BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
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National Institute of Building Sciences

Provider Number: G168

Lessons Learned from the 2017 Hurricanes: A Technical Evaluation of Building Performance & the Impact of Code Adoption and Enforcement

TU2A: Resilience: Learning from the Past, Adapting to the Future

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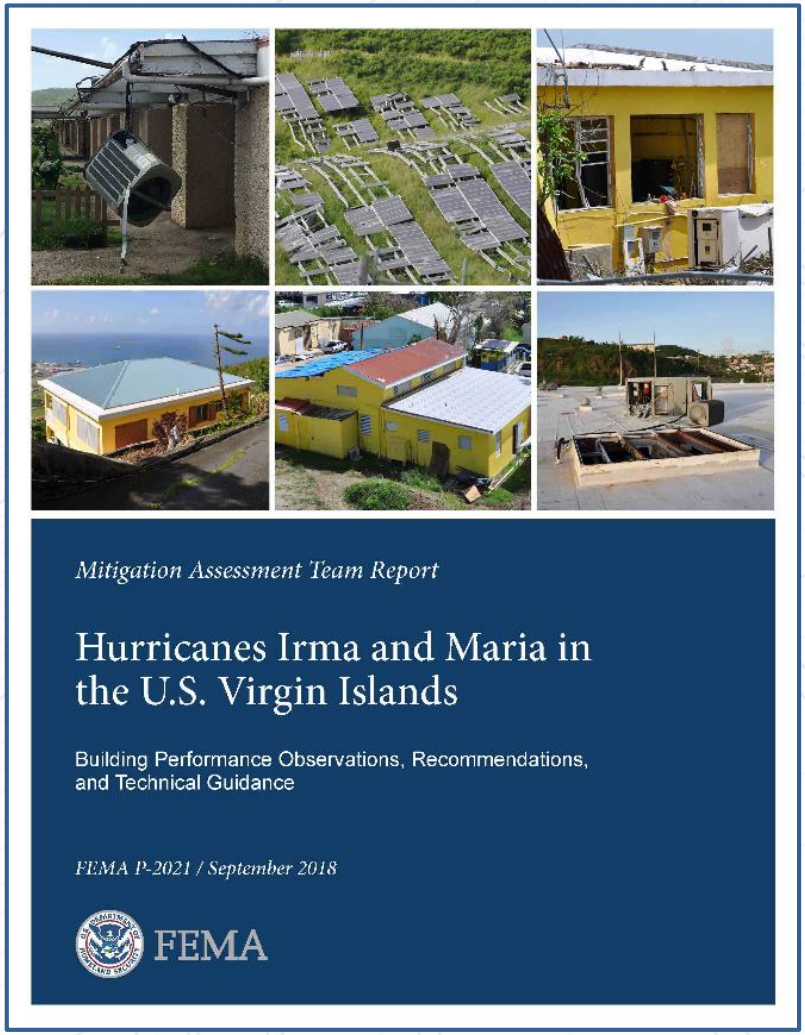
January 8th, 2019

CONTINUING EDUCATION AIA

Agenda

- FEMA Mitigation Assessment Team (MAT) Program
- 2017 Hurricane MAT - TX, USVI, PR, FL
  - General Observations
  - Lessons Learned/ Key Recommendations
  - Building Science SME Support



Mitigation Assessment Team (MAT)

- The Federal Emergency Management Agency (FEMA) Mitigation Assessment Team (MAT) Program is managed by the Building Science Branch at FEMA Headquarters.
- Following a natural disaster, the team conducts field assessments and makes technical observations on the performance of buildings subjected to the effects of the natural hazard event.

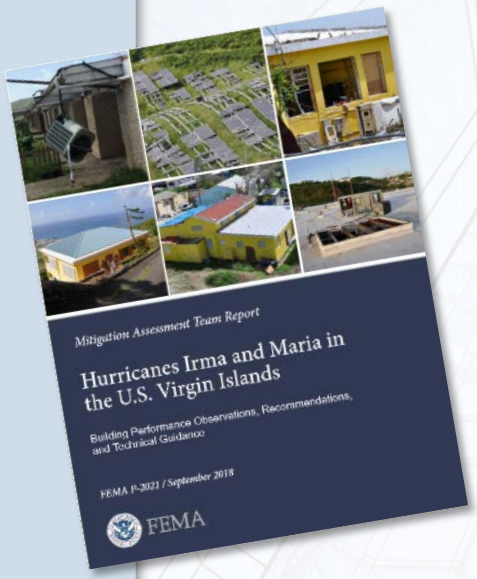
FEMA MAT MITIGATION ASSESSMENT TEAM

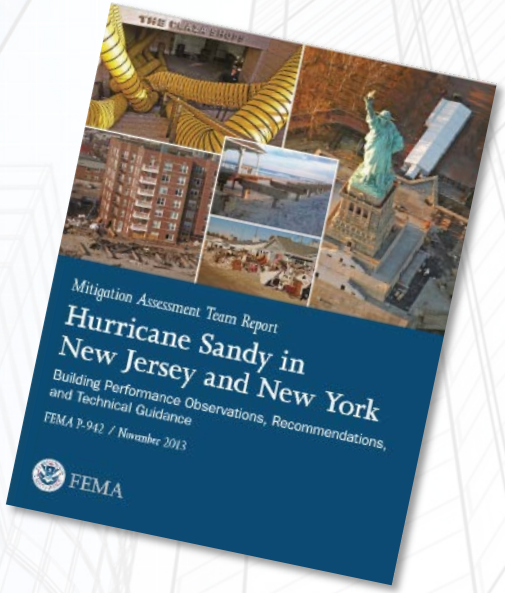
What does the MAT do?

- Observes building performance under severe hazard events.
- Determines causes of building damage, failure and success.
- Evaluates performance of mitigation projects.
- Provides design and construction strategic recommendations for reducing damage and protecting lives in hazard areas.
- Draws on combined resources of federal, state, local, academia, and private sectors.
- Supports building science/ building code elements of NDRF.

Mitigation Assessment Team (MAT)

The MAT's observations are used to recommend changes to building codes and standards groups, prepare recovery advisories, gather information to improve guidance and influence construction practices during repair, support the integration of hazard mitigation measures into the repair process, provide technical assistance related to codes and standards, and contribute to research efforts.

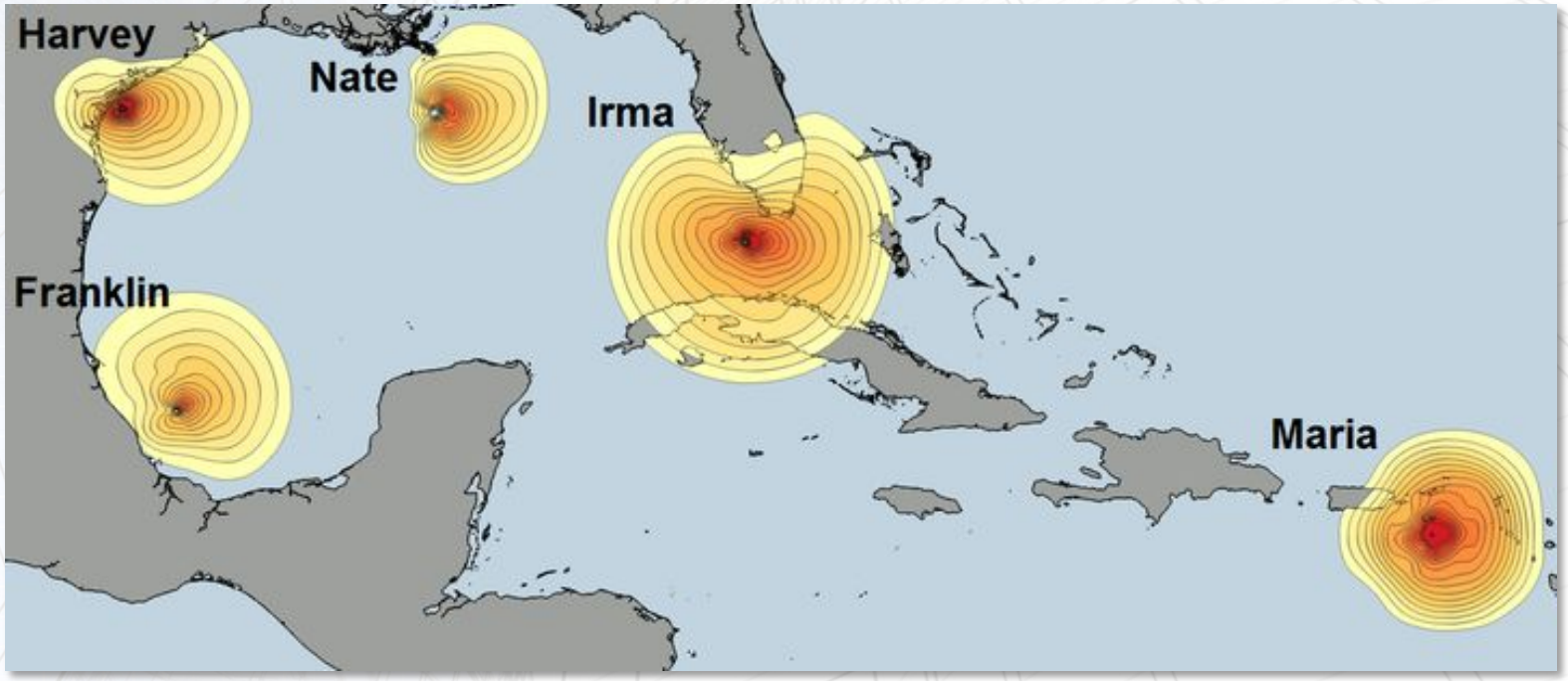




2017 Hurricanes

FEMA Mitigation Assessment Teams

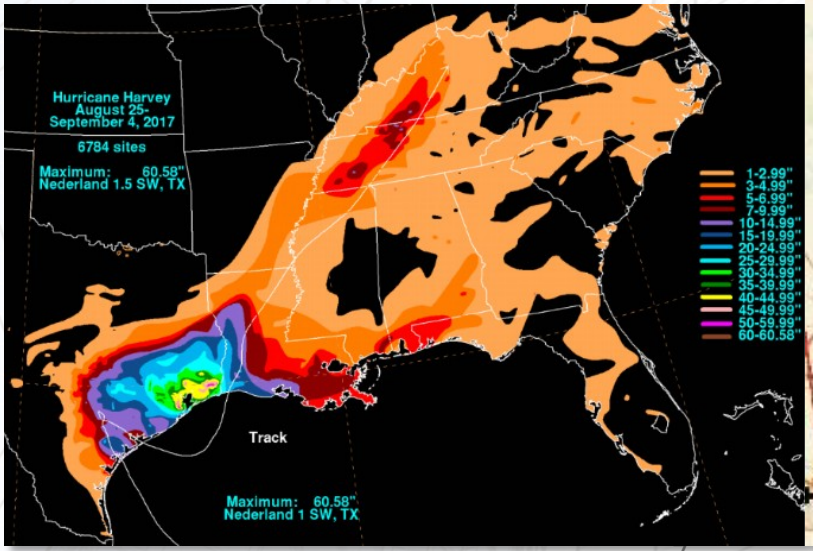
- Harvey – TX
- Irma – USVI, PR, & FL
- Maria – USVI & PR



Source: www.rms.com

Hurricane Harvey – Texas

- Landfall as a Category 4 hurricane
- Winds of 130 mph near Rockport and Fulton, TX
- System remained over Texas for several days, resulting in constant rain from Houston to western LA



General Observations – TX MAT (Wind)

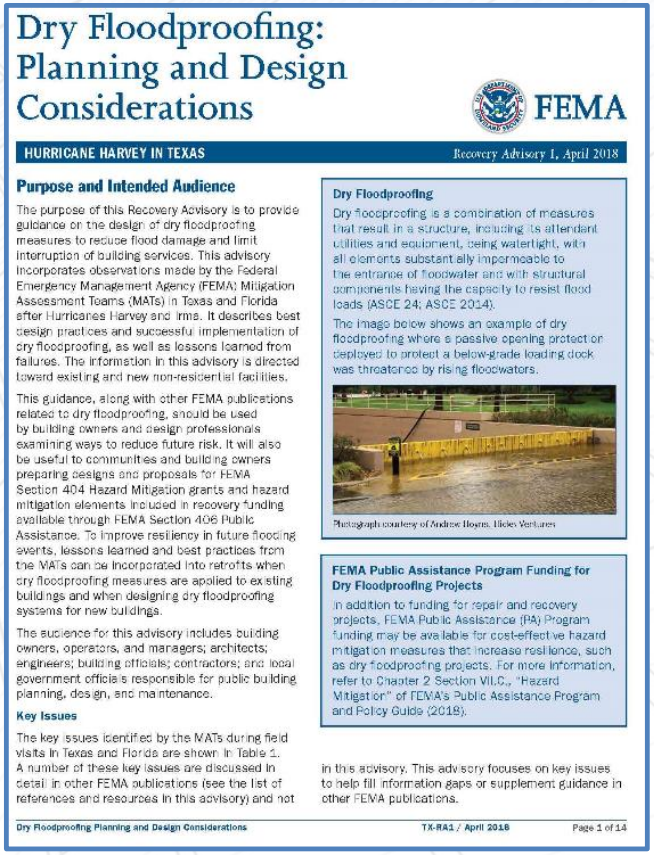
- Extensive water damage primarily due to inadequately secured roof top equipment
- Similar damage to school in Fulton, TX Recovery Advisory 2 *Attachment of Rooftop Equipment in High-Wind Regions*

General Observations – TX MAT (Flood)

- **Elevation matters** - damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings

General Observations – TX MAT (Floodproofing)

- Dry Floodproofing System Failures
  - Overtopping Failure of Opening Protection
  - Structural Failure of Flood Barrier
  - Failure to Identify and Protect Lowest Point of Entry
  - Failure to Maintain Structural Integrity of the Flood Barrier
  - Seepage Issues
  - Sanitary Sewer or Stormwater System Flows
- Flood Vulnerability Assessments
- Planning and Pre-Design Considerations
- Design Considerations



Dry Floodproofing: Planning and Design Considerations

FEMA

HURRICANE HARVEY IN TEXAS — Recovery Advisory 1, April 2018

Purpose and Intended Audience

The purpose of this Recovery Advisory is to provide guidance on the design of dry floodproofing measures to reduce flood damage and limit interruption of building services. This advisory incorporates observations made by the Federal Emergency Management Agency (FEMA) Mitigation Assessment Teams (MATs) in Texas and Florida after Hurricanes Harvey and Irma. It describes best design practices and successful implementation of dry floodproofing, as well as lessons learned from failures. The information in this advisory is directed toward existing and new non-residential facilities.

This guidance, along with other FEMA publications related to dry floodproofing, should be used by building owners and design professionals examining ways to reduce future risk. It will also be useful to communities and building owners preparing designs and proposals for FEMA Section 404 Hazard Mitigation grants and hazard mitigation elements included in recovery funding available through FEMA Section 406 Public Assistance. To improve resiliency in future flooding events, lessons learned and best practices from the MATs can be incorporated into retrofits when dry floodproofing measures are applied to existing buildings and when designing dry floodproofing systems for new buildings.

The audience for this advisory includes building owners, operators, and managers; architects; engineers; building officials; contractors; and local government officials responsible for public building planning, design, and maintenance.

Key Issues

The key issues identified by the MATs during field visits in Texas and Florida are shown in Table 1. A number of these key issues are discussed in detail in other FEMA publications (see the list of references and resources in this advisory) and not in this advisory. This advisory focuses on key issues to help fill information gaps or supplement guidance in other FEMA publications.

Dry Floodproofing

Dry floodproofing is a combination of measures that result in a structure, including its attendant utilities and equipment, being watertight, with all elements substantially impermeable to the entrance of floodwater and with structural components having the capacity to resist flood loads (ASCE 24; ASCE 2014).

The image below shows an example of dry floodproofing where a passive opening protection deployed to protect a below-grade loading dock was threatened by rising floodwaters.

Photograph courtesy of Andrew Hayes, Hicks Ventures

FEMA Public Assistance Program Funding for Dry Floodproofing Projects

In addition to funding for repair and recovery projects, FEMA Public Assistance (PA) Program funding may be available for cost-effective hazard mitigation measures that increase resilience, such as dry floodproofing projects. For more information, refer to Chapter 2 Section VII.C., "Hazard Mitigation" of FEMA's Public Assistance Program and Policy Guide (2018).

Dry Floodproofing Planning and Design Considerations — TX-RA1 / April 2018 — Page 1 of 14

General Observations – TX MAT (Floodproofing)

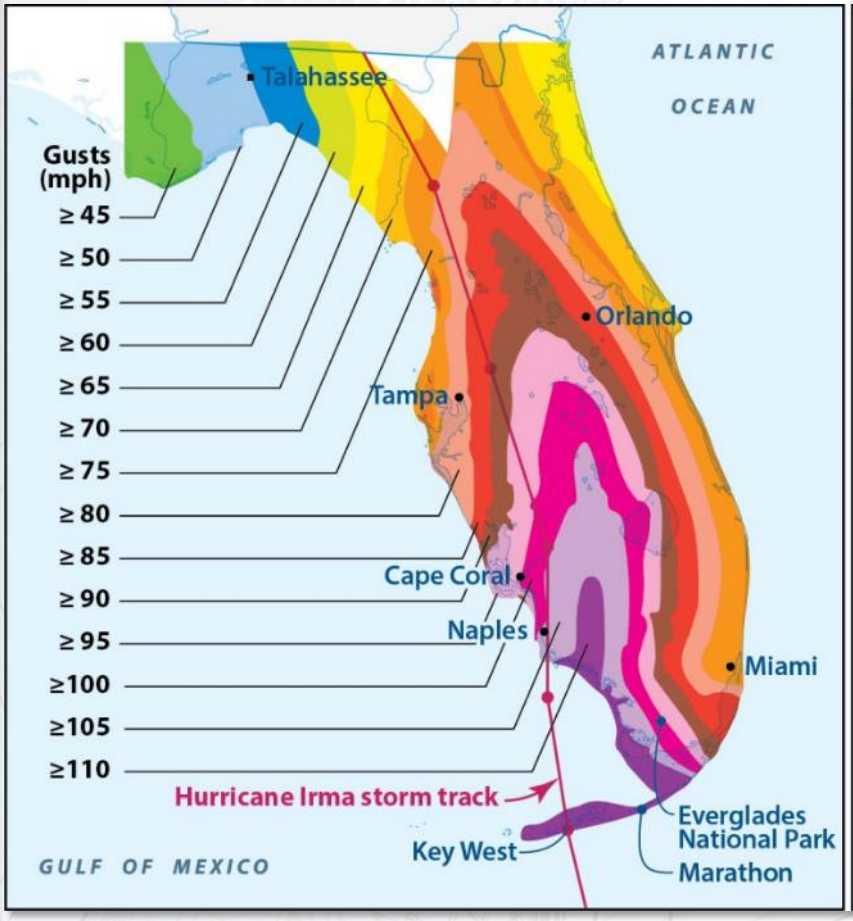
General Observations – TX MAT (Floodproofing)

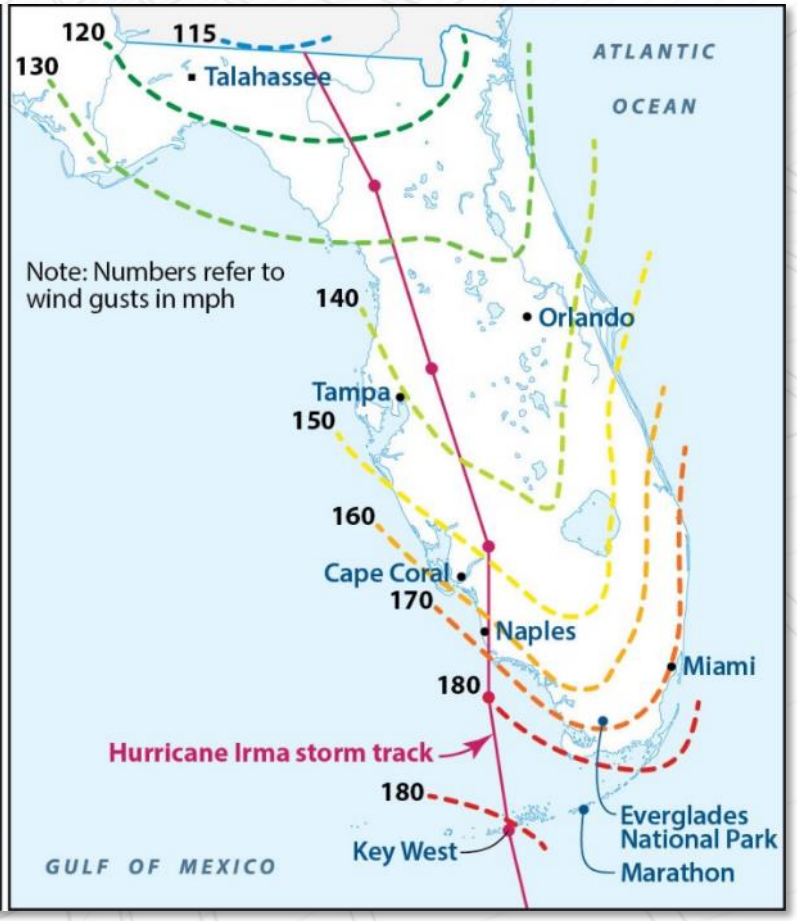
Lessons Learned: Hurricane Harvey MAT in Texas

- Roof-mounted equipment lacked adequate attachments.
- Widespread flood damage was observed within and outside the regulatory floodplain.
- Damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings.
- Dry floodproofing measures failed under less than design flood conditions.
- Dry floodproofed buildings sustained damage and experienced significant loss of function while repairs were completed

Hurricane Irma – Florida

- Landfall 1: Cudjoe Key Sep 10 at 9AM EDT (130 mph-Cat 4)
- Landfall 2: Marco Island Sep 10 at 3:30PM EDT (115 mph-Cat 3)



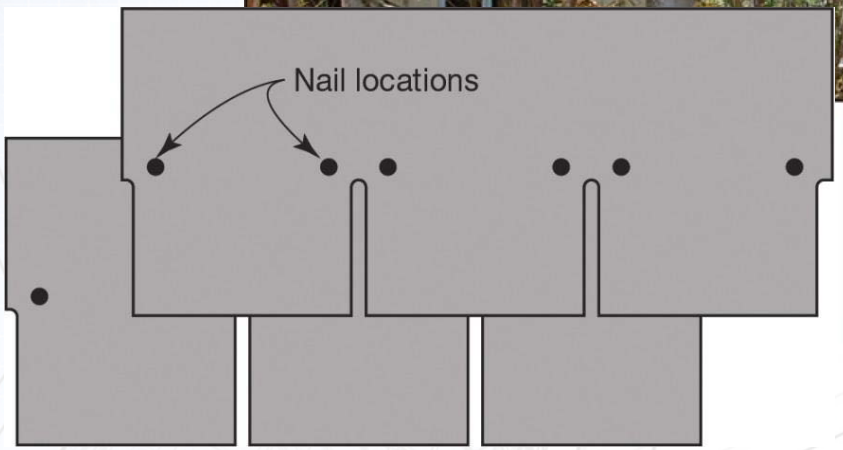


General Observations – FL MAT (Building Envelope)

- Roof Covering
- Opening Protective Systems
- Wall Covering
- Soffits

General Observations – FL MAT (Roof Covering)

Asphalt shingle loss was fairly widespread – in some cases, installation was faulty



General Observations – FL MAT (Soffits)

- Soffit damage widespread
- Vinyl and metal soffits damaged
- Fascia cover loss common with damaged soffit
- Soffit edges exposed to more wind
- **FL Recovery Advisory 2,** Soffit Installation in Florida


Soffit Installation in Florida

FEMA

HURRICANE IRMA IN FLORIDA

Purpose and Intended Audience

Florida Building Code and International Code Council Codes

Key Issues

The Recovery Advisory Addresses

Soffit Design Wind Loads and Installation in the Florida Building Code

Soffit Vents

General Observations – FL MAT (Wall Covering)

Wall Covering: Vinyl siding damage on 2017 construction – faulty installation factored into some failures

General Observations – FL MAT (Opening Protection)

- Damage less common
- All sites visited are within ASCE 7 WBDR
- Both examples from Little Torch Key

General Observations – FL MAT (Breakaway Wall)

- Visited on pre-MAT
- Siding (wind) damage (preceded flood)
- Water depth 9 in (front) to 24 in (rear) above top of slab

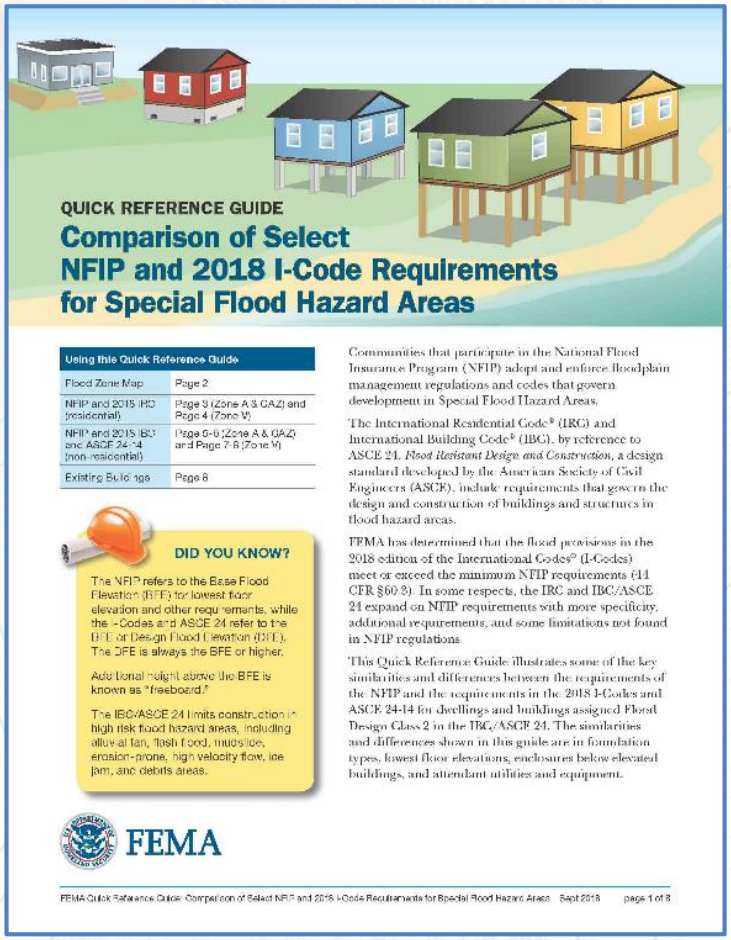
Effective Zone, BFE: AE 11 ft NGVD
Est. Depth of Water during Irma: ~ 1 ft above grade

Lessons Learned – Irma MAT (FL)

- The MAT observed evidence of inadequate resistance to wind loads for roof coverings, soffits, and certain wall coverings of residential buildings
- In some cases improper materials and installation contributed to building envelope damages; increased inspections may be needed
- Damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings
- This team also focused on dry floodproofing and had similar lessons learned to the TX Harvey MAT

Building Science SME Support – Irma MAT (FL)

Quick Reference Guide - *Comparison of Select NFIP and 2018 I-Code Requirements for Special Flood Hazard Areas*



QUICK REFERENCE GUIDE

Comparison of Select NFIP and 2018 I-Code Requirements for Special Flood Hazard Areas

Using this Quick Reference Guide	
Flood Zone Map	Page 2
NFIP and 2015 IRC (residential)	Page 3 (Zone A & CAZ) and Page 4 (Zone V)
NFIP and 2015 IBC and ASCE 24-14 (non-residential)	Page 6-6 (Zone A & CAZ) and Page 7-6 (Zone V)
Existing Buildings	Page 8

DID YOU KNOW?

The NFIP refers to the Base Flood Elevation (BFE) for lowest floor elevation and other requirements, while the I-Codes and ASCE 24 refer to the BFE or Design Flood Elevation (DFE). The DFE is always the BFE or higher.

Additional height above the BFE is known as "freeboard."

The IBC/ASCE 24 limits construction in high risk flood hazard areas, including alluvial fan, flash flood, mudslide, erosion-prone, high velocity flow, ice jam, and debris areas.

Communities that participate in the National Flood Insurance Program (NFIP) adopt and enforce floodplain management regulations and codes that govern development in Special Flood Hazard Areas.

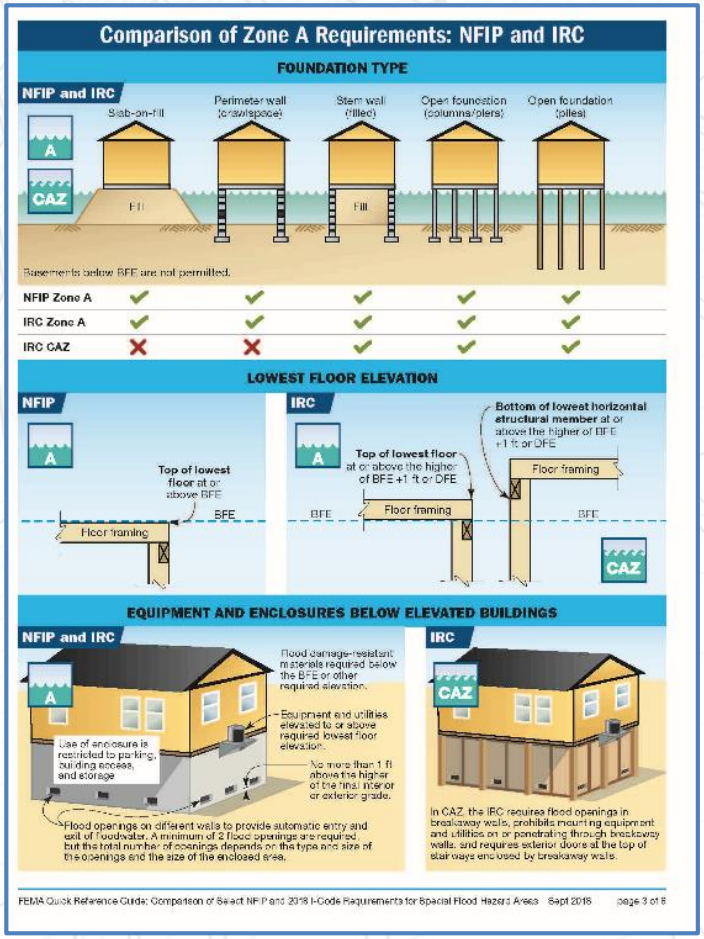
The International Residential Code® (IRC) and International Building Code® (IBC), by reference to ASCE 24, *Flood Resistant Design and Construction*, a design standard developed by the American Society of Civil Engineers (ASCE), include requirements that govern the design and construction of buildings and structures in flood hazard areas.

FEMA has determined that the flood provisions in the 2018 edition of the International Codes® (I-Codes) meet or exceed the minimum NFIP requirements (44 CFR §60.3). In some respects, the IRC and IBC/ASCE 24 expand on NFIP requirements with more specificity, additional requirements, and some limitations not found in NFIP regulations.

This Quick Reference Guide illustrates some of the key similarities and differences between the requirements of the NFIP and the requirements in the 2018 I-Codes and ASCE 24-14 for dwellings and buildings assigned Flood Design Class 2 in the IBC/ASCE 24. The similarities and differences shown in this guide are in foundation types, lowest floor elevations, enclosures below elevated buildings, and attendant utilities and equipment.

FEMA

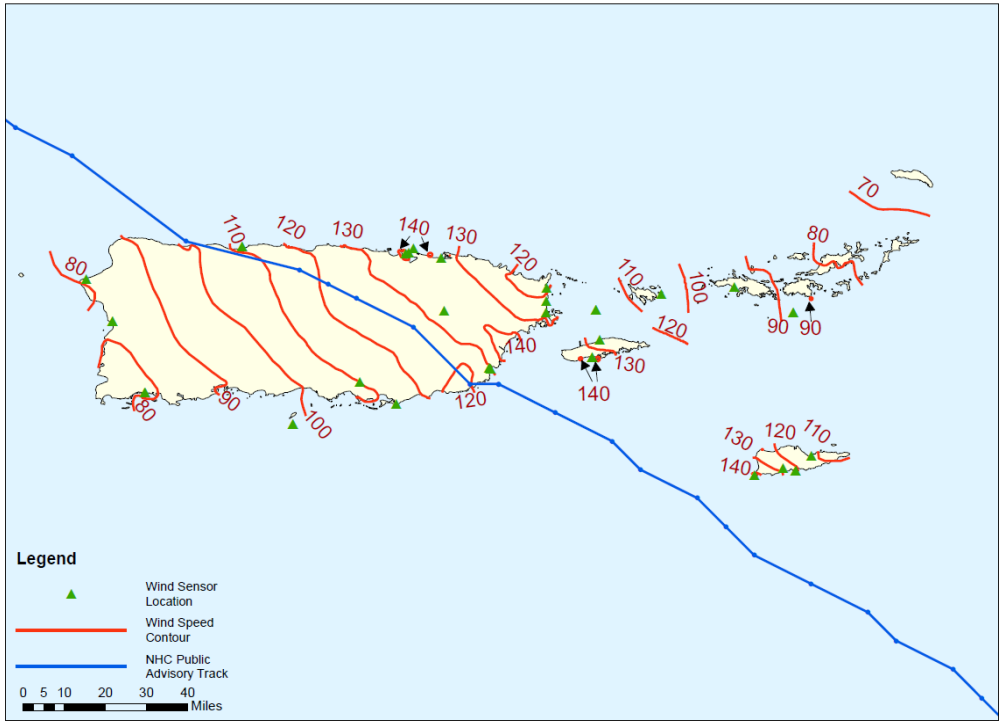
FEMA Quick Reference Guide: Comparison of Select NFIP and 2018 I-Code Requirements for Special Flood Hazard Areas Sept 2018 page 1 of 8



FEMA Quick Reference Guide: Comparison of Select NFIP and 2018 I-Code Requirements for Special Flood Hazard Areas Sept 2018 page 3 of 8

Hurricanes Irma & Maria – Puerto Rico

- Wind and Flood Impacts to Residential Buildings and Critical Facilities
- Topographic Effects, Erosion, Landslides, Storm Surge, Riverine
- Implementation of Georges MAT Recommendations
- Adoption of I-Codes, Corrosive Protection, Flood Risk Education
- Performance of post-Georges Construction and Mitigation Projects
- New Secure Housing Program, Storm Shutters, Generators
- Alternative Energy Systems including Solar Rooftop solar systems and solar farms



General Observations: Puerto Rico MAT

Shortcomings Observed

- Informal construction
  - Lack of continuous load path
  - Unpermitted
  - Not designed IAW Building Code
- Water intrusion through roofs and openings
- Rooftop equipment attachment
- Ground-mounted PV performance variable
- Siting
  - Landslide
  - Erosion
  - SFHA
  - Topographic Wind Speed-Up
- Corrosion Failures
  - Connections and Structural Members
- Tile Roof Attachment

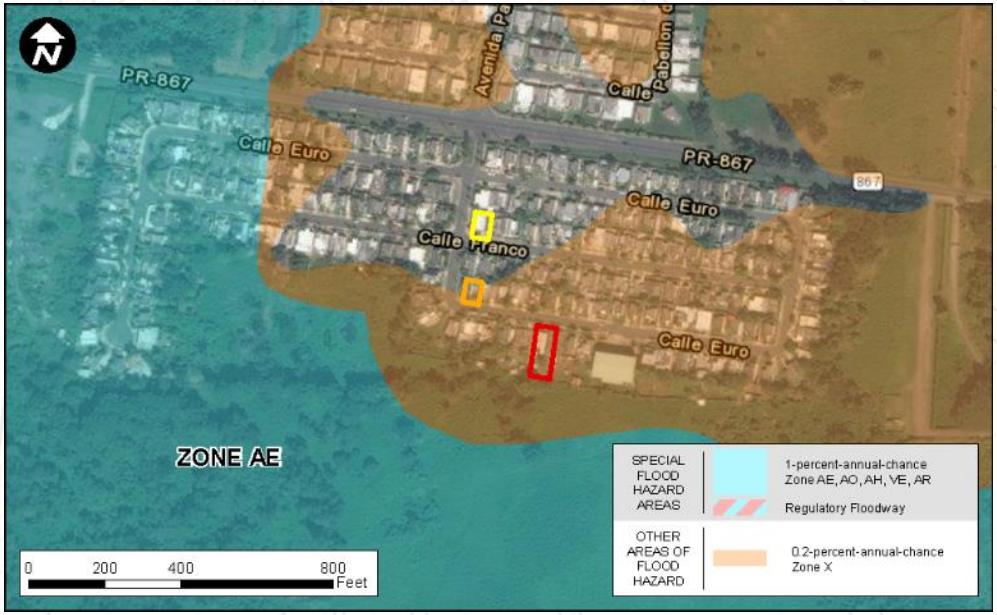
General Observations: Puerto Rico MAT

Successes Observed

- Mitigation successes from FEMA-sponsored, locally supported mitigation programs:
  - New Secure Housing Program
  - Wind Retrofits (e.g., fire station shutters)
- Rooftop solar water heaters
- Flood damage resistant materials

New Secure Housing Program

- Program following Hurricane Georges in 1998
- Built to 1997 UBC
- Replaced vulnerable buildings with building-code-compliant concrete houses
- Successes and opportunities



PR MAT Location: Punta Baja, Humacao

- Direct hit from Maria
  - High winds, storm surge, large waves
  - Some buildings saw 7-9 feet (2.1-2.7 meters) of surge
  - 2005 & 2009 FIRMs show AE and V Zones
  - Advisory Mapping adds Coastal A Zones
- Apartment building elevated on fill to 2009 BFE did not flood (but many at grade did)
- Elevated wood-framed building destroyed

PR MAT Location: Punta Baja, Humacao

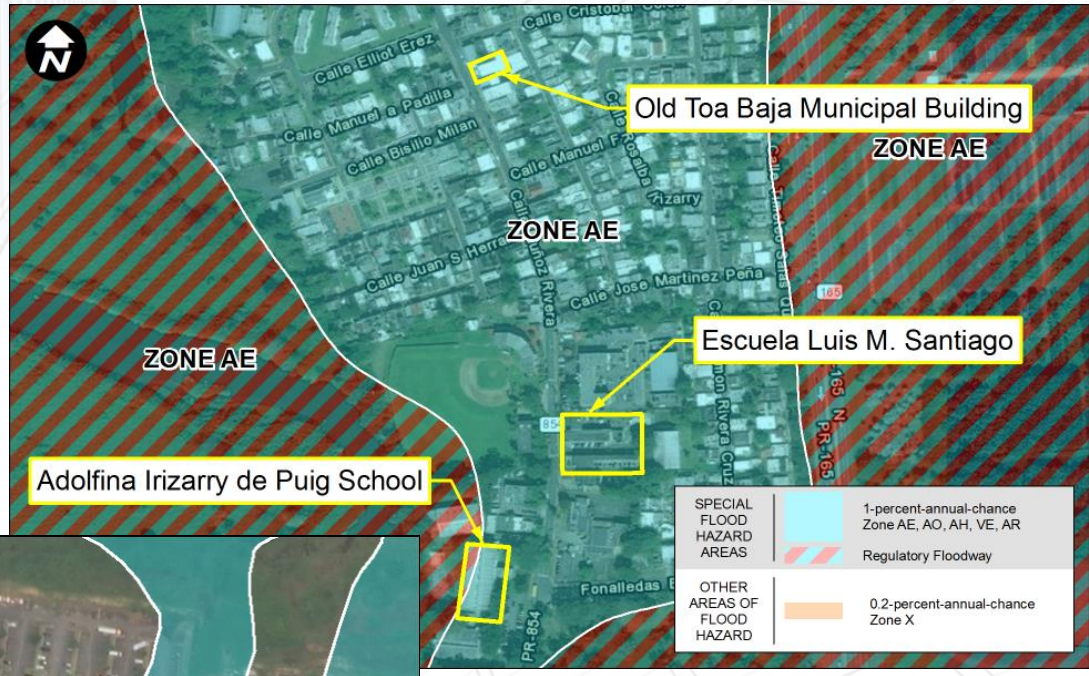
- Elevated wood-framed house that was destroyed and that survived
- The elevated concrete house performed well

PR MAT Location: Toa Baja Municipal Building

- Did not flood in 2017 hurricanes
- Underground parking structure
- Roof and glazing damage allowed water intrusion requiring the building to be closed

PR MAT Location: Toa Baja Municipal Building

- New building in 1996 to reduce flood risk



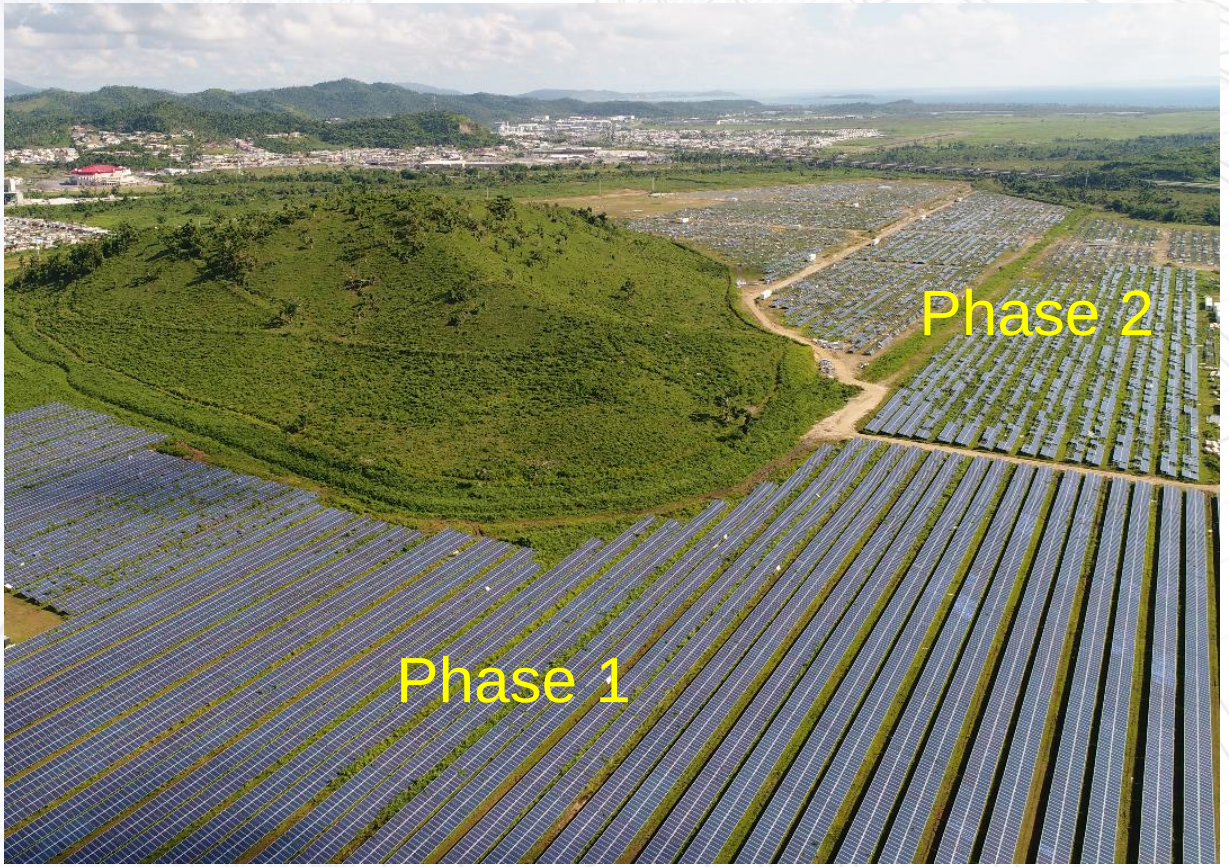
- Still in SFHA but elevated on fill

PR MAT Location: Vega Alta Municipal Building

- Shutters on east windows only
- Glazing failures led to water intrusion

PR MAT Location: Reden Solar Array, Humacao

- Large ground-mounted PV array
- Topography & construction may have contributed to performance differences between phases 1 and 2…



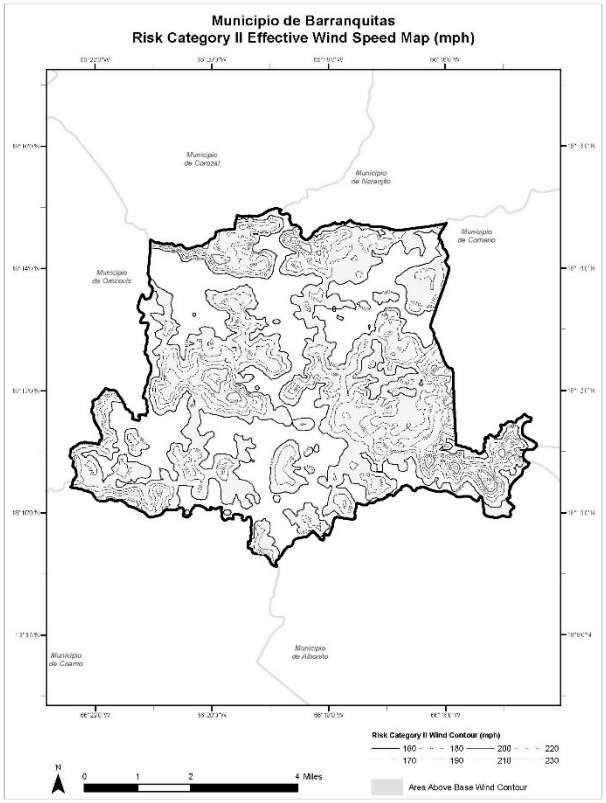
PR MAT Location: Reden Solar Array, Humacao

- Deformed hat clip still bolted to its supporting lateral rail
- PV panel was lifted out of position when hat clip was bent upward by wind uplift pressures
- Deformed steel lateral rails
- C-shaped lateral rail connections were unable to maintain connection to the steel beams in high winds.

Key Recommendations: Puerto Rico MAT

- Adopt the latest building code from ICC and update regularly.
- Publish prescriptive residential designs.
- Require construction documents to list critical parameters and load path connections.
- Perform vulnerability assessments for public buildings and critical facilities.
- Require design professionals and contractors to be licensed and registered.
- Develop hazard-resistant design guidance for alternative energy systems.
- Improve/construct life-safety hurricane shelter facilities (P-361/ICC 500).

Building Science SME Support – Puerto Rico MAT



- Topographic Wind Speed-Up Microzoning incorporated into 2018 PRBC

- Support for Building Code update to 2018 I-Codes
  - Includes strengthening amendments based on PR MAT Recommendations
- *Prescriptive Residential Designs*
  - *In collaboration with PR College of Architects and College of Engineers*
- Best Available Refuge Area for Hurricane Shelters Job Aid
  - Assist PRDOH "Vivienda" with selection protocols
- Cost & Constructability Analysis for 2018 PRBC Update
  - from 2009 to 2018 IRC
- Guidelines for Wind Vulnerabilities Assessments for Critical Facilities
- Multi-Hazard Design Trainings

Hurricanes Irma & Maria – USVI

FEMA's Building Science Branch deployed a MAT composed of National and Regional experts to affected areas in the USVI starting in October and November, 2017.

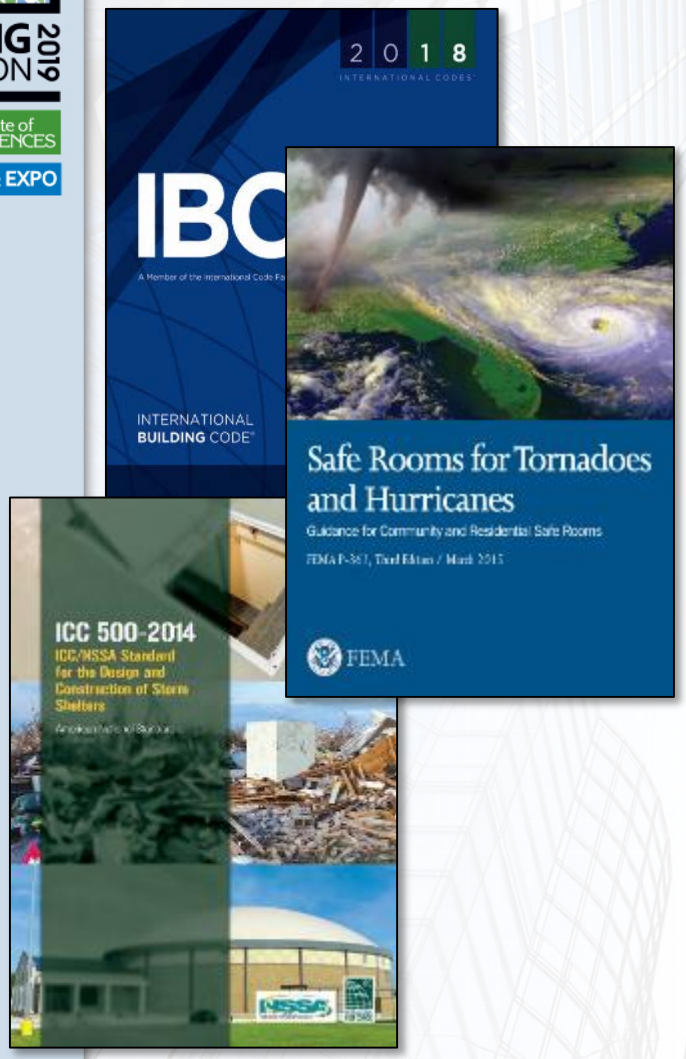
Focus:

- Assess performance of residential, nonresidential, and critical facilities
- Performance of structures after Hurricane Marilyn (1995)
- Photovoltaic (PV) facilities
- Topographic Effects on Building Performance
- Building Codes

General Observations: USVI MAT

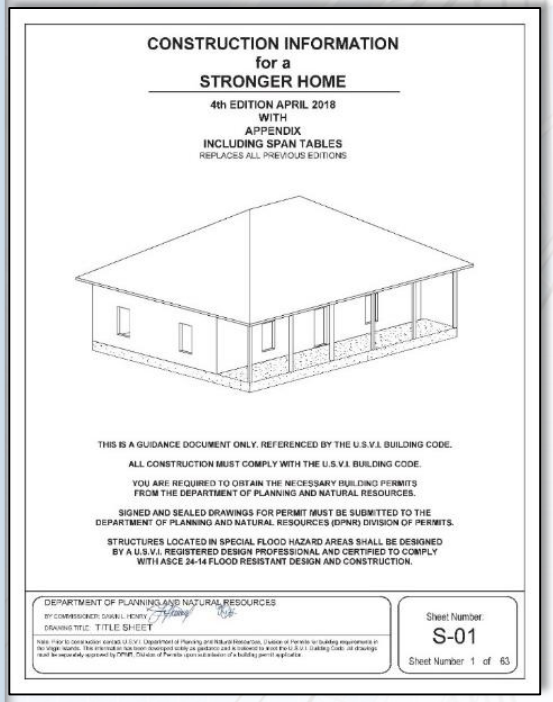
- Mitigation Successes from FEMA-sponsored and locally supported wind-mitigation programs including:
  - Home Protection Roofing Program
  - Construction Information for a Stronger Home (Stronger Homes Guide)
- Permitting and code enforcement is as important as the code itself
- Use of flood-resistant materials allowed some homes/buildings to rapidly recover
  - From flooding
  - From wind-driven rain and water intrusion

Key Recommendations: USVI MAT



- Adopt the latest building code from ICC
- Improve permitting and code enforcement programs
- Vulnerability Assessments for Public Buildings and Critical Facilities
- Hazard-resistant design guidance needed for alternative energy systems
- Improve/construct life-safety hurricane shelter facilities (P-361/ICC 500)

Building Science SME Support – USVI MAT


CONSTRUCTION INFORMATION
for a
STRONGER HOME

4th EDITION APRIL 2018
WITH
APPENDIX
INCLUDING SPAN TABLES
REPLACES ALL PREVIOUS EDITIONS

THIS IS A GUIDANCE DOCUMENT ONLY. REFERENCED BY THE U.S.V.I. BUILDING CODE.

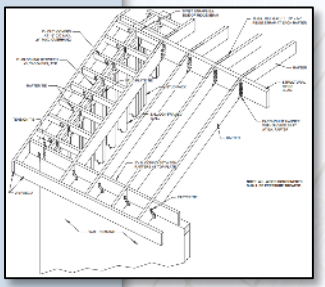
ALL CONSTRUCTION MUST COMPLY WITH THE U.S.V.I. BUILDING CODE.

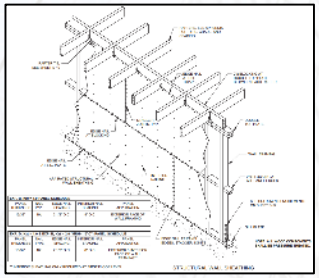
YOU ARE REQUIRED TO OBTAIN THE NECESSARY BUILDING PERMITS FROM THE DEPARTMENT OF PLANNING AND NATURAL RESOURCES.

SIGNED AND SEALED DRAWINGS FOR PERMIT MUST BE SUBMITTED TO THE DEPARTMENT OF PLANNING AND NATURAL RESOURCES (DPNR) DIVISION OF PERMITS.

STRUCTURES LOCATED IN SPECIAL FLOOD HAZARD AREAS SHALL BE DESIGNED BY A U.S.V.I. REGISTERED DESIGN PROFESSIONAL AND CERTIFIED TO COMPLY WITH ASCE 24-14 FLOOD RESISTANT DESIGN AND CONSTRUCTION.

DEPARTMENT OF PLANNING AND NATURAL RESOURCES
DRAWING TITLE: TITLE SHEET
Sheet Number
S-01
Sheet Number 1 of 63





- *Construction Information for a Stronger Home, 4th Edition*
- Ongoing SME support for JFO, DPNR, other requests and support
- Support for Building Code update to 2018 I-Codes
- Develop prescriptive design details in support residential design plan sets as permitted by the USVI Building Code
- Provide Building Science training activities for designers, contractors, and local officials

2017 Hurricane MAT Themes

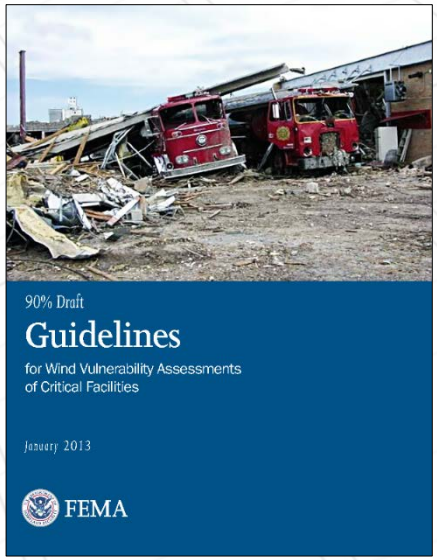
- Building codes work! AND hazard mitigation too!
- Codes and standards are the minimum requirement – performance reflects that
- A thorough vulnerability assessment is critical
- Redundancy, freeboard, additional level of protection is key
- Code officials expressed a need to reduce workload post-disaster
- Ensure seismic resistance is incorporated into all “new construction”
- Education of microzoning/topography and landslides into building code and guidance
- Performance of ‘homemade’ versus ‘tested’ (ASTM, ANSI, etc.) products
- Overestimating resources/implementation capacity
- Continued need to spread awareness of best practices

2017 Hurricane Building Science Branch Products

- Completed (*or soon to be completed*)
  - Sixteen Recovery Advisories across the four MAT
  - USVI Prescriptive Guide - *Construction Information for a Stronger Home, 4th Edition*
  - Four MAT Reports
  - Building Code Adoption Technical Assistance
    - Puerto Rico
      - Fact Sheets 2009 versus 2018 IBC/IRC
      - Cost & Constructability Analysis for 2018 PRBC Update
      - Topographic Wind Speed-Up Microzoning Maps
  - FEMA Flood Quick Reference Guide
  - Community Education and Outreach Flyers for select Building Science Branch Publications

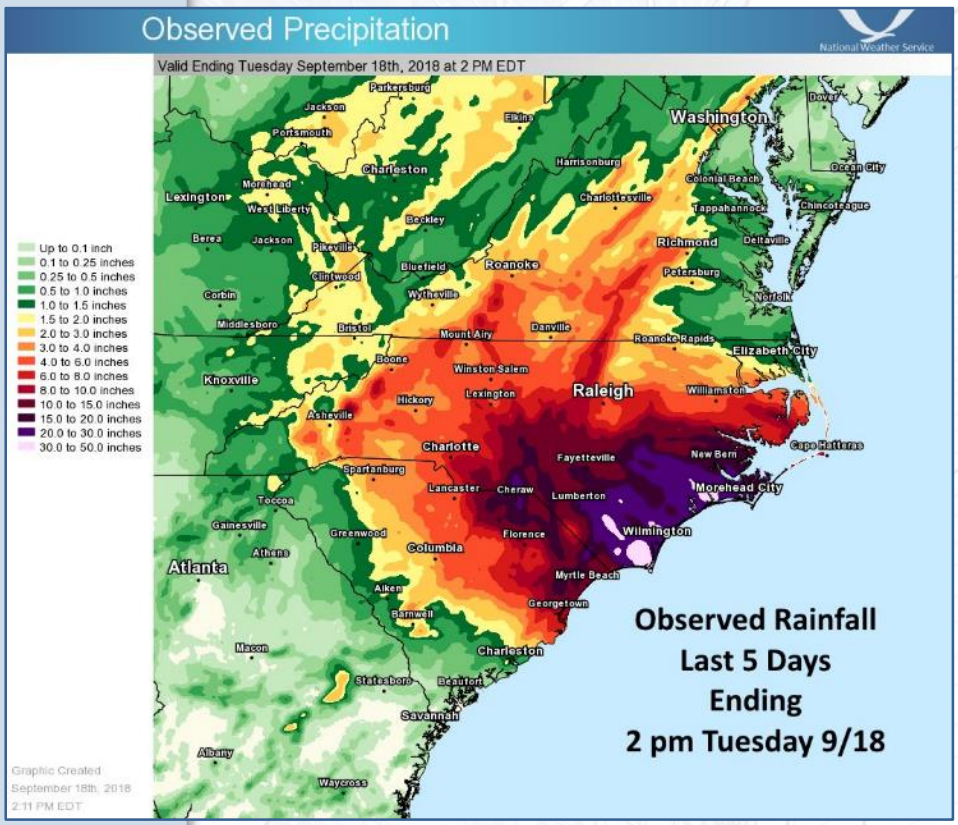
2017 Hurricane Building Science Branch Products

- Ongoing
  - PR Prescriptive Residential Designs Guide
  - Best Available Refuge Area Guidance
  - Wind Vulnerability Assessment Publication



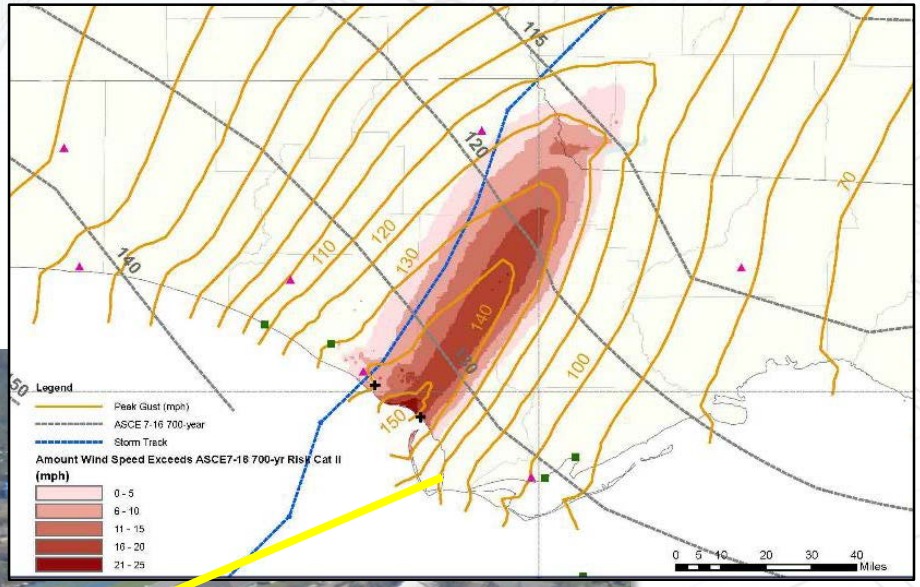
…and the research continues in 2019

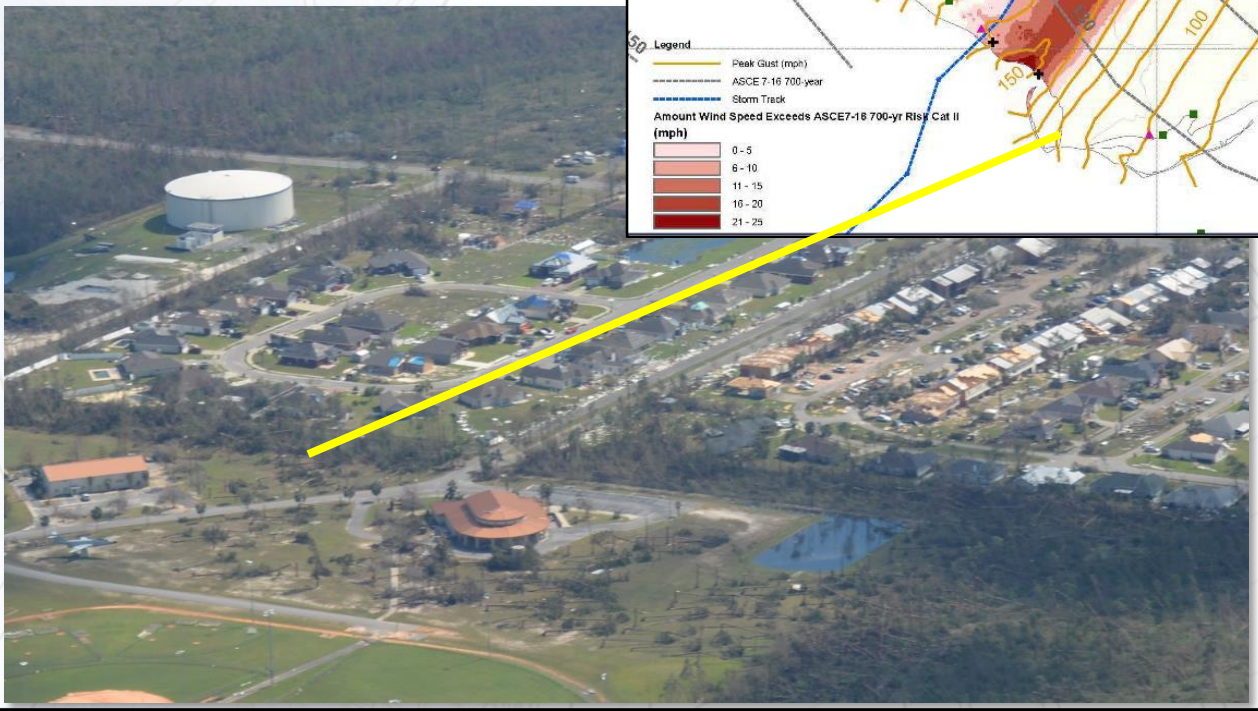
- Hurricane Florence (NC Pre MAT)



…and the research continues in 2019

- Hurricane Michael





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