LA).

Figure 3-3: Typical flood depth of at-grade slab foundation residences; inset illustrates flood depth of 31 inches above the at-grade slab foundation (Slidell, LA).

Figure 3-4:
The damage to some elevated Zone V residences was limited to the loss of stairs (Mandeville, LA).

Figure 3-5:
Minimal damage was observed in most elevated residences. The USGS HWM near this location was 9.74 feet, compared to an effective BFE of Zone A14 (EL12), Katrina ABFE of Zone AE (EL13), and preliminary FIRM of Zone VE (EL16) (Orleans Parish, LA).

3.2 Residential Wind Damage

Wind damage to one- and two-family residential buildings was minor. The most common damage observed was to exterior finishes (vinyl siding, soffit material, fascia, etc.) and included minor roof cover loss. Age of construction was a major contributing factor to the extent of wind damage. As expected, the building envelopes on older houses did not perform as well as those on new houses. The one exception to this observation was the widespread loss of underside paneling in relatively new elevated coastal construction (see Section 3.7). Typical residential wind damage is shown in Figures 3-6 and 3-7.

As anticipated, new residential buildings constructed under the FEMA Pilot Mitigation Reconstruction Program had no observed wind damage (see Figure 3-8); however, the number of properties built under this program was surprisingly low. In some cases, typically because of structural concerns, local communities were unable to complete a traditional elevation project because the structure would not be compliant with minimum standards of the 2003 I-Codes or other local codes and ordinances (because structural integrity may be questionable, the structure cannot be retrofitted to withstand current design wind speeds, etc.).

PILOT MITIGATION RECONSTRUCTION PROGRAM

Under the Pilot Mitigation Reconstruction Program, eligible Applicants can receive Federal mitigation funds to demolish an existing structure and construct an improved, elevated structure on the same site. This may include pre-existing structures that were Substantially Damaged or destroyed as a result of a declared event.


Figure 3-6: Loss of standard vinyl siding to recently elevated residential building; use and/or damage of high-wind siding was not observed by the MAT (Plaquemines Parish, LA).

Figure 3-7: Roof soffit and fascia damage to Exposure C residential building (Plaquemines Parish, LA).

Figure 3-8: Pilot Mitigation Reconstruction Program project; no observed wind damage (Mandeville, LA).

3.3 Foundation Performance

The MAT observed a wide range of foundations in residential buildings. Foundation types included closed-style foundations like slab-on-grade, crawlspace on perimeter foundation walls, and backfilled stem walls, and open-style foundations like piers and piles. The MAT also observed several homes that were originally constructed with slab-on-grade foundations that had been elevated with their slabs intact. In those homes, the elevated slabs were typically supported on masonry or concrete piers.

Most non-elevated single-family or duplex residential buildings observed were constructed using a concrete slab-on-grade or masonry crawlspace foundation. Many of these buildings were pre-FIRM and experienced significant flood damage from inundation and the resulting hydrostatic and hydrodynamic forces. Side-by-side comparisons of non-elevated and elevated buildings in Slidell and Mandeville are shown in Figures 3-9 and 3-10. The elevated house had no observed damage, while the non-elevated house had interior finish, flooring, HVAC, plumbing, electrical, and contents damage caused by over 2 feet of flooding. The MAT consistently observed that the non-elevated houses experienced far greater flood damage than houses constructed on elevated foundations built to the ABFE or the preliminary FIRM developed after Hurricane Katrina. Flood depths in non-elevated houses in St. Tammany Parish were observed to be from 2 to 4 feet. However, in some locations of Plaquemines Parish, flood depths reached the rooftops of non-elevated homes. The deeper the flooding, the more damage the inundation caused; thus, the greatest damage was observed in Plaquemines Parish, especially along the East Bank of the Mississippi River.

Elevated foundations for existing single-family residential buildings were typically concrete or masonry piers supporting elevated slabs. Many of the home elevation projects were completed after Hurricane Katrina using FEMA Hazard Mitigation funds. Some elevated foundation projects involved detaching the home from its slab-on-grade foundation, elevating the walls, roof, and other portions of the structure, and constructing a new elevated wood-framed first floor, while leaving the existing slab-on-grade in place. A few of the elevated houses the MAT observed were entirely new structures constructed on piers or piles as part of the Pilot Mitigation Reconstruction Program. Many elevated foundations were raised an entire story to comply with local freeboard requirements as well as to accommodate vehicle parking or storage underneath the building. Local building officials informed the MAT that they preferred reconstruction over other elevation techniques because it eliminated the uncertainty in the structural capacity of the existing slab and structure and allowed new housing to be constructed to current prescriptive codes and standards.

Figure 3-9: Neighboring residential buildings; the elevated residence had no observed damage, while the non-elevated home had significant interior damage caused by more than 2 feet of flooding (red arrow indicates flood depth) (Slidell, LA).

Figure 3-10: House elevated as part of the HMGP Pilot Mitigation Reconstruction Program (Mandeville, LA).

Elevated Slab Concerns

The MAT observed many residential buildings where the existing slab had been elevated in place. The process to elevate a structure with a slab-on-grade foundation begins with excavating around the existing foundation to allow a network of lifting beams to be placed underneath the existing slab. Once the beams are in place, the home is lifted on the network of beams using hydraulic jacks. As with traditional elevation projects, there is a risk for cracking due to differential lifting, as shown in Figure 3-11. The elevated home is then supported on temporary timber cribbing or shoring until the permanent elevated foundation is completed. Figure 3-12 shows a home supported on timber cribbing. Permanent elevated foundations typically consist of reinforced concrete or masonry piers. Once the permanent foundations are in place and have been connected with the slab, the cribbing and other temporary supports are removed.

Figure 3-11: Slab-on-grade elevation with structural cracks due to differential lifting (Slidell, LA).

Figure 3-12: Slab-on-grade elevation in progress (Slidell, LA).

The MAT observed several slab-on-grade elevations with the following features:

- Vertical supports consisting of square masonry or concrete piers or 3-inch pipe columns that supported the elevated slabs. Pier and column spacing varied greatly. Most spans were approximately 6 feet; some exceeded 12 feet. In some cases the permanent supporting foundations were constructed using mini-piers. These mini-piers consisted of concrete blocks connected to one another with a series of threaded steel dowel rods, cable, or other material running through a hole in the center of each block.

- A decorative perimeter wall finish was placed around the base of the elevated houses to provide an attractive covering for the uneven appearance of the raised grade slab.

Local building officials who the MAT interviewed in both Slidell and Mandeville on October 8 and 9, 2012, expressed concerns about slab-on-grade foundation elevation projects. Although neither of the building officials had documented any foundation failures, one official had received numerous reports of buildings in the community with structural cracks associated with this technique, and both expressed concerns about the lack of data provided by owners' representatives on the existing slab (i.e., concrete thickness, steel reinforcement) and the pier-to-slab connections.

The MAT's field observations of completed and ongoing slab elevation projects confirmed the observations of local building officials and revealed the following concerns:

- **Insufficient slab reinforcement/thickness:** Elevated concrete slabs were often found to be of minimal thickness with limited wire mesh steel reinforcement and/or insufficient concrete cover of the wire mesh, as shown in Figure 3-13. This was also observed in ongoing residential building slab elevation projects with attached garages.

Figure 3-13: Elevated slab with insufficient steel cover (Slidell, LA).

- **Lack of pier-to-slab connections:** Different types of elevated foundation-to-floor framing connections were observed, including bolted connections for pile foundations and grouted connections for pier foundations. However, elevated slabs were often observed to have no visible connection to their piers. Where connections were observed, they appeared to be structurally insufficient, as shown in Figure 3-14.

Figure 3-14: Structurally insufficient connection to pier. This house had a total of 7 such connections out of 17 piers supporting the structure (Mandeville, LA).

3.4 Utilities

The most prevalent damage to elevated residential buildings observed by the MAT was flood damage to electrical service components (see Figure 3-15). The NEC and local utility company requirements control where electrical service components can be located. The NEC requirements primarily focus on safe clearances around energized lines and safe working space; utility company requirements incorporate access requirements based on local conditions so they can control, maintain, and repair the equipment. Utility companies commonly require the center of electrical meters to be placed 4 to 6 feet above the finished grade to allow access for recording electrical usage as well as disconnecting or removing the electrical meters if they need to discontinue electric service to a home. Utility repairs to individual residences are typically some of the last repairs to be made, which impedes recovery and extends power outages, especially if the equipment is beyond repair and needs to be replaced.

When allowed by the local utility company, placing all electrical equipment above the flood level prevents floodwater from damaging it. The MAT observed several residences where components were elevated and accessible by stairs, walkways, or decks. These elevated structures typically supported condensers and other mechanical equipment (e.g., generators). When the equipment was properly elevated above potential flood levels, the damage to it was minimal.

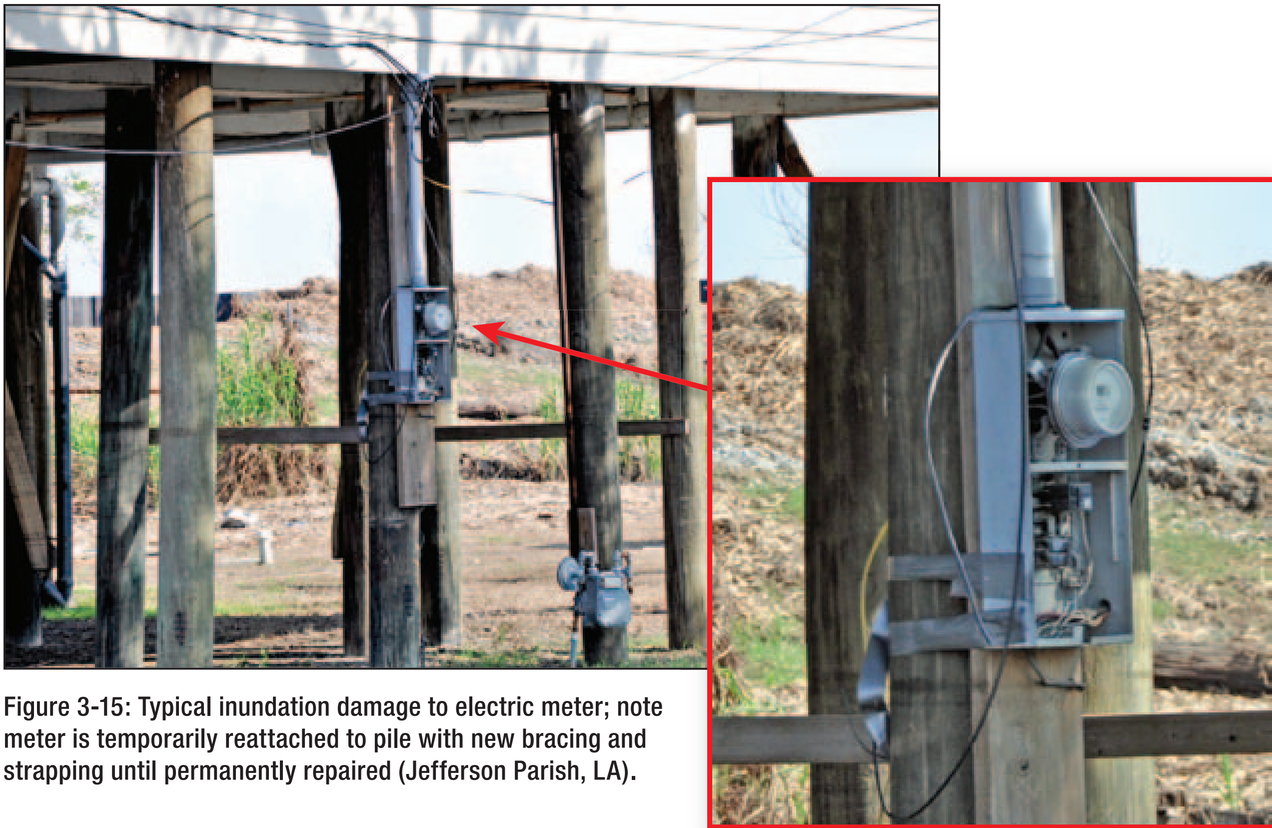


Figure 3-15: Typical inundation damage to electric meter; note meter is temporarily reattached to pile with new bracing and strapping until permanently repaired (Jefferson Parish, LA).

Proper elevation of equipment involves installing it above design flood levels and maintaining access for utility workers and first responders. Figure 3-16 shows an example of elevated electrical service components.

When conditions or local utility company requirements limit elevation of electrical meters and they must be situated below design flood levels, it is critical not to attach utilities to breakaway walls or other building components not designed to resist flood loads. Figure 3-17 shows an example of a home where the utilities are attached to foundation piers. See the *Minimizing Flood Damage to Electrical Service Components* Recovery Advisory in Appendix D for more details on recommended practices for utility placement.

A service drop is an overhead electrical line running from a utility pole to a home. Traditionally, the lines enter residential buildings through a weatherhead that penetrates the roof (see Figure 3-18). The MAT observed service drops along rooftops and along the sides of the houses. At times, vertical clearance requirements constrain the service drop location to rooftops, but in most circumstances there is some flexibility in where the connection is installed. When the service drop was attached to the roof, the MAT observed some instances where a utility pole collapsed or wind-borne debris struck it, causing the weatherhead to shift in a way that tore the roof and allowed water to penetrate. This was less likely when the service drop was installed on the side of the house. Overhead clearance requirements or the locations of the utility pole and the electrical meter may dictate whether a weatherhead is attached to the roof or the side of the house.

Figure 3-16:
Residential building with electric meter installed adjacent to side entrance (Mandeville, LA).

Figure 3-17:
Electric meter attached to foundation pier (Plaquemines Parish, LA).

Figure 3-18:
Post-Katrina residential reconstruction with service drop attached to the side of house (Slidell, LA).

3.5 Stairs

The MAT observed a variety of exterior stairway configurations on elevated residential buildings in St. Tammany and Plaquemines Parishes. Stairway materials ranged from wood to masonry and wrought iron. In many neighborhoods, exterior stairs on residential buildings were curved or segmented in multiple directions as shown in Figure 3-19. This is often done for aesthetic reasons, to reduce the visual impact of the elevation on the structure.

Figure 3-19: Curved and split stair configurations for elevated residential buildings (Mandeville, LA).

The MAT observed damage to these exterior stairways, most frequently along Lakeshore Drive in Mandeville, as shown in Figure 3-20. Many of the homes with stairway damage had long runs of wooden stairs with solid risers oriented perpendicular to the direction of the flow of floodwater and no intermediate landings. Stairs of this type suffered the most severe damage or complete loss.

Figure 3-20: Front and side view of stair damage to elevated waterfront residential building due to closed riser, inadequate foot anchoring, and insufficient connection with the building frame (Mandeville, LA).

3.6 Enclosed Areas

The NFIP defines an *enclosure* as the portion of an elevated building below the lowest elevated floor that is either partially or fully enclosed by rigid walls. This area is to be used solely for parking, storage, and building access. The *lowest floor* is defined as the lowest floor of the lowest enclosed area (including the basement). The area within an enclosure is not considered the lowest floor provided that it is built in compliance with the applicable non-elevation design requirements of 44 CFR §60.3.

The MAT observed a variety of enclosed areas below elevated buildings, including several partially enclosed areas (see Figure 3-21), some fully enclosed areas, and a small number of above-grade enclosed areas (see Figure 3-22).

All enclosures below the BFE must be made of flood damage-resistant materials; in Zone A they must also have openings that allow floodwater levels inside and outside to rise simultaneously to equalize the hydrostatic pressure. Often, homeowners finish these areas as additional living space, which is in violation of the NFIP. The MAT observed damage to enclosures that were not constructed with flood damage-resistant materials (see Figure 3-23).


Figure 3-21: Residential building under construction with a partially enclosed area—front closed/rear open with effective BFE of A13 (EL12), Katrina ABFE of Zone AE (EL13), and preliminary FIRM of Zone VE (EL14) (Madisonville, LA).

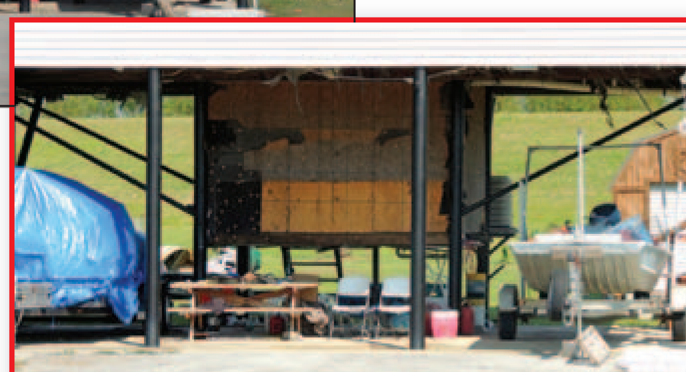



Figure 3-22: Example of above-grade enclosure below elevated residence (Plaquemines Parish, LA).

Figure 3-23: Enclosed area that was not finished with flood-resistant materials, nor did it have flood openings (Plaquemines Parish, LA).

For enclosures below elevated homes in Zone V, rigid walls are not permitted. Enclosures in these areas must use breakaway wall construction, which is designed to fail under flood-loading conditions. Areas used for building access, storage, and vehicle parking in Zone V are required to be open or enclosed with lattice or breakaway walls. In addition, the MAT observed above-grade enclosures at a few sites. The primary issue with above-grade enclosures is that they may not be intended to fail under flood-loading conditions and, thus, may cause additional loading to foundation elements or cause damage to spread upward. The ramps into these above-grade enclosures can also become flood-borne debris and potentially impact the foundation and/or surrounding buildings. Any damage to enclosures below the lowest floor must not result in damage to the foundation, the utility connections, or the elevated portion of the building. For homeowners in Zone V, having breakaway enclosure walls below an elevated building will result in somewhat higher flood insurance premiums than having a completely open foundation.

3.7 Underside of Elevated Buildings

The MAT observed hurricane wind damage to paneling and sheathing on the underside of several elevated homes in Plaquemines Parish. Paneling torn completely away became a source of wind-borne debris with the potential to damage neighboring buildings, and the loss of this layer of protection allowed water infiltration. Figure 3-24 shows an example of a residential building that experienced a loss of sheathing underneath the elevated first floor.

Figure 3-24:
Loss of the sheathing from the underside of an elevated building due to wind gusts (reported to exceed 80 mph) that exceeded the capacity of the vinyl siding (Plaquemines Parish, LA).

Although the wind loads underneath a building are significantly less than those on the roof system, the potential loads imposed on the sheathing system should be calculated to determine the fastener size and spacing required to adequately attach the material. The MAT team observed that, in many instances, vinyl paneling material used to cover the underside of elevated buildings frequently tore at the connection point or failed because fasteners pulled out. Less damage was observed at elevated buildings where the covering material was wood that was properly fastened to the framing above. The use of wood or more rigid materials may not eliminate all damage during high-wind events, but it will minimize the damage. See the *Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings* Recovery Advisory in Appendix D for more details on recommended practices.

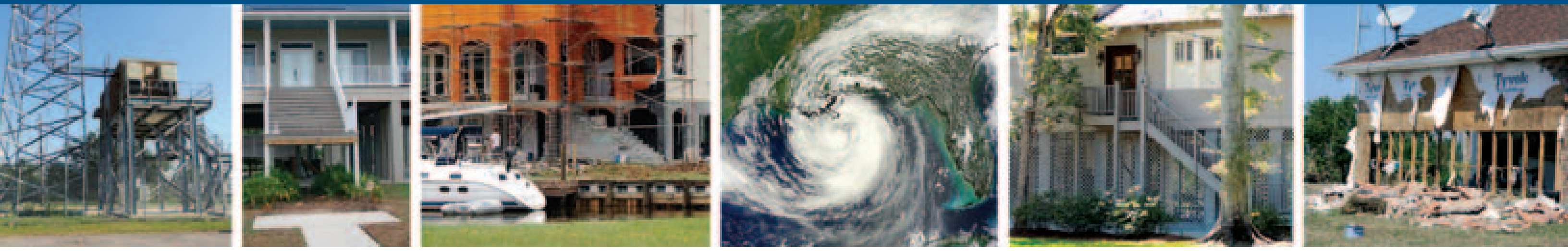
3.8 Fire-Resistant Materials

The MAT observed several elevated structures with combustible materials or vehicles stored under the elevated portion of the home. In many cases, the underside of the elevated structure did not have a fire-resistant floor assembly. The residential structures observed by the MAT often had plywood sheathing or a wood finish material over standard wood floor joists or the lowest horizontal structural member, as seen in Figure 3-25. Using standard exterior grade plywood sheathing alone or wood finish material, such as wainscoting, is dangerous if the area underneath the elevated building requires a fire-resistant floor system. If the area underneath an elevated building is used for parking or storing even small quantities of fuel or other potentially combustible materials, most building codes require partitioning these areas from living spaces. For structures with elevated concrete slabs, the MAT observed several instances of conduits, plumbing, or other penetrations through the concrete slab without a compliant fire stop system, solid fire blocking, or a fire barrier.

Figure 3-25:
Elevated house with combustible materials and vehicle parking below elevated space (Mandeville, LA).

Such conduits, as shown in Figure 3-26, would allow fire beneath the slab to enter the structure. The elevated structure should be constructed in accordance with the IRC or IBC. The 2012 IRC Table R302.6 requires not less than 5/8-inch Type X gypsum board or equivalent for habitable rooms above a garage. See the *Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings* Recovery Advisory in Appendix D for more detail on fire-resistant assemblies in elevated structures.

Figure 3-26:
Elevated house with open space to interior of the home that would allow fire to spread (Mandeville, LA).



HURRICANE ISAAC IN LOUISIANA

4 Nonresidential Construction and Infrastructure

During a disaster, communities rely heavily on certain services, including emergency responders, power, water and communication networks, and shelters.

Similar to the method used for assessing residential construction, the MAT focused on infrastructure and nonresidential buildings that were repaired or reconstructed after Hurricane Katrina that experienced flood conditions during Isaac. Based on the data gathered and damage assessment reports available prior to field investigations, the MAT observed three types of nonresidential construction: community centers, critical facilities, and infrastructure. Very few low-rise office and light commercial buildings experienced flood damage in areas visited by the MAT.

4.1 Community Centers

The Braithwaite Auditorium is a large reinforced masonry and concrete frame building constructed on an elevated concrete foundation system with a concrete slab underneath. The auditorium was rebuilt in 2011 as a result of damage caused by Hurricane Katrina. The elevation of the facility was based on the 2009 preliminary FIRM BFE (Zone VE [EL21]) rather than the Hurricane Katrina ABFE (Zone AE [EL 18]), with the lowest horizontal structural member more than 19 feet above grade (see Figure 4-1). This placed the structure above the flood levels of Hurricane Isaac, which were approximately 11 feet above grade (see Figure 4-2). However, not all utilities and associated

Figure 4-1:
The Braithwaite Auditorium was rebuilt to the preliminary BFE following damage caused by Hurricane Katrina (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

Figure 4-2:
HWM visible on glass at entrance to elevators below lowest floor of Braithwaite Auditorium (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

equipment were elevated to the same height as the structure. The building has an elevator for handicap access as well as a generator for emergency power (see Figure 4-3); the automatic transfer switch and other electrical service components for this equipment were both damaged by Hurricane Isaac. No damage was observed inside the auditorium (see Figure 4-4).

Figure 4-3: The Braithwaite Auditorium has an elevated generator for emergency power (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

Figure 4-4: No damage was observed in the auditorium (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

The auditorium building was elevated much higher than any of the homes in the nearby neighborhood. In fact, the auditorium's lowest floor was higher than some rooftops in this neighborhood. As a result, the new auditorium suffered minimal damage compared to surrounding residential buildings, which were inundated with 8 to 10 feet of water (see Figure 4-5). The primary damage the MAT observed at the auditorium was to the electrical equipment. Although the facility was used shortly after the storm, the generator transfer switch and other electrical components below the lowest floor were in need of repair (see Figure 4-6).

As part of Hurricane Katrina recovery, the Port Sulphur Community Center was constructed in 2010 with FEMA Public Assistance funding (see Figure 4-7). Plaquemines Parish consolidated 10 existing facilities into four community centers with similar construction to the Braithwaite Auditorium. These new centers were built to preliminary FIRM BFE (Zone VE [EL13]) rather than the Hurricane Katrina ABFE (Zone AE [EL 10]). No damage was observed by or reported to the MAT for the Port Sulphur Community Center; there was no flooding in this area.

Figure 4-5: Residences in the Braithwaite Park subdivision were inundated with more than 8 feet of water; the auditorium (red arrow) is at the north end of the subdivision (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

AERIAL COURTESY OF NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA); GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/.

Figure 4-6:
The Braithwaite Auditorium generator transfer switch and other electrical components were built at grade and damaged by floodwaters (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

Figure 4-7:
Recently constructed Port Sulphur Community Center; no damage was observed or reported for the elevated facility (Port Sulphur [West Bank] – Plaquemines Parish, LA).

4.2 Critical Facilities

The MAT observed the Woodlawn Fire Station in Plaquemines Parish (Figure 4-8). The Woodlawn Fire Station was built on the site of an abandoned high school. The fire station bay is a pre-engineered metal building with a metal roof and walls and brick façade. The fire station has four apparatus bays but housed 10 emergency vehicles prior to the hurricane. Firefighters serving the Woodlawn Fire Station said that the site of the station was selected because “it has never been flooded before.” Although the MAT did not observe visible structural damage, the station did receive flooding of approximately 8 feet.

Figure 4-8: Woodlawn Fire Station (Woodlawn [East Bank] – Plaquemines Parish, LA).

According to a representative of the fire department, nine pieces of equipment (fire engines, command vehicles, etc.) and all of the fire department gear (hoses, safety equipment, clothing, tools, etc.) were significantly damaged and, therefore, were not available for response and recovery operations. One fire truck was undamaged because a firefighter drove the truck to the top of a levee prior to inundation. Figure 4-9 shows a post-storm inundation aerial for reference. The fire department did not have a formal continuity of operations or contingency plan in place in the event of a hurricane, but had onsite portable generators that allowed the fire station to serve as a community shelter for the duration of the rescue operations.

Figure 4-9: Post-Hurricane Isaac aerial of Woodlawn Fire Station (Woodlawn [East Bank] – Plaquemines Parish, LA).
AERIAL COURTESY OF NOAA; GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/.

The MAT observed several Plaquemines Parish schools that were under construction. To comply with flood elevation requirements, the new schools were being constructed more than 10 feet above grade (see Figures 4-10 through 4-12). The MAT verified that, based on the flood elevations in the area, these schools would not have been inundated during Hurricane Isaac.

Figure 4-10: The recently completed Parish Learning Center was constructed approximately 10 feet above grade (Port Sulphur [West Bank] – Plaquemines Parish, LA).

Figure 4-11:
South Plaquemines High School under construction; the preliminary BFE at this site is Zone VE (EL 15) (Boothville [West Bank] – Plaquemines Parish, LA).

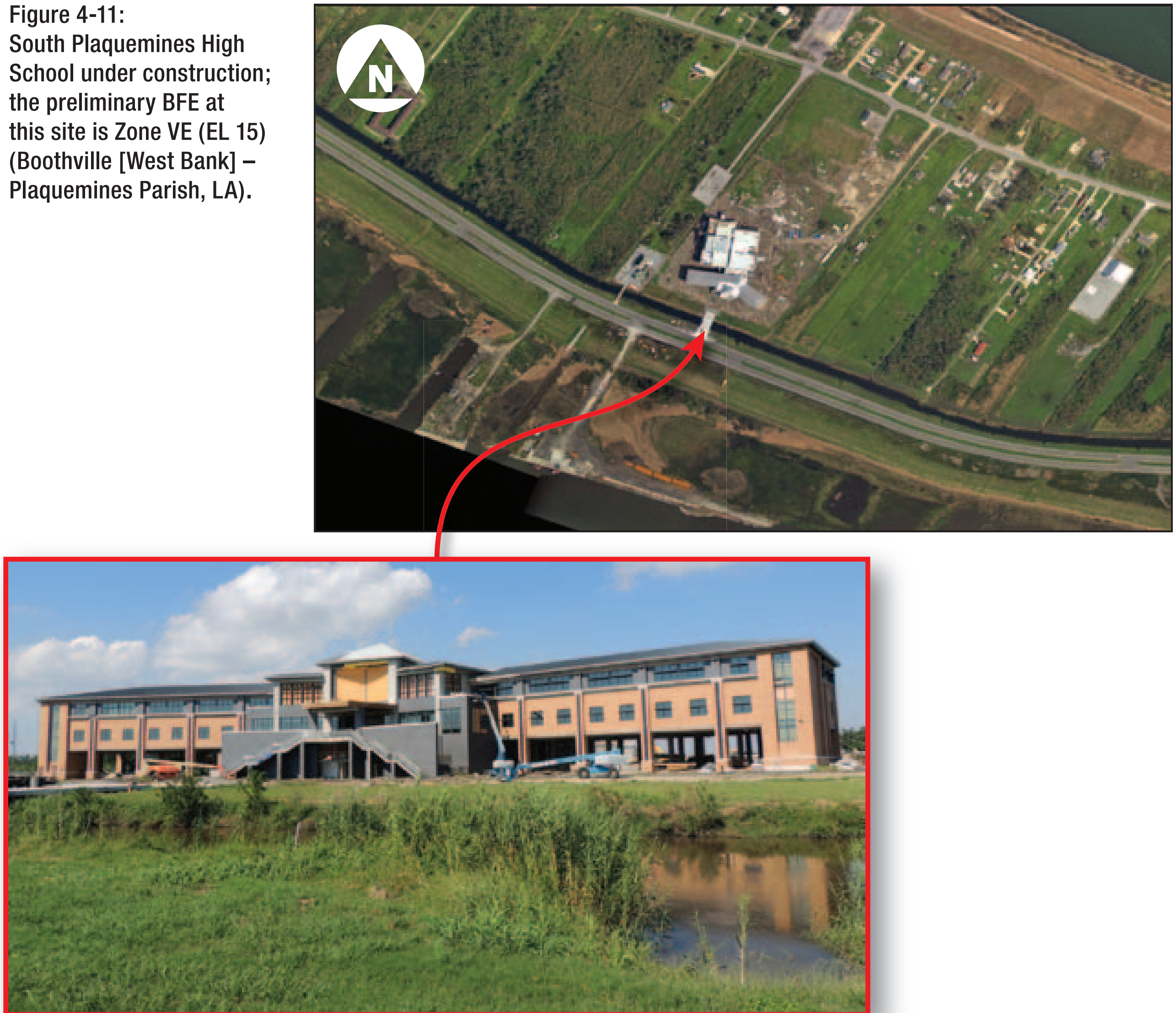


Figure 4-12:
The Phoenix Pre-K–12 School under construction; the preliminary BFE at this site is Zone AE (EL 17) (Phoenix [East Bank] – Plaquemines Parish, LA).

4.3 Infrastructure

The MAT visited three substations in Plaquemines Parish, as well as various pump stations and cellular towers, throughout areas impacted by Hurricane Isaac. The three substations were inundated by floodwater, and the damage forced the utility companies to de-energize them. In two of the three substations, utility companies used temporary trailer-mounted substations to energize downstream electrical distribution lines while repairs were made (see Figure 4-13).

In two of the substations, most electrical equipment was placed at or near grade, and the placement offered little protection from floods. In the third substation, some flood protection was evident. In that substation, several pieces of electrical equipment were elevated on steel frames, some several feet above grade (Figure 4-14). Also, a protective berm was constructed around the perimeter of that substation. The berm was reportedly constructed after the substation flooded during Hurricane Katrina. During Hurricane Isaac, the berm was overtopped and the substation was inundated (see Figures 4-15 through 4-17).

Figure 4-13:
Electrical repairs being completed after substation equipment was inundated by floodwaters (Braithwaite [East Bank] – Plaquemines Parish, LA).

Figure 4-14:
Substation equipment elevated several feet above grade (Belle Chase [West Bank] – Plaquemines Parish, LA).

Figure 4-15:
A berm was constructed around the perimeter of this substation to protect it after Hurricane Katrina (Belle Chase [West Bank] – Plaquemines Parish, LA).

Figure 4-16:
Flood inundation depths were 4 to 5 feet above grade at the substation protected by the berm that was overtopped (Belle Chase [West Bank] – Plaquemines Parish, LA).

Figure 4-17: The protective berm (red arrow) was overtopped, resulting in damage to the substation; note cellular tower (yellow arrow) northwest of the substation (Belle Chase [West Bank] – Plaquemines Parish, LA).

AERIAL COURTESY OF NOAA; GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/.

The MAT observed several cellular towers with equipment elevated on platforms (see Figure 4-18). The MAT did not observe flood damage to the cellular tower equipment.

Figure 4-18: Cellular tower equipment on elevated platform near Port Sulphur Community Center (Port Sulphur [West Bank] – Plaquemines Parish, LA).

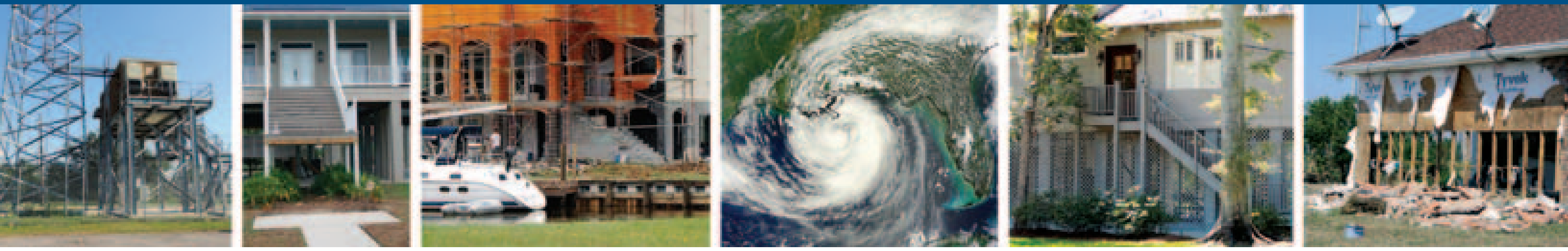
The MAT visited stormwater pumping stations in Slidell and Plaquemines Parish. Both were located in SFHAs, and both were repaired and mitigated after Hurricane Katrina under FEMA's Public Assistance Program. The elevation projects included installing new equipment and foundations, relocating control panels, and installing a generator with fuel tank and transfer switch for emergency power generation (see Figures 4-19 through 4-21). The MAT did not observe damage at either pump station, and both remained operational during the storm.

Figure 4-19: Post-Hurricane Isaac aerial of the pump station south of Braithwaite Park (Braithwaite Park [East Bank] – Plaquemines Parish, LA).

AERIAL COURTESY OF NOAA; GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/.

Figure 4-20: Elevated stormwater pump station south of Braithwaite Park reconstructed after Hurricane Katrina with FEMA Public Assistance funds (Braithwaite [East Bank] – Plaquemines Parish, LA).

Figure 4-21: The control panels and generator at this pump station were elevated as part of a mitigation measure with FEMA Public Assistance funds; insets illustrate connections between equipment and platform (Slidell, LA).



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5 Evaluation of Elevation Projects

Hurricane Isaac's landfall and impact in Louisiana afforded the MAT the unique opportunity to observe the performance of mitigation measures put in place as a result of Hurricane Katrina.

One of the primary objectives of the Hurricane Isaac MAT was to evaluate the performance of buildings constructed or elevated after Hurricane Katrina. To assess the performance of mitigation projects, this chapter compares damage to buildings located adjacent to one another as well as pre- versus post-Katrina construction of the same building. The chapter also examines buildings that were originally built to a higher elevation than surrounding structures. Sites were randomly selected based on communities visited while the MAT conducted field investigations and the availability of data to complete the comparisons. The damage summaries are based on observations made by the MAT as well as data collected from other sources (Substantial Damage determinations,

> A **depth-damage function** is a mathematical relationship between the depth of floodwater above or below the first floor of a building and the amount of damage that can be attributed to that water.

interviews with building officials, community damage summary reports, etc.). Estimated damage in this section is based on *depth-damage functions* used to estimate building, contents, and loss-of-function based on flood depths at each structure. Although the assessments of buildings are as accurate as possible based on MAT observations, statements made herein are not intended to represent final judgments as to the severity of damage to individual buildings.

The two adjacent properties (see Figures 5-1 and 5-2) along Highway 23 in Plaquemines Parish were in the inundation area during Hurricane Isaac and located within the SFHA (effective FIRM – Zone A13 [EL5] 05/01/1985; Katrina ABFE – Zone AE [EL10]; Post-Katrina Preliminary FIRM – Zone VE [EL16]). The slab-on-grade house was built about 2004/2005 and was severely damaged during Hurricane Isaac. Winds caused roof cover loss, and approximately 5 feet of flood inundation damaged interior and exterior finishes (see Figures 5-3 through 5-7). The elevated wood-frame house was built on masonry piers about 2007 and received minor damage during Hurricane Isaac. Most of the damage to the elevated house was limited to the exterior finishes, including roof cover loss, and was caused by wind (see Figure 5-8); water did not reach the first floor. Estimated damages based on depth-damage functions are included in Table 5-1.

Figure 5-1: Comparison of elevated versus at-grade constructions (Plaquemines Parish, LA).

Figure 5-2: Post-Hurricane Isaac aerial of the residences in Figure 5-1 (Plaquemines Parish, LA).

SOURCE: NOAA; GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/

Figure 5-3:
Roof cover loss at non-elevated residential building (Plaquemines Parish, LA).

Figure 5-4:
Interior damage to the garage of the non-elevated residence (Plaquemines Parish, LA).

Figure 5-5:
Exterior damage to the garage of the non-elevated residence (Plaquemines Parish, LA).

Figure 5-6:
Interior damage to the non-elevated residence (Plaquemines Parish, LA).

Figure 5-7:
Interior damage to the non-elevated residence (Plaquemines Parish, LA).

Figure 5-8:
Exterior damage (wood siding) to the elevated house (Plaquemines Parish, LA).

Table 5-1: Estimated Isaac Damages at Adjacent Properties Along Highway 23 (West Bank)

Description	Flood Depth Above Lowest Floor (feet)	Estimated Damages*
Slab-on-Grade	5	$148,243
Elevated	<0	$4,000

* Assumes 1,600-square-foot residence with building construction cost of $100 per square foot.

The single-family residence on Lakeshore Drive in Mandeville was a slab-on-grade property during Hurricane Katrina (see Figure 5-9) and had 3 to 4 feet of flooding in 2005. The property is in the SFHA (effective FIRM – VE [EL12] 05/16/2012; Katrina ABFE – Zone VE [EL15]) after Hurricane Katrina (see Figure 5-10). The building was not inundated during Hurricane Isaac. See Table 5-2 for a comparison of estimated damages.

Figure 5-9: Single-family residence post-Katrina (Mandeville, LA).

Figure 5-10: Single-family residence elevated post-Katrina (Mandeville, LA).

Table 5-2: Estimated Katrina versus Isaac (pre- versus post-elevation) Damages at Lakeshore Drive Property

Description	Flood Depth Above Lowest Floor (feet)	Estimated Damages*
Slab-on-Grade	5	$162,643
Elevated	<0	No observed damage

* Assumes 2,000-square-foot residence with building construction cost of $100 per square foot.

A nonresidential building along Lakeshore Drive in Mandeville was floodproofed 2 to 3 feet above ground level prior to Hurricane Katrina but experienced flooding of 7 feet that overtopped the floodproofed elevation by 4 feet (see Figures 5-11 through 5-13). After being Substantially Damaged by Hurricane Katrina, the building was reconstructed on an open foundation (see Figure 5-14). The building was not inundated during Hurricane Isaac. See Table 5-3 for a comparison of estimated damages. The property is located within the SFHA (effective FIRM – Zone VE [EL12] 05/16/2012; Katrina ABFE – Zone VE [EL15]).

Figure 5-11:
A nonresidential building on Lakeshore Drive in Mandeville post-Hurricane Katrina (Mandeville, LA).

Figure 5-12:
Entrance to nonresidential building on Lakeshore Drive in Mandeville post-Hurricane Katrina (Mandeville, LA).

Figure 5-13: Interior damage from Hurricane Katrina to nonresidential building on Lakeshore Drive (Mandeville, LA).

Figure 5-14: The same nonresidential building along Lakeshore Drive in Mandeville elevated post-Hurricane Katrina (Mandeville, LA).

Table 5-3: Estimated Isaac Damages at Lakeshore Drive Nonresidential Property

Description	Flood Depth Above Lowest Floor (feet)	Estimated Damages*
Slab-on-Grade	4	$172,587
Elevated	<0	No observed damage

* Assumes 1,800-square-foot building with building construction cost of $120 per square foot.

In one of the areas with the deepest inundation from Hurricane Isaac, the MAT visited an elevated property that almost avoided flood damage. This residence along Highway 39 was built in 2009 and is located within the SFHA (effective FIRM – Zone A6 [EL3] 05/01/1985; Katrina ABFE – Zone AE [EL18]; Post-Katrina Preliminary FIRM – AE [EL17]). Although the house was inundated with 2 feet of water, the damage was much less compared to older homes nearby that were built at grade (see Figures 5-15 through 5-17). Estimated damages based on depth-damage functions are shown in Table 5-4.

Figure 5-15: Post-Hurricane Isaac aerial of elevated residence along Highway 39 (Plaquemines Parish, LA).

SOURCE: NOAA; GENERATED FROM HURRICANE ISAAC RESPONSE IMAGERY VIEWER AT HTTP://STORMS.NGS.NOAA.GOV/STORMS/ISAAC/

Figure 5-16: Elevated house built in 2009 on Highway 39 had approximately 2 feet of water infiltrate the first floor; inset: yellow line illustrates observed HWM on door (Plaquemines Parish, LA).

Figure 5-17:
Debris pile near at-grade residence (Plaquemines Parish, LA).

Table 5-4: Estimated Isaac Damages at Adjacent Properties Along Highway 39 (East Bank)

Description	Flood Depth Above Lowest Floor (feet)	Estimated Damages*
Slab-on-Grade	8	$244,389
Elevated	2	$61,969

* Assumes 1,600-square-foot residence with building construction cost of $100 per square foot.

The MAT visited the Frenier Fishing Village, a small community along the west bank of Lake Pontchartrain, with estimated building ages ranging from less than 5 years to more than 30 years old. The entire community is located in the Coastal High Hazard Area (effective FIRM – Zone VE [EL16] 11/04/2010; Katrina ABFE – N/A; Historic FIRM – Zone V16 [EL16]) and consists of about a dozen residential and nonresidential buildings. All buildings were constructed on an open foundation; however, the first floor elevations vary from approximately 1 to 12 feet above grade. As a result, the magnitude of flood damage from Isaac varied from collapse/failure to no damage (see Figures 5-18 through 5-25). See Table 5-5 for a comparison of estimated damage.

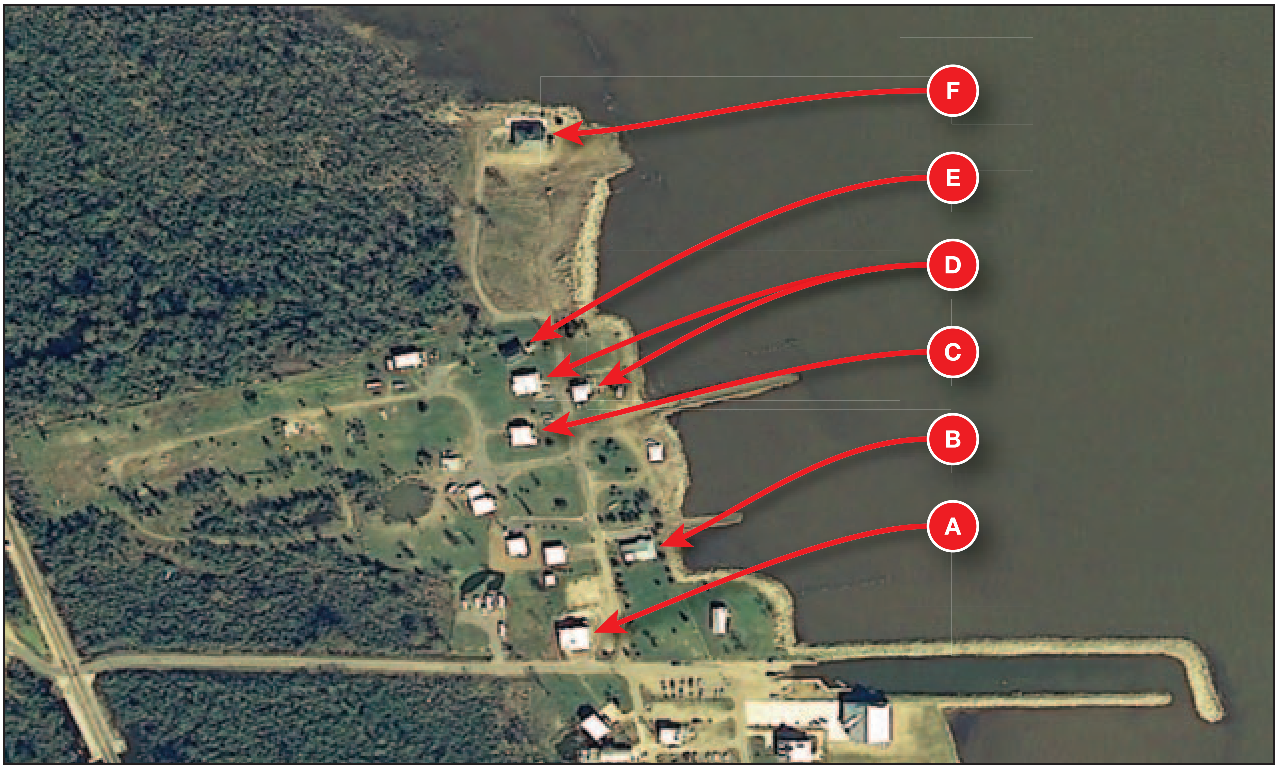


Figure 5-18: 2008 aerial of the Frenier Fishing Village (St. John the Baptist Parish, LA).

AERIAL COURTESY OF LOUISIANA LA COASTAL WETLANDS PLANNING, PROTECTION AND RESTORATION ACT AND THE USGS NATIONAL WETLANDS RESEARCH CENTER; GENERATED FROM HTTP://LACOAST.GOV/NEW/PUBS/MAP_DATA/2008DOQQ/DEFAULT.ASPX.

Figure 5-19: Surge damage to lakefront residential structure (Structure B in Figure 5-18) (St. John the Baptist Parish, LA).

Figure 5-20:
Elevated residence with no observed damage (Structure E in Figure 5-18) (St. John the Baptist Parish, LA).

Figure 5-21:
Remains of residential building that was approximately 2 to 3 feet above grade (Structure D in Figure 5-18) (St. John the Baptist Parish, LA).

Figure 5-22:
Debris pile of waterfront single-family residence along the west bank of Lake Pontchartrain (Structure D in Figure 5-18) (St. John the Baptist Parish, LA).

Figure 5-23: Residential building elevated approximately 3 to 4 feet above grade that lost stairs and received other damage below the lowest floor (Structure C in Figure 5-18) (St. John the Baptist Parish, LA).

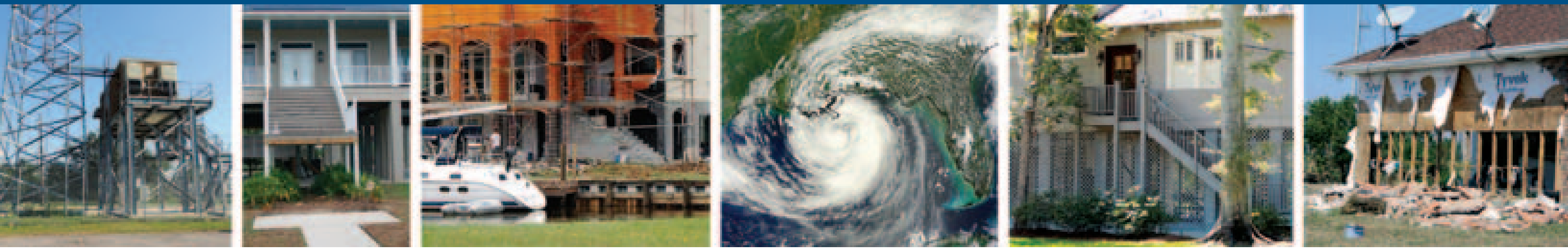
Figure 5-24: Nonresidential structure with damage to the screen surrounding the area under the lowest floor (Structure A in Figure 5-18) (St. John the Baptist Parish, LA).

Figure 5-25:
Residence built about 2000 with minimal damage to partially enclosed areas below the lowest floor (Structure F in Figure 5-18) (St. John the Baptist Parish, LA).

Table 5-5: Estimated Isaac Damages at Adjacent Properties in Frenier Fishing Village

Description	Flood Depth Above Lowest Floor (feet)	Estimated Damages*
1 to 2 Feet Above Lowest Horizontal Structural Member (Structure D)	2	Destroyed
1 Foot Above Lowest Horizontal Structural Member (Structure B)	0-1	Substantially damaged
Elevated and New Construction (Structures A, C, E, & F)	< 0	$3,000

* Assumes 1,500-square-foot residence with building construction cost of $100 per square foot.



HURRICANE ISAAC IN LOUISIANA

6 Conclusions and Recommendations

The conclusions and recommendations presented in this report are based on the MAT's observations in the areas studied; evaluations of relevant codes, standards, and regulations; and meetings with State and local officials and other interested parties. They are intended to assist the State of Louisiana, communities, businesses, and individuals in the reconstruction process and to help reduce future damage and impacts from flood and design level wind events similar to Hurricane Isaac.

Section 6.1 discusses conclusions and recommendations related to residential buildings. Section 6.2 includes conclusions and recommendations related to critical facilities and infrastructure. Section 6.3 discusses outreach and NFIP reform, Section 6.4 discusses best practices, and Section 6.5 discusses conclusions and recommendations related to building codes and floodplain management regulations.

6.1 Residential Construction

Louisiana State Emergency Officials estimate 59,000 residences were damaged by Hurricane Isaac. Flood depths reached as high as the rooftops of structures on foundations at or slightly above grade, but structures elevated to the BFE were largely undamaged.

Generally, the post-Katrina mitigated structures were not tested during Isaac. Because Hurricane Isaac's flood elevations did not exceed effective BFEs in areas visited by the MAT, excluding areas in LaPlace and along the East Bank of the Mississippi River in Plaquemines Parish, observations of severe flood damage to one- and two-family residential buildings were rare. Elevated residences that were either new construction or post-Katrina elevation projects had minimal or no flood damage compared to adjacent non-elevated structures.

6.1.1 Elevating to the Preliminary FIRM

Conclusion

Buildings elevated to the best available elevation data, including preliminary FIRMs, are far less likely to suffer damage in a flood. The MAT observed this in side-by-side comparisons of neighboring buildings in St. Tammany and Plaquemines Parishes. In these cases, one of the buildings was elevated and the other was not. When the area was flooded, the elevated building suffered little or no damage, while the non-elevated building was severely damaged. Most Louisiana parishes affected by Hurricane Isaac had not adopted the preliminary FIRMs. However, many communities adopted the ABFEs after Hurricane Katrina, which often represented the best available information for that community. Although this information may not be as current as the preliminary FIRMs in some areas, buildings elevated to these ABFEs suffered less damage than those not elevated. In addition, based on discussions with local building officials and the MAT review of local ordinances (Section 2.3), the MAT determined that some communities affected had adopted some form of freeboard requirement to elevate buildings above the regulatory BFEs.

Recommendation

Residential buildings should be built to the preliminary FIRM or best available elevation data, such as ABFEs. In addition, the adoption of freeboard requirements is beneficial. To facilitate this, NFIP communities in Louisiana should either adopt the preliminary FIRMs that were developed after Hurricane Katrina or require the use of the Hurricane Katrina ABFEs in determining structure elevation. Further, the communities should consider adopting freeboard requirements in accordance with ASCE 24-05. If the flood risk data indicate the structure is located within a flood zone subject to wave action, then the building should be elevated on an open foundation.

6.1.2 Slab-on-Grade Elevation Projects

Conclusions

Considering information regarding the slab's structural properties may minimize the potential for structural cracking during elevation. Properties that should be considered include slab thickness, steel reinforcement, and concrete cover of the steel reinforcement. Insufficient slab thickness, steel reinforcement, or concrete cover of the steel reinforcement can result in bending, shear, or deflection failure of the elevated slab when exposed to design live and dead loads. This is illustrated in Section 3.3 for elevations observed in Slidell and Mandeville, where the slab thickness and steel reinforcement cover appeared to be deficient.

A lack of connections between the substructure and the superstructure increases the risk of failure during a design level flood or hurricane. Elevated slabs with no or minimal connections to their piers may not be able to withstand significant lateral or uplift forces from design flood and wind events. The MAT observed homes both elevated and in the process of being elevated that did not have sufficient connections between the foundation piers and the slab. Although the MAT did not observe failure of these connections, Hurricane Isaac was not a design level flood or wind event in most of the locations visited.

Recommendations

Gather information regarding the slab's reinforcement and structural properties during the design phase. Before beginning an elevation project for a home with a slab-on-grade foundation, the slab should be assessed to determine whether, once elevated, it can function as a structural element without the risk of failure when the structural system is exposed to design live and dead loads. In most cases, this will require drilling holes to measure slab thickness before excavation and thoroughly evaluating the slab after excavation. Slabs that are not adequate to support design loads without bending, shear, or deflection failure should be removed and replaced or reinforced.

FEMA-funded elevation projects should include details of the new foundation's capability to resist lateral forces from flood and wind loads as well as undermining by erosion or localized scour. Shallow foundations in areas visited by the MAT were most vulnerable to undermining. Piles and piers are susceptible to failure when improperly sized and/or spaced.

Properly detail and design the connections and load path between the substructure and superstructure. These connections must be able to withstand the significant lateral and uplift forces present in a design flood or wind event.

6.1.3 Stairs for Building Access

Conclusion

The design and location of stairways providing access to elevated buildings affects how they perform in a flood. More specifically, stairs with closed risers that are perpendicular to the flood source incur greater flood loads. The MAT observed several instances where long runs of exterior stairs with no intermediate landings and closed risers that were oriented perpendicular to the direction of flood flow experienced significant damage. This often resulted in complete loss of building access as shown in Section 3.5.

Recommendation

Design staircases to provide a reasonable means of safe and convenient access to the building. Stairways leading from ground level to elevated structures are vulnerable to flood forces and frequently separate from the point of attachment. Proper materials and connections are essential for adequate performance. For residential buildings, stairs should be constructed with partially open risers in accordance with building code requirements and should be oriented perpendicular to the direction of flood flow to reduce flood damage, as shown in Figure 6-1. Constructing these stairs with open risers will reduce the forces incurred by the stair structure and thus reduce the likelihood that they will fail during a flood. If constructing stairs with open risers is not possible, construct stairs such that there are intermediate landings with supports that can resist flood forces.

Figure 6-1: Residential stairs with partially open risers to reduce potential flood damage (Mandeville, LA).

6.1.4 Utilities and Electrical Service Components

Conclusions

Utilities located below the BFE are more likely to sustain damage in a flood than those that are elevated. The MAT observed many instances of flood damage to electrical service components, even among elevated residential buildings. This was because either some or all of the electrical service components were located below the BFE. The MAT also observed utilities that had been successfully elevated, and as a result sustained minimal to no damage during Hurricane Isaac. Elevated equipment was generally accessible by stairs, walkways, and decks. Commonly elevated equipment consisted of condensers and other mechanical equipment such as generators.

Overhead electric service drop lines attached to the roof may fail in hurricane conditions. Where the service drop was attached to the roof, the MAT observed some instances where a utility pole collapsed or wind-borne debris struck it, causing the weatherhead to shift in a way that tore the roof and allowed water to penetrate.

Recommendations

Elevate electrical service components to or above the BFE. Submersion of electrical components during a flood causes damage that prevents power from being supplied to residences after floodwaters have receded. However, the NEC and local utility companies specify where electrical components can be installed, and the location is dictated by clearance and accessibility requirements. If elevating all service components is not possible, the electrical box should be elevated at the very least, as the replacement of that piece of equipment is the responsibility of the homeowner. In addition, meters and boxes below the BFE should not be attached to breakaway walls or other components not designed to resist flood loads.

Overhead electric service drop lines should be attached to the side of the residence if possible. Although service drops attached to the side of a house have the potential to allow heavy rains to penetrate the wall if the connection shifts, the water penetration is less problematic than for service drops attached through the roof.

6.1.5 Enclosed Areas

Conclusion

Above-grade enclosed areas located beneath elevated structures are likely to be damaged in a flood. The MAT observed a variety of enclosed areas beneath elevated structures, including partially enclosed areas and above-grade enclosures. According to the NFIP, all enclosures below the BFE must be constructed using flood damage-resistant materials. However, homeowners often finish these areas and use them as additional living space. Where damage was observed by the MAT, it occurred because flood damage-resistant materials were not used in the construction of the enclosed area. In addition, the failure of these above-grade enclosed areas creates debris that may impact surrounding structures.

Recommendation

Above-grade enclosed areas should be constructed of flood damage-resistant materials and should have walls designed to break away under flood loads. Solid breakaway wall panels used for enclosures become large flood-borne debris elements when they break away. Lattice or louvers should be used in the construction of these enclosed areas instead of solid breakaway walls, as they reduce debris and cost less to repair. If solid breakaway walls are used, they should have flood openings. Although not required by the NFIP or building codes, adding flood openings may delay the failure of the walls under flooding conditions below the BFE, reduce flood-borne debris, and reduce repair costs.

6.1.6 Fire Separation in Elevated Homes

Conclusion

Fire protection of homes elevated to protect against the flood hazard should be a design consideration. The MAT observed elevated buildings with inadequate fire separation between occupied space and below-BFE parking, access, and storage areas. Many of the elevated residential buildings observed by the MAT had plywood sheathing or wood finish materials applied over standard wood floor joists or the lowest horizontal structural member. Elevations of residential buildings with concrete slabs were also observed to be lacking fire stop systems, solid fire blocking, or a fire barrier at penetrations.

Recommendation

Fire separation should be provided for elevated residential structures. For elevated buildings where the below-BFE space is used for parking or storage of flammable materials, fire separation is needed on the exposed underside of the building. Fire separation should meet the guidelines of the 2012 IRC Table R302.6 for habitable rooms above a garage, which requires not less than 5/8-inch Type X gypsum board or equivalent. This material should also be flood damage resistant.

6.1.7 Building Envelope

Conclusion

Insufficient attachment and/or material selection for the underside covering of elevated floor systems, as well as for roof covering and siding, may contribute to failure during wind events. The MAT observed widespread loss of underside paneling in relatively new elevated coastal construction. Although the most common building envelope damage observed by the MAT was loss of roof covering and vinyl siding, the damage to underside coverings was not anticipated. More specifically, for the loss of roof covering and vinyl siding, older homes typically suffered greater wind damage, but the loss of underside paneling was observed in relatively new construction.

Recommendation

Use proper fastener selection, attachment methods, and materials during construction. Homeowners should consider mitigation measures such as upgrading the attachment of the roof covering to the roof deck, applying a moisture barrier/housewrap over exterior walls, and upgrading the attachment of vinyl siding to exterior wall sheathing. Retrofitting residential structures to protect against wind damage should be done in conjunction with elevation projects to provide a more comprehensive protection system for the structure.

6.2 Nonresidential Construction and Infrastructure

Critical facilities performed as expected. Those elevated to or above the BFE and those located outside the 500-year floodplain sustained little to no damage. Facilities located in areas prone to flooding and not mitigated sustained damage.

6.2.1 Community Centers, Critical Facilities, and Schools

Conclusion

Facilities were usable after the event if they had been constructed above or outside of the 500-year floodplain. The MAT visited several community centers constructed in Plaquemines Parish after Hurricane Katrina. The following are brief summaries of the observations at each.

Braithwaite Auditorium. Reconstructed post-Katrina, the auditorium was built to the preliminary FIRM BFE (VE21), rather than the Katrina ABFE (AE18). Hurricane Isaac's flood depths of 11 feet at the auditorium were well below the structure's lowest horizontal structural member. Damage at the auditorium was primarily to electrical equipment located below the building's lowest horizontal structural member.

Boothville Community Center. Constructed in 2011, the community center is elevated 10 feet above grade. The building was undamaged by Isaac's floodwaters, but damaged by driven rain that penetrated the building after strong winds damaged the wall covering.

Woodlawn Fire Station. Hurricane Isaac flooded this station, located in Plaquemines Parish, with 8 feet of water. The station was not flooded by previous storms, including Hurricane Katrina. Despite being inundated with floodwater, no visible structural damage to the station was observed. However, nine pieces of equipment including fire trucks, engines, and ambulances and all of the department's fire gear were significantly damaged by floodwaters and unavailable for response and recovery efforts during Hurricane Isaac.

School Buildings. The MAT visited several schools throughout Plaquemines Parish that are under construction. The new schools are being constructed 10 feet above grade. The MAT verified that these new schools' first floors would not have been inundated by Hurricane Isaac.

Recommendations

Construct critical facilities outside of or above the 500-year floodplain. Community centers that were elevated to the preliminary FIRM BFE were observed to have little or no flood damage. New and replacement community centers and critical facilities should be sited outside the 500-year floodplain, where possible; where not possible, critical facilities should be elevated to the preliminary FIRM BFE, rather than the Hurricane Katrina ABFE. In most instances, the preliminary FIRM BFEs are higher than Hurricane Katrina ABFEs and afford more protection.

Equipment and utilities for community centers and critical facilities should also be elevated to the preliminary FIRM BFE. If elevation of these components is not feasible for critical facilities in Zone A, they should be dry floodproofed to an elevation several feet above the BFE.

Consider evacuation and continuity of operations plans in design. The elevation of and floodproofing measures for critical and public facilities are limited to the DFE; therefore, communities must plan accordingly. The facilities will be protected to reduce building damage and functional downtime following a major flood, but communities must still develop evacuation, continuity of operations, and sheltering plans along with triggers to implement these plans based on existing forecast capabilities and estimated implementation timelines.

6.2.2 Infrastructure

Conclusion

Electrical substations located in flood hazard areas are vulnerable to significant damage during flood events. Because the locations of substations are heavily dictated by the routing of the transmission lines that supply them and by the population that they serve, placing substations outside of areas prone to flooding is often not possible. The MAT observed several substations that had sustained flood damage and as a result were not operational or relied on temporary or emergency equipment.

Recommendations

Where feasible, new electrical substations should be located outside of SFHAs. When new electrical substations are constructed in SFHAs, they should be considered Risk Structure Category IV per ASCE 24, and vulnerable equipment should be elevated or protected to or above the elevation required in ASCE 24. Elevating vulnerable equipment within the substation will reduce damage and reduce the amount of time the substation is offline. Such equipment includes control panels, high-voltage circuit breakers, switchgear, and panelboards that supply electrical loads within the substation. This equipment can be readily elevated if platforms or other means to access equipment for maintenance and repairs is provided. Some equipment, such as large power transformers, is difficult to elevate, but damage can be reduced if all vulnerable components like gauges, transducers, and controls are placed as high as possible.

For existing substations located in SFHAs, critical equipment should be relocated as high as practical to reduce the potential for flood damage or a minimum of 3 feet above grade. Elevated platforms should be provided to allow access for maintenance, service, and repairs.

6.3 Outreach and NFIP Reform

Conclusion

Outreach efforts are in place and functioning well. Currently, the State of Louisiana and Louisiana State University conduct outreach to communicate with residents and business owners about the NFIP and the upcoming reform to the NFIP enacted through the Biggert-Waters Flood Insurance Reform and Modernization Act of 2012. Outreach focuses on educating the public on the implications of property owners elevating their buildings above the BFE in relation to insurance premiums and protecting against flood events that exceed the BFE.

Recommendation

Outreach efforts should continue and should focus on educating the public about the following new provisions contained within the Biggert-Waters Act (EDEN 2012):

- Pre-FIRM (subsidized) rates will be discontinued for all business properties, secondary residences, and residences that meet the definition of "severe repetitive loss property," through a series of 25 percent per year increases in flood insurance premiums until the premium reflects the actuarial rate for the property. When any Pre-FIRM-rated property is sold, the new flood policy will reflect actuarial rates; this includes both primary residences and properties for which the loss of subsidy is being phased out. In addition, no extension of subsidy will be provided for new policies, policies that have a lapse in coverage as a result of deliberate choice of the policyholder, or any prospective policyholder who refuses to accept any offer for mitigation assistance by the Administrator.

- Grandfathered rates will be discontinued, with policies moving to actuarial rates over a period of 5 years. Each annual increase in premium over those 5 years will reflect 20 percent of the *difference* between the grandfathered and actuarial rates. The rate increase will begin with the first renewal following the effective date of the FIRM in which the higher risk is identified; the schedule of 20 percent increases will not change with a sale of the property.

6.4 Best Practices

This section presents the findings of building performance evaluations conducted separately from the MAT assessments but that are relevant to the focus of this report.

Conclusions

Review of post-Katrina projects highlighted best practices. FEMA's Hazard Performance Analysis (HPA) Group evaluated residential structures in Barataria, Mandeville, and Slidell that had been elevated after Katrina using HMGP funds and were also located in areas flooded by Hurricane Isaac.

The HPA Group evaluated 13 elevated properties along Bayou Barataria in an area not protected by a Federal levee. Although the storm surge for Hurricane Isaac was not as severe as that of Hurricane Katrina, the duration of flooding was longer. All 13 properties had been elevated, some as much as 36 inches above the BFE, and none were flooded by Hurricane Isaac. Homes along Bayou Barataria that were not elevated were flooded by Hurricane Isaac's storm surge, which varied from 18 to 24 inches above grade (HPA 2012a).

In Mandeville, the HPA Group evaluated 14 elevated residences. All had been elevated and all were undamaged by Hurricane Isaac floodwaters. In examining losses avoided, the HPA Group focused on one home and compared the pre-mitigated floor elevation to the depth of flooding. They found that, had the house not been elevated, it would have been inundated with 36 inches of water (HPA 2012b).

The HPA Group also evaluated 54 elevated properties in Slidell. Thirty-nine of the 54 homes were impacted by Hurricane Isaac, and it was determined that the elevation of these homes reduced the flood damage. Homes in this area that had not been elevated were inundated by 30 to 36 inches of water. The remaining 15 properties evaluated were in areas not affected by Hurricane Isaac flooding (HPA 2012c).

New residential buildings constructed under the FEMA HMGP Reconstruction Grant Pilot for Hurricanes Katrina, Rita, and Wilma had no observed damage; however, the number of properties built under this program was low compared to the number of elevation projects. The Reconstruction Grant Pilot requires that a community first evaluate the feasibility of elevating a building before considering reconstruction. If a community chooses not to support structural elevation, either due to non-compliance with existing codes or because of unaddressed vulnerabilities, then mitigation reconstruction may be considered as an alternative.

Recommendations

Distribute HPA reports to the public. FEMA and the State should distribute the Hazard Performance Analysis of Post-Katrina Mitigated Properties reports for three communities in Louisiana (Jefferson Parish, and Slidell and Mandeville in St. Tammany Parish) to the public to encourage mitigation.

States should conduct losses avoided studies of mitigated properties after future flood events to evaluate project effectiveness. Such studies would compare the losses that would have been incurred for mitigated homes had they not been mitigated to the losses that were actually incurred.

Local building officials should increase public awareness of the FEMA HMGP Reconstruction Grant Pilot for Hurricanes Katrina, Rita, and Wilma. The lack of mitigation reconstruction projects may be a result of numerous factors (limited awareness of the pilot program, grant process, financial reasons, etc.), but local officials should be encouraged to make building owners aware of this program, especially when older, non-compliant buildings are being considered for elevation projects. Communities should not support or permit elevation projects of structures that do not comply with all local codes and standards, not just the local floodplain management ordinance.

6.5 Codes and Regulations

The following sections present conclusions and recommendations that are based on the MAT's review of building codes and floodplain regulations in Louisiana and six of the communities visited by the MAT.

6.5.1 Louisiana Revised Statutes and Building Codes

6.5.1.1 Existing Statutes

Conclusions

A number of existing statutes remain unchanged and create conflicts with new statutes. The MAT's review of the Louisiana Revised Statutes found that, subsequent to passage of Act 12 in 2005, a number of older statutory provisions remain unchanged and, thus, appear to create conflicts with more recent statutory provisions. For example, R.S. 33:1236(35)(b) permits parishes to adopt the Southern Building Code and other obsolete codes, while Act 12, in R.S. 40:1730.21–40 specifies that all municipalities and parishes shall enforce the codes adopted by the State, which are based on the I-Codes (see Chapter 2).

Another example of conflicting statutory provisions that could lead to misinterpretation is the use of the term "extensive alteration" (R.S. 40:1730.28), which has no direct relationship to whether work on existing buildings located in flood hazard areas is determined to be Substantial Improvement or Substantial Damage.

The MAT's review of the statutes also determined that State amendments to the model I-Codes exempt several buildings from the LSUCC, including farm structures, residential accessory structures, private recreational structures (such as hunting or fishing camps), and additions to dwellings that pre-date the first LSUCC. An explicit exemption applies to the construction or improvement of certain industrial facilities engaged in specific activities, provided the facilities are "inside the restricted access area" (R.S. 40:1730.29). Although R.S. 40:1730.30 specifies that the "standards" published by FEMA for the NFIP apply to "residential construction," the impression is left that the listed exempt structures are not required to comply with local floodplain management regulations enforced by NFIP-participating communities.

The State of Louisiana Hazard Mitigation Strategy, in Section Eight, identifies a number of refinements or corrections to Act 12:

- Regulation of additions and improvements to existing structures
- Refining the definition of "work area" such that extensive alterations, renovations, and repairs are covered, even if less than 50 percent of the total area is involved (see IRC Appendix J)
- Resolving confusion in wording that implies that commercial properties under the NFIP are not covered by the LSUCC

Recommendations

Review existing statutes to determine and resolve conflicts. The Louisiana State Uniform Construction Code Council should review the existing statutes to identify provisions that conflict with Act 12 or that appear contradictory, and should evaluate whether to act on the recommendations in the Louisiana State Hazard Mitigation Strategy. Based on the review, the Council should request "cleanup" legislation.

In addition, misinterpretation could be avoided if the statutes include a clear statement that all structures that are exempt or otherwise not within the scope of the LSUCC are still subject to local floodplain management regulations. Communities that participate in the NFIP are required to regulate all development; any perceived barriers that could prevent fulfilling that requirement should be removed.

6.5.1.2 LSUCC and Administrative Provisions

Conclusion

LSUCC excludes Chapter 1 – Administration from the building code. As part of its adoption of the building code, the Council excludes IBC Chapter 1 – Administration. Many Louisiana communities separately adopt one or more of the administrative chapters of the I-Codes, sometimes with amendments, and some communities write their own administrative provisions. For example, Plaquemines Parish adopted the administrative chapters of each of the I-Codes included in the LSUCC. The City of Slidell adopted each of the codes that make up the LSUCC, thereby including the administrative chapters. The City of Mandeville wrote complete administrative provisions, although requirements similar to the administrative provisions of the I-Codes specific to flood hazard areas are not included.

Recommendations

Communities should review local provisions to ensure that requirements related to enforcing flood provisions are sufficient. Communities in Louisiana handle the administrative provisions in a number of ways. Communities should compare their locally adopted provisions for administration and enforcement of the LSUCC to the administrative provisions of Chapter 1, Scope and Administration, of the IBC and IRC [1] to ensure that requirements related to enforcing the flood provisions are sufficient. In addition, local code administrative provisions should be reviewed by the NFIP State Coordinating Agency and FEMA when conducting Community Assistance Visits.

6.5.1.3 Existing Buildings

Conclusion

With respect to existing buildings, the LSUCC incorporates the IEBC and the IRC. The IRC is scoped to cover work that can only be performed on existing dwellings (e.g., alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, location, removal, demolition). Communities are permitted to adopt IRC Appendix J, Existing Dwellings. Despite this, based on discussion with the Louisiana State Uniform Construction Code Council's Administrator, some code officials and others may not clearly understand whether and how existing dwellings are regulated, which may lead to different interpretations.

Recommendation

The Council should provide a clear statement that work on existing dwellings is subject to the LSUCC. In particular, the NFIP and code requirement to regulate Substantial Improvement and restoration of Substantial Damage should be enforced.

6.5.1.4 Flood Protection in Subsidence Areas

Conclusion

The State of Louisiana Hazard Mitigation Strategy, in Section Eight, recommends that the State "establish a state freeboard requirement for construction in areas with significant (to be defined) subsidence rates, such that during the useful life of a building (e.g., as defined by FEMA BCA standards) no increased risk should be encountered." Subsidence has occurred throughout the area affected by Hurricane Isaac, which may be a contributing factor to increased flood risk and damage.

1 http://www.fema.gov/building-science/building-code-resources

Recommendation

The State should act on the recommendation in the Louisiana Hazard Mitigation Strategy to **establish a State freeboard requirement for construction in areas with significant (to be defined) subsidence rates.**

6.5.2 Code Officials and Continuing Education

Conclusion

After Hurricane Katrina, FEMA awarded an HMGP grant to the State to help build State and local capacity to enforce building codes. The State has a continuing education requirement for code officials. Some funding was used for training and education, which contributed to a significant increase in the number of certified code officials. FEMA, the NFIP State Coordinating Agency (Louisiana Department of Transportation and Development), the Louisiana Floodplain Management Association, and the Louisiana Building Code Alliance offer or sponsor floodplain management training courses. The Association of State Floodplain Managers lists nearly 200 individuals who are Certified Floodplain Managers.[2]

Recommendation

The State Hazard Mitigation Strategy indicates the Council may convert regional training seminars to an "interactive, on-line certification program." The Council should evaluate this activity in the interest of increasing opportunities for code officials to learn about the code and obtain continuing education credits. The content of the courses should be reviewed to determine whether the flood provisions of the code are addressed.

Floodplain management courses offered or sponsored by FEMA, the NFIP State Coordinating Agency, and the Louisiana Floodplain Management Association should be submitted to the Louisiana State Uniform Construction Code Council to determine whether the content, in whole or in part, warrants continuing education credits for code officials. The State and the Building Officials Association of Louisiana should notify building officials when floodplain management courses are offered.

6.5.3 Local Floodplain Management Regulations and Codes

6.5.3.1 Additional Elevation (Freeboard)

Conclusion

The requirements of local floodplain management regulations and the flood provisions of the LSUCC are enforced together. In general, any higher standard adopted in local regulations is deemed to prevail, especially a requirement for additional elevation (freeboard). The MAT's review of local regulations for Plaquemines Parish and the cities of Mandeville and Slidell determined

2 http://www.floods.org/Certification/certlist.asp#LA (accessed January 9, 2013)

that those cities require some additional elevation (see Tables 2-2, 2-3, and 2-4). The building codes include a requirement for some additional elevation (see excerpts of the IBC and IRC[3] and Highlights of ASCE 24 [FEMA 2010c][4]).

Recommendation

Communities should reevaluate the benefits of adopting additional elevation requirements so that new construction and Substantially Improved buildings are elevated higher than the minimum requirements of the LSUCC. This is especially important in areas where land subsidence has contributed to flood risk that is not reflected on FIRMs. Of particular benefit will be additional elevation requirements for dwellings, because the building code does not require freeboard for most dwellings. At a minimum, local officials should be diligent in enforcing the elevation requirements of the building code, which has some elevation requirements that exceed the minimum NFIP elevation requirements and, thus, also exceed any local floodplain requirement that is the same as the NFIP.

6.5.3.2 Consistency with the NFIP

Conclusion

The MAT's review of the floodplain management regulations for Jefferson Parish, St. John the Baptist Parish, and Plaquemines Parish and the Cities of Madisonville, Mandeville, and Slidell identified one or more specific provisions that may not be fully consistent with the minimum requirements of the NFIP. Although the flood provisions of the LSUCC are consistent with the NFIP, because a number of buildings and some additions are not subject to the building code, complete local floodplain management regulations are necessary.

Recommendation

The NFIP State Coordinating Agency and the FEMA Regional Office should review the floodplain management regulations adopted by communities affected by Hurricane Isaac to verify the MAT's conclusion that one or more provisions may not be fully consistent with the NFIP. Identified deficiencies should be corrected as soon as possible by adoption of amendments to those regulations.

6.5.3.3 Agreements for Enforcement

Conclusion

The statute provides that municipalities and parishes may enter into agreements with other governmental entities, or with certified third parties, to issue permits and enforce the building code (R.S. 40:1730.24 and 25). Because the building codes include flood provisions, those agreements cover buildings in flood hazard areas, but do not explicitly cover other requirements adopted by communities in their local floodplain management regulations. Although Plaquemines Parish and

3 http://www.fema.gov/building-science/building-code-resources

4 http://www.fema.gov/library/viewRecord.do?id=3515

the Cities of Mandeville and Slidell do not have such agreements, other communities in the State do, especially in the more rural areas.

Recommendation

The NFIP State Coordinating Agency and the Council should encourage communities that have agreements with other governmental entities or agreements with certified third parties to review those agreements and include specific provisions related to local floodplain management requirements that are not already in the building code, such as an explicit requirement to conduct floodplain management inspections and make Substantial Damage determinations. Model language should be prepared to facilitate inclusion in third-party agreements. These provisions are also important if a community has adopted a higher standard that affects buildings (such as additional elevation), so that the entity responsible for permits and code enforcement is aware of those higher standards and can ensure that buildings and certain additions not subject to the building code are regulated. In addition, because local floodplain management regulations are adopted for participation in the NFIP, the agreements should include a specific requirement that the entity providing services participate in Community Assistance Visits and Community Assistance Contacts conducted by the NFIP State Coordinating Agency and FEMA.

6.5.3.4 Manufactured Homes

Conclusion

Statutory provisions for manufactured homes are not in the same section of law as the building code, but are found in R.S. 51:912.21–31. Oversight of manufactured home installers and of installation requirements (foundations, anchoring, and set up) was recently transferred to the Office of the State Fire Marshal. For installation in floodprone areas, the statute explicitly requires compliance with FEMA's Manufactured Home Installation in Flood Hazard Areas (1985).

Recommendation

FEMA's most recent revision of the guidance publication referenced in R.S. 51:912.21–31is FEMA P 85, *Protecting Manufactured Homes from Floods and Other Hazards* (2009c). The NFIP State Coordinating Agency should work with the Office of the State Fire Marshal to distribute notices of the revised document to manufactured home installers and local officials. Of particular interest to many manufactured home installers and local officials is the inclusion of a number of pre-engineered foundation solutions that are designed for a range of both wind and flood conditions.

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B Bibliography and Additional FEMA Resources

ACI (American Concrete Institute). 1989. *Building Code Requirements for Masonry Structures.* ACI-530-88/ASCE 5-88. Farmington Hills, MI.

ASCE (American Society of Civil Engineers). 2005. *Flood Resistant Design and Construction*, ASCE/SEI 24-05. Reston, VA.

ASCE. 2010. *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI Standard 7-10. Reston, VA.

Associated Press. 2012. "Hurricane Isaac damaged 59,000 homes in Louisiana, officials estimate," *The Times-Picayune*. September 28, 2012. http://www.nola.com/hurricane/index.ssf/2012/09/hurricane_isaac_damaged_59000.html

ASTM (American Society for Testing and Materials). 1996. *Standard Test Method for Windload Resistance of Rigid* (Poly Vinyl Chloride) (PVC) Siding. ASTM D 5206. West Conshohocken, PA.

ASTM. 2008. *Standard Test Method for Wind Resistance of Asphalt Shingles (Uplift Force/Uplift Resistance Method)*. ASTM D 7158. West Conshohocken, PA.

ASTM. 2009a. *Standard Specification for Rigid (Poly Vinyl Chloride) (PVC) Siding*. ASTM D 5206. West Conshohocken, PA.

ASTM. 2009b. *Test Method for Wind-Resistance of Asphalt Shingles (Fan Induced Method)*. ASTM D 3679. West Conshohocken, PA.

Cooperative Institute for Meteorological Satellite Studies, Space Science Engineering Center, University of Wisconsin-Madison. 2012. *Tropical Cyclones: A Satellite Perspective.* http://tropic.ssec.wisc.edu/storm_archive/2012/storms/isaac/isaac.html

EDEN (Extension Disaster Education Network). 2012. "Flood Premiums Rising Dramatically," December 12, 2012. http://eden.lsu.edu/Topics/Hazards/Floods/NFIP/Pages/FloodPremiumsRisingDramatically.aspx

FEMA (Federal Emergency Management Agency). 1985. *Manufactured Home Installation in Flood Hazard Areas*, FEMA 85. Washington, D.C., September 1985.

FEMA. 2006a. *Hurricane Katrina in the Gulf Coast: Building Performance Observations, Recommendations, and Technical Guidance*. FEMA 549. Washington, D.C., July 2006.

FEMA. 2006b. *Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations*, FEMA 550. Washington, D.C., July 2006.

FEMA. 2007a. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings*, FEMA 543. Washington, D.C., January 2007.

FEMA. 2007b. *Reducing Flood Losses Through the International Codes: Meeting the Requirements of the National Flood Insurance Program*, FEMA 9-0372, Third Edition. Washington, D.C., December 2007.

FEMA. 2008a. *Design and Construction Guidance for Breakaway Walls Below Elevated Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program*, NFIP Technical Bulletin 9, August 2008.

FEMA. 2008b. *Flood Damage-Resistant Materials Requirements for Buildings in Special Flood Hazard Areas in accordance with the National Flood Insurance Program*, NFIP Technical Bulletin 2, August 2008.

FEMA. 2008c. *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program*, NFIP Technical Bulletin 5, August 2008.

FEMA. 2008d. *Hurricane Ike in Texas and Louisiana: Building Performance Observations, Recommendations, and Technical Guidance*, FEMA P-757. Washington, D.C., July 2009.

FEMA. 2008e. *Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas in accordance with the National Flood Insurance Program*, NFIP Technical Bulletin 1, August 2008.

FEMA. 2009a. *Homeowner's Guide to Retrofitting (Second Edition)*, FEMA P-312. Washington, D.C., December 2009.

FEMA. 2009b. *Local Officials Guide for Coastal Construction*, FEMA P-762. Washington, D.C., February 2009.

FEMA. 2009c. *Protecting Manufactured Homes from Floods and Other Hazards*, FEMA P-85. Washington, D.C., November 2009.

FEMA. 2010a. "Attachment of Brick Veneer in High-Wind Regions," *Technical Fact Sheet No. 5.4, Home Builder's Guide to Coastal Construction*, Technical Fact Sheet Series, FEMA 499. Washington, D.C., December 2010.

FEMA. 2010b. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Wind*, FEMA P-424. Washington, D.C., December 2010.

FEMA. 2010c. *Highlights of ASCE 24, Flood Resistant Design and Construction*. Washington, D.C., December 2010.

FEMA. 2010d. "Minimizing Water Intrusion Through Roof Vents in High-Wind Regions," *Technical Fact Sheet No. 7.5, Home Builder's Guide to Coastal Construction*, Technical Fact Sheet Series, FEMA 499. Washington, D.C., December 2010.

HPA (Hazard Performance Analysis Group). 2012a. *Hazard Performance Analysis of Post-Katrina Mitigated Properties in Jefferson Parish Area*. FEMA Hazard Analysis and Performance Group Report, September 2012.

HPA. 2012b. *Hazard Performance Analysis of Post-Katrina Mitigated Properties in Slidell, LA, St. Tammany Parish Area*. FEMA Hazard Analysis and Performance Group Report, September 2012.

HPA. 2012c. *Hazard Performance Analysis of Post-Katrina Mitigated Properties in the Town of Mandeville, LA, St. Tammany Parish Area*. FEMA Hazard Analysis and Performance Group Report, September 2012.

ICC (International Code Council). 2009a. *International Building Code*, 2009 edition. Washington, D.C.

ICC. 2009b. *International Residential Code*, 2009 edition. Washington, D.C.

Isidore, Chris, 2012. "Isaac threatens Gulf oil production," CNNMoney. August 27, 2012. http://money.cnn.com/2012/08/27/news/economy/isaac-oil-prices/index.html

Llanos, Miguel, 2012. "Mandatory evacuations outside New Orleans as Isaac nears hurricane strength," *NBC News (via MSN)*. August 27, 2012. http://usnews.nbcnews.com/_news/2012/08/27/13501215-mandatory-evacuations-outside-new-orleans-as-isaac-nears-hurricane-strength?lite

Louisiana Public Service Commission. 2012. "Hurricane Isaac Friday Update." Media release. August 31, 2012. http://www.lpsc.org/_docs/_press/Press%20Release2.pdf

Louisiana State Uniform Construction Code Council. 2010. *Louisiana State Uniform Construction Code.*

NFPA (National Fire Protection Association. 2012. *Building Construction and Safety Code*, NFPA 5000, 2012 edition. Quincy, MA.

NFPA. 2011. *National Electrical Code*, NFPA 70, 2011 edition.

NFIP (National Flood Insurance Program). 2012a. *Flood Insurance Manual, effective October 1, 2012.* Washington, D.C., revised October 2012. National Flood Insurance Program. 2012.

NFIP. 2012b. *The National Flood Insurance Program Community Status Book, State of Louisiana*. October 1, 2012.

NHC (National Hurricane Center). 2011. *The Deadliest, Costliest, and Most Intense United States Tropical Cyclones from 1851 to 2010 (and Other Frequently Requested Hurricane Facts)*. National Weather Service, National Hurricane Center. NOAA Technical Memorandum NWS NHC-6. http://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf

NHC. 2012. *Hurricanes in History*. National Weather Service, National Hurricane Center. http://www.nhc.noaa.gov/outreach/history/

NOAA (National Oceanic and Atmospheric Administration). 2012a. *Hurricane Isaac Response Imagery Viewer*. http://storms.ngs.noaa.gov/storms/isaac/

NOAA. 2012b. *NOAA Water Level and Meteorological Data Report: Hurricane Isaac*. http://tidesandcurrents.noaa.gov/publications/Hurricane_Isaac_2012_Water_Level_and_Meteorological_Data_Report.pdf

NOLA Defender. 2012. "Corps closes more floodgates as Hurricane Isaac approaches," NOLA Defender. http://www.noladefender.com/content corps-closes-m23ore-floodgates-hurr67icane-isaac-approaches

Sanburn, Josh. 2012. "Hurricane Isaac causes billions in damage, but far less than Katrina," *Time Business & Money*. August 31, 2012. http://business.time.com/2012/08/31/hurricane-isaac-causes-billions-in-damage-but-far-less-than-katrina/

SBCCI (Southern Building Code Congress International). 1985. *Hurricane Resistant Residential Construction Code*.

The Times Picayune, 2012. "Hurricane Isaac's death toll: Editorial," *The Times-Picayune*. September 2, 2012. http://www.nola.com/opinions/index.ssf/2012/09/hurricane_isaacs_death_toll_ed.html

USACE (U.S. Army Corps of Engineers). 2012. *Hurricane Isaac with and without 2012 100-Year HSDRRS Evaluation*. Preliminary Report, November 2012. http://www.mvn.usace.army.mil/pao/HurrIsaacwapp.pdf

USGS (U.S. Geological Survey). 2012. *Hurricane Isaac's Path Through Louisiana*. USGS Isaac Storm Tide Mapper: http://wim.usgs.gov/isaacstormtidemapper/stormtidemapper.html

U.S. Department of Housing and Urban Development. 2006. *Manufactured Home Construction and Safety Standards*, Title 24 Code of Federal Regulations (CFR) Part 3280. Revised as of April 1, 2006.

Vanacore, Andrew. 2012 "Hurricane Isaac damage could cost billions to repair," *The Times-Picayune*. September 4, 2012. http://www.nola.com/hurricane/index.ssf/2012/09/cost_of_isaac_repairs_could_be.html

FEMA Publications and Resources

FEMA post-disaster reports available through FEMA publications: 1-800-480-2520 and at http://www.fema.gov/fema-mitigation-assessment-team-reports

FEMA 55, *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas*. June 2000. http://www.fema.gov/library/viewRecord.do?id=1671

FEMA 85, *Manufactured Home Installation in Flood Hazard Areas*. September 1985.

FEMA 320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business*. August 2008. http://www.fema.gov/library/viewRecord.do?id=1536

FEMA 361, *Design and Construction Guidance for Community Safe Rooms*. August 2008. http://www.fema.gov/library/viewRecord.do?id=1657

FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*. January 2004. http://www.fema.gov/library/viewRecord.do?id=1986

FEMA 431, *Tornado Protection: Selecting Refuge Areas in Buildings*. November 2003. http://www.fema.gov/library/viewRecord.do?id=1563

FEMA 499, *Home Builder's Guide to Coastal Construction, Technical Fact Sheet Series*, 31 sheets. August 2005. http://www.fema.gov/library/viewRecord.do?id=2138

FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings*. January 2007. http://www.fema.gov/library/viewRecord.do?id=2441

FEMA 549, *Hurricane Katrina in the Gulf Coast: Building Performance Observations, Recommendations, and Technical Guidance*. July 2006. http://www.fema.gov/library/viewRecord.do?id=1857

FEMA 550, *Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations*. July 2006. http://www.fema.gov/library/viewRecord.do?id=1853

FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings*. June 2007. http://www.fema.gov/library/viewRecord.do?id=2739

FEMA 9-0372, *Reducing Flood Losses Through the International Codes: Meeting the Requirements of the National Flood Insurance Program*. December 2007. http://www.fema.gov/library/viewRecord.do?id=2094

FEMA P-85, *Protecting Manufactured Homes from Floods and Other Hazards*, November 2009. http://www.fema.gov/library/viewRecord.do?id=1577

FEMA P-762, *Local Officials Guide to Coastal Construction*. February 2009. http://www.fema.gov/library/viewRecord.do?id=3647

NFIP Technical Bulletins

http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins

FIA-TB-0: User's Guide to Technical Bulletins

FIA-TB-1: Openings in Foundation Walls and Walls of Enclosures (updated 2008)

FIA-TB-2: Flood Damage-Resistant Materials Requirements (updated 2008)

FIA-TB-3: Non-Residential Floodproofing – Requirements and Certification

FIA-TB-4: Elevator Installation

FIA-TB-5: Free-of-Obstruction Requirements (updated 2008)

FIA-TB-6: Below-Grade Parking Requirements

FIA-TB-7: Wet Floodproofing Requirements

FIA-TB-8: Corrosion Protection of Metal Connectors in Coastal Areas

FIA-TB-9: Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings (updated 2008)

FIA-TB-10: Ensuring that Structures Built on Fill In or Near Special Flood Hazard Areas are Reasonably Safe from Flooding

FIA-TB-11: Crawlspace Construction for Buildings Located in Special Flood Hazard Areas

NFIP Evaluation Studies

http://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-evaluation

Evaluation of the National Flood Insurance Program's Building Standards

http://www.fema.gov/library/viewRecord.do?id=2592

FEMA Safe Room Web Site

http://www.fema.gov/safe-rooms

C Acronyms

Acronym	Definition
ABFE	Advisory Base Flood Elevation
ASCE	American Society of Civil Engineers
BFE	base flood elevation
CFR	Code of Federal Regulations
CRS	Community Rating System
DFE	design flood elevation
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
HMGP	Hazard Mitigation Grant Program
HPA	Hazard Performance Analysis (Group)
HSDRRS	Hurricane and Storm Damage Risk Reduction System
HVAC	heating, ventilation, and air conditioning
HWM	high water mark
IBC	International Building Code
ICC	International Code Council
I-Codes	International Code Series
IEBC	International Existing Building Code
IFGC	International Fuel Gas Code

IMC	International Mechanical Code
IRC	International Residential Code for One- and Two-Family Dwellings
JFO	Joint Field Office
LHSM	lowest horizontal structural member
LSUCC	Louisiana State Uniform Construction Code
MAT	Mitigation Assessment Team
mph	miles per hour
NAVD 88	North American Vertical Datum of 1988
NEC	National Electrical Code
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
R.S.	Revised Statute
SBCCI	Southern Building Code Congress International
SFHA	Special Flood Hazard Area
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

D Recovery Advisories for Hurricane Isaac

FEMA has prepared new Recovery Advisories (RAs) that present guidance to engineers, architects, homeowners, and local officials on mitigation measures that can be taken to minimize building damage in a hurricane event. Two advisories have been prepared and are included in this appendix:

RA1: Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings

RA2: Minimizing Flood Damage to Electrical Service Components

These advisories are also available online at http://www.fema.gov/library/viewRecord.do?id=6727.

Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings

FEMA

HURRICANE ISAAC RECOVERY ADVISORY RA1, December 2012

Purpose

The purpose of this Hurricane Recovery Advisory is to describe practices for minimizing damage to the underside of elevated buildings (see Figure 1) resulting from high-wind events. The undersides of elevated coastal buildings are typically covered with paneling (vinyl or aluminum soffit sheeting) or sheathing (plywood) to protect the insulation and metal connectors used for the floor system. These undersides are often damaged by high winds during hurricanes, allowing water to be driven into the building.

Figure 1. Loss of the covering from the underside of an elevated building due to high winds (Plaquemines Parish, LA, Hurricane Isaac)

Key Issues

- Hurricane winds can pull off paneling or sheathing from the underside of elevated buildings.
- Lost paneling or sheathing can become wind-borne debris, which can damage property.
- Hurricane winds can drive large amounts of water through areas where paneling or sheathing has been lost or where gaps have been created.
- If the area underneath an elevated building is used for parking or storing small quantities of fuel or other potentially combustible materials, depending on how the space is categorized by the building code or local building official, these areas may be required to meet code requirements to partition these areas from living spaces. In addition, the use of fire-resistant-rated assemblies on the underside of elevated buildings are often not properly addressed.

The information in this recovery advisory is intended to help minimize the loss of underside paneling or sheathing on elevated coastal buildings during high-wind events. Minimizing damage to these underside coverings will prevent damage to floor systems as well as water infiltration.

Fire-Resistant-Rated Assemblies

Many elevated buildings use the space underneath as a parking or storage area. According to building codes, the barrier between this space and the living area should be treated as a partition between a garage or parking area and a living area. Garages and parking areas must be separated from living areas with a fire-resistant floor or wall assembly. A variety of materials can be used; typically gypsum or an approved equivalent material is required to meet the guidelines for a fire-resistant-rated assembly. The purpose of the assembly is to prevent a fire from a vehicle or flammable/combustible material from spreading too quickly into the living space, thereby allowing the occupants sufficient time to escape the building prior to the structure's collapse, while minimizing their exposure to fire and smoke.

Use of Space Below the Elevated Building

Key Issues

- Floodplain management regulations restrict the use of building space below the base flood elevation to vehicle parking, building access, and storage (see Figure 2).
- Local regulations may require parking/garage areas to be separated from the living space with a fire-resistant-rated floor assembly.

Codes and Guidelines

The building should be constructed in accordance with the International Residential Code or the International Building Code, depending on design requirements. Although these codes have slightly different requirements, depending on how the space is categorized by the building code, both may require a fire-resistant-rated assembly to be used between the parking area and living space.

In addition to meeting applicable code requirements, the area below the elevated building must also meet the requirements of the NFIP as described in NFIP Technical Bulletins (TBs) TB 1, *Openings in Foundation Walls and Walls of Enclosures*; TB 5, *Free-of-Obstruction Requirements*; and TB 9, *Design and Construction Guidance for Breakaway Walls*.

Figure 2. Space under an elevated building used as a parking area (St. Tammany Parish, LA, Hurricane Isaac)

Mitigation Guidance for Covering the Underside of an Elevated Building

Key Issues

- Underside paneling or sheathing assemblies for elevated structures should utilize flood-damage-resistant materials.
- These assemblies may be required to meet the fire-resistance-rating criteria for a garage depending on how the space is categorized by the building code or local building official.
- These assemblies should be designed to resist wind loads based on the adopted wind speed maps for the area where the building is located.

Material Selection

The materials selected for the underside of an elevated building need to meet the requirements of NFIP TB 2, *Flood Damage-Resistant Materials Requirements*, and any additional building code requirements related to flood protection. If required by the code in the building's jurisdiction, designers should research the materials to ensure that they can be used to construct a fire-resistant-rated assembly that will also resist wind loads.

Coastal areas are corrosive environments, and any fasteners used on the exterior of the building must be resistant to corrosion. Corrosion-resistant fasteners should be used for the entire floor system assembly and all paneling or sheathing materials. The compatibility of the fasteners with the materials must be verified. Ideally, corrosion-resistant fasteners should be used even in areas where the assembly is covered with paneling or sheathing material.

Creating a Fire-Resistant-Rated Assembly

FEMA post-disaster damage assessments have reported that plywood sheathing performs well in high-wind conditions. However, plywood sheathing alone is insufficient if the underside of the elevated building requires a fire-resistant-rated floor system. Although fire-retardant-treated plywood that meets some of the fire-resistance requirements is available, it is not a substitute for fire-resistive gypsum, a common material in many fire-resistant-rated assemblies.

Some alternative products may meet the fire-resistance requirement. The designer should contact the manufacturer to verify that the material will create a code-compliant assembly when used with the other materials in the assembly (floor system). The proposed design should be submitted to the local building official for approval. Building codes often require assemblies of a designated fire resistance to be documented by a recognized testing and listing organization/laboratory (e.g., Underwriters Laboratory). All structural elements, such as piles, posts, or columns, should be evaluated to determine if additional fire protection is needed. For instance, sprinkler systems may be required to meet building code requirements in some jurisdictions.

Creating a Wind-Resistant Assembly

Currently, no design standards provide guidance on how to calculate wind loads underneath an elevated building. Although the wind loads underneath the building are significantly less than those on the roof system, designers should try to determine the potential loads imposed on the plywood sheathing system to determine the appropriate fastener size and spacing to adequately attach the plywood sheathing. If a refined wind load analysis will not be performed, it may be appropriate to use the plywood sheathing fastening requirements for low-slope roof systems with the design wind speed for the area where the building is located. In many cases, floor joists are spaced at 16 inches, rather than a roof truss spacing of approximately 24 inches on center, which may adjust typical fastener spacing due to the tighter spacing of support members (joists).

FEMA post-disaster assessments have observed that vinyl siding or soffit paneling material used to cover the underside of elevated buildings frequently fails, usually as a result of the vinyl tearing or fasteners pulling out (see Figure 3). FEMA has observed less damage to underside coverings from high-wind events where the covering material is wood (typically plywood sheathing). The use of wood or more rigid materials may not eliminate all damage during high-wind events, but it will minimize damage to the underside covering material from tear out around fasteners or buckling (see Figure 4).

Figure 3. Covering under an elevated building was lost when the vinyl soffit paneling tore around fastener heads during high winds (Plaquemines Parish, LA, Hurricane Isaac)

Figure 4. Wood sheathing under a house near the one shown in Figure 3 did not fail; this is not a fire-resistant-rated assembly (Plaquemines Parish, LA, Hurricane Isaac)

Designing the Complete Assembly

If the area underneath an elevated building is categorized, by the code or building code official, such that it requires a fire-resistant-rated assembly and must meet flood-resistance requirements and adequately resistant wind loads, it will result in a complex assembly of materials.

If common construction materials are to be used, a fire-resistant-rated assembly can be constructed using a standard plywood subfloor, floor joists with insulation between the joists, a layer of exterior-grade plywood sheathing, and a layer of 5/8-inch-thick Type X paperless gypsum wallboard. Although this approach exposes the gypsum wallboard to wind-borne debris, it will reduce the likelihood of plywood sheathing loss due to high winds. The plywood layer should be fastened to the floor joists to minimize plywood sheathing loss and deflection in high-wind events. The plywood sheathing layer will prevent the gypsum wallboard from deflecting in a high-wind event and thus minimize loss of the gypsum. (Reversing the drywall and the plywood layers requires the fasteners attaching the plywood to the floor joists to bridge the gypsum; these fasteners may then be a potential point of failure.)

As a final step, the gypsum wallboard should be covered with an exterior-grade paint or sealant consistent with the gypsum wallboard manufacturer's specifications. Any assembly requiring a fire-resistance rating must be verified with the appropriate building material listing service and by the local building official for building code compliance.

This Recovery Advisory describes one approach to designing an assembly, and while other techniques exist, designers must consider appropriate wind loads, use flood-damage-resistant materials, and provide fire resistance. For example, other materials, such as some fiber cement sheathing products, may meet the wind-loading requirements for the plywood sheathing and fire-resistance requirements of the gypsum wallboard. However, designers should always check with the manufacturer. The entire floor assembly should be assessed as a whole rather than as individual products.

References

APA, The Engineered Wood Association. 2009. *Fire-Retardant-Treated (FRT) Plywood*. (*http://www.apawood.org*)

APA, The Engineered Wood Association. 2005. *Fire-Rated Systems, Design/Construction Guide*. (*http://www.apawood.org*)

Federal Emergency Management Agency (FEMA). 2008a. National Flood Insurance Program (NFIP) Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures*. (*http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins*)

FEMA. 2008b. NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements*. (*http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins*)

FEMA. 2008c. NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements*. (*http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins*)

FEMA. 2008d. NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls*. (*http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins*)

International Code Council. *International Building Code*. 2006/2009/2012. (*http://www.iccsafe.org*)

International Code Council. *International Residential Code*. 2006/2009/2012. (*http://www.iccsafe.org*)

Minimizing Flood Damage to Electrical Service Components

FEMA

HURRICANE ISAAC RECOVERY ADVISORY *RA2, December 2012*

Purpose

The purpose of this Hurricane Recovery Advisory is to describe practices for minimizing damage to electrical service components during coastal and riverine flood events (see Figure 1). It's primary focus is on services of less than 300 volts, which are typical of residential homes. Considering flood risks when designing and constructing electrical services can ensure that outage durations resulting from flooding are minimized and that utility and code requirements are met.

Key Issues

- Floods can damage electrical utility meters and disconnect switches and other electrical service components. Damaged components can delay recovery time and extend the duration of power outages.
- Preventing flood damage requires placing all electrical equipment above the flood level, but utility company requirements and the National Electrical Code (NEC) place limits on where electrical service equipment can be located.

The following information is intended to help homeowners and builders identify options for locating electrical service components to minimize flood risks. Figure 2 clarifies some terminology and shows some of the necessary clearance requirements.

Figure 1. Electrical components installed below the lowest floor system are subject to increased flood damages and lengthy outage durations (St. Tammany Parish, LA)

National Electrical Code and Local Utility Requirements

Key Issues

- The NEC may dictate the locations for some electrical service components because of clearance requirements
- NEC requirements do not directly address flood protection needs
- Local utilities may have additional requirements that dictate the location of electrical service components
- Local utilities may also require an external disconnection at the metering equipment so that emergency response personnel can safely de-energize all power without entering the structure

NEC Requirements

NEC contains requirements for electrical services that significantly affect their design and construction. The code dictates:

- Clearance to energized conductors
- Means to disconnect electrical power from a home
- Clearances around electrical service components

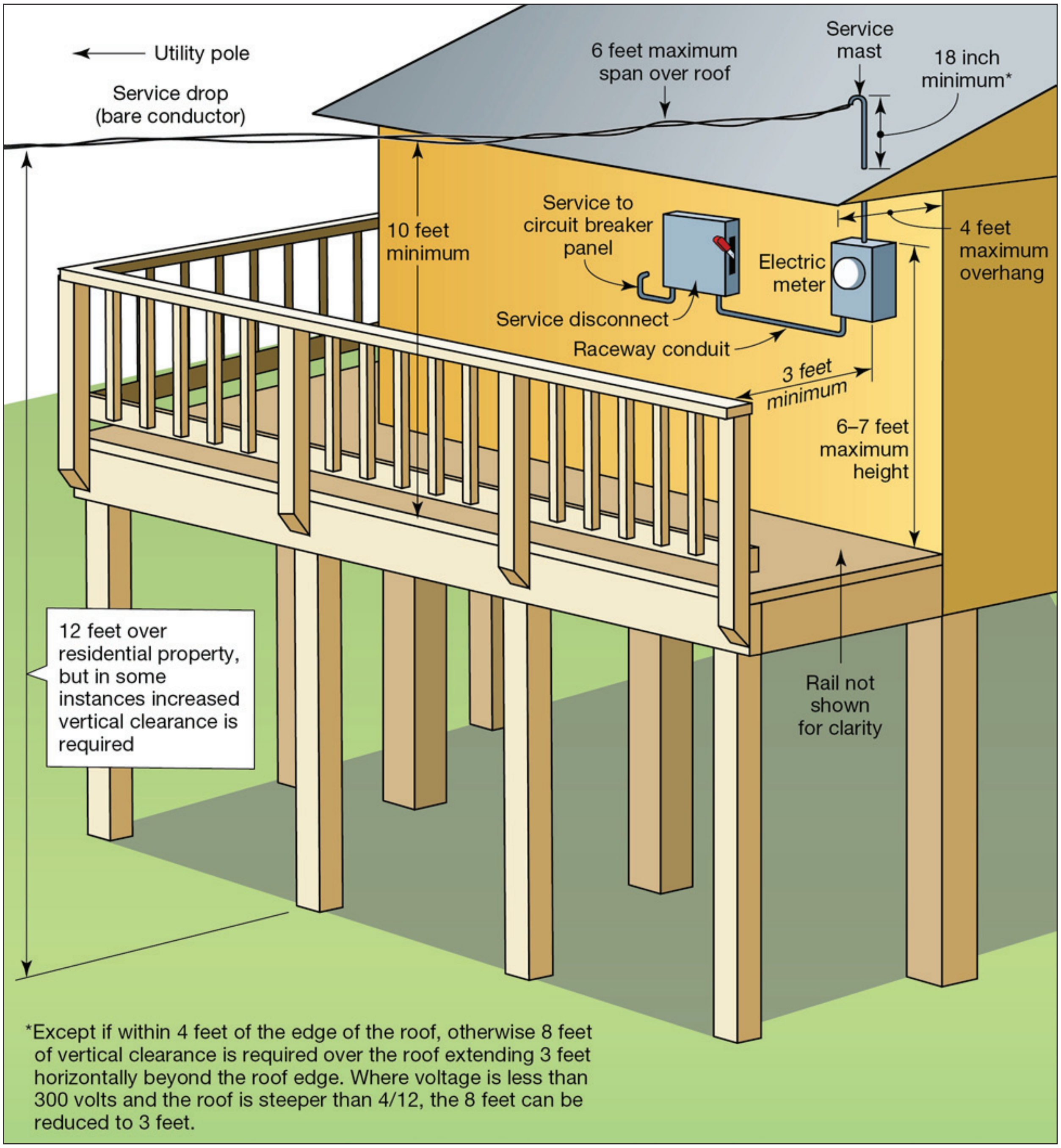

Figure 2. Illustration identifies some of the electrical service components and some of the NEC requirements for residential electrical service. Other clearance requirements come into effect if the service drop (an overhead electrical line running from a utility pole to a home) is attached near a door or window or is attached to the side of the house rather than to the roof as shown in the illustration.

NEC ***clearance requirements*** prevent people from coming in contact with energized conductors (electrical lines). Clearances above roofs, doors, windows, driveways, and walking surfaces (stair landings, decks, balconies, etc.) must meet NEC requirements. When electrical components are elevated to avoid flooding, the NEC requirements for clearance must still be maintained.

NEC requirements for ***service disconnecting means*** ensures power to a building can be shut off in the event of an emergency like fire or flooding, or when electrical equipment must be de-energized for servicing. Main circuit breakers mounted within electrical service panelboards are often used to disconnect the service. Separate enclosed circuit breakers or separate fused disconnect switches mounted between the electrical meters and the electrical panelboards can also be used. The NEC requires that service disconnecting means be readily accessible. The NEC allows the use of remote control as a disconnecting means if the remote control device is readily accessible.

The NEC also governs ***working space around electrical equipment***, and requires a clear area around electrical equipment to allow a utility worker or electrician to work without obstructions. Meeting these requirements often affects the placement and location of electrical service components. Equipment that must be serviced or repaired when energized must have sufficient working clearance to protect electricians as they perform service and repairs.

> **National Electrical Code and National Electrical Safety Code**
>
> The National Fire Protection Association (NFPA) 70, also known as the National Electrical Code (NEC), is the minimum standard incorporated by many building codes and adopted by many States and municipalities. The NEC governs all wiring downstream of the electrical service point, which delineates on-premise wiring from that operated by the electrical utility. Wiring upstream of the electrical service point is governed by other standards, like the National Electrical Safety Code (NESC, ANSI/IEEE C2).
>
> For more information, refer to: *http://standards.ieee.org/about/nesc/2012.html.*

Electrical Utility Company Requirements

In addition to the NEC requirements for electrical services, electrical utility companies also have requirements that must be met. Utility companies commonly require the center of electrical meters to be placed within 4- to 6-feet of the finished grade to allow access for recording electrical usage from manually read meters. The 4- to 6-foot requirement also allows utility workers to remove the electrical meters from meter boxes if they need to discontinue electric service to a home. The specific requirements for the elevation of the center of the meter above grade should be verified with the utility company. Some utility companies allow electric meters to be accessed from elevated stairs, walkways, or decks, particularly when not used solely for meter access (and thus more likely to be maintained in a serviceable condition). When accessible from elevated structures, the electrical meters and other service components can be elevated to reduce or alleviate flood risk without restricting access for utility company personnel.

Choosing Locations for Electrical Service Components

Key Issues

- Locating electrical service components above potential floodwaters
- Maintaining access for utility workers

National Flood Insurance Program Requirements

The National Flood Insurance Program (NFIP) requires that buildings in a Special Flood Hazard Area:

> *… be constructed with electrical heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.*

Although the NFIP does not regulate equipment owned by utilities, such as electric meters, FEMA recommends that electrical services be designed so that all equipment is elevated above flood levels to prevent flood damage (Figure 3) or that most of the electric service equipment be placed above flood levels to minimize flood damage (Figure 4).

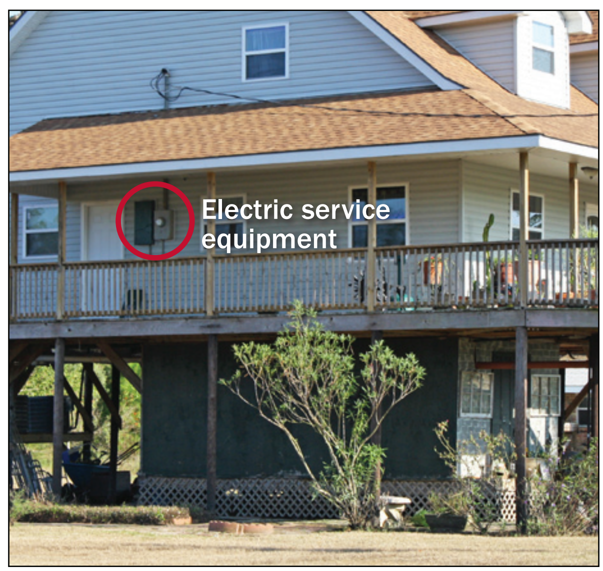

Figure 3. Example of the preferred method of elevating all electrical components (St. Tammany Parish, LA)

Figure 3 shows a house where the electrical meter and all other electrical service components are all located above the elevated lowest floor. For floods that do not rise above the level of the elevated lowest floor, service equipment will not be damaged by flood waters (with the possible exception of an easily repairable grounding conductor that bonds the meter enclosure and service panel to a ground rod below). Workers can easily access the electrical meter from the stairs and elevated deck to read the meter or remove it to shut off power to the home.

In some situations, elevating the meter may not be possible, but all other electrical service components may be elevated (see Figure 4). Because there are no stairs or elevated decks to provide access for an elevated meter, the utility meter is located within 4 to 6 feet of grade and remains vulnerable to flooding, but can be repaired or replaced after floodwaters recede. Flood risks to the electrical equipment, while not eliminated, are greatly reduced at this home. The service disconnecting means is mounted nearly 10 feet above grade; it is equipped with a hookstick that allows remote operation. The electrical service panel (located inside opposite the service disconnect) is also elevated and protected from flooding.

Figure 4. Other than the electrical meter, all the electrical components are elevated and protected from flooding at this home. The system incorporates an electrical service disconnect that is remotely operable with a hookstick (St. Tammany Parish, LA).

Other Considerations

- In addition to adhering to the elevation requirements in areas with high-velocity floodwaters, any utilities located below the design flood elevation should be placed on the landward side of the building and attached to foundation elements, such as piles or columns.
- Utilities such as meters, conduits, or service masts (see Figure 2 for terminology) should not be attached to breakaway walls or elements that are not designed to resist flood loads.
- Conduits and electrical cables should not be mounted on breakaway walls or cross open areas below the design flood elevation.
- All electrical components, both above and below the design flood elevation, should be designed to drain and prevent the accumulation of water.
- Branch circuits and secondary electrical components placed below design flood elevations should be designed so that they can be electrically isolated from the rest of the system. This will allow electrical power to be safely restored to the home before completing all flood-related electrical repairs.
- For additional information regarding the proper installation of electrical components in flood-prone areas, see FEMA P-348, *Protecting Building Utilities from Flood Damage* (1999), and FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010).

References and Resources

The following references and resources provide information on proper installation of other portions of the electrical system and the other utilities.

FEMA. 2010. FEMA P-499, *Home Builder's Guide to Coastal Construction*. (*http://www.fema.gov/library/viewRecord.do?id=2138*)

FEMA. 2008. NFIP Technical Bulletin 5-08, *Free-of-Obstruction Requirements*. (*http://www.fema.gov/plan/prevent/floodplain/techbul.shtm*)

FEMA. 2008. NFIP Technical Bulletin 9-08, *Design and Construction Guidance for Breakaway Walls*. (*http://www.fema.gov/plan/prevent/floodplain/techbul.shtm*)

FEMA. 1999. FEMA P-348, *Protecting Building Utilities from Flood Damage*. (*http://www.fema.gov/library/viewRecord.do?id=1750*)

International Code Council (ICC). *International Building Code*. 2006/2009/2012. (*http://www.iccsafe.org*)

ICC. *International Residential Code*. 2006/2009/2012. (*http://www.iccsafe.org*)

National Fire Protection Association. NFPA 70: National Electrical Code. 2011. (*http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=70&cookie%5Ftest=1*)

E High Water Marks

High water mark (HWM) data for Hurricane Isaac was provided to the Mitigation Assessment Team (MAT) by the U.S. Geological Survey (USGS). However, all of the data points provided are located outside of the area protected by the Hurricane and Storm Damage Risk Reduction System (HSDRRS), so the team was unable to compare many of the HWMs to previous HWMs observed during Hurricane Katrina. Many of the affected areas during Hurricane Katrina were within the HSDRRS. To better understand the flood depths observed in the field, these data were compared to the effective base flood elevation (BFE), the post-Katrina Advisory Base Flood Elevation (ABFE), and the preliminary BFE (as applicable) in the New Orleans areas affected by Hurricane Isaac. Figure E-1 shows the locations of the HWMs used for this analysis.

Table E-1 provides the comparison of elevations for the data points shown in Figure E-1. Most points located within the 100-year flood zone have HWM elevations that are lower than the effective, advisory, and preliminary BFEs for the location, indicating that Hurricane Isaac was below a design flood event. Some areas within the 500-year floodplain (Zone X shaded) did experience flooding during Hurricane Isaac. The HWMs for these areas mostly fall in St. John the Baptist Parish, which adopted preliminary maps in 2010. The highlighted rows in Table E-1 represent locations where the HWM elevation was higher than the effective BFE. All elevations in the table are referenced to the North American Vertical Datum of 1988 (NAVD 88).

Although the USGS points all lie outside of the HSDRRS, the U.S. Army Corps of Engineers found that the HSDRRS did generally perform as expected. With the HSDRRS in place, the levees and floodwalls were not overtopped. The limited extent of damage within the HSDRRS system also supports this determination.

Figure E-1: Locations of USGS HWMs used in the MAT analysis.

Table E-1: Elevations and Flood Zones for HWM Locations (elevations referenced to NAVD 88)

HWM ID	Latitude	Longitude	HWM Elevation	Effective Zone (BFE, feet)	ABFE Zone (BFE, feet)	Preliminary Zone (BFE, feet)	Parish
HWM-LA-JEF-005	29.75909	-90.10209	4.35	AE (EL 7)	AE 8	AE (EL 8)	Jefferson
HWM-LA-JEF-004	29.73223	-90.12875	3.93	AE (EL 8)	AE 9	AE (EL 8)	Jefferson
HWM-LA-JEF-001	29.68025	-90.10141	5.09	AE (EL 9)	VE 10	VE (EL 11)	Jefferson
HWM-LA-JEF-002	29.66820	-90.10934	4.92	VE (EL 11)	VE 10	VE (EL 11)	Jefferson
HWM-LA-JEF-003	29.73444	-90.12459	3.50	AE (EL 7)	AE 9	AE (EL 8)	Jefferson
HWM-LA-ORL-004	30.12564	-89.86719	5.19	V16 (EL 15)	VE 16	VE (EL 14)	Orleans
HWM-LA-ORL-003	30.14968	-89.74074	9.77	V19 (EL 15)	VE 16	VE (EL 16)	Orleans
HWM-LA-ORL-028	30.14508	-89.74825	6.09	V16 (EL 15)	VE 16	VE (EL 15)	Orleans
HWM-LA-ORL-001	30.07725	-89.84861	6.87	V16 (EL 13)	VE 14	VE (EL 15)	Orleans
HWM-LA-ORL-029	30.12434	-89.86669	5.87	V16 (EL 15)	VE 16	VE (EL 14)	Orleans
HWM-LA-ORL-002	30.06708	-89.83292	8.61	A14 (EL 13)	AE 14	VE (EL 14)	Orleans
HWM-LA-ORL-005	30.06643	-89.80586	9.74	A14 (EL 12)	AE 13	VE (EL 16)	Orleans
HWM-LA-ORL-017	30.6688	-89.80633	9.74	A14 (EL 12)	AE 13	VE (EL 16)	Orleans
HWM-LA-PLA-202	29.51200	-89.76480	7.97	A16 (EL 11)	AE 12	AE (EL 12)	Plaquemines
HWM-LA-PLA-010	29.25280	-89.35805	6.33	V21 (EL 15)	VE 16	VE (EL 12)	Plaquemines
HWM-LA-PLA-205	29.59507	-89.84190	7.80	A13 (EL 5)	AE 10	VE (EL 15)	Plaquemines
HWM-LA-PLA-201	29.76060	-90.01770	14.25	B	AE 18	VE (EL 21)	Plaquemines
HWM-LA-PLA-204	29.55910	-89.88480	7.10	A16 (EL 9)	N/A	AE (EL 11)	Plaquemines
HWM-LA-STB-001	29.84669	-89.76403	11.33	A15 (EL 13)	AE 16	AE (EL 17)	St. Bernard
HWM-LA-STB-004	29.81886	-89.61126	9.40	A15 (EL 14)	N/A	VE (EL 18)	St. Bernard
HWM-LA-STJ-006	30.08688	-90.44575	7.18	AE (EL 9)	A 12	AE (EL 9)	St. John the Baptist
HWM-LA-STJ-007	30.08590	-90.44424	5.75	AE (EL 9)	A 12	AE (EL 9)	St. John the Baptist
HWM-LA-STJ-005	30.08213	-90.46706	7.41	AE (EL 8)	N/A	AE (EL 8)	St. John the Baptist
HWM-LA-STJ-210	30.06922	-90.45872	7.71	AE (EL 8)	N/A	AE (EL 8)	St. John the Baptist
HWM-LA-STJ-001	30.08883	-90.50602	5.52	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-002	30.08830	-90.50597	5.08	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-003	30.08327	-90.51130	5.45	Shaded X	N/A	N/A	St. John the Baptist

Table E-1: Elevations and Flood Zones for HWM Locations (elevations referenced to NAVD 88) (concluded)

HWM ID	Latitude	Longitude	HWM Elevation	Effective Zone (BFE, feet)	ABFE Zone (BFE, feet)	Preliminary Zone (BFE, feet)	Parish
HWM-LA-STJ-004	30.07714	-90.54957	5.60	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-200	30.07794	-90.57258	3.63	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-201	30.07639	-90.57231	4.89	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-202	30.07594	-90.59753	5.41	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-203	30.05756	-90.62594	6.45	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-204	30.05778	-90.63572	6.53	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-205	30.08775	-90.48217	6.00	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-206	30.08469	-90.48700	6.96	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-209	30.08131	-90.52483	5.56	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-211	30.05664	-90.46103	8.39	Shaded X	N/A	N/A	St. John the Baptist
HWM-LA-STJ-207	30.09450	-90.48853	6.44	AE (EL 6)	N/A	AE (EL 6)	St. John the Baptist
HWM-LA-STJ-208	30.09536	-90.49397	6.18	AE (EL 6)	N/A	AE (EL 6)	St. John the Baptist

HWM = high water mark

BFE = base flood elevation

ABFE = Advisory Base Flood Elevation

N/A = Not applicable

Note: Highlighted rows represent locations where the HWM elevation was higher than the effective BFE.