Hurricane Irma: Voluntary Home Buyout Program

Florida Department of Economic Opportunity
107 E. Madison Street Caldwell Building
Tallahassee, FL 32399

Rebuild Florida

This application is to be used by Units of General Local Government to apply to the Florida Department of Economic Opportunity to receive funding as a subrecipient.

APPLICANT NAME

Monroe County, FL	South Florida Regional Planning
COUNTY	COG/Regional Planning Commission

DR-4332 - 2017

Disaster Declaration Number and Year

LOCAL GOVERNMENT INFORMATION

Local Government Applicant:	City of Marathon, Florida	Eligible County:	Monroe County, FL
Local Contact:	George Garrett	DUNS #:	
Title:	Planning Director	E-mail:	garrettg@ci.marathon.fl.us
Mailing Street Address:	9805 Overseas Highway	Phone Number	305-289-4111
City:	Marathon State: FL	Zip Code:	33050-3339
Executive Official with Authority to Sign Application:	Chuck Lindsey	Phone Number	305-289-4130
Title:	City Manager	E-mail:	Cityofmarathon@ci.marathon.fl.us
Executive Official Address (if different):	9805 Overseas Highway		
City:	Marathon State: FL	Zip Code:	33050-3339

Please list any other UGLG members of this Application Team, if any:	Contact Person:	Email Address:
Senior Planner	Brian Shea	Sheab@ci.marathon.fl.us
Planner	Geovanna Torres	Torresg@ci.marathon.fl.us

Please confirm you submitted a signed resolution authorizing Executive Official to sign application and certifications. Yes: ☒ No: ☐

APPLICATION PREPARER INFORMATION

Application Preparation Agency or Firm:	City of Marathon, FL
Contact:	George Garrett
Address:	9805 Overseas Highway
Phone Number:	305-289-4111
Email:	garrettg@ci.marathon.fl.us

Check Type of Agency Preparing Application:

Private Firm:	☐	Government Agency:	☒
Regional Planning Council:	☐	Other, specify:	

APPLICATION INFORMATION

Total CDBG-DR Funding Requested:	$5 Million
List jurisdictions for proposed recovery activities (municipalities, Tribal governments, unincorporated areas):	City of Marathon, FL

Please confirm the local government covered by the National Flood Insurance Program? Yes: ☒ No: ☐

Please confirm the proposed activities are consistent with the local comprehensive plan? Yes: ☒ No: ☐

APPLICATION FOR FEDERAL ASSISTANCE SF-424

Each applicant for Community Development Block Grant Disaster Recovery (CDBG-DR) funding must certify by signing Form SF-424 that local certifications included in the application guide governing this funding have been followed in the preparation of any CDBG-DR program application, and, if funded, will continue to be followed. *(Note: False certification can result in legal action against the jurisdiction)*.

> *"Warning: Any person who knowingly makes a false claim or statement to HUD may be subject to civil or criminal penalties under 18 U.S.C. 287, 1001 and 31 U.S.C. 3729."*

Further, by signing the SF-424 and submitting with the application, the signee authorizes the state or any of its duly authorized representatives to verify the information contained therein. Title 18, Section 1001 of the U.S. code states that a person is guilty of a FELONY for knowingly and willingly making false statements to any department of the United States Government.

All applications must be accompanied by a completed and signed Application for Federal Assistance SF-424, OMB Number: 4040-0004, Expiration Date: 10/31/2019. SF424_2_1-V2.1

INTRODUCTION AND INSTRUCTIONS

INTRODUCTION: This application is for the Rebuild Florida Voluntary Home Buyout Program. It is to be used by Units of General Local Government (UGLGs) to apply as a subrecipient for funding of Hurricane Irma damaged residential home buyouts in the UGLG's local community. This program is administered by the Florida Department of Economic Opportunity (DEO) and funded by the U.S. Department of Housing and Urban Development (HUD) Community Development Block Grant-Disaster Recovery (CDBG-DR) allocation as described in Public Laws 115-56 and 115-123.

CDBG-DR funds must be used for disaster-related expenses in the most impacted and distressed areas, for low-moderate-income households, with a focus on those households that did not have flood insurance at the time of Hurricane Irma.

UGLG applicants are required to provide sufficient detail about the buyout of residential property, national objective, geographic/target area that will receive benefit, estimated costs and materials needed, projected schedule to completion, any potential environmental impact, and other details specific to the buyout or activity involved. The application must be completed in its entirety in order to be considered for funding.

Applicants are encouraged to develop residential home buyout activities in a manner that considers an integrated approach to housing, fair housing obligations, economic revitalization, and overall community recovery. Applicants must document how the residential home buyout activities will address long-term recovery and promote community resilience.

Applicants are required to comply with the Federal Fair Housing Law (The Fair Housing Amendment 1988) 24 C.F.R. § 570.487(b), and the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended (URA), 42 USC 4601 – 4655, 49 CFR part 24, 24 CFR part 42, and 24 CFR 570.606.

All applicants funded as subrecipients must carry out all activities in a manner that does not result in a prohibited duplication of benefits as defined by Section 312 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1974 (42 U.S.C. 5155 *et seq.*) and described in Appropriations Acts. As a funded subrecipient, all successful applicants must comply with HUD's requirements for duplication of benefits, imposed by the Stafford Act, applicable Federal Register Notice(s), HUD's duplication of benefit guidance, and DEO's duplication of benefits policies and procedures. The Subrecipient shall also develop and implement duplication of benefit policies and procedures consistent with these regulatory and guidance sources. DEO will monitor each subrecipient for compliance with duplication of benefits rules, regulations, guidance, policies and procedures, as well as compliance with all other federally required cross-cutting regulations.

INSTRUCTIONS:

1. Complete and sign the SF-424 as indicated above.
2. Complete this Voluntary Home Buyout application.
3. AUDIT: If applicable, provide the most recent Single Audit in accordance with 2 CFR Part 200, Uniform Administration Requirements, Cost Principles, and Audit Requirements for Federal Awards. Rebuild Florida staff will review single audit requirements for applicable subrecipients, who have open contracts with DEO.
4. ANNUAL FINANCIAL STATEMENTS: Provide the most recent financial statement prepared in accordance with 2 CFR 200.510. Include a schedule of expenditures and schedule of findings and questioned costs.
5. KEY STAFF: Provide the names and contact information for staff that will provide local oversight of the application, the potential contract,

and all applicable requirements.
6. Provide LOCAL PROCUREMENT POLICIES AND PROCEDURES along with other required documentation.

For detailed instructions on completing the application, see page 14 of this application.

CITIZEN PARTICIPATION DETERMINED THE NEEDS IN THIS PLAN BY:

Did the applicant carry out citizen participation procedures in accordance with the Citizen Participation Plan as required by the governing documentation? Refer to your governing Federal Register and the Voluntary Home Buyout Program Designs for specific information regarding Citizen Participation Plans. Yes ☒ No ☐

Detail where citizens of the target area, with low to moderate income were given opportunities to participate in the determination process.

Once the applicant clicks on the 'Opportunity' box, events may be added by clicking the "+" button located to the right

Opportunity: Public hearing conducted and posted citizen's participation plan Date: 8/13/2019

Date of resolution authorizing application submission: 7/22/2019

COMMUNITY NEEDS ASSESSMENT

DESCRIPTION OF THE NEED(S) ADDRESSED IN THIS APPLICATION

In this section, provide full and complete answers to each of the questions below. Descriptions should include the cause of the damage, current condition of the activity, and a detailed description of the project that coincides with the information contained in both Tables 1 and 2.
The Buyout or activity must demonstrate impacts from Hurricane Irma. CDBG-DR funds must be used to buyout residential areas in support of permanent open space supporting green infrastructure or other floodplain management systems.

The situation addressed in this application first occurred: 9/10/2017

1. Please describe the impact from Hurricane Irma and any subsequent flooding or storm related conditions that continue to exacerbate the flood prone areas (include date and duration), the areas (example: subdivisions, cities, etc.) receiving disaster-related damage, and the threat that was posed to public health and safety:

On September 10, 2017, Hurricane Irma struck the Florida Keys as a category 4 hurricane bringing devastating winds and coastal flooding of up to 9 feet to the City of Marathon, Monroe County. While no part of the island chain was spared, the Middle and Lower Keys were hit the hardest. Monroe County and its municipalities including Key West, Marathon, Key Colony Beach, Layton and the Village of Islamorada were all impacted.

Destruction of the housing stock in the Florida Keys remains the largest challenge following Hurricane Irma. It is estimated that 85 percent of the local housing stock received some degree of damage as a result of the storm. More than 4,000 homes were destroyed or majorly damaged and of these, the hardest hit were the mobile homes, manufactured homes, and non-compliant older homes built on the ground vulnerable to storm surge. Within the City of Marathon, as many as 394 homes were considered destroyed post storm. Letters went out to 1,796 residents initially, indicating that their homes may have received substantial damage, based on FEMA and the City of Marathon's definition of Substantial Damage. In addition, many boats and other liveaboard marine vessels, that served as primary homes, were damaged or destroyed.(See Damage Assessment Summary and Housing Strategy Flyer)

2. Describe the impacts to the community (especially over time):

Reconstruction of affordable workforce housing faces many challenges due to high construction costs in this island community, a lack of insurance or underinsurance, stringent wind load construction standards of 180 mph, significant flood elevation requirements, and the requirement for all homes with more than 50 percent damage (substantial damage) to be rebuilt to the current building code.

For many working families and retirees, rebuilding a safe, code compliant, elevated home remains beyond their financial means. Affordable workforce housing was at a critical level before Hurricane Irma and has now reached crises levels with a significant impact on the economic sector.

According to a recent Business Recovery Survey (see Attachments) conducted by Monroe County, in partnership with the local Chambers of Commerce, eighty percent of the mostly small businesses in the County experienced an extended outage in the aftermath of the storm. Even today, twenty months after the Hurricane, a majority of the responding businesses continue to experience a significant business downturn. Tourism, a $2.7 billion industry in the Keys that employs about half of the county's workforce, experienced a significant decline. In September of 2018, Monroe County saw a 40 percent decline in hotel room demand. In addition, many employers struggled to find workers to open their businesses as the homes that traditionally housed the workforce was decimated leading employees to move outside the community to find alternative housing.

3. Describe the proposed project.

The voluntary home buyout program was created to encourage risk reduction through the purchase of residential property in high flood-risk areas impacted by Hurricane Irma. This project allows City of Marathon to purchase private residential properties at the pre-Hurricane Irma fair market value for both the land and the structure. Priority properties are located in highly flood and storm surge vulnerable areas, low-and moderate-income areas. Any existing structures will be demolished, and the property will be used for permanent open space. Most of the homes identified for the Voluntary Home Buyout Program are homes that were substantially damaged or destroyed as a result of Hurricane Irma. Many of the homeowners were either non-insured or under insured due to the very high cost of wind and flood insurance in the City of Marathon. Removing these high risk structures will reduce risk for the community.

4. Describe how the proposed activities will address damage affected by Hurricane Irma and a benefit to LMI if applicable.

The home buyout program is a rare opportunity to remove Hurricane Irma impacted unsafe structures, which threaten public health and safety. It will allow us to permanently remove the highest risk homes in the FEMA designated Velocity Zones that received up to 9 feet of storm surge. The NFIP designated repetitive loss structures and severe repetitive loss structures, mobile homes, as well as, non-code compliant aging structures which were destroyed by Irma. In the Florida Keys, these aging structures and mobile homes represented the workforce housing. By removing these non-code compliant vulnerable structures, we hope to create safer and resilient living environments for all City of Marathon and Monroe County residents.

5. Describe the impact of not taking action.

The Unsafe homes in the most vulnerable areas of the Keys, that were significantly damaged or destroyed by Hurricane Irma, that have not been demolished pose a public hazard for the community. Furthermore, if allowed to remain within the neighborhood, these homes could contribute to economic and social degradation the community already significantly weakened by Hurricane Irma. Many of these homes should not be allowed to be rebuilt in locations that will continue to be highly vulnerable to flooding and storm surge and at the highest risk for impacts from sea level rise over time.

6. List and attach materials submitted as documentation of the Hurricane Irma related condition:

Post Hurricane Irma Housing Damage Assessment Results Summary and Housing Mitigation Strategy Program Flyer, 2019 Hurricane Irma Business Recovery Survey(Attachment 9), Post Disaster Hurricane Irma Analysis (Draft) (Attachment 10), City of Marathon (Attachment 11)

AFFIRMATIVELY FURTHERING FAIR HOUSING

Any locality receiving CDBG-DR funds must certify that it will affirmatively further fair housing as stated on page 3 under "Introductions and Instructions" of this application. Using the drop-down box below, identify the activities already achieved to affirmatively further fair housing, and those new activities to be undertaken if an award is made from CDBG-DR and when that activity will be complete. Localities should be aware that, in the event of funding, these fair housing efforts will be monitored. Other activities may be eligible, and the applicant should contact Rebuild Florida to determine eligibility.

What methods and criteria were used to prioritize the projects in the application, including affirmatively furthering fair housing?

The methods and criteria used to prioritize the projects was consistent the process outlined in the VHB Program Guidelines (p.3). Benefit to LMI households (LMI= 5pts, 62 years or older= 5pts, children= 5pts, disabled/special needs= 5pts); No flood insurance= 10pts; matching contribution= 25pts. In addition to the State mandated priority projects, the City of Marathon also allocated 5 pts for homes that were substantially damaged; 5 pts for homes that are located in the V Zone; 5 pts for repetitive loss structures, 10 pts for severe repetitive loss structures, and 5 pts for high probability of sea level rise inundation. (See DRAFT Resolution Attachment 12).

Activity(ies)

Click within the area and add events by clicking the "+" button located to the right

Passing a Fair Housing ordinance, Developing a strategy to pass a Fair Housing Ordinance

Date Achieved 4/21/2010 To be complete by Click or tap to enter a date.

Click within the area and add events by clicking the "+" button located to the right

Enforcing Fair Housing guidelines that are equivalent to a Fair Housing Ordinance

Date Achieved 7/31/2019 To be complete by Click or tap to enter a date.

Click within the area and add events by clicking the "+" button located to the right

Provide Fair Housing information on the City of Marathon Voluntary Home Buyout internet page

Date Achieved 8/1/2019 To be complete by Click or tap to enter a date.

Click within the area and add events by clicking the "+" button located to the right

Establishing a local complaint and monitoring process

Date Achieved 8/1/2019 To be complete by Click or tap to enter a date.

LIST OF UNMET NEEDS

Taking into consideration the disaster-related damage described, citizen participation responses, and the assessment of housing and affirmatively furthering fair housing, provide a list (in priority order) of all the disaster-related needs still unmet from Hurricane Irma.

Click within the area and add events by clicking the "+" button located to the right

- Unsafe, substantially damaged structures
- Affordable Workforce Housing options
- Skilled Workforce Access to financial resources for recovery
- Economic recovery and business sustainability
- Environmental restoration

LONG-TERM PLANNING

Applicants must develop their community recovery projects in a manner that considers an integrated approach to housing, fair housing obligations, infrastructure, economic revitalization, and overall community recovery. Long-term planning processes should also be considered. Disaster recovery presents communities with unique opportunities to examine a wide range of issues including (1) housing quality and availability, (2) road and rail networks, (3) environmental issues, (4) the adequacy of existing infrastructure, (5) opportunities for the modernization of public facilities and the built environment, (6) the development of regional and integrated systems, and (7) the stimulation of the local economy impacted by the disaster.

Applicants must provide a brief description of how the project addressed in this application forms part of an integrated approach to recovery or long-term planning efforts in the community.

Describe the applicant's overall recovery plan and how the project addressed in this application furthers that plan. Include information about how the project will specifically address the long-term recovery and restoration of housing in the most impacted and distressed areas. Include how the community will be more resilient against future disasters as a result of these projects.

The City of Marathon worked with the County in the development of a Housing Task Force that included municipal, state and federal partners to develop a Comprehensive Post Disaster Housing Strategy. The City of Marathon Board of Commissioners held a special meetings to address Housing Recovery Strategies. These strategies included a deep dive review of the Comprehensive Plan and Land Development Code to find ways that would accelerate the recovery of lost affordable housing stock that will serve our workforce who are the backbone and strength of our tourism economy. The City is currently seeking to acquire mobile home parks and scattered lots is lower risk areas to build affordable, resilient, compliant workforce housing. Additional strategies included expediting permitting processes and creating additional density bonus opportunities to make room for more housing stock where appropriate. Improved development review processes were established in an effort to entice redevelopment of affordable workforce housing across the Florida Keys. As an Area of Critical State Concern, there is a need for concern about protecting the lives and the economic future of the people who are our workforce and call the Keys home. The ACSC regulations reinforce our reality that we must place a high concern on the evacuation of our citizens in times of impending danger from hurricanes and be ever mindful of how we develop the islands for safety and environmental reasons. The City of Marathon deems that we have a responsibility to provide safe, decent and sanitary living conditions that are affordable and sustainable. This program will allow the Florida Keys to acquire damaged homes on the most vulnerable, sensitive lands that will be set aside as green space; thereby, reducing the aging non-compliant housing stock and refocusing development it lower risk areas.

PROCUREMENT INFORMATION

All applicants are required to follow the procurement guidelines set forth in 2 CFR §200.318-§200.326 for grant administration, environmental, and engineering services if using CDBG-DR funds to pay third-party vendors for those services.

Along with this application, applicants must provide a copy of local procurement policies and procedures. Further, the applicant must provide copies of any procurement solicitations, bids, awards and contracts during DEO monitoring visits.

1. Has the applicant chosen to use a third-party administrator to administer the proposed project? Yes ☒ No ☐

If Yes, will the vendor also provide environmental services? Yes ☒ No ☐

If Yes to either question, and the vendor has been procured, provide the vendor's name, phone, and email.

If Yes, but the vendor has not been procured, adhere to 2 CFR §200.318-§200.326 regulations in the procurement process.

Company Name: We propose an inter-local agreement with the Monroe County Land Authority as a third-party

Contact Name: Charles Pattison

Phone: 305-295-5185

Email: Pattison-Charles@MonroeCounty-FL.gov

2. Has the applicant procured any other services? Yes ☐ No ☒

If Yes, and the vendor has been procured, provide the vendor's name, phone, and email.

If Yes, but the vendor has not been procured, adhere to 2 CFR §200.318-§200.326 regulations in the procurement process.

Type of Service	N/A		
Company Name	N/A		
Contact Name	N/A	Phone	N/A
Email	N/A		

UNIFORM RELOCATION ASSISTANCE AND REAL PROPERTY ACQUISITION ACT (URA)

a. Does the project require relocation assistance or any other activity requiring compliance with the URA? Yes, No or N/A

☐ ☒ ☐

b. Will the assistance requested cause the displacement of families, individuals, farms, or businesses? Yes or No

☐ ☒

If yes, explain	Under the VHBP, owners are not eligible for assistance under the URA; however, TENANTS who are displaced as a result of the owner's sale of the property to Monroe County are entitled to assistance under the URA. City of Marathon will only assist property owners of primary homes not rental properties.
Should any proposed projects cause the displacement of people, Rebuild Florida will work with the Subrecipient to follow the requirements set forth under the Uniform Relocation Assistance and Real Property Acquisition Policies Act, and applicable waivers.	

PROJECT SUMMARY

The Project Summary consists of three parts for each target area, Disaster Risk Reduction Area designation, and/or activity: (1) summarize problem(s), (2) location and buyout description, and (3) detailed actions to address problems.

1. Summarize the problem(s) to be addressed within the application by target area.

This project has identified 17 properties that sustained significant Hurricane Irma damage and are located in a high-risk flood areas within the City of Marathon. Many sustained repetitive flooding related impacts. The program will allow the removal of damaged residential structures; therefore, reducing overall community risk (Attachment 2 for maps)

2. Identify the project title and location of each activity and all buyouts. Provide a map identifying the project location.

NOTE: For the title, the spelling and capitalization of the project titles/locations identified in this application must be consistently used throughout to ensure clear identification of each project. For example, a project title of "Big Grounds, Site 3" here should appear as “Big Grounds, Site 3” at every other reference in this application. An inconsistent reference such as "big grounds subdivision" or “#3 Big Street” elsewhere in the application could cause delays in the eligibility review process

Project Title:	City of Marathon Home Buyout Project Sites 1-17 detailed on the attached spreadsheet (Attachment 1).
Location:	City of Marathon detailed on the attached spreadsheet and maps (Attachments 1 & 2)).
What is the end use of the property:	The end use for all VHBP Sites Projects 1-17 is for green space.
Incentives or Additional activities	

3. Identify the action(s) to resolve the problem(s) and their anticipated outcomes. Include specific materials and quantities.

Due to the scale and number of projects currently registered in the Volunteer Home Buyout Program, it is difficult to anticipate specific materials and quantities, which might be problematic

4. If you are leveraging funds, provide the source of the funds, the funding amount, and a description of its use.

City of Marathon is not leveraging any funds.

NATIONAL OBJECTIVES

National Objective being met:

☒ 1. Activities benefiting low- and moderate- income persons.

☐ LMHI (Housing Incentive) ☒ LMB (Household Buyout) ☒LMH (Area Benefit)

☐ 2. Prevention/Elimination of Slums or Blight. ☐ Area Basis ☐ Spot Basis

	Yes	No
Has the proposed project area been officially designated as a slum or blighted area?	☐	☒

If yes, what conditions are present in the area to designate and qualify the area as a slum or blighted area?

Describe the boundaries of the slum or blighted area. (Do not use this field to document the Census Tract / Block Group data.)

N/A

Enter the percentage of deteriorated buildings / properties in the area at the time it was designated a slum or blighted area (enter value as decimal). N/A

If the activity qualifies for CDBG-DR assistance on the basis that public improvements throughout the area are in a general state of deterioration, enter a description of each type of improvement in the area and its condition at the time the area was designated as slum / blight.

Enter the year the area was designated as a slum / blighted area. N/A

☒ 3. Urgent Need

	Yes	No
Do the existing conditions pose a serious and immediate threat to the health or welfare of the community?	☐	☒
Is the applicant able to finance the project on their own? Or are other sources of funding available?	☐	☒

Provide justification of the beneficiary identification method used to meet the National Objective:

TABLE 1 - CONTRACT BUDGET AND BENEFICIARY IDENTIFICATION

Complete a separate table for each activity or target area. Only one Table 1 is needed if the same target area, beneficiaries, and national objective apply. If any of these are different, add a new Table 1. Refer to the Application Guide for instructions.

Provide comprehensive budget information to include all Other Funds (FEMA, insurance, local, etc.) committed to

the proposed projects. Use the + button to add additional projects. Use the X button to remove a project.

Refer to the Application Guide for instructions.

BUDGET AND BENEFICIARY TABLE:

Activity Description:	Total Units	LMI Units	LMI %	National Objective	Total CDBG-DR Request	Other Sources	Activity Total
Buyout	17			LMB	$4,577,111	0	$4,577,111
Housing Incentive				LMHI	$205,700		$205,700
Summary Total:	0	0	0.0		$4,782,811		$4,782,811

TABLE 2 - GRANT PROJECT BUDGET BREAKDOWN

Provide comprehensive budget information.

Project Title: City of Marathon Voluntary Home Buyout Program

Activity Description	Description of Task	Funding Type	Explanation	Budget
Land and Structure Buyout	Purchase of land and structure and FMV	Project	Purchase of land and structure and FMV	$4,577,111
Appraisal	Appraisal of land and structure ($500)	Project	Contract service to appraise property	$8,500
Environmental Review	Conduct environmental review of properties ($3,000)	Project	Contract services for environmental review	$51,000
Demolition	Demolish all structures on site ($8,000)	Project	Contract demolition services	$136,000
Legal services	Conduct legal services to support buyout	Project	Contract legal services ($500)	$8,500
Administration	Conduct administrative support of buyout ($100)	Project	Administer buyout and regulatory services ($100)	$1,700
Implement program requirements in accordance with CDBG-DR Regulations		Planning	Payment of services for third-party administration	TBD
Manage financial services and audit		Planning		TBD
Total				$

PROJECT SCHEDULE

Highlight the projected length in months for each phase by clicking on the desired months. If a phase is not applicable, leave it blank. Projects are expected to be completed within 24 months following execution of the contract between the applicant and the DEO. Provide any comments regarding the schedule that may be helpful.

Project Title:

Months	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Professional Services Procurement																									
Application & Policy Development/ Outreach Plan applicable	X	X	X																						
Broad Environmental Review			X	X	X																				
Bid Advertisement/Contract Award						X																			
Buyout							X	X	X	X	X	X	X	X	X										
Mitigation Activities																X	X	X							
General Administration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Audit and Closeout																								X	X

Note: If the proposed project requires a schedule longer than 24 months, justification must be provided.

Comments:

N/A

LOCAL CERTIFICATIONS

Every application must be signed by the authorized signatory. By signing this application, the signee authorizes the state or any of its duly authorized representatives to verify the information contained herein. It should be noted that 18 USC § 1001 states that any person who (1) knowingly or willfully falsifies, conceals, or covers up by any trick, scheme, or device of material fact, (2) makes any materially false, fictitious, or fraudulent statement or representation; or (3) makes or uses any false writing or document knowing the same to contain any materially false fact, fictitious, or fraudulent statement is a federal offense and punishable under the law. Title 18, Section 1001 of the U.S. code states that a person is guilty of a FELONY for knowingly and willingly making false statements to any department of the United States Government.

Each application for CDBG Disaster Recovery funding must also be accompanied by a completed and signed Application for Federal Assistance Standard Form 424 (SF-424).

Each applicant must comply with the provisions of the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ) regulations, the requirements set forth in title 24 of the Code of Federal Regulations (CFR) part 58, and applicable DEO-Rebuild Florida policy directives. All applicable federal and state laws, including environmental, labor (Davis-Bacon), procurement procedures and contract requirements of 2 CFR 200.318 -200.326, and civil rights requirements apply to the use of these funds. Each applicant certifies, in compliance with the requirements presented in Volume 81, Number 224 of the Federal Register effective February 9, 2018, that:

a. It has in effect and is following a residential anti-displacement and relocation assistance plan in connection with any activity assisted with funding under the CDBG-DR program;
b. It follows and is compliant with restrictions on lobbying required by 24 CFR part 87, together with disclosure forms, if required by part 87;
c. It will comply with the acquisition and relocation requirements of the Uniform Act (URA), as amended, and implementing regulations at 49 CFR part 24, except where waivers or alternative requirements are provided in the Federal Register notice.
d. It will comply with section 3 of the Housing and Urban Development Act of 1968 (12 U.S.C. 1701u) and implementing regulations at 24 CFR part 135.

- It is following a detailed citizen participation plan that satisfies the requirements of 24 CFR 91.105 Public Participation Plan as it pertains to local government administration of CDBG-DR funds. or 91.115 Public Participation Plan as it pertains to State administration of CDBG-DR funds., as applicable (except as provided for in notices providing waivers and alternative requirements for this grant). Also, each Unit of General Local Government (UGLG) receiving assistance from a state grantee must follow a detailed citizen participation plan that satisfies the requirements of 24 CFR 570.486 (except as provided for in notices providing waivers and alternative requirements for this grant). It is the responsibility of the UGLG receiving assistance to develop and implement a compliant citizen participation plan.
- Funds will be used solely for necessary expenses related to disaster relief, long-term recovery, restoration of infrastructure and housing, and economic revitalization in the most impacted and distressed areas for which the President declared a major disaster in 2017 pursuant to the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1974 ((42 U.S.C. 5121 *et seq.*) related to the consequences of Hurricane Irma.
- The grant will be conducted and administered in conformity with title VI of the Civil Rights Act of 1964 (42 U.S.C. 2000d) and the Fair Housing Act (42 U.S.C. 3601-3619) and implementing regulations, and that it will affirmatively further fair housing.

a. It has adopted the following policies:

i. A policy prohibiting the use of excessive force by law enforcement agencies within its jurisdiction against any individuals engaged in non-violent civil rights demonstrations; and

ii. A policy of enforcing applicable state and local laws against physically barring entrance to or exit from a facility or location that is the subject of such nonviolent civil rights demonstrations within its jurisdiction.

Date ____DRAFT DOCUMENT FOR REVIEW_________________

Printed Name____

Title____

Email____

Phone Number____

Authorized Signature____________________________________

Sponsored by: Lindsey

CITY OF MARATHON, FLORIDA
RESOLUTION 2019-081

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MARATHON, FLORIDA, PROVIDING FOR THE MONROE COUNTY VOLUNTARY HOME BUYOUT LOCAL PROGRAM PRIORITIZATION CRITERIA FOR SELECTION OF PROPERTIES INTERESTED IN THE VOLUNTARY HOME BUYOUT PROGRAM UTILIZING COMMUNITY DEVELOPMENT BLOCK GRANT - DISASTER RECOVERY FUNDING.

WHEREAS, Hurricane Irma impacted the Florida Keys in September 10, 2017 destroying or majorly damaging over 4000 residential structures in Monroe County, approximately 400 of which were within the City of Marathon, thus, severely impacting the workforce housing crises; and

WHEREAS, $75 Million dollars have been allocated from the Community Development Block Grant – Disaster Recovery (CDBG-DR) funds with a $10 Million set aside for Monroe County for the Voluntary Home Buyout Program; and

WHEREAS the purpose of Rebuild Florida's CDBG-DR Voluntary Home Buyout Program is to acquire properties that are in high-risk flood areas to help reduce the impact of future disasters, and to assist property owners to relocate to less risk prone areas. These funds will support property acquisition, structure demolition and conversion of the land to open space or storm water improvements that alleviate flooding. The property must be deed-restricted in perpetuity to open space uses or to restore and/or conserve the natural floodplain functions; and

WHEREAS the program specifies prioritization criteria which must be implemented within each jurisdiction in compliance with CDBG-DR regulations; and

WHEREAS, the County may develop additional local prioritization criteria in order to fairly and equitably prioritize homeowners for the voluntary home buyout program while focusing on the program's purpose to reduce community risk,

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF MARATHON, FLORIDA, THAT:

Section 1. The above recitals are true and correct and incorporated herein.

Section 2. The City of Marathon proposes to prioritize property owners in the CDBG-DR Voluntary Home Buyout Program of primary homes that are not rental properties.

Section 3. The local program will retain the BPAS from properties that have been purchased by the Voluntary Home Buyout Program for Administrative Relief.

Section 4. The proposed City of Marathon point allocation criteria are as follows:

1. 5 pts for homes that were substantially damaged;
2. 5 pts for homes that are located in the V Zone;
3. 5 pts for repetitive loss structures;
4. 10 pts for severe repetitive loss structures, and
5. 5 pts for high probability of sea level rise inundation (Surge Zone 1).

Section 5. The City Clerk shall retain a certified copy of this Resolution for the purposes of documenting the Florida Voluntary Home Buyout Program.

Section 6. Effective Date. This Resolution shall become effective immediately upon its adoption.

PASSED AND APPROVED by the City Council of the City of Marathon, Florida, this 13th day of August, 2019.

THE CITY OF MARATHON, FLORIDA

____

John Bartus, Mayor

AYES:
NOES:
ABSENT:
ABSTAIN:

ATTEST:

____
Diane Clavier, City Clerk

(City Seal)

APPROVED AS TO FORM AND LEGALITY FOR THE USE AND RELIANCE OF THE CITY OF MARATHON, FLORIDA ONLY:

____
David Migut, City Attorney

DRAFT

Sponsored by: Lindsey

CITY OF MARATHON, FLORIDA
RESOLUTION 2019-082

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MARATHON, FLORIDA, REQUESTING SPECIFIC ASSISTANCE FROM THE MONROE COUNTY LAND AUTHORITY (MONROE COUNTY COMPREHENSIVE PLAN LAND AUTHORITY) IN THE ACQUISITION OF PROPERTIES SELECTED FOR PURCHASE UNDER THE FLORIDA VOLUNTEER HOME BUYOUT PROGRAPM; AND PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the Monroe County Comprehensive Plan Land Authority (thereinafter, "Authority") acquires property for conservation, recreation, and affordable housing in Monroe County, Florida within the Florida Keys and Key West Areas of Critical State Concern; and

WHEREAS, the Authority was established to assist in the implementation of land use plans and to serve as an intermediary between land owners and government agencies that regulate land use; and

WHEREAS, the Authority is a component unit of Monroe County government created by the Board of County Commissioners on October 1, 1986 pursuant to Florida Statutes section 380.0663 and Monroe County Ordinance 031-1986; and

WHEREAS, the Authority operates under Florida Statutes sections 380.0661 through 380.0685 and uses a fiscal year period of October 1 to September 30; and

WHEREAS, the taxes and fees received by the Authority consist of a surcharge on admissions and overnight occupancy at state parks in the unincorporated county in the amounts authorized by Florida Statutes section 380.0685 and a half-cent of the tourist impact tax charged on lodging in the Keys authorized by Florida Statutes section 125.0108; and

WHEREAS, the City of Marathon is participating in the Rebuild Florida Voluntary Home Buyout Program (FVHBP); and

WHEREAS, the City wishes to utilize the services and functions of the Authority to carry out the intent of the FVHBP to purchase property on a voluntary basis whose structures have been severely damaged by the impact of Hurricane Irma on September 10, 2017,

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF MARATHON, FLORIDA, THAT:

Section 1. The above recitals are true and correct and incorporated herein.

Section 2. The City is requesting the services and functions of the Authority to carry out the broadest intent of the FVHBP to purchase property on a voluntary basis whose structures have been severely damaged by the impact of Hurricane Irma on September 10, 2017.

Section 3. The City Clerk shall forward a certified copy of this Resolution to the Executive Director of the Monroe County Land Authority, the Chair of the Land Authority Board, and the Attorney for the Board.

Section 4. Effective Date. This Resolution shall become effective immediately upon its adoption.

PASSED AND APPROVED by the City Council of the City of Marathon, Florida, this 13th day of August, 2019.

THE CITY OF MARATHON, FLORIDA

____

John Bartus, Mayor

AYES:
NOES:
ABSENT:
ABSTAIN:

ATTEST:

____

Diane Clavier, City Clerk

(City Seal)

APPROVED AS TO FORM AND LEGALITY FOR THE USE AND RELIANCE OF THE CITY OF MARATHON, FLORIDA ONLY:

____

David Migut, City Attorney

REPORT DATE: 08/01/19

ROW	SURVEY COMPLETED BY				ACKNOWLEDGEMENT FORM COMPLETED BY				MAILING ADDRESS #1					
	FIRST NAME	LAST NAME	FIRST NAME	LAST NAME	FIRST NAME	LAST NAME	FIRST NAME	LAST NAME	HOUSE NO (MAIL)	STREET NAME (MAIL)	UNIT NO (MAIL)	CITY (MAIL)	STATE (MAIL)	ZIP (MAIL)
1	DAVID	WILBER	DAVID	WILBER	DAVID	WILBER			1240	91st COURT OCEAN		MARATHON	FL	33050
2	FRED	ROTH	FRED	ROTH					13344	OVERSEAS HWY		MARATHON	FL	33050
3	THOMAS	MORRIS							383	112 ST OCEAN		MARATHON	FL	33050
4	MICHELE	COOK			MICHELE	COOK			109	AVENUE D	307	MARATHON	FL	33050
5	KENNETH	ALBERT			KENNETH	ALBERT			H28	MIRIAM ST		KEY WEST	FL	33040
6	HOWARD	LEITNER			HOWARD	LEITNER			PO BOX 522632			MARATHON SHORES	FL	33052
7	HOWARD	LEITNER							PO BOX 522632			MARATHON SHORES	FL	33052
8	HOWARD	LEITNER							PO BOX 522632			MARATHON SHORES	FL	33052
9	HOWARD	LEITNER							PO BOX 522632			MARATHON SHORES	FL	33052
10	HOWARD	LEITNER							PO BOX 522632			MARATHON SHORES	FL	33052
11	HOWARD	LEITNER							PO BOX 522632			MARATHON SHORES	FL	33052
12	LORI	RITTEL			LORI	RITTEL			305	27 ST OCEAN		MARATHON	FL	33050
13	JOSEPH	CALCASOLA	GENEGIEVE	CALCASOLA					2026	HARBOR DR		MARATHON	FL	33050
14	ANTONIO	CASTILLO			ANTONIO	CASTILLO			14409	SW 141 PL		MIAMI	FL	33186
15	KRISTINE	LATER			KRIS	LATER			8800	OVERSEAS HWY		MARATHON	FL	33050
16	Leland	Cranmer							8036	PORPOISE DR		MARATHON	FL	33050
17	David	Marciniak							PO BOX 500701			MARATHON	FL	33050

C/O		PHONE #1	PHONE #2	EMAIL #1	EMAIL #2	PROPERTY INFO					
FIRST NAME	LAST NAME					HOUSE NO (PROPERTY)	STREET NAME (PROPERTY)	UNIT NO (PROPERTY)	CITY/KEY (PROPERTY)	PARCEL	TITLE HOLDER
		772-321-1901		Dwilber1240@yahoo.com		6099	OVERSEAS HWY	52E	MARATHON	00338830-001880	WILBER DAVID
		305-923-9542		Roth246@yahoo.com		6099	OVERSEAS HWY	93	MARATHON	00338830-002690	ROTH FRED M
		314-570-5799		tommorris1001@gmail.com		383	112 ST OCEAN		MARATHON	00344450-000000	MORRIS THOMAS A TRUST AGREEMENT 9/24/2015
		305-783-8342		michelecookcpa@hotmail.com		200	39 ST		MARATHON	00337670-000000	COOK MICHELE REVOCABLE TRUST 2/28/2014
		305-393-5760		kennyalbert2@aol.com		473	W 105 ST		MARATHON	00332710-000000	ALBERT KENNETH
		305-890-3235		howlys3@gmail.com		N/A	N/A		GRASSY KEY	00374650-000000	HJ3 INC
		305-890-3235		howlys3@gmail.com		57478	OVERSEAS HWY		GRASSY KEY	00374660-000000	HJ3 INC
		305-890-3235		howlys3@gmail.com		N/A	N/A		GRASSY KEY	00374670-000000	HJ3 INC
		305-890-3235		howlys3@gmail.com		57468	OVERSEAS HWY		GRASSY KEY	00374680-000000	HJ3 INC
		305-890-3235		howlys3@gmail.com			OVERSEAS HWY		GRASSY KEY	00374690-000000	HJ3 INC
		305-890-3235		howlys3@gmail.com			OVERSEAS HWY		GRASSY KEY	00374700-000000	HJ3 INC
		406-439-5040		Lori.Rittel@gmail.com		305	27 ST OCEAN		MARATHON	00321400-000000	RITTEL LORI
		860-917-1963		Gencal@sgtjoe.net		2026	HARBOR DR		MARATHON	00330730-000000	CALCASOLA JOSEPH J, CALCASOLA GENEVIEVE W
		786-307-3102				495	110 ST OCEAN		MARATHON	00343760-000000	CASTILLO ANTONIO
GRANTAIR SERVICE INC		305-743-3717		kris@marathonaviation.com		858	83 ST		MARATHON	00347680-000000	GRANTAIR SERVICES INC
						8036	PORPOISE DR		MARATHON	00329980-000000	Leland Cranmer
						592	83 ST		MARATHON	00347630-000000	David Marciniak

SF OF HOME	YEAR BUILT	FOUNDATION TYPE	FLUM	BFE	FLOOD ZONE	SUBSTANTIAL DAMAGE	GPS COORD	DEMO PERMIT APPLIED FOR	LOCATION MAP	TOPO MAP	FIRM MAP	FLOOD INSURANCE DURING IRMA (Y/N)	ANNUAL HOUSEHOLD INCOME	DISABLED (Y/N)	HANDICAPPED (Y/N)	HAS SPECIAL NEEDS (Y/N)	OCCUPANTS OLDER THAN 62 YRS OF AGE (Y/N)	OCCUPANTS UNDER 18 YRS OF AGE (Y/N)
N/A	N/A	N/A	RH	8	AE 8	NO	-81.070 24.715	NO	X	X	12087C1379K	N	$40,000.00	N	N	N	N	N
N/A	N/A	N/A	RH	10	AE 10	NO	-81.070 24.713	NO	X	X	12087C1379K		$100,000.00					
1031	1955	CONCRETE SLAB	RM	8	AE 8	NO	-81.035 24.728	NO	X	X	12087C1381K		$38,000.00	Y	Y		Y	
638	1965	CONCRETE SLAB	RH	8	AE 8	NO	-81.089 24.714	NO	X	X	12087C1379K	Y	$25,000.00	N	N	N	N	N
N/A	N/A	N/A	RH	7	AE 7	NO	-81.041 24.727	NO	X	X	12087C1381K	Y	$36,000.00	N	N	N	N	N
N/A	N/A	N/A	MU	13	VE 13	NO	-80.963 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
1280	1978	N/A	MU	13	VE 13	NO	-80.963 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
N/A	N/A	N/A	MU	13	VE 13	NO	-80.963 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
2492	1987	CONC PILINGS	MU	13	VE 13	NO	-80.963 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
N/A	N/A	N/A	RL	13	VE 13	NO	-80.964 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
N/A	N/A	N/A	RL	13	VE 13	NO	-80.964 24.753	NO	X	X	12087C1164K	N	$31,215.00	N	N	N	N	N
634	1969	CONCRETE SLAB	RM	7	AE 7	NO	-81.099 24.709	NO	X	X	12087C1378K	Y	$63,000.00	N	N	N	N	N
1247	1961	CONCRETE SLAB	RM	8	AE 8	NO	-81.060 24.727	NO	X	X	12087C1381K		$99,000.00				Y	
921	1951	CONCR FTR	RM	9	AE 9	NO	-81.036 24.727	NO	X	X	12087C1381K	N		N	N	N	Y	Y
N/A	N/A	N/A	RH	9	AE 9	NO	-81.055 24.721	NO	X	X		Y	NOT PROVIDED	N	N	N	N	N
N/A	N/A	CONCRETE SLAB	RM	9	AE9	NO	-81.058 24.729	NO	X	X		N		Y	Y	N	Y	N
N/A	N/A	N/A	RM	8	AE8	NO	-81.054 24.721	NO	X	X		Y		N	N	N	N	Y

DESCRIPTION OF DAMAGE
My real property was completely destroyed by Hurricane Irma. A vacant lot with building rights now remain.
Damaged trailer beyond repair was forced to dispose of it.
Flood
Flooding
home was totally destroyed.was red tagged and demolished.i have letter 0f substantial damage.just an empty lot now
Home was blown out with and front structure cut in half and gutted. 6 contiguous parcels: 00374650-000000 00374660-000000 00374670-000000 00374680-000000 00374690-000000 00374700-000000
Home was blown out with and front structure cut in half and gutted. 6 contiguous parcels: 00374650-000000 00374660-000000 00374670-000000 00374680-000000 00374690-000000 00374700-000000
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Home was blown out with and front structure cut in half and gutted. 6 contiguous parcels: 00374650-000000 00374660-000000 00374670-000000 00374680-000000 00374690-000000 00374700-000000
Home was blown out with and front structure cut in half and gutted. 6 contiguous parcels: 00374650-000000 00374660-000000 00374670-000000 00374680-000000 00374690-000000 00374700-000000
Declared substantially damaged by the City of Marathon. House has to be rebuilt on stilts and will not be permitted for repair.
FIELD NOT COMPLETED
House was totaled by flooding in Hurricane Irma and was demoed in April 2018.

[redacted]

Homesteaded?	SPECIAL CIRCUMSTANCES	DATE SURVEY RECEIVED	DATE ACKNOWLEDGEMENT FORM SIGNED	JUST MARKET VALUE (PRE-STORM 2017 - MC PROPERTY ASSESSOR'S OFFICE)	LAND VALUE (PRE-STORM 2017 - MC PROPERTY ASSESSOR'S OFFICE)	PROPOSED VALUE	APPRAISAL VALUE	VERIFICATION CONTACT	NOTES?	VERIFICATION VISIT
N		07/16/19	07/16/19	$125,146.00	$104,136.00	$150,175.20				
N		07/17/19		$40,905.00	$30,833.00	$49,086.00				
Y		07/21/19		$355,921.00	$214,200.00	$427,105.20				
N		07/21/19	07/21/19	$115,643.00	$31,800.00	$138,771.60				
N		07/19/19	07/19/19	$70,830.00	$55,448.00	$84,996.00				
N		07/21/19	07/21/19	$361,314.00	$359,294.00	$433,576.80				
N		07/21/19	07/21/19	$496,187.00	$402,995.00	$595,424.40				
N		07/21/19	07/21/19	$129,871.00	$115,398.00	$155,845.20				
N		07/21/19	07/21/19	$791,746.00	$388,585.00	$950,095.20				
N		07/21/19	07/21/19	$86,589.00	$86,589.00	$103,906.80				
N		07/21/19	07/21/19	$42,405.00	$42,405.00	$50,886.00				
Y		07/22/19	07/22/19	$141,262.00	$45,094.00	$169,514.40				
Y		07/22/19		$292,450.00	$67,893.00	$350,940.00				
Y			07/23/19	$233,217.00	$108,000.00	$279,860.40				
N		07/24/19	07/24/19	$154,044.00	$57,200.00	$184,852.80				
N				$216,693.00	$88,210	$260,031.60				
N				$160,036.00	$57,200.00	$192,043.20				

NO LONGER INTERESTED REASON	NOT QUALIFIED REASON	DEO REBUILD (Y/N)	DEO COUNTY REVIEW COMPLETE (Y/N)	DEO REBUILD APPLICATION STATUS	BUYOUT?

BUYOUT INFO

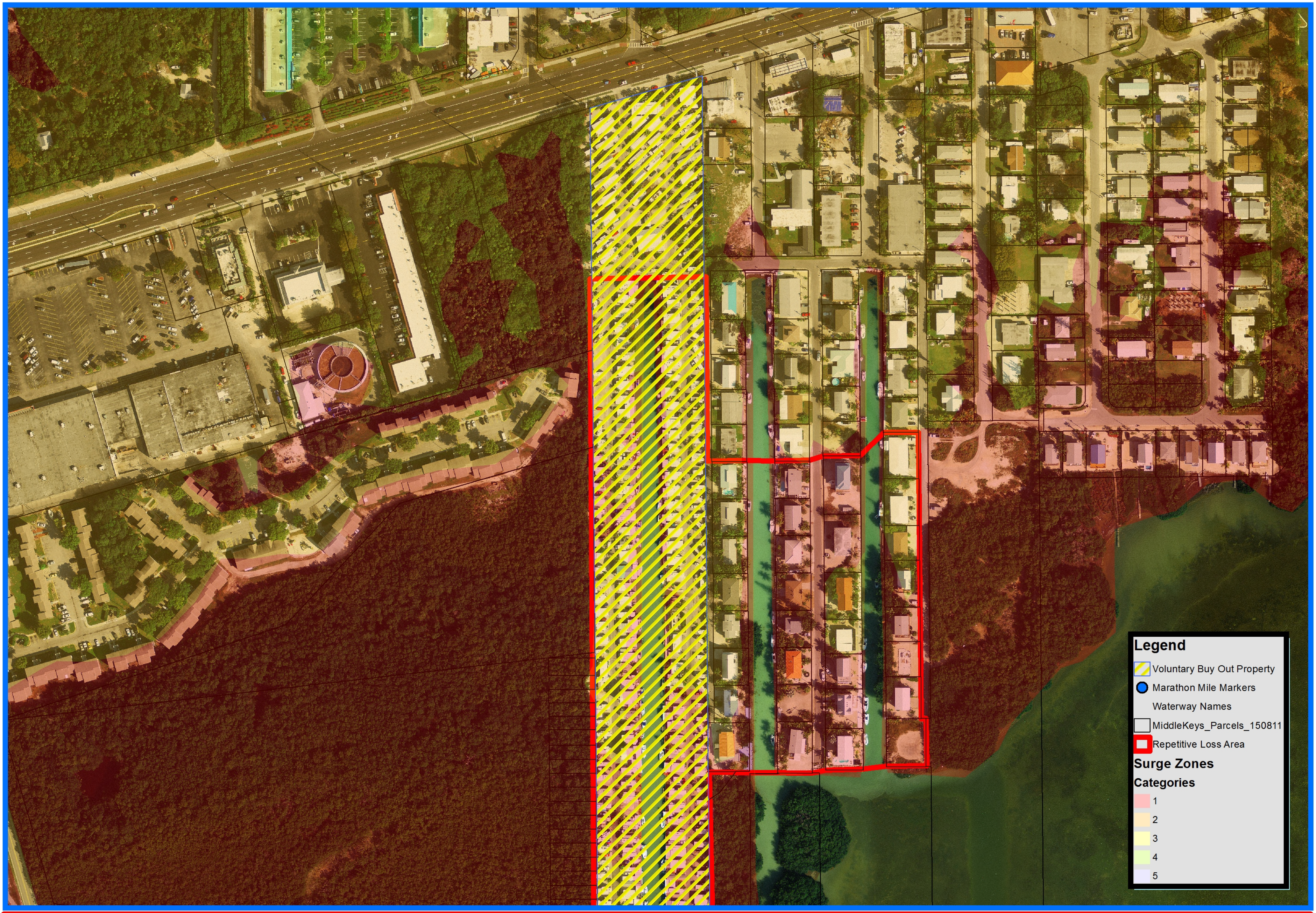
BUILDINGS REMAINING ON PROPERTY? [Verified by researching MCPA for current bldgs on property and demo permits applied for.]	**DEMO REQUIRED?**	**DEMOLITION COSTS**	**SOFT COSTS**
YARD ITEMS	#REF!	#REF!	
NO	#REF!	#REF!	
YES			
YES			
NO			
YARD ITEMS			
YES			
NO			
YES			
NO			
NO			
YES			
NO			

PROJECT MANAGEMENT	RENTAL TENANT OCCUPIED?	TOTAL PROJECT COSTS	OFFER AMOUNT
#REF!		#REF!	
#REF!		#REF!	

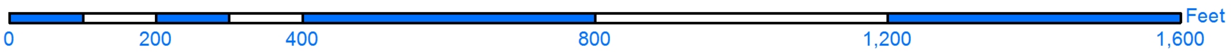
City of Marathon, Florida
Official Map Product

0 200 400 800 1,200 1,600 Feet

City of Marathon, Florida
Official Map Product



City of Marathon, Florida
Official Map Product



City of Marathon, Florida
Official Map Product

0 200 400 800 1,200 1,600 Feet

City of Marathon, Florida
Official Map Product

0 200 400 800 1,200 1,600 Feet

City of Marathon, Florida
Official Map Product

Feet
0 200 400 800 1,200 1,600

City of Marathon, Florida
Official Map Product

0 200 400 800 1,200 1,600 Feet

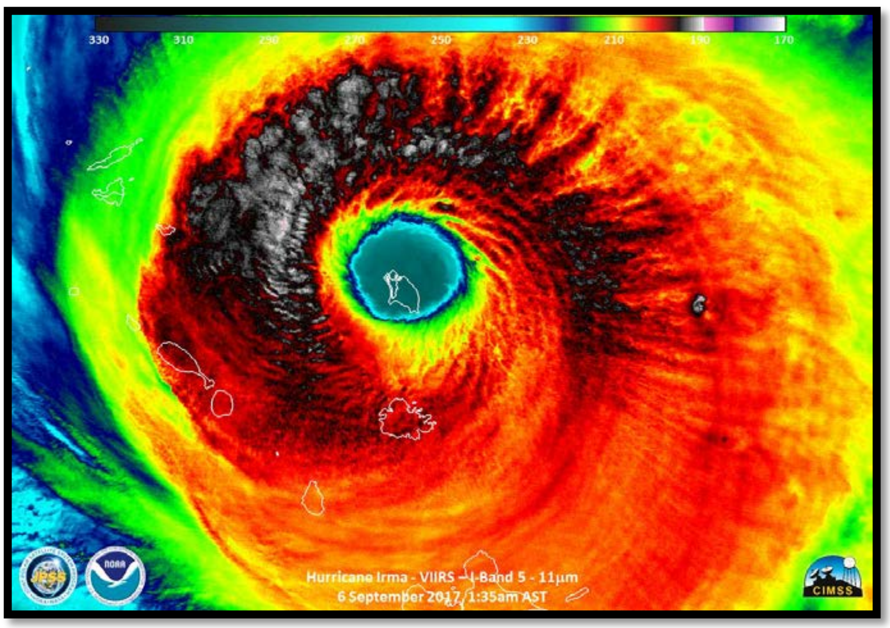
NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE IRMA

(AL112017)

30 August–12 September 2017

John P. Cangialosi, Andrew S. Latto, and Robbie Berg
National Hurricane Center
30 June 2018[1]



VIIRS SATELLITE IMAGE OF HURRICANE IRMA WHEN IT WAS AT ITS PEAK INTENSITY AND MADE LANDFALL ON BARBUDA AT 0535 UTC 6 SEPTEMBER.

Irma was a long-lived Cape Verde hurricane that reached category 5 intensity on the Saffir-Simpson Hurricane Wind Scale. The catastrophic hurricane made seven landfalls, four of which occurred as a category 5 hurricane across the northern Caribbean Islands. Irma made landfall as a category 4 hurricane in the Florida Keys and struck southwestern Florida at category 3 intensity. Irma caused widespread devastation across the affected areas and was one of the strongest and costliest hurricanes on record in the Atlantic basin.

[1] Original report date 9 March. Second version on 30 May updated casualty statistics for Florida, meteorological statistics for the Florida Keys, and corrected a typo. This version corrects the year of the last category 5 hurricane landfall in Cuba and corrects a typo in the Casualty and Damage Statistics section.

Hurricane Irma

30 AUGUST–12 SEPTEMBER 2017

SYNOPTIC HISTORY

Irma originated from a tropical wave that departed the west coast of Africa on 27 August. The wave was then producing a widespread area of deep convection, which became more concentrated near the northern portion of the wave axis on 28 and 29 August. By 0000 UTC 30 August, satellite images indicated that a well-defined surface circulation had developed and since deep convection was already sufficiently organized, it is estimated that the system became a tropical depression at this time when it was centered about 120 n mi west-southwest of São Vicente in the Cabo Verde Islands. Banding features increased after genesis, and the depression became a tropical storm 6 h later. The "best track" chart of Irma's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[2].

While moving westward to the south of a mid-level ridge over the eastern Atlantic, Irma strengthened rapidly in environmental conditions of low vertical wind shear and a fairly moist lower troposphere while it was over marginally warm sea surface temperatures (SSTs). Irma developed a ragged eye around the time it became a hurricane near 0600 UTC 31 August, which was only 30 h after it became a tropical depression. Irma reached hurricane strength when it was still located over the eastern Atlantic about 400 n mi west of the Cabo Verde Islands. Later on 31 August, Irma turned west-northwestward as the ridge to the north of the cyclone weakened a little. Meanwhile, Irma continued to rapidly strengthen, and it reached major hurricane status (>= 100 kt) by 0000 UTC 1 September, only two days after genesis. This 70-kt increase in intensity over a 48-h period is a remarkable rate that is only achieved by a small fraction of Atlantic tropical cyclones (about 1 in 30). Although Irma was a very intense hurricane at this time, the inner core was quite compact with hurricane-force winds estimated to extend no more than 15 n mi from the center (Fig 4).

After becoming a category 3 hurricane, Irma's intensification paused with the eye occasionally becoming cloud filled and deep convection in the eyewall appearing less intense. Irma fluctuated between category 2 and 3 strength from 0000 1 September to 0000 UTC 4 September. The main causes for the intensity fluctuations were likely eyewall replacement cycles and intrusions of dry air. Meanwhile, the hurricane turned west-southwestward in response to a strong high pressure system to its north (Fig 5a), and lost 2.5° of latitude between 2 and 4 September. This south of west motion was very significant because it brought the cyclone over higher SSTs and in a position poised to affect the northern Leeward Islands.

[2] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

By early on 4 September, Irma's eye was growing in size and becoming better defined, and deep convection around the eye was gaining symmetry. Irma was on a strengthening trend once again, likely due to the completion of an eyewall replacement cycle, and it was headed toward the northern Leeward Islands. Irma turned west-northwestward, due to the erosion of the western side of the mid-level ridge (Fig 5b), and went through another round of rapid intensification. The hurricane reached its maximum intensity of 155 kt around 1800 UTC 5 September, when it was located about 70 n mi east-southeast of Barbuda. As a category 5 hurricane, Irma made landfall on Barbuda around 0545 UTC 6 September with maximum winds of 155 kt and a minimum pressure of 914 mb (Fig. 6a).

After crossing Barbuda, Irma continued to exhibit an impressive satellite appearance and made its second landfall on St. Martin at 1115 UTC that day, with the same wind speed and pressure as for its Barbuda landfall. Still moving west-northwestward to the south of a mid-level ridge, Irma made its third landfall on the island of Virgin Gorda in the British Virgin Islands at 1630 UTC 6 September still as a 155-kt category 5 hurricane. Later that day, as Irma moved away from the Virgin Islands, reconnaissance data from the Air Force indicated that the major hurricane had weakened slightly and had a double wind maximum, indicative of concentric eyewalls. The double eyewall structure was also evident in Doppler radar data from San Juan, Puerto Rico (Fig. 7). Even though Irma was no longer at its peak intensity, it remained a category 5 hurricane with a larger wind field than it had previously (Fig. 4). The eye of Irma tracked about 50 n mi to the north of the northern shore of Puerto Rico and the Dominican Republic from 1800 UTC 6 September to 1800 UTC 7 September, with the strongest winds to the north of the center.

The eye of Irma passed just south of the Turks and Caicos Islands around 0000 UTC 8 September, and it made landfall on Little Inagua Island in the Bahamas at 0500 UTC that day at category 4 intensity, with estimated maximum winds of 135 kt and a minimum pressure of 924 mb. This slight weakening ended Irma's 60-h period of sustained category 5 intensity, which is the second longest such period on record (behind the 1932 Cuba Hurricane of Santa Cruz del Sur). Irma then turned slightly to the left, due to a building subtropical ridge, and moved toward the northern coast of Cuba (Fig. 5c). Reconnaissance and microwave data indicate that the inner core had become better organized, and it is estimated that Irma strengthened to a category 5 hurricane again around 1800 UTC 8 September, only 18 h after weakening below that threshold.

Irma then intensified a little more and made its fifth landfall near Cayo Romano, Cuba, at 0300 UTC 9 September, with estimated maximum winds of 145 kt (Fig. 6b). This marked the first category 5 hurricane landfall in Cuba since Huracan sin Precedentes in 1924. Irma tracked along the Cuban Keys throughout that day, and its interaction with land caused it to weaken significantly, first to a category 4 storm a few hours after landfall in the Cuban Keys and then down to a category 2 hurricane by 1800 UTC that day when the eye was very near Isabela de Sagua. Shortly after that time, the forward speed of Irma slowed, and it began to make a turn to the northwest, which caused the core of the hurricane to move over the Florida Straits early on 10 September.

When Irma moved over the warm waters of the Florida Straits, the hurricane reintensified once again. Data from the Air Force Hurricane Hunters indicate that Irma became a category 4 hurricane by 0600 UTC 10 September when it was centered about 55 n mi south-southeast of Key West, Florida. Meanwhile, Irma had turned to the north-northwest in the flow between a subtropical ridge over the western Atlantic and a mid- to upper-level low pressure system over the Gulf of Mexico (Fig 5d). The category 4 storm made yet another landfall near Cudjoe Key in the lower Florida Keys around 1300 UTC that day with maximum winds of 115 kt and a minimum pressure of 931 mb (Fig 6c).

The convective pattern of the hurricane then became more ragged, likely due to increasing southwesterly vertical wind shear, and in response, Irma weakened to a category 3 hurricane around 1800 UTC 10 September. Irma made its final landfall near Marco Island, Florida, at 1930 UTC 10 September (Fig. 6d), with estimated maximum winds of 100 kt and minimum pressure of 936 mb. Once inland over southwestern Florida, Irma weakened quickly, due to the influences of land and strong wind shear, while moving north-northwestward on the east side of a large cyclonic gyre that was centered over the Gulf of Mexico. Irma's center tracked just east of Naples and Ft. Myers by 0000 UTC 11 September as a category 2 hurricane and passed between Tampa and Orlando by 0600 UTC that day as a category 1 storm. Although Irma was weaker while over Florida, the wind field of the hurricane spread out significantly, with tropical-storm-force winds extending up to 360 n mi from the center (Fig. 4).

Irma weakened to a tropical storm by 1200 UTC 11 September when it was centered about 20 n mi west of Gainesville, Florida. While Irma was moving across northern Florida, most of the deep convection was located well to the northeast of the center, and the strongest winds were confined to the northeast coast of Florida and southeastern Georgia. The center of Irma moved over southern Georgia just west of Valdosta around 1800 UTC that day with maximum winds of 45 kt, and the system became a remnant low with 25-kt winds once it crossed into Alabama by 0600 UTC 12 September. The remnant low continued northwestward while weakening and dissipated shortly after 1200 UTC 13 September over southeastern Missouri.

METEOROLOGICAL STATISTICS

Observations in Irma (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Global Precipitation Mission (GPM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Irma.

Aircraft observations include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from 15 flights (including 56 center fixes) of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command and 8 flights (including 26 center fixes) of the NOAA Aircraft Operations Center (AOC). In addition, the NOAA AOC G-IV aircraft flew 8 synoptic surveillance flights around Irma.

National Weather Service WSR-88D Doppler radar data from San Juan, Puerto Rico; Miami, Florida; Key West, Florida; Melbourne, Florida; Jacksonville, Florida; Tampa, Florida; and Tallahassee, Florida, were used to make center fixes and obtain velocity data while Irma was near the U. S. coast. Météo-France radar data from Guadeloupe and Martinique as well as radar data from the Institute of Meteorology of Cuba were also helpful in tracking the center of Irma.

Selected ship reports of winds of tropical storm force or greater associated with Irma are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Winds and Pressure

Irma's estimated peak intensity of 155 kt from 1800 UTC 5 September to 1200 UTC 6 September is based on a blend of multiple SFMR surface wind estimates and flight-level winds observed by the Air Force Reserve and NOAA Hurricane Hunters during that time period. The highest unflagged SFMR surface wind estimate from the Air Force Reserve was 160 kt at 1633 UTC 5 September. The flight-level winds measured during that mission were around the same speed. The peak 700-mb flight-level winds of 164 kt, which correspond to a peak surface wind of 145–150 kt, were measured by the Air Force Reserve early on 6 September. The NOAA Hurricane Hunters measured maximum 750-mb flight-level winds of 167 kt, which correspond to about 150 kt at the surface, and peak SFMR winds of 152 kt. It should be noted that this intensity estimate is somewhat uncertain given the disparity between the peak SFMR winds and the intensity supported by the highest flight-level winds. The 155-kt peak intensity of Irma is 5 kt lower than the operational assessment in favor of blending the flight-level and SFMR reports.

Irma's estimated minimum central pressure of 914 mb at 0600 UTC 6 September is based on a dropwindsonde surface pressure measurement of 915 mb at 0503 UTC 6 September, which was accompanied by a surface wind of 15 kt. This estimate is also consistent with a weather station on St. Barthelemy that reported a minimum pressure of 915.9 mb, and a station on Barbuda that reported a minimum pressure of 916.1 mb. The Barbuda station reported sustained winds of 105 kt and a gust of 139 kt when it was in the southern eyewall. Also, an unofficial observation in St. Barthelemy reported a maximum wind gust of 173 kt.

Caribbean Islands

Around 1700 UTC 6 September, the center of Irma passed just north of Buck Island in the U.S. Virgin Islands, where sustained winds of 92 kt and a gust of 119 kt were reported.

Irma's center passed about 50 n mi north of San Juan, Puerto Rico, just before 0000 UTC 7 September. The lowest pressure observed on mainland Puerto Rico during Irma was from a National Ocean Service (NOS) station in Fajardo, which recorded a pressure of 980.1 mb at 2118 UTC 6 September. The highest wind speed reported in Puerto Rico was 48 kt with a gust of 64 kt at an NOS site at La Puntilla in San Juan Bay at 2230 UTC 6 September.

The Turks and Caicos Islands experienced the northern eyewall of Hurricane Irma around 0000 UTC 8 September. However, no observations were available from these locations due to failure of the observing equipment.

The hurricane then took a long duration track along or near the northern coast of Cuba from 8 September through early 10 September. Irma approached the northern coast of eastern Cuba late on 8 September, with sustained 10-minute winds of 44 kt and a peak gust of 63 kt observed in the town of Velasco at 1959 UTC. The lowest pressure recorded on land that day was 991.0 mb at 2100 UTC in La Jiquima, Holguin. Irma tracked near or over the Cuban Keys on 9 September and, at 1430 UTC, a coastal station at Caibarien recorded sustained winds of 85 kt with an accompanying gust of 122 kt, and a minimum pressure of 969.9 mb when Irma's center passed approximately 15 n mi northeast of that location. The lowest recorded pressure in Cuba during Irma was 933.1 mb at Cayo Coco at 0520 UTC 9 September, which was in the eye of the hurricane at that time. The western eyewall was also sampled at that station, with sustained winds of 83 kt and a gust of 105 kt observed at 0500 UTC that day. The highest wind speed recorded in Cuba was just inland of Cayo Coco at a station near Camilo, Cienfuegos, where sustained winds of 108 kt and a gust of 138 kt were measured at 0720 UTC 9 September. Early on 10 September, Irma departed the coastal region of central Cuba as it turned north-northwestward toward Florida. Tropical storm conditions continued over a portion of Cuba that day, with sustained winds of 49 kt and a gust of 73 kt observed at San Antonio de los Banos. Although observations were not available from Havana, two observations recorded tropical-storm-force winds just southeast of the capital city.

United States

The earliest significant report of high winds in Florida came from an observation at Alligator Reef Light at 1159 UTC 10 September, where sustained winds of 62 kt and a gust of 81 kt were measured. At 1204 UTC that day, a minimum pressure of 977.0 mb was recorded at that same station when the center of Irma was nearly 50 n mi to its west-southwest. The lowest pressure reported in the Florida Keys was 933.7 mb at 1216 UTC by a spotter in Big Pine Key. The strongest wind speed in the Florida Keys was reported by an automated station on Big Pine Key, where a 104-kt gust at an observing site of 6 meter elevation was recorded (10 m is standard height).

Irma made its final landfall near Marco Island, Florida, at 1930 UTC 10 September. A spotter in Marco Island reported a minimum pressure of 936.9 mb, with maximum sustained winds of 97 kt and a gust of 112 kt. In addition, the Marco Island Police Department reported a wind gust of 113 kt at 1900 UTC, and the Naples Municipal Airport reported a 123-kt wind gust around the same time. Sustained hurricane force winds extended well inland over the southern Florida peninsula. At Government Cut off of Miami Beach sustained winds of 65 kt at an elevation of 23 meters occurred, and a wind gust of 97 kt was measured at Deerfield Beach. Nearly all of the inland observations in the Miami-Dade and Broward County metro area reported sustained winds just below hurricane force. At 1903 UTC that day, the Opa Locka Airport reported 2-minute averaged sustained winds of 56 kt with a gust of 74 kt, and several other nearby stations reported similar wind speeds.

The hurricane continued northward across central Florida with hurricane conditions decreasing in areal coverage when Irma's center approached the Orlando and Tampa areas. Tropical storm conditions were experienced on both the west and east coasts of the state on 10 and 11 September. The center passed near Plant City at 0509 UTC 11 September, where a spotter reported a minimum pressure of 964.4 mb. At 0142 UTC, a couple of hours before the eyewall and strongest winds arrived, that spotter measured 10-second 7-meter winds of 63 kt and a gust to 71 kt. Reports from both sides of the state confirmed Irma's expansive wind field. For example, buoy 42036 offshore of Tampa in the Gulf of Mexico measured 44 kt sustained winds at 5-meters with a 10-min averaging period at 0420 UTC 11 September. Also in the Gulf of Mexico, at 0823 UTC that day, buoy 42039 offshore of Pensacola measured 37 kt sustained winds at an elevation of 4 meters. Off the east coast, buoy 41009 off of Cape Canaveral measured sustained winds of 56 kt at 4 meters.

Irma moved across north-central Florida through early 11 September and then moved into southeastern Georgia late that day and early 12 September. Tropical storm conditions were reported across much of northern Florida, especially to the east of the center. The Jacksonville International Airport measured sustained 2-minute 10-meter winds of 51 kt at 1053 UTC 11 September with a gust of 75 kt. At the Gainesville Regional Airport, closer to where the center passed, a minimum pressure of 979.5 mb was observed at 1053 UTC with maximum sustained 2-minute 10-meter winds of 40 kt.

Several sites in Georgia and South Carolina reported tropical storm conditions from Irma on 11 September. These reports include locations as far north as the Atlanta International Airport, which measured 2-minute 10-meter winds of 39 kt at 1910 UTC and a gust of 56 kt. At 1609 UTC, Charleston International Airport in South Carolina measured 2-minute 10-meter winds of 42 kt and a gust of 52 kt.

Figure 8 shows observed maximum sustained wind speeds during Hurricane Irma for Cuba and portions of the southeastern United States, and Fig. 9 show maps of maximum wind gusts for the same geographical areas.

Landfall Intensity Estimates

Barbuda: The estimated landfall intensity of 155 kt at 0545 UTC 6 September is based on a blend of SFMR surface wind values near 160 kt and flight-level winds of 161 kt, which reduce to about 145 kt at the surface, measured by the Air Force Hurricane Hunters around the time of landfall. The lowest pressure observed in Barbuda was 916.1 mb.

St. Martin: The estimated landfall intensity of 155 kt at 1115 UTC 6 September is based on similar data to the Barbuda landfall with SFMR values around 155 kt.

British Virgin Islands: The estimated landfall intensity of 155 kt at 1630 UTC 6 September on Virgin Gorda is based on SFMR winds around 155 kt.

Bahamas: The estimated landfall intensity of 135 kt on Little Inagua Island at 0500 UTC 8 September is based on flight-level winds reported by the Air Force of 147 kt, which reduce to 132 kt at the surface, and an ADT estimate of 7.0/140 kt.

Cuba: The estimated landfall intensity of 145 kt near Cayo Romano at 0300 UTC 9 September is based on SFMR winds of 145 kt measured by the Air Force a few hours before landfall.

Florida Keys: The estimated landfall of 115 kt at 1300 UTC 10 September near Cudjoe Key is based on SFMR winds between 110 and 120 kt just prior to landfall.

Southwest Florida: The estimated landfall intensity of 100 kt at 1930 UTC 10 September near Marco Island is based on a sustained surface wind measurement of 97 kt from a nearby weather spotter.

Storm Surge[3]

Caribbean

Significant storm surge occurred on the island of Barbuda, where Irma made landfall as a category 5 hurricane. A tide gauge on the island, maintained by the Antigua and Barbuda Meteorological Service, recorded a peak water level of 7.9 ft Mean Higher High Water (MHHW), suggesting that inundation of at least 8 ft above ground level occurred on parts of the island.

Significant storm surge likely occurred on the U.S. Virgin Islands, especially on St. Thomas and St. John. However, specific inundation amounts are not available. The NOS tide gauge at Charlotte Amalie on St. Thomas went offline during the storm and did not transmit a peak water level, and the other tide gauge reports are likely not representative of the highest inundation on the islands. Maximum inundation levels of 1 to 2 ft above ground level occurred along the coast of Puerto Rico. The highest water level observation there from a tide gauge was 1.5 ft MHHW at Arecibo along the north coast of Puerto Rico.

The Instituto de Meteorología de Cuba reports that Irma produced significant coastal flooding along the north coast of Cuba due to storm surge and large waves. In Ciego de Ávila Province, the sea rose by 3 to 3.5 m (~10 to 11.5 ft) and penetrated inland more than 800 m (0.5 miles) from the coast. Wave heights on Cayo Coco were estimated to be between 5 and 6 m (16 to 20 ft) high. In Camagüey Province, water reached a height of 2 m (6.5 ft) and pushed inland 200 m (650 ft) from the coast on Cayo Romano, where Irma made landfall as a category 5 hurricane. Wave heights there were observed to be over 8 m (26 ft) high. In Puerto Piloto, the sea retreated offshore by 10 to 12 m (33 to 39 ft) due to the southerly winds on the eastern side of Irma's circulation. The sea rose by as much as 3 m (10 ft) in Caibarién in Villa Clara Province, and the surge penetrated approximately 2 km (1.2 miles) inland in Isabela de Sagua. Unprecedented storm surge flooding occurred in portions of La Habana Province, in some cases surpassing the coastal floods produced by the Storm of the Century (March 1993) and Hurricane Wilma (October 2005). Water levels reached 2.25 m (7.4 ft) in some locations.

Florida Keys

The combined effect of storm surge and the tide produced maximum inundation levels of 5 to 8 ft above ground level for portions of the Lower Florida Keys from Cudjoe Key eastward to Big Pine Key and Bahia Honda Key, near and to the east of where Irma's center made landfall. NHC and WFO Key West conducted a survey of the area and found a high water mark of 6.0 ft above ground level in a garage on Big Pine Key. Accounting for land elevation at the house, the

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[3] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

high water mark measurement converts to 7-8 ft MHHW, implying that maximum inundation heights were 8 ft above ground level at the lowest spots near the shoreline on Big Pine Key. Several high water marks of at least 4 ft above ground level were also surveyed by the United States Geological Survey (USGS) in this area, with the highest mark being 5.45 ft above ground level (6.71 ft North American Vertical Datum (NAVD88) / 6.8 ft MHHW) on Little Torch Key.

Maximum inundation levels of 4 to 6 ft above ground level occurred across the Middle and Upper Keys. A high water mark of 4.11 ft above ground level was surveyed in Key Largo, and a mark of 3.72 ft above ground level was recorded in Marathon. The NOS tide gauge on Vaca Key measured a peak water level of 2.6 ft MHHW. Farther south, maximum inundation levels of 2 to 4 ft above ground occurred on the Lower Keys west of Cudjoe Key to Key West. The NOS gauge on Key West recorded a peak water level of 2.7 ft MHHW.

Southwestern Florida

The combined effect of storm surge and the tide produced maximum inundation levels of 6 to 10 ft above ground level along the unpopulated coast of southwestern Florida between Cape Sable and Cape Romano, within Everglades National Park and the Ten Thousand Islands National Wildlife Refuge (Fig. 10). In Everglades City, a USGS storm tide sensor recorded a wave-filtered water level of 8.31 ft NAVD88 (which converts to 7.5 ft MHHW). The USGS also surveyed two high water marks in Everglades City that were greater than 5 ft above ground level. In Goodland, a USGS storm tide sensor measured a water level of 7.03 ft NAVD88 (6.1 ft MHHW), and several high water marks of 2-3 ft above ground level were surveyed in the area. Since Irma's eastern eyewall moved onshore between Everglades City and Goodland, peak inundation along that portion of the coast could have been as much as 10 ft above ground level; however, there were no observations in that area to definitively corroborate this estimate. Inundation of at least 6 ft above ground level likely occurred along the coast of the remainder of Everglades National Park south of Everglades City. Observations from stream gauges jointly funded by the National Park Service and South Florida Water Management District indicate that water levels reached 7.01 ft NAVD88 (6.1 ft MHHW) at Shark River, 5.3 ft NAVD88 (5.5 ft MHHW) at Garfield Bight, and 5.5 ft NAVD88 at Lostmans River.

Maximum inundation levels of 3 to 5 ft above ground level occurred along the remainder of the southwestern coast of Florida from Marco Island northward through Naples to Ft. Myers, an area which was affected by weakened onshore winds within Irma's deteriorating western eyewall. The National Ocean Service (NOS) tide gauge at Naples measured a water level of 4.25 ft MHHW, while the gauge at Ft. Myers on the Caloosahatchee River recorded a water level of 3.28 ft MHHW. In addition, USGS storm tide sensors in Naples and at Delnor-Wiggins State Park near Naples Park measured water levels of 5.06 ft NAVD88 (4.5 ft MHHW) and 3.90 ft NAVD88 (3.4 ft MHHW), respectively.

Before inundation occurred along portions of the southwestern coast of Florida, strong offshore winds on the northern side of Irma's circulation initially blew water away from the coast and caused water levels to recede below normal levels. The NOS tide gauge at Naples recorded a minimum water level of 4.8 ft below MHHW (2.0 ft below Mean Lower Low Water [MLLW]) before Irma's center arrived. Once the center moved north of Naples and the winds shifted to onshore, the water level at the site increased by 9 ft in only 3 hours, and 6 ft within the first hour.

Florida East Coast

The combined effect of storm surge and the tide produced maximum inundation levels of 4 to 6 ft above ground level for portions of Miami-Dade County in southeastern Florida, especially along Biscayne Bay. A USGS storm tide sensor at Matheson Hammock Park in Miami measured a peak water level of 5.75 ft NAVD88 (5.6 ft MHHW), consistent with a high water mark of 5.1 ft above ground level which was surveyed in the park. The NOS tide gauge on Virginia Key recorded a peak water level of 3.7 ft MHHW.

Significant flooding occurred in downtown Miami; however, the flooding was likely caused by a combination of heavy rainfall and urban runoff, wave overwash becoming trapped behind seawalls, and seawater coming up from below through the city's drainage systems. Soil samples were collected by the Physical Oceanography Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) in the Brickell area of downtown Miami two days after Irma, and their analysis indicates that there was a notable gradient of soluble salts and electrical conductivity of the soil from the bayfront to Brickell Avenue. Along Brickell Bay Drive, directly adjacent to the bay, soluble salt concentrations averaged around 3400 parts per million (ppm), with an average electrical conductivity of 6-7 millisiemens per centimeter (mS/cm). Similar concentration and conductivity values were analyzed from soil samples collected up to one block from the coast on Key Biscayne. These soil samples can be characterized as being moderately saline. The highest sampled conductivity along Brickell Bay Drive was 9.83 mS/cm, characterized as strongly saline. Along Brickell Avenue, a few blocks inland from the bay, soluble salt concentrations averaged around 1000 ppm, with an average electrical conductivity of about 2 mS/cm, on the threshold between non-saline and slightly saline. AOML's analysis suggests that saltwater inundation in Downtown Miami was largely confined within a block or two of the bay, and much of the flooding that occurred in other parts of the downtown area, including along Brickell Avenue, was the result of rainfall runoff that was unable to drain into the bay due to elevated water levels caused by the storm surge.

Maximum inundation levels of 2 to 4 ft above ground level occurred across coastal sections of northern Miami-Dade, Broward, and Palm Beach Counties. A storm tide sensor mounted to an electrical pole at a park on Biscayne Bay just north of downtown Miami measured a wave-filtered water level of 1.5 ft above ground level (3.35 ft NAVD88 / 3.1 ft MHHW), while a sensor along a canal in Pompano Beach (Broward County) recorded a wave-filtered water level of 3.4 ft NAVD88 (3.1 ft MHHW). In Palm Beach County, a storm tide sensor along the Intracoastal Waterway in Boca Raton recorded a wave-filtered water level of 3.05 ft NAVD88 (2.7 ft MHHW), and the NOS tide gauge at Lake Worth measured a peak water level of 1.5 ft MHHW. Farther north, maximum inundation levels of 1 to 3 ft above ground level occurred across coastal sections of Martin, St. Lucie, Indian River, and southern Brevard Counties.

Even though Irma made landfall along the southwestern coast of Florida, the hurricane's large wind field produced significant storm surge flooding along the northeastern coast of Florida, where a maximum of 3 to 5 ft of inundation above ground level occurred from Cape Canaveral northward to the Florida-Georgia border. The NOS tide gauge on Trident Pier at Port Canaveral measured a peak water level of 4.2 ft MHHW, and a USGS storm tide sensor at Ormand Beach recorded a water level of 4.37 ft NAVD88 (4.5 ft MHHW). Farther north, a storm tide sensor on the Matanzas River south of St. Augustine recorded a wave-filtered water level of 6.65 ft NAVD88 (4.8 ft MHHW), and the USGS surveyed several high water marks of 2 to 4 ft above ground level in that area. The highest was a mark of 3.3 ft above ground level near Vilano Beach. Along the coast of extreme northeastern Florida, a storm tide sensor at Jacksonville Beach recorded a wave-filtered water level of 6.55 ft NAVD88 (4.1 ft MHHW). In addition, the NOS gauges at Mayport (Bar Pilots Dock) and Fernandina Beach both measured peak water levels of 3.6 ft MHHW.

Significant flooding occurred along the banks of the St. Johns River, likely due to a combination of storm surge and rainfall runoff into the river. The NOS gauge at the I-295 bridge on the south side of Jacksonville measured a peak water level of 5.3 ft MHHW, while gauges at Southbank Riverwalk in Downtown Jacksonville and at Racy Point recorded peak water levels of 4.9 ft MHHW and 4.0 ft MHHW, respectively. As an illustration of the combined effect of storm surge and rainfall runoff, observations from a USGS station in downtown Jacksonville showed that salinity within the river gradually increased from less than 5 parts per thousand (ppt) on 8 September to about 30 ppt (just a little less than the average salinity of the ocean) late on 10 September. These data indicate that the initial water rises were likely due to easterly winds ahead of Irma pushing seawater upstream in the St. Johns River. However, the USGS data then showed salinity decreasing rapidly back to normal levels at the downtown site on 11 September, while the water level at the site continued to increase and reached its maximum about six hours after the salinity peak. This suggests that the freshwater input from rainfall runoff was also a significant contributor to the flooding that occurred along the St. Johns River.

Florida Central West Coast

The combined effect of storm surge and the tide produced maximum inundation levels of 1 to 2 ft above ground level along the west coast of Florida north of Charlotte Harbor to Apalachee Bay. NOS tide gauges along the west coast, including within Tampa Bay, generally recorded peak water levels of a little more than 1 ft MHHW, with the highest observation being 1.7 ft MHHW at the McKay Bay Entrance near Downtown Tampa.

Offshore winds on the northern side of Irma's circulation initially caused water levels to recede below normal levels along much of the west coast of Florida, including Tampa Bay. In fact, some normally submerged areas went virtually dry, allowing people to (inadvisably) walk out onto the sea or bay floor, while also stranding marine vessels and even manatees (Fig. 11). At the McKay Bay Entrance near Downtown Tampa, the NOS tide gauge measured a minimum water level of 7.4 ft below MHHW (4.7 ft below MLLW), which was more than 6 ft below normal tide levels. The water level in Tampa Bay at St. Petersburg was about 5 ft below normal, reaching a minimum of 6.0 ft below MHHW (3.7 ft below MLLW), and the water level was so low at Old Port Tampa that the gauge was unable to obtain a reading for several hours.

Georgia and South Carolina

The combined effect of storm surge and the tide produced maximum inundation levels of 3 to 5 ft above ground level along the coast of Georgia and much of South Carolina. In Georgia, the NOS tide gauge at Fort Pulaski measured a peak water level of 4.7 ft MHHW, while in South Carolina, the NOS gauge at Charleston recorded a peak water level of 4.2 ft MHHW. Water levels of 3.4 ft MHHW and 2.9 ft MHHW were also reported at the tide gauges at Oyster Landing and Springmaid Pier (Myrtle Beach), respectively. Although the storm surge produced by Irma was less than that produced by Hurricane Matthew (2016) along the coast of South Carolina, slightly higher tides, as well as closer timing of high tide with the peak storm surge, caused water levels at the Charleston and Springmaid Pier NOS gauges to exceed those observed during Matthew.

Rainfall and Flooding

Even though Puerto Rico did not experience a direct hit from Irma, rainfall totals between 10 and 15 inches occurred over high elevations in the central portion of the island between 5 and 7 September. Irma also produced very heavy rainfall across a large portion of Cuba. Instituto de Meteorología de Cuba provided multiple reports over 10 inches, with the maximum observed rainfall of 23.90 inches measured in Topes De Collantes. The second highest report was in Sancti Spiritus where 19.02 inches was measured. Several rivers in Cuba reached major flood stage. In particular, the Zaza River, in the municipality of Cabaiguán, was the most affected as Irma caused one of the largest measured floods of this river on record.

Irma produced heavy rain across much of the state of Florida, and rainfall totals of 10 to 15 inches were common across the peninsula and the Keys (Fig. 12). The maximum reported storm-total rainfall was near Ft. Pierce, Florida, in St. Lucie County, where 21.66 inches of rain was measured between 9 and 12 September. The heavy rainfall caused flooding of streets and low-lying areas across much of the Florida peninsula. In Indian River County, 12 people were rescued from flood waters, and in Orange County residents were rescued from flooded homes. Heavy rains of 6 to 10 inches occurred across the Florida Keys. Flooding occurred on most rivers in northern Florida, and major or record flood stages were reported at rivers in Bradford, Clay, Marion, Flagler, Duval, Putnam, St. Johns, Nassau, and Alachua counties. The St. John's River set record flood stages at many locations in Duval County, causing major flooding in the Jacksonville metropolitan area, where hundreds of people were rescued. Similar flooding occurred in Bradford County where record flood stages were set at Alligator Creek, Hampton Lake, Lake Sampson, and New River.

In Georgia, major flooding occurred in St. Simon's Island and along the Satilla River. Rainfall totals were generally between 5 and 10 inches in coastal Georgia, and the maximum rainfall measured in the state was 10.34 inches in Nahunta in Brantley County from 11 to 12 September. Lesser rainfall amounts occurred over inland Georgia and South Carolina where rainfall totals between 3 and 7 inches were common. In South Carolina, the maximum rainfall total was 9.07 inches in Beaufort from 10 to 13 September. These rains caused some flash flooding and minor to moderate river flooding in South Carolina. Several rescues occurred in Chatham County in Georgia and in Jasper County in South Carolina due to the flooding. Even after Irma became a remnant low pressure system it still produced heavy rains in Alabama, where up to 5 inches accumulated. Rainfall totals near 6 inches occurred in the mountains of western North Carolina.

Tornadoes

Irma produced 25 confirmed tornadoes: 21 in Florida and 4 in South Carolina (Fig 13). Of the tornadoes, 3 were EF-2 (on the Enhanced Fujita Scale), 15 were EF-1, and 7 EF-0. The majority of the tornadoes occurred along the east coast of central and northern Florida. One of the EF-2 tornadoes touched down in Mims, Florida, with estimated winds of 100 to 110 kt. This tornado caused severe roof damage to numerous homes and uprooted many trees in the area. An EF-2 tornado struck near Crescent Beach, Florida, with peak winds between 95 and 115 kt. This tornado caused significant structural damage to vacation rentals in the area. Another EF-2 tornado hit Polk City, Florida, knocking down seven high power transmission poles.

Weaker but still notable tornadoes in Florida included an EF-1 that went through Miramar and caused tree and roof damage. An EF-1 tornado affected St. Augustine causing significant damage to a cemetery. Another EF-1 tornado with peak winds in the 85 to 95 kt range occurred in Merritt Island and damaged numerous homes and a church.

In South Carolina, the strongest tornado that occurred from Irma was an EF-1 in John's Island. This tornado caused home and tree damage along a 0.5 mile path.

CASUALTY AND DAMAGE STATISTICS

Irma caused 47 direct deaths[4] as a result of its strong winds, heavy rains, and high surf across the Caribbean Islands and the southeastern United States. The majority of the causalities were in the Caribbean Islands, where Irma's winds were the strongest. Eleven direct deaths were reported combined in Saint Martin and Saint Barthelemy, 9 in Cuba, 4 in Sint Maarten, 4 in the British Virgin Islands, 3 in the U.S. Virgin Islands, 3 in Barbuda, 1 in Barbados, 1 in Haiti, and 1 in Anguilla.

In the United States, 10 direct deaths were reported, and an additional 82 indirect deaths occurred, 77 of which were in Florida. Hundreds more were injured before, during, or after the hurricane. About 6 million residents in Florida were evacuated from coastal areas.

Barbuda

This small island took a direct hit from Irma at its peak intensity. Irma's catastrophic winds caused destruction across the island, damaging or destroying about 95% of the structures, including the local airport (Fig 14). The island had no water or communications after the storm, and was considered nearly uninhabitable. Irma caused most Barbudans to leave their island for Antigua, with the remaining islanders evacuating soon thereafter when Hurricane Jose threatened, leaving Barbuda uninhabited for the first time in 300 years. Few residents have returned as of February 2018. Preliminary estimates of property damage on the island are between 150 and 300 million USD.

[4] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect" deaths.

Saint Martin/Sint Maarten

Like Barbuda, Saint Martin took a direct hit from the catastrophic category 5 hurricane. Total damage on the island is estimated to be around 1.5 billion USD. According to media reports, on the Saint Martin (French) side of the island, 90% of the structures were damaged with 60% of those being considered uninhabitable. Irma's intense winds heavily damaged the marina and ripped trees out of the ground. Total losses are estimated to be near 1 billion USD.

On the Dutch side of the island (Sint Maarten), Irma caused severe damage to the airport and damaged or destroyed about 70% of the structures. In addition to the 4 deaths, the hazards from Irma injured 23 people.

St. Barthelemy

St. Barthelemy was in the southern eyewall of Hurricane Irma and suffered significant damage, like the surrounding islands. Preliminary assessments from the French government indicate that economic losses could exceed 480 million USD.

Anguilla

The northern eyewall of Irma passed over Anguilla and caused widespread damage and one death. Most homes and schools were destroyed, and the only hospital on the island was severely damaged. About 90% of the roads were impassable, and the strong winds uprooted numerous trees and power poles. Economic losses from the hurricane are estimated to be at least 190 million USD.

U.S. and British Virgin Islands

Irma was responsible for three deaths in the U.S. Virgin Islands. Damage in the U.S. Virgin Islands was most notable in St. Thomas and St. John (Fig 14). In both of these islands, widespread catastrophic damage was reported, and the islands were stripped of most of their foliage. Numerous reports of collapsed homes, businesses, and power lines were reported. In addition, the fire and police stations collapsed and the hospitals experienced major damage. In St. Croix, although the damage was not as severe, about 70% of the homes and structures suffered damage.

Irma's direct hit on the British Virgin Islands caused extensive damage there. Four deaths occurred during the storm there, and numerous buildings and roads were destroyed in Tortola. Authorities from the islands reported that it would take several months to restore electricity.

Puerto Rico

Although Irma's eyewall passed to the north of Puerto Rico, tropical-storm-force winds and heavy rains caused widespread power outages and minor damage to homes and businesses. Weak structures on the island collapsed and numerous trees were uprooted. There was also a near-total loss of electricity and water supply for several days. Three indirect deaths occurred in Puerto Rico from Hurricane Irma.

In the island of Culebra, there was also a near-total power and water loss. Many homes on the island were destroyed or suffered major damage, and widespread uprooted trees were reported.

Turks and Caicos Islands

Irma's northern eyewall passed near or over the Turks and Caicos Islands, causing significant damage to the islands' structures and communication infrastructure. In particular, the island of Providenciales, including its hospital, was heavily damaged. No deaths occurred during Irma, but the damage was estimated to be at least 500 million USD.

The Bahamas

Most of the southeastern Bahamian islands experienced hurricane conditions. According to media reports, Irma damaged about 70% of the homes on Great Inagua Island, and widespread damage also occurred on Crooked Island. The central and northwestern Bahamas were well outside of Irma's most intense winds, but many of these islands experienced tropical storm conditions and minor damage.

Dominican Republic and Haiti

The island of Hispaniola was not directly impacted by Irma, as the eye of the hurricane passed to the north of the Dominican Republic and Haiti, and damage there was minor compared to some of the surrounding islands. One death was reported in Haiti from Irma.

Cuba

Irma struck a portion of the Cuban Keys as a category 5 hurricane. Nine direct deaths in Cuba are blamed on Irma. During the storm, two women on a Havana bus were killed when a balcony tumbled onto the vehicle. Two men died when their home collapsed on them in Havana, and three men died in their individual homes in the provinces of Matanzas, Ciego de Avila, and Camagüey. Also, an 89-year-old woman was found drowned in the water in front of her Vedado home, her death likely due to Irma's storm surge.

In terms of damage, the tourist areas of Cayo Coco, Cayo Guillermo, Cayo Santa Maria and the town of Calibarien (Fig. 14) were hit the hardest, with widespread damage reported in those areas. Severe damage also occurred in the provinces of Ciego de Ávila and Villa Clara. More than 150,000 homes were damaged with nearly 15,000 completely destroyed by Irma in Cuba. Irma also greatly affected the country's poultry farms with 466 of them being destroyed. Across the island, uninsured losses from damage caused by Irma is estimated to be near 200 million USD, which is the highest value in Cuba during the past 55 years.

United States

There were 10 direct deaths in the United States, and a breakdown by state is as follows: Florida – seven, Georgia – two, South Carolina – one. The NOAA National Centers for Environmental Information (NCEI) estimates that wind and water damage in the United States caused by Irma totaled approximately 50.0 billion USD, with a 90% confidence interval of 37.5 to 62.5 billion USD. This makes Irma the fifth-costliest hurricane to affect the United States, behind Katrina (2005), Harvey (2017), Maria (2017) and Sandy (2012).

Loss of life and specific damage by state is discussed below:

Florida

There were seven direct deaths in Florida from Hurricane Irma. The Monroe County Medical Examiner reported that three adult males drowned in the middle or lower Florida Keys during Hurricane Irma's passage. Two of the victims were found near the boats on which they lived just offshore. The remaining circumstances and events responsible for the deaths are not known. The locations where the victims were found had been subjected to extreme wind and ocean conditions, including large waves and storm surge. Given the presence of multiple possible contributing factors, storm-related and otherwise, we are not able to conclusively attribute these "direct" deaths primarily to any particular hazard.

Two direct deaths occurred in Duval County, where a 59-year-old male and a 54-year-old female drowned due to fresh water flooding when their tent was submerged in water in the woods. An 89-year-old male drowned in Manatee County when he went outside during the hurricane to secure his boat to the dock and fell into a canal. In Broward County, an 86-year-old male opened the front door during the hurricane and a gust of wind caused him to fall and hit his head fatally. Of the 80 indirect deaths in Florida, a combination of falls during preparations for Irma's approach, vehicle accidents, carbon monoxide poisoning from generators, chainsaw accidents, and electrocutions were mainly to blame. In Broward County, 14 indirect deaths occurred in one nursing home due to overheating when air conditioners failed as power faltered.

The damage was the most severe in the Florida Keys where Irma struck as a category 4 hurricane. In the Middle and Lower Keys, most homes were badly damaged or destroyed, and many structures became uninhabitable. There were widespread power outages and extensive tree damage throughout the island chain. More than 40 injuries were reported after the storm. More than 1,300 boats were damaged or destroyed, and many of them were displaced due to the storm surge. Estimates from FEMA indicate that 25% of buildings were destroyed, 65% were significantly damaged, and 90% of houses sustained some damage. Approximately 75% of the residents in the Keys evacuated before Irma.

In Collier County, Florida, where Irma came ashore near Marco Island as a category 3 hurricane, there was significant damage. The majority of the structures in Everglades City suffered major wind and/or water damage. At least 88 buildings were destroyed county-wide, and 1,500 buildings were badly damaged. There was heavy tree and power pole damage in Marco Island, Golden Gate, and portions of Naples.

In Miami-Dade County, about 1,000 homes sustained major damage. About 50% of the agricultural industry was damaged with estimated losses near 245 million USD. Otherwise, there was widespread tree and power pole damage in the Miami-Fort Lauderdale metro area, and some damage occurred along the Biscayne Bay shoreline due to storm surge.

Although Irma was weakening while it moved northward over Florida, there was still a fair amount of damage in the central portion of the state. A combination of Irma's strong winds, embedded tornadoes, and heavy rains caused minor to moderate damage to many structures and widespread tree damage. In Brevard County, more than 7,000 homes sustained damage, including 450 that were destroyed or suffered major damage. Moderate to locally severe beach erosion was observed at the coast. Near Orlando, in Osceola County, about 4,000 structures were damaged, and the estimated cost in that county is near 100 million USD. Irma also caused significant damage to the southwest and central Florida orange groves, totaling about 760 million USD.

In northern Florida, flooding was the biggest issue. Heavy rains and rivers that reached major or record flood stage caused significant flooding in the Jacksonville area. Flood waters rushed into the city's streets and reached up to 5 ft deep in some locations. The flooding in Jacksonville was record-breaking in some locations, and overall Irma was responsible for one of the worst flooding events in the city's 225+ year history. The northeastern portion of the state also experienced hurricane-force wind gusts and embedded tornadoes that caused structural damage to homes and businesses. There was also widespread tree and power line damage across the area.

Figure 15 shows examples of some of the damage from across the state of Florida.

Georgia

Tropical-storm-force winds and heavy rains from Irma caused two direct deaths in Georgia. In Fulton County, a 55-year-old man was crushed by a tree that fell on his home while he slept. A 67-year-old woman in Forsythe County perished when a tree fell on her vehicle while she was in her driveway. An indirect death occurred when a man in Worth County had a heart attack while he was climbing off the roof of his shed during Irma.

In Camden County, numerous trees and power lines were damaged due to the strong winds. Dozens of people were rescued by boats near the coast from flooding caused by storm surge and rainfall. Across the state, there were widespread downed trees, and over 1.5 million people lost power during the storm.

South Carolina

One direct death occurred from Irma in South Carolina. A 57-year-old man was fatally struck by a falling tree limb during the storm. Two indirect deaths occurred from vehicle accidents during the storm, and another person died of carbon monoxide poisoning.

In Beaufort County, numerous trees and power lines were downed from tropical-storm-force winds and tornadoes. Storm surge damaged Fripp Island, where the sea wall was breached and homes were inundated. On Lady's Island, strong winds damaged the airport infrastructure, and runways were inundated. Storm surge also caused minor damage in downtown Charleston and surrounding areas within the tidal zone. Severe beach erosion occurred on the Folly Beach, Isle of Palms, and Sullivan Island.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis predictions for Irma were somewhat successful, but the cyclone formed sooner than predicted. Table 4 provides the number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. The tropical wave that led to the development of Irma was introduced in the TWO and given a low (<40%) chance of genesis during the next five days 78 h before Irma formed. The system was given a medium (40-60%) and high chance (> 60%) 48 h and 36 h before genesis, respectively. For the short term (48-h) forecasts, NHC gave the disturbance a low and medium chance of genesis 42 h and 30 h before it formed, respectively, but it was not assessed to a have a high chance until 12 h before genesis occurred. The global models were not consistent in showing development of Irma, and most of them were too slow in predicting its formation. This was the main cause for the limited lead time of formation in the NHC forecasts.

Track

A verification of NHC official track forecasts for Irma is given in Table 5a. Official forecast track (OFCL) errors were roughly 30-40% lower than the mean official errors for the previous 5-yr period for all forecast times. At 96 and 120 h, the climatology and persistence model (OCD5) errors were larger than their 5-yr averages, which suggests that Irma was a more difficult hurricane than usual to forecast at those longer time periods. Figure 16 shows OFCL forecasts plotted against the best track for Irma. The NHC forecasts had a slight left-of-track bias while the hurricane was over the central Atlantic, as the subtropical ridge to the north of the tropical cyclone weakened a little more than anticipated during the early stages of Irma's lifecycle. A moderate right-of-track bias in the NHC forecasts is evident while Irma was over the western Atlantic and when it was forecast to move over the southeastern United States. Irma moved west of many of the predicted tracks because the subtropical ridge built westward more than expected (Fig 5c), which delayed the northward turn toward Florida.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b and illustrated in Fig. 17. Among the individual models, the European Centre for Medium-Range Weather Forecasts model (EMXI) was the best-performing model and the only one to consistently beat the NHC official forecasts. The NOAA HFIP Corrected Consensus Approach (HCCA) model and the Florida State Superensemble (FSSE) also performed very well and had lower average errors than the official forecasts at most time periods. Figure 18 shows the tracks of the typically better-performing models when Irma was forecast to be near the Bahamas, Cuba, and the southeastern United States. Among the guidance shown, all of the models had a right-of-track bias and predicted Irma to turn northward sooner and farther east over Florida, but the bias was the smallest in the ECMWF and UKMET models, which handled the large-scale steering features better than the GFS and HWRF models.

Intensity

A verification of NHC official intensity forecasts for Irma is given in Table 6a. The NHC official intensity forecast errors were larger than their 5-yr means at all forecast times, but the OCD5 errors were also notably larger than their respective 5-yr means at all forecast times, indicating that Irma's intensity was more difficult to forecast than for a typical tropical cyclone. The NHC forecasts during the early stages of Irma's lifecycle were too low because the extended period of rapid intensification was under-forecast. Conversely, the NHC forecasts did not expect Irma to interact with Cuba as much as it did, and consequently, Irma weakened more than expected when it was near that island.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b and illustrated in Fig 19. Among the individual models, the Hurricane Weather Research and Forecast System (HWFI), Hurricanes in a Multi-scale Ocean-coupled Non-hydrostatic model (HMNI), and the Coupled Ocean/Atmosphere Mesoscale Prediction System Tropical Cyclone model (CTCI) had similar or slightly lower errors than the NHC official forecasts. On the other hand, the Statistical Hurricane Intensity Prediction Scheme (DSHP), Logistic Growth Equation Model (LGEM), Global Forecast System (GFSI), and EMXI all had notably larger errors than the NHC official forecasts. An illustration of selected intensity model biases is given in Fig 20. All of the models shown had a low bias beyond 36 h, with DSHP and LGEM having a significant low bias of around 20 kt at 96 and 120 h, which was not surprising given that Irma maintained its category 5 intensity for an unusually long time. The NHC official forecasts had a small high bias through 48 h, and a slight low bias at later forecast hours.

Watches and Warnings

Coastal tropical storm and hurricane watches and warnings associated with Irma are listed in Table 7 and illustrated in Fig. 21. Storm surge watches and warnings are given in Table 8.

NHC provided support to many government meteorological services for areas around the Caribbean Sea, including Barbados (which has responsibility for Dominica), France (for Martinique, Guadeloupe, and St. Martin), Antigua (which also has responsibility for Montserrat, St. Kitts, Nevis, Barbuda, Anguilla and the British Virgin Islands), the Netherlands (which has responsibility for Saba and St. Eustatius), St. Maarten, Dominican Republic, the Bahamas, and Cuba.

For the United States, a hurricane watch was first issued for the southern Florida coastline from Jupiter Inlet southward on the east coast and from Bonita Beach southward on the west coast, including the Florida Keys, at 1500 UTC 7 September. Since sustained tropical-storm-force winds first reached the Florida Keys within the hurricane watch area around 2100 UTC 9 September, a lead time of 54 h was provided. The hurricane watch area was upgraded to a hurricane warning at 0300 UTC 8 September, a lead time of 42 h before the tropical-storm-force winds began. Hurricane watches and warnings were subsequently issued at various times for much of the remainder of Florida. Tropical storm watches and warnings were issued for the Georgia coast and much of the coast of South Carolina.

Storm surge watches and warnings associated with Irma are given in Table 8. At various points in time, the NWS issued storm surge warnings for most of the Florida coast—from the Florida-Georgia border southward on the east coast and from the Ochlockonee River southward on the west coast, including the Florida Keys, Tampa Bay, and the lower portion of the St. Johns River north of the I-295 bridge. Storm surge warnings were also issued for the coast of Georgia and for the coast of South Carolina south of the South Santee River (Fig. 22). NWS issued the initial storm surge watch for Irma along the Florida coast from Jupiter Inlet to Bonita Beach, including the Florida Keys, at 1500 UTC 7 September, and that same area was upgraded to a storm surge warning at 0300 UTC 8 September. Storm surge watches and warnings were subsequently extended and modified northward along both the Atlantic and Gulf Coasts, encompassing almost the entire coastline from the South Santee River to the Ochlockonee River by 0300 UTC 10 September. Water level observations and high water mark surveys indicate that at least 3 ft of inundation (which NHC uses at a 10% probability of occurrence as a first-cut threshold for the storm surge watch/warning) occurred in areas within the bounds of the storm surge warning area roughly from Charlotte Harbor southward around the Florida Peninsula to Miami-Dade and Broward Counties, including the Florida Keys. At least 3 ft of inundation also occurred within the storm surge warning area from near Cape Canaveral northward to the South Santee River.

The Storm Surge Warning north of Charlotte Harbor to the Ochlockonee River, including Tampa Bay, did not verify, as water level observations suggested inundations of less than 3 ft above ground level occurred in that area. However, the storm surge warning along that portion of the coast was necessary, given that a slight westward deviation in Irma's track, or the continuation of strong winds on the back side of the storm, would have produced significantly more inundation (Fig. 22). Elsewhere, some portions of the southeastern coast of Florida generally had 3 ft or less of inundation. The Storm Surge Warning was discontinued from North Miami Beach to Jupiter Inlet at 0300 UTC 10 September in anticipation of the fact that coastal inundation within that area would likely not reach warning criteria.

NHC's first forecast for maximum storm surge heights in Florida (at 1500 UTC 7 September) was 5 to 10 ft above ground level within the storm surge watch area from Jupiter Inlet to Bonita Beach, including the Florida Keys. By the next day, the risk of significant storm surge increased for the southwestern coast of Florida, and NHC's forecast was increased to 6 to 12 ft above ground level from Cape Sable to Captiva at 1500 UTC 8 September and then 10 to 15 ft above ground level at 1500 UTC 9 September. Maximum inundation heights from Irma were analyzed to be around 10 ft above ground level, at the lower end of the forecast range, in the unpopulated area between Cape Sable and Cape Romano. Storm surge inundation forecasts for the Florida Keys (5 to 10 ft), extreme southeastern Florida (4 to 6 ft), the east coast of Florida (2 to 4 ft), and Georgia and South Carolina (4 to 6 ft) were generally accurate, with the highest observations falling within each of those ranges. However, storm surge inundation forecasts were generally too high for the rest of the west coast of Florida, largely because Irma made landfall well to the south on Marco Island. Had the hurricane deviated only slightly to the west and made landfall farther up the west coast, inundation from storm surge would have been significantly higher in those areas (Fig. 23), and potentially devastating for the Naples-Fort Myers area.

NHC does not have responsibility for issuing warnings for inland flooding, but coordinates with the Weather Prediction Center (WPC) on hazard statements included in NHC public products. The risk of life-threatening flash flooding from Florida to South Carolina was first mentioned in the NHC Public Advisory at 1500 UTC 7 September. The threat of inland flooding was included as a "Key Message" in NHC's Tropical Cyclone Discussion beginning the following day.

Impact-Based Decision Support Services (IDSS) and Public Communication

The NHC began providing IDSS to emergency managers on 1 September, several days before Irma neared the U.S. Virgin Islands and Puerto Rico, and the service continued through 11 September, when Irma was inland over the southeastern United States. The IDSS included calls and briefings coordinated through the FEMA Hurricane Liaison Team, embedded at NHC. The briefings included the territories of Puerto Rico and the U.S. Virgin Islands, the states of Florida, Georgia, South Carolina, and FEMA Regions 4 and 2, as well as Federal/State video-teleconferences. At the request of the state of Florida, the NHC began to provide the state with twice-daily IDSS coordination calls beginning September 4, six days before landfall. That day, the Florida governor declared a state of emergency.

The NHC also collaborated with the affected NWS offices to ensure a consistent message, and NWS meteorologists provided IDSS for local and state emergency management offices during this event.

Although the average track errors for Irma were fairly small, there were differences in the details of the numerical model forecasts that were key to the implied magnitude and location of the greatest impacts in South Florida and the Florida Keys, including whether the center would move closer to the east or west coast of the Florida peninsula. Despite those differences, the NHC forecasts were relatively steady in showing an increasing risk for the area as Irma approached. Language in advisory products such as the Tropical Cyclone Discussion (TCD) and in media and emergency management briefings emphasized the threat and the accompanying uncertainty. For example, four days before landfall, the TCD stated that "Irma is forecast to turn northwestward and northward, but there is still a fair amount of uncertainty regarding the exact timing and location of recurvature", and one of the TCD "Key Messages" at that time said, "Direct impacts from wind, storm surge, and rainfall are possible in the Florida Keys and portions of the Florida Peninsula beginning later this week and this weekend. However, given the forecast uncertainty at these time ranges, it is too soon to specify the location and magnitude of these impacts." Two days before landfall in the Keys, the TCD said "This turn will occur, but the precise moment is still uncertain, and that is why NHC emphasizes that nobody should focus on the exact track of the center."

Due to the possibility of Irma affecting NHC in Miami, a back-up operation was initiated, which included a deployment of three NHC forecasters and two Central Pacific Hurricane Center forecasters to the NOAA Center for Weather and Climate Prediction in the Washington, D.C. area. While NHC maintained operations for Hurricane Irma in Miami, forecasters at the back-up location produced advisories for Hurricanes Jose and Katia, which were active at the same time as Irma. The rest of the NHC staff continued Irma and other forecast operations, remaining within the office during a 36-h shelter-in-place activation coinciding with Irma's local threat and impact.

In addition, an NHC media pool was in operation from 5–10 September to provide live briefings to national and local television outlets in both English and Spanish. NHC provided around 300 live interviews through the pool, comprising 201 to local television stations, 78 to network TV, 14 to radio stations, and 10 to print media. It also gave more than 200 media interviews by phone. NHC was also active on social media to keep the public informed in real-time on the latest NHC/NWS forecasts and warnings, with posts on Twitter generating 98 million impressions and Facebook posts reaching more than 18.9 million users and causing more than 12.9 million post engagements. Regarding the NHC website, over 500 million pages were viewed between 1–30 September resulting in approximately 9 billion hits, primarily due to Hurricane Irma. Just prior to Irma's landfall in Florida, the NHC website had approximately 1.1 billion hits (57 million page views) on one day, equaling the total number of hits received during the entirety of Hurricane Matthew in 2016. At advisory times, over 200,000 users were simultaneously accessing information on the NHC website. The 7 billion hits attributed to Irma is approximately 3 times the traffic ever handled by the NHC website during a single storm event.

The above-noted activities were conducted in addition to previously-mentioned support that NHC provided to government meteorological partner agencies in the Caribbean.

ACKNOWLEDGMENTS

Data in Table 3 were compiled from Post Tropical Cyclone Reports issued by the NWS Forecast Offices (WFOs) in San Juan, Miami, Tampa Bay/Ruskin, Melbourne, Tallahassee, Jacksonville, and Charleston. Additional data were used from reports sent by WFOs in Peachtree City and Columbia. Data from the Weather Prediction Center, National Data Buoy Center, NOS Center for Operational Oceanographic Products and Services, United States Geological Survey, Storm Prediction Center, and the Cuban Meteorological Service were also used in this report. Jose Rubiera from the Cuban Meteorological Service was very helpful in sending data and damage information from Cuba. The authors would also like to thank the following individuals at the National Hurricane Center: Laura Paulik for creating the storm surge figures, Jeri Schwietert for producing the wind watch/warning graphic, Lixion Avila for collecting data and reports from Caribbean countries, Jack Beven for helping collect and quality control surface observations, and Gladys Rubio for translating information from Spanish to English. Brad Klotz of the Hurricane Research Division was also very helpful in analyzing some of the aircraft data.

Table 1. Best track for Hurricane Irma, 30 August–12 September 2017.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
30 / 0000	16.1	26.9	1008	30	tropical depression
30 / 0600	16.2	28.3	1007	35	tropical storm
30 / 1200	16.3	29.7	1006	45	"
30 / 1800	16.3	30.8	1004	50	"
31 / 0000	16.3	31.7	999	55	"
31 / 0600	16.4	32.5	994	65	hurricane
31 / 1200	16.7	33.4	983	80	"
31 / 1800	17.1	34.2	970	95	"
01 / 0000	17.5	35.1	967	100	"
01 / 0600	17.9	36.1	967	100	"
01 / 1200	18.4	37.3	967	100	"
01 / 1800	18.8	38.5	967	100	"
02 / 0000	19.1	39.7	967	100	"
02 / 0600	19.1	41.1	967	100	"
02 / 1200	18.9	42.6	973	95	"
02 / 1800	18.7	44.1	973	95	"
03 / 0000	18.5	45.5	973	95	"
03 / 0600	18.2	46.7	973	95	"
03 / 1200	17.9	47.9	969	100	"
03 / 1800	17.6	49.2	965	100	"
04 / 0000	17.3	50.4	959	100	"
04 / 0600	17.0	51.5	952	105	"
04 / 1200	16.8	52.6	945	110	"
04 / 1800	16.7	53.9	944	115	"
05 / 0000	16.6	55.1	943	125	"
05 / 0600	16.6	56.4	933	135	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
05 / 1200	16.7	57.8	929	150	"
05 / 1800	16.9	59.2	926	155	"
06 / 0000	17.3	60.6	915	155	"
06 / 0600	17.7	61.9	914	155	"
06 / 1115	18.1	63.1	914	155	"
06 / 1200	18.1	63.3	915	155	"
06 / 1800	18.6	64.7	916	150	"
07 / 0000	19.2	66.2	916	150	"
07 / 0600	19.7	67.6	920	145	"
07 / 1200	20.2	69.0	921	145	"
07 / 1800	20.7	70.4	922	145	"
08 / 0000	21.1	71.8	919	140	"
08 / 0600	21.5	73.2	925	135	"
08 / 1200	21.8	74.7	927	135	"
08 / 1800	22.0	76.0	925	140	"
09 / 0000	22.1	77.2	924	145	"
09 / 0600	22.4	78.3	930	130	"
09 / 1200	22.7	79.3	941	110	"
09 / 1800	23.1	80.2	938	95	"
10 / 0000	23.4	80.9	932	100	"
10 / 0600	23.7	81.3	930	115	"
10 / 1200	24.5	81.5	931	115	"
10 / 1800	25.6	81.7	936	100	"
11 / 0000	26.8	81.7	942	80	"
11 / 0600	28.2	82.2	961	65	"
11 / 1200	29.6	82.7	970	50	tropical storm
11 / 1800	30.9	83.5	980	45	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
12 / 0000	31.9	84.4	986	35	"
12 / 0600	32.9	85.6	997	25	low
12 / 1200	33.8	86.9	1000	20	"
12 / 1800	34.8	88.1	1003	15	"
13 / 0000	35.6	88.9	1004	15	"
13 / 0600	36.2	89.5	1004	15	"
13 / 1200	36.8	90.1	1005	15	"
13 / 1800					dissipated
06 / 0600	17.7	61.9	914	155	maximum wind and minimum pressure
06 / 0545	17.7	61.8	914	155	landfall on Barbuda
06 / 1115	18.1	63.1	914	155	landfall on St. Martin
06 / 1630	18.5	64.4	915	155	landfall on Virgin Gorda, British Virgin Islands
08 / 0500	21.5	73.0	924	135	landfall on Little Inagua, Bahamas
09 / 0300	22.3	77.9	924	145	landfall near Cayo Romano, Cuba
10 / 1300	24.7	81.5	931	115	landfall on Cudjoe Key, Florida
10 / 1930	25.9	81.7	936	100	landfall near Marco Island, Florida

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Irma, 30 August–12 September 2017. Note that many wind observations are taken from anemometers located well above the standard 10 m observation height.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
02 / 0700	BATFR1	18.6	42.0	310 / 41	1002.8
05 / 1600	J8PE3	13.6	61.0	170 / 38	1009.1
06 / 0900	C6FM9	13.2	59.9	290 / 35	1014.2
09 / 0600	3FOB5	23.2	82.5	030 / 42	1005.0
09 / 0700	3FOB5	23.2	82.8	030 / 35	1006.0
09 / 1800	CQGZ	19.4	80.4	260 / 35	1004.7
10 / 0300	J8PE4	19.4	80.3	250 / 38	1005.0
10 / 0600	C6FZ8	20.6	81.9	250 / 35	1001.0
10 / 0600	PLSF1	24.7	82.8	040 / 50	993.4
10 / 2000	C6FN5	26.6	88.3	050 / 40	1005.1
10 / 2100	WMCU	25.9	77.8	130 / 45	1003.6
10 / 2100	SAUF1	29.9	81.3	060 / 38	1007.5
11 / 0000	WDD612	26.2	78.6	120 / 64	1000.1
11 / 0000	C6FN5	27.8	88.8	060 / 52	1006.1

Table 3. Selected surface observations for Hurricane Irma, 30 August–12 September 2017.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Antigua and Barbuda									
Barbuda NOS Site (BARA9 - 9761115) (17.59N 61.82W)	06/0536	916.1	06/0454	105	139	7.94		7.9	
Virgin Islands									
International Civil Aviation Organization (ICAO) Sites									
Henry E Rohlsen AP (TISX) (17.68N 64.90W)	06/1653	995.9	06/1843	33 (2 min, 10 m)	55				
Cyril E. King AP (TIST) (18.33N 64.97W)			06/1153	51* (2 min, 10 m)	76*				
*Site damaged during storm									
Weatherflow Sites									
Buck Island (XBUK) (18.28N 64.90W)	06/1653	969.6	06/1723	92 (12.1 m)	119				
Rupert Rock (XRUP) (18.33N 64.93W)			05/1750	72 (5.5 m)	115				
Sandy Point NWR (XCRX) (17.68N 64.90W)			06/1903	36 (14 m)	51				
Savana Island (XSAV) (18.34N 65.08W)			06/1815	50 (6.1 m)	77				
NOS Sites									
Charlotte Amalie, St. Thomas (CHAV3 - 9751639) (18.34N 64.92W)	06/1742	967.5	06/1736	55	85	1.45[J]	1.71[J]	1.3[J]	
Lameshur Bay, St. John (LAMV3 - 9751381) (18.32N 64.72W)	06/1736	945.1				1.62	1.60	1.2	
Christiansted Harbor, St. Croix (CHSV3 - 9751364) (17.75N 64.71W)	06/1706	995.0	06/1642	33	50	2.28	2.01	1.7	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Lime Tree Bay, St. Croix (LTBV3 - 9751401) (17.69N 64.75W)	06/1706	996.4	06/1848	43	53	0.60	0.80	0.5	
Puerto Rico									
International Civil Aviation Organization (ICAO) Sites									
Luis Munoz Marin Intl AP (TJSJ) (18.45N 66.00W)	06/1656	993.4	06/1828	42 (2 min, 10 m)	60				
Roosevelt Roads AP (TJNR) (18.25N 65.64W)	06/1654	991.0	06/1905	42 (2 min, 10 m)	57				
Weatherflow Sites									
Del Rey Marina (XREY) (18.29N 65.63W)			06/1215	35 (5 min, 10 m)	59				
Isla Culebrita Light (XCUL) (18.34N 65.08W)	06/1840	952.1	06/1815	50 (5min, 10 m)	77				
Las Mareas (XMRS) (17.94N 66.26W)			07/0104	39 (5 min, 10 m)	47				
San Juan NAVAID (XJUA) (18.29N 65.63W)			06/2140	41 (5 min, 14.3 m)	46				
NOS Sites									
Arecibo (AROP4 - 9757809) (18.48N 66.70W)	07/0036	998.7	07/0130	38	47	1.37		1.5	
Esperanza, Vieques Island (ESPP4 - 9752695) (18.09N 65.47W)	06/2006	991.9	06/2130	45	56	1.44	1.57	1.2	
Fajardo (FRDP4 - 9753216) (18.33N 65.63W)	06/2118	980.1	06/1930	35	50	1.21		1.2	
Isabel Segunda, Vieques Island (VQSP4 - 9752619) (18.15N 65.44W)			06/2000	42	55	1.80		1.0	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
La Puntilla, San Juan Bay (SJNP4 - 9755371) (18.46N 66.12W)	06/2300	989.3	06/2230	48	64	1.55	2.10	1.3	
Culebra (CLBP4 - 9752235 (18.30N 65.30W)	06/1948	981.5				1.74		1.0	
Yabucoa Harbor (YABP4 – 9754228) (18.06N 65.83W)			06/2224	22	37	1.11		0.8	
Magueyes Island (MGIP4 – 9759110) (17.97N 67.05W)	07/0012	1001.9	07/0354	29	39	0.56		0.7	
Mayaguez (MGZP4 – 9759394) (18.22N 67.16W)	07/0018	1001.5	07/0606	27	36	1.37	2.00	1.3	
Mona Island (MISP4 – 9759938) (18.09N 67.94W)	07/0630					1.47	1.50	1.1	
NWS Cooperative Observer Program (COOP) Sites									
Barranquitas (USAP4) (18.18N 66.31W)									7.05
Bayamon (BAYP4) (18.38N 66.16W)									13.04
Ciales (VILP4) (18.33N 66.47W)									10.27
Comerio (COMP4) (18.22N 66.22W)									7.07
Orocovis (OROP4) (18.22N 66.39W)									9.13
San Lorenzo (SLGP4) (18.19N 65.97W)									6.35
Utuado (VIVP4) (18.27N 66.70W)									6.74
Villalba (VINP4) (18.13N 66.48W)									7.50

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Cuba									
International Civil Aviation Organization (ICAO) Sites									
Frank País/Holguin Arpt (78372) (20.79N 76.32W)	08/2015	991.2							8.08
Hermanos Ameijeiras/ Las Tunas Arpt (MUVT/78357) (20.99N 76.94W)	08/2200	992.9	08/2225	38 (1 min, 10 m)	60				4.10
MUCA, Venezuela (78346) (22.03N 78.79W)	09/0700	981.3	09/0800	36 (1 min, 10 m)	62				8.33
MUTD, Trinidad (78337) (21.78N 79.98W)	09/1250	983.4	09/1417	40 (1 min, 10 m)	62				12.46
Punta de Maisí Arpt (MUMA/78369) (20.24N 74.14W)	08/0825	996.7	06/1612	35 (1 min, 10 m)	52				2.96
Other Sites									
Aguada De Pasajeros (78335) (22.38N 80.85W)	09/2055	981.2	10/0225	36	46				6.05
Bauta (78376) (22.97N 82.53W)	10/0800	997.5	10/0235	40	51				3.07
Caibarien (78348) (22.52N 79.45W)	09/1200	969.9	09/1430	85	122				17.11
Camaguey 09 (78355/elev.122m) (21.40N 77.85W)	09/0300	982.2	09/0350	38	67				7.53
Camilo Cienfuegos (78347) (22.15N 78.75W)	09/0650	959.8	09/0720	108	138				11.50
Cantarrana (78344) (21.92N 80.17W)	09/1800	981.1	09/2310	36	48				4.63
Caujeri (78319) (20.22N 74.81W)	08/0400	998.0	08/0600	40 (1 min, 10 m)	59				3.41

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Cayo Coco (78339) (22.52N 78.45W)	09/0520	933.1	09/0500	83	105				
El Jibaro (78341) (21.72N 79.22W)	09/1000	982.8	09/1440	42	63				13.79
El Yabu (78343) (22.43N 79.98W)	09/1500	981.5	09/1345	39	77				7.56
Esmeralda (78352) (21.85N 78.12W)	09/0400	965.7	09/0400	60	130				10.20
Florida (78350) (21.52N 78.23W)	09/0300	984.2	09/0500	43	73				6.38
Guaro (78370) (20.67N 75.78W)	08/1830	994.1	08/1740	40 (1 min, 10 m)	59				4.20
Jaguey Grande (78331) (22.63N 81.27W)	09/1900	982.0	09/1940	38	64				6.57
Jovellanos (78330) (22.78N 81.18W)	09/2200	979.8	09/2200	50	60				3.94
Jucaro (78345) (21.62N 78.85W)	09/0700	984.3	09/0700	38	78				7.61
La Jiquima (78362) (20.93N 76.53W)	08/2100	991.0	09/0412	37 (1 min, 10 m)	53				7.28
Matanzas 4 (78326) (23.02N 81.52W)	09/1800	976.5	09/1450	30	63				12.49
Nuevitas (78353) (21.53N 77.25W)	09/0000	977.2	09/0320	42	87				7.54
Palenque de Yatera (78334) (20.45N 74.92W)	08/1110	998.0	08/1015	23 (1 min, 10 m)	43				16.69
Palo Seco (78354) (21.13N 77.32W)	09/0100	991.0	09/0250	28	60				7.93

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Pinares De Miyari (78371/elev. 646m) (20.48N 75.80W)	09/1800	930.0							8.17
Puerto Padre (78358) (21.20N 76.62W)	09/0850	993.7	08/1430	52 (1 min, 10 m)	69				4.15
Sagua La Grande (78338) (22.82N 80.08W)	09/1800	963.0	09/1235	68	94				11.55
San Antonio Banos (78328/MUSA) (22.87N 82.51W)	10/0045	966.8	10/0100	49	73				4.47
Sancti Spiritus (78349) (21.93N 79.45W)	09/1200	977.2	09/1515	45	70				19.02
Santiago De Las Vegas (78373) (22.97N 82.38W)			09/2100	44	56				3.20
Topes De Collantes (78342) (21.92N 80.02W)	09/1300	961.8	09/1835	38	59				23.90
Union De Reyes (78327) (22.77N 81.53W)	09/2305	976.9	09/1830	41	68				4.19
Velasco (78378) (21.08N 76.30W)	08/1959	998.6	08/1728	44 (1 min, 10 m)	63				7.44
NOAA and Marine Partner Buoys									
Canaveral (41009) (28.50N 80.18W)	11/0230	993.7	11/0245	56 (1 min, 4 m)	66				
COMPS C12 (42022) (27.50N 83.74W)				48 (? min, 3.1 m)	61				
Edisto (41004) (32.50N 79.10W)	11/1850	1003.1	11/1505	45 (1 min, 4 m)	58				
Grays Reef (41008) (31.40N 80.87W)	11/1450	995.1	11/0910	44 (10 min, 5 m)	60				
NE Puerto Rico (41043) (21.13N 64.86W)	06/2200	1007.5	06/2346	39 (1 min, 4 m)	47				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Pensacola (42039) (28.79N 86.01W)	11/1050	1000.9	11/0823	37 (1 min, 4 m)	41				
San Juan (41053) (18.50N 66.10W)	06/1900	988.9	06/1900	39 (1 min, 4 m)	52				
S. of St. John, VI (41052) (18.30N 64.80W)	06/1100	992.4	06/1500	44 (1 min, 4 m)	56				
Viques Island (41056) (18.30N 65.50W)	06/2030	985.7	06/2110	43 (1 min, 4 m)	55				
West Tampa (42036) (28.50N 84.52W)	11/0850	990.9	11/0420	44 (10 min, 5 m)	56				
United States									
Florida									
International Civil Aviation Organization (ICAO) Sites									
Albert Whitted Airport (KSPG) (27.77N 82.63W)	11/0453	973.8	11/0053	47 (2 min, 10 m)	60				
Cape Canaveral AFD Skid Strip (KXMR) (28.46N 80.56W)	11/0441	990.1	11/0207	51 (2 min, 10 m)	70				12.08
Craig Municipal Airport (KCRG) (30.33N 81.52W)	11/1153	987.0	11/1227	40 (2 min, 10 m)	61				
Daytona Beach Intl (KDAB) (29.18N 81.05W)	11/0937	984.8	11/0246	47 (2 min, 10 m)	68				
Fort Myers Page Field (KFMY) (26.58N 81.97W)	10/2253	952.4	10/2216	50 (2 min, 10 m)	73				10.60
Fort Pierce/St. Lucie Co Intl (KFPR) (27.49N 80.36W)	11/0238	987.8	10/2306	62 (2 min, 10 m)	77				15.88
Ft. Lauderdale Executive (KFXE) (26.20N 80.17W)	10/2202	989.5	10/1847	53 (2 min, 10 m)	72				9.57
Ft. Lauderdale International (KFLL) (26.07N 80.15W)	10/2120	989.0	10/0153	46 (2 min, 10 m)	61				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Gainesville Regional Airport (KGNV) (29.68N 82.27W)	11/1053	979.5	11/0527	40 (2 min, 10 m)	50				12.40
Hollywood North Perry Airport (KHWO) (26.00N 80.24W)	10/1701	993.3	10/1651	49 (2 min, 10 m)	68				
Jacksonville Intl Airport (KJAX) (30.49N 81.69W)	11/1156	986.6	11/0748	51 (2 min, 10 m)	75				9.20
Jacksonville Naval Air Station (KNIP) (30.24N 81.68W)	11/1153	984.6	11/1053	43 (2 min, 10 m)	63				7.08
Key West Intl Airport (KEYW) (24.56N 81.76W)			10/1115	52 (2 min, 10 m)	82				
Leesburg Intl Airport (KLEE) (28.82N 81.80W)	11/0820	977.0	11/0735	42 (2 min, 10 m)	60				
Mayport Naval Station (KNRB) (30.39N 81.42W)	11/1152	988.5	11/0738	59 (2 min, 10 m)	76				7.96
Melbourne Intl Airport (KMLB) (28.10N 80.64W)	11/0532	988.1							11.84
Miami Executive/West Kendall (KTMB) (25.65N 80.43W)	10/1718	986.8	10/1110	48 (2 min, 10 m)	63				
Miami International (KMIA) (25.80N 80.29W)	10/2116	988.8	10/1313	46 (2 min, 10 m)	63				
Naples Municipal Airport (KAPF) (26.15N 81.77W)	10/1932	959.4	10/1801	53 (2 min, 10 m)	71				
Okeechobee County AP (KOBE) (27.26N 80.85W)			11/0315	40 (2 min, 10 m)	62				
Opa Locka Airport (KOPF) (25.91N 80.28W)	10/2112	988.8	10/1903	56 (2 min, 10 m)	74				8.03
Orlando Executive (KORL) (28.54N 81.33W)	11/0804	981.4	11/0504	49 (2 min, 10 m)	68				
Orlando Intl Airport (KMCO) (28.42N 81.31W)	11/0720	980.4	11/0519	51 (2 min, 10 m)	69				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Orlando/Sanford (KSFB) (28.77N 81.24W)	11/0746	982.1	11/0651	48 (2 min, 10 m)	65				
Pompano Beach Airpark (KPMP) (26.24N 80.11W)	10/2205	990.1	10/2039	60 (2 min, 10 m)	76				
Punta Gorda Airport (KPGD) (26.92N 81.99W)	11/0053	962.7	10/2153	44 (2 min, 10 m)	64				
Regional Southwest (KRSW) (26.54N 81.76W)	10/2353	958.1	10/2153	54 (2 min, 10 m)	77				9.70
Saint Augustine Airport (KSGJ) (29.97N 81.33W)	11/0656	994.3	11/0506	45 (2 min, 10 m)	62				
Saint Petersburg (KPIE) (27.91N 82.69W)	11/0553	975.0	11/0553	43 (2 min, 10 m)	64				
Sarasota Airport(KSRQ) (27.40N 82.55W)	11/0353	975.5	11/0120	42 (2 min, 10 m)	61				
Tampa International Airport (KTPA) (28.82N 81.80W)	11/0553	971.8	11/0335	40 (2 min, 10 m)	58				
West Palm Beach International (KPBI) (26.68N 80.09W)	10/2320	990.2	10/2101	57 (2 min, 10 m)	79				
Winter Haven Airport (KGIF) (28.05N 81.75W)	11/0453	971.5	11/0445	44 (2 min, 10 m)	66				
Texas Tech University Hurricane Research Team StickNet (South Florida Observations)									
2 NNW Royal Palm Hammock (0111A) (26.04N 81.62W)			10/2008	74 (1 min, 2.25 m)	99				
4 E Orangetree (0103A) (26.29N 81.51W)			10/2151	61 (1 min, 2.25 m)	77				
5 SW Florida City (0214A) (25.40N 80.56W)			10/1558	66 (1 min, 2.25 m)	77				
6 E Miccosukee Village (0105A) (25.76N 80.67W)			10/1703	48 (1 min, 2.25 m)	66				
9 E Miles City (0102A) (26.16N 81.19W)			10/1636	45 (1 min, 2.25 m)	60				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
9 ESE Golden Gate (0112A) (26.15N 81.54W)			10/2052	52 (1 min, 2.25 m)	77				
Miami Beach (0104A) (25.76N 80.12W)			10/2239	52 (1 min, 2.25 m)	64				
Miles City (0220A) (26.15N 81.34W)			10/2032	55 (1 min, 2.25 m)	73				
Hollywood Beach (0106A) (26.05N 80.11W)			10/1954	49 (1 min, 2.25 m)	60				
Station 109A (26.05N 80.11W)			10/1727	51 (1 min, 2.25 m)	68				
Station 110A (26.37N 81.76W)			10/2142	60 (1 min, 2.25 m)	66				
Coastal-Marine Automated Network (C-MAN) and NOS Sites									
Clearwater Beach (CWBF1) (27.98N 82.83W)	11/0606	976.2	11/0548	62 (6 min, 6.7 m)	77	1.67	1.85	0.9	
Fort Myers (FMRF1) (26.65N 81.87W)	10/2324	953.0	10/2254	44	59	3.88	3.55	3.3	
Fowey Rock (FWYF1) (25.59N 80.10W)	10/1900	989.5	10/1830	73 (10 min, 44 m)	87				
Fred Howard Park COMPS (FHPF1) (28.15N 82.80W)	11/0612	974.7	11/0436	60 (6 min, 10 m)	73				
Lake Worth Pier (LKWF1) (26.61N 80.03W)			10/2100	55	79	2.23	2.05	1.5	
Key West (KYWF1) (25.55N 81.81W)	10/1236	956.6	10/1224	63 (15 m)	81	3.29	2.73	2.7	
Middle Tampa Bay (MTBF1) 27.66N 82.59W)			11.0130	56	68				
Molasses Reef (MLRF1) (25.01N 80.38W)	10/1300	984.7	10/1200	60 (10 min, 16 m)	78				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Naples (NPSF1) (26.13N 81.81W)	10/2054	939.7	10/2200	56	72	5.14	4.83	4.3	
Mayport (Bar Pilots Dock) (MYPF1) (30.40N 81.43W)	11/1218	988.3	11/0736	57	78	6.44	5.58	3.6	
Old Port Tampa (OPTF1) (27.86N 82.55W)	11/0418	972.5	11/0254	50	60	2.37		1.2	
Port Manatee (PMAF1) (27.642N 82.56W)	11/0418	973.3				2.17	1.87	1.2	
St. Petersburg (SAPF1) (27.76N 82.63W)	11/0506	975.1	10/2342	33	52	2.17	1.96	1.2	
McKay Bay Entrance (MCYF1) (27.91N 82.43W)						3.07	2.75	1.7	
Port Canaveral - Trident Pier (TRDF1) (28.42N 80.59W)	11/0700	990.1	11/0942	46	59	4.60	5.23	4.2	
Pulaski Shoals Light (PLSF1) (24.69N 82.77W)	10/1500	986.5	10/1200	57 (10 min, 12 m)	72				
St. Augustine (SAUF1) (29.86N 81.26W)	11/0700	986.0	11/0720	59	73				
Sand Key (SANF1) (24.46N 82.77W)	10/1150	966.1							
Vaca Key (VCAF1) (24.71N 81.1W)	10/1318	964.2	10/1342	54	81	2.72	2.20	2.6	
Venice (VENF1) (27.07N 82.45W)	11/0200	974.9	11/0200	57 (10 min, 12 m)	69				
Virginia Key (VAKF1) (25.73N 80.16W)	10/1918	989.0	10/1900	46	62	3.92	3.87*	3.7	
Fernandina Beach (FRDF1) (30.67N 81.47W)	11/1312	990.0	11/1548	30	52	7.78	6.34	3.6	
Dames Point (DMSF1) (30.39N 81.56W)						5.97	5.11	3.7	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
I-295 Bridge, St. Johns River (BKBF1) (30.18N 81.68W)	11/1142	983.9	11/0648	50	60	5.71[L]	5.63[L]	5.3[L]	
Southbank Riverwalk, St. Johns River (8720226) (30.32N 81.66W)						6.61[L]	5.56[L]	4.9[L]	
Racy Point, St. Johns River (RCYF1) (29.80N 81.55W)						4.72[L]	4.60[L]	4.0[L]	
Cedar Key (CDRF1) (29.13N 83.03W)	11/0936	977.2	11/1536	31	47	2.59	2.71	1.2	
Apalachicola (APCF1) (29.73N 84.98W)	11/1206	995.6	11/0918	34	45	0.93	1.68	0.8	
Panama City (PACF1) (30.15N 85.67W)	11/1942	999.3	11/1918	25	39	0.56	1.08	0.3	
Panama City Beach (PCBF1) (30.21N 85.88W)	11/2206	999.4	11/2218	29	38	0.59	1.28	0.3	
Pensacola (PCLF1) (30.40N 87.21W)	11/2054	1004.0	10/2224	17	28	1.00	1.56	0.6	
Weatherflow Sites									
Alligator Reef Light (XALG) (24.85N 80.62W)	10/1204	977.0	10/1159	62	81				
Biscayne Bay Light 20 (XKBS) (25.65N 80.19W)	10/1824	987.2	10/1824	53	75				
Boca Raton (XBOC) (26.37N 80.08W)	10/2038	986.2	10/2058	44	69				
Boyton Beach (XBOY) (26.54N 80.05W)	10/2037	989.4	10/2017	44	68				
Buck Island (XJAK) (30.39N 81.48W)	11/1235	983.0	11/0735	55	69				
Carysfort Reef Light (XCFL) (25.23N 80.21W)	10/1325	986.8	10/1240	62 (14.3 m)	81				

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Cocoa Beach Club (XCOA) (28.31N 80.63W)			11/0022	47	72				
Crandon Key Biscayne (XCRN) (25.72N 80.15W)	10/2120	990.8	10/1555	48	65				
Crescent Beach Summerhouse (XHSE) (29.71N 81.23W)	11/1005	987.0	11/1025	47	60				
Dania Pier (XDAN) (26.05N 80.11W)			10/1839	55	70				
Dinner Key (XDIN) (25.71N 80.21W)	10/1803	990.3	10/1828	50	71				
Dodge Island Miami (XDGE) (25.76N 80.14W)	10/1917	987.0	10/1917	48	69				
DORAL (XURB) (25.85N 80.37W)	10/2111	984.7	10/1701	43 (15 min, 5 m)	67				
Grant-Valkaria - Indian River (XIND) (27.96N 80.53W)			10/2306	44	58				
Government Cut (XGVT) (25.75N 80.10W)	10/1907	983.0	10/1852	65	79				
Hobe Sound (XHOB) (27.05N 80.17W)			10/2144	40	62				
Huguenot Park (XHUP) (30.41N 81.41W)	11/1116	985.0	11/0746	57	74				
Isles of Capri (XCAP) (26.03N 81.60W)	10/2012	934.8	10/1957	62	86				
Jacksonville Beach Pier (XJAX) (30.29N 81.39W)	11/1010	986.0	11/1310	49	65				
Jensen Beach (XJEN) (27.22N 80.20W)			10/2345	48	61				
Juno Beach Pier (XJUP) (26.89N 80.06W)	10/2354	987.9	10/2354	61	74				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Jupiter (XOAK) (26.91N 80.07W)	10/2126	987.5	10/2301	42	67				
Key West Coast Guard Sector (XSMS) (24.57N 81.79W)	10/1225	952.9	10/1140	53	77				
Lewis St. Johns (XLWS) (29.91N 81.33W)	11/1044	984.0	11/1149	45	65				
Merritt Island - Banana River - SR520 (XCCB) (28.36N 80.65W)			11/0107	49	63				
Merritt Island - Banana River - SR528 (XMER) (28.40N 80.66W)			11/0120	51	82				
Melbourne Beach Aquarina (XAQU) (27.94N 80.49W)			10/2302	48	65				
Miramar (XFLM) (25.96N 80.30W)	10/2152	982.0	10/1827	43 (15 min, 5 m)	73				
Morningside Park Miami (XMSP) (25.82N 80.18W)	10/1924	987.5	10/1854	55	73				
New Smyrna Beach (XNSB) (29.04N 80.90W)			11/0309	53	71				
Port Everglades (XPEG) (26.08N 80.12W)	10/2145	985.2	10/2005	61	74				
Port Everglades South (XPES) (26.06N 80.13W)	10/2137	988.1	10/1852	40	71				
Smith Shoal Light (XSMS) (24.72N 81.92W)	10/1230	964.6	10/1210	67	84				
South Key Largo (XSKL) (25.10N 80.43W)	10/1347	980.8	10/1347	54	74				
South Miami (XSOM) (25.63N 80.30W)	10/1730	986.4	10/1300	50	71				
St. Lucie Power Plant (XSTL) (27.35N 80.24W)			10/2304	62	87				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Tamarac (XCVN) (26.19N 80.30W)	10/2123	986.1	10/1853	43 (5 min, 10 m)	61				
Terminal Channel Jacksonville (XTRM) (30.33N 81.62W)	11/1158	983.0	11/1143	40	65				
Titusville - Parrish Park North (XPAR) (28.63N 80.81W)			11/0220	49	65				
Turkey Point (XTKY) (25.43N 80.35W)	10/1726	977.4	10/1746	62	81				
Upper Matecumbe Key (XUMK) (24.92N 80.64W)	10/1256	976.3	10/1436	61	81				
US Air Force Sites									
USAF Tower 1 (KSC0001) (28.43N 80.57W)			11/0220	68 (16.5 m)	82				
USAF Tower 108 (KSC0108) (28.54N 80.57W)			11/0205	49 (16.5 m)	81				
USAF Tower 211 (KSC0211) (28.61N 80.62W)			11/0220	40 (16.5 m)	73				
USAF Tower 211 (KSC0211) (28.61N 80.62W)			11/0220	40 (16.5 m)	73				
USAF Tower 3 – Lower (KSC0003) (28.46N 80.53W)			11/0202	49 (3.7 m)					
USAF Tower 3 – Upper (KSC0003) (28.46N 80.53W)			11/0205	58 (16.5 m)	74				
USAF Tower 300 (KSC0300) (28.40N 80.65W)			11/0230	56 (16.5 m)	79				
USAF Tower 311 (KSC0311) (28.60N 80.57W)			11/0220	48 (16.5 m)	72				
USAF Tower 397 – Lower (KSC0397) (28.60N 80.57W)			11/0015	81 (78.9 m)	94				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
USAF Tower 397 – Upper (KSC0397) (28.60N 80.57W)			11/0015	90 (139.6 m)	101				
USAF Tower 403 (KSC0403) (28.60N 80.57W)			11/0220	44 (16.5 m)	72				
USAF Tower 412 (KSC0412) (28.61N 80.67W)			11/0219	56 (16.5 m)	76				
USAF Tower 418 (KSC0418) (28.71N 80.73W)			11/0145	42 (16.5 m)	69				
USAF Tower 19 (KSC0019) (28.74N 80.70W)			11/0315	54 (16.5 m)	70				
USAF Tower 506 (KSC0506) (28.52N 80.64W)			11/0130	42 (16.5 m)	72				
Remote Automated Weather Stations (RAWS) and HADS Sites									
Big Cypress Reservation (TS909) (26.30N 80.98W)			11/0105		49				8.23
Big Pine Key (TS607) (24.72N 81.39W)			10/1438	48 (10 min, 6.1 m)	104				12.54
Brighton Seminole 3 NNW (TS896) (27.12N 81.08W)				23 (6 m)	47				7.74
Chekika (CHKF1) (25.62N 80.58W)			10/1723	49 (10 min, 6 m)	78				13.63
Deerfield Beach (DFBS1) (26.29N 80.12W)			10/2200	51 (15 m)	97				
Golden Gate Estates 5 SE (PHWF1) (26.15N 81.58W)			10/2211	21 (10 min, 6 m)	59				10.41
Homestead (STDF1) (25.50N 80.50W)			10/1700	45 (15 min, 10 m)	63				9.16
Honeymoon (HMRF1) (26.19N 81.07W)			10/2145		59				10.55

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Immokalee (IMKF1) (25.50N 80.50W)			10/2300	56 (15 min, 10 m)	72				14.48
Loxahatchee NWR (LOHF1) (26.49N 80.43W)			10/2232	40	66				8.08
Miles City 7 NE (RKIF1) (26.25N 81.30W)			10/2045	31 (6 min, 10 m)	65				10.23
North Key Largo Handar (KLNF1) (25.19N 80.35W)	10/1400	987.5	10/1330	45	63				7.16
Oasis Ranger Station (OASF1) (25.86N 81.03W)			10/1637	39 (10 min, 6 m)	67				9.90
Ochopee (OCOF1) (25.90N 81.32W)			10/1903	55 (10 min, 6 m)	83				9.61
Panther East (PSTF1) (26.17N 81.36W)			10/1711	31	65				10.73
Raccoon Point (RACF1) (25.98N 80.90W)			10/1722		62				7.72
Royal Palm Ranger Station (LPIF1) (25.39N 80.68W)			10/1623	48 (10 min, 6 m)	79				11.31
South Florida Water Management District Sites									
Ave Maria (AVEMARIA) (26.30N 81.43W)			10/2200	57 (15 min, 8 m)	77				
Belle Glade (BELLW) (26.65N 80.63W)			10/2245	44 (15 min, 8 m)	62				
Brighton (S75WX) (27.19N 81.13W)			10/2345	48 (15 min, 8 m)	68				
Clewiston (CFSW) (26.73N 80.89W)			10/2300	43 (15 min, 8 m)	60				
Ft. Pierce (NCSF1) (27.47N 80.47W)									15.18

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Golden Gate Estates (SGGEW) (26.14N 81.58W)			10/2130	47 (15 min, 8 m)	84				10.36
Kissimmee River (S65DWX) (27.31N 81.02W)			10/2000	46 (15 min, 8 m)	63				
Lake Hatchineha (WRWX) (28.05N 81.40W)			11/0000	36 (15 min, 8 m)	48				6.78
Lake Istokpoga (S68) (27.33N 81.25W)									6.82
Lake Okeechobee Center (LZ40) (26.90N 80.79W)			11/0030	52	67				
Lake Okeechobee North (L001) (27.14N 80.79W)			11/0115	52	65				
Lake Okeechobee South (L006) (26.82N 80.78W)			11/0030	52	62				
Lake Okeechobee West (L005) (26.96N 80.94W)			11/0030	55	68				
Lake Tohopekaliga (S61W) (28.14N 81.35W)			11/0200	37 (15 min, 8 m)	70				
Miccosukee Village (3AS3W) (25.85N 80.77W)			10/1715	59 (15 min, 8 m)	75				
North Kissimmee River (S65AMW) (27.66N 81.13W)									7.69
Ortona (S78W) (26.79N 81.30W)			11/0015	44 (15 min, 8 m)	65				
The Redland (S331W) (25.61N 80.51W)			10/1700	44 (15 min, 8 m)	61				
Rotenberger WMA (ROTNWX) (26.33N 80.88W)			10/2130	47 (15 min, 8 m)	65				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Ten Mile Creek (TMWF1) (27.40N 80.43W)			10/1745	39 (15 min, 8 m)	57				11.82
West Palm Beach Forrest Hill (FHCHSX) (26.65N 80.07W)			10/1630	38 (15 min, 8 m)	67				
Yeehaw Junction - (YEHF1) (27.68N 81.02W)									10.61
United States Geological Survey (USGS) Storm Tide Sensors									
Everglades City (FLCOL03237) (25.85N 81.39W)							8.31		
Goodland (FLCOL03176) (25.92N 81.65W)							7.03		
Crescent Beach (FLSTJ03125) (29.76N 81.25W)							6.65		
Jacksonville Beach (FLDUV21045) (30.29N 81.39W)							6.55		
Miami – Dinner Key (FLMIA03335) (25.73N 80.24W)							5.75		
Lakes by the Bay – Black Creek Marina (FLMIA03786) (25.54N 80.33W)							5.61		
Miami – Matheson Hammock Park (FLMIA21077) (25.68N 80.26W)							5.36		
Marco Island – Tigertail Beach (FLCOL03171) (25.95N 81.74W)							5.20		
Naples (FLCOL03296) (26.13N 81.81W)							5.06		
Port of the Islands – Faka Union Canal (FLCOL03089) (25.96N 81.51W)							4.86		

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Miami – Black Creek (FLMIA21052) (25.55N 80.35W)							4.84		
Bonita Springs (FLLEE03292) (26.37N 81.81W)							4.64		
Ormond Beach (FLVOL03138) (29.29N 81.05W)							4.37		
Henderson Creek (FLCOL03148) (26.05N 81.71W)							4.12		
Homestead – Turkey Point (FLMIA03794) (25.44N 80.33W)							4.07		
Delnor-Wiggins State Park (FLCOL03294) (26.28N 81.83W)							3.90		
Karl E. Johnson State Park (FLLEE03288) (26.40N 81.88W)							3.56		
Pompano Beach (FLBRO03525) (26.22N 80.10W)							3.41		
Miami – Albert Pallot Park (FLMIA03213) (25.81N 80.19W)							3.35		
Boca Raton – Silver Palm Park (FLPAL03554) (26.35N 80.08W)							3.05		
CoCoRaHS Sites									
Aberdeen (FL-PB-77) (26.56N 80.17W)									8.68
Aberdeen 2 WNW (FL-PB-2) (26.58N 80.20W)									8.96
Alachua 5.2 NNW (FL-AL-56) (29.84N 82.51W)									11.03

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Apopka (FL-OR-16) (28.68N 81.47W)									11.58
Apopka (FL-OR-43) (28.67N 81.46W)									11.80
Arcadia 7.1 WSW (FL-DS-1) (27.18N 81.96W)									11.34
Auburndale 3.0 SSW (FL-PK-01) (28.03N 81.82W)									11.00
Avon Park 0.6 NW (FL-HL-10) (27.60N 81.51W)									9.42
Babson Park 0.9 NW (FL-PK-58) (27.84N 81.54W)									9.85
Biscayne Park (FL-MD-33) (25.88N 80.18W)									8.19
Belleview 4.8 E (FL-MR-18) (29.05N 81.97W)									9.50
Bloomingdale 1.3 ESE (FL-HB-14) (27.87N 82.24W)									7.32
Brooksville 1.2 E (FL-HN-17) (28.56N 82.37W)									6.59
Boynton Beach 1 WNW (FL-PB-70) (26.54N 80.10W)									7.56
Bunnell 1.0 ENE (FL-FL19) (29.47N 81.24W)									8.48
Chiefland 8.4 ENE (FL-LV-9) (29.50N 82.72W)									7.92
Chuluota (FL-SM-8) (28.65N 81.12W)									11.22
Cudjoe Key 0.9 SSW (FL-MN-6) (24.66N 81.51W)									9.76

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
De Land (FL-VL-21) (29.04N 81.33W)									11.53
De Land - Cocorahs (FL-VL-9) (29.10N 81.36W)									11.82
Englewood 3.7 NNW (FL-SS-44) (27.00N 82.39W)									6.30
Florida Gardens 3 N (FL-PB-87) (26.67N 80.18W)									6.61
Ft. Pierce (FL-SL-41) (27.56N 80.40W)									17.25
Gainesville 1.7 SE (FL-AL-26) (29.65N 82.32W)									10.94
Gainesville 2.4 SW (FL-AL-50) (29.64N 82.36W)									10.75
Gainesville 2.4 NW (FL-AL-57) (29.69N 82.36W)									12.22
Gainesville 3.8 W (FL-AL-10) (29.67N 82.40W)									10.89
Gainesville 5.4 W (FL-AL-48) (29.67N 82.43W)									8.87
Gainesville 7.5 WSW (FL-AL-60) (29.63N 82.45W)									11.15
Gainesville 7.7 W (FL-AL-55) (29.67N 82.46W)									10.33
Hernando 1.6 N (FL-CT-11) (28.93N 82.37W)									10.28
High Springs 3.2 SW (FL-AL-17) (29.78N 82.63W)									8.23
Interlachen 8.8 S (FL-MR-46) (29.48N 81.90W)									11.51
Keystone Heights 1.8 ESE (FL-CY-24) (29.76N 82.01W)									10.36

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Keystone Heights 3.5 ENE (FL-CY-7) (29.79N 81.98W)									6.78
Keystone Heights 10 NE (FL-CY-38) (29.88N 81.91W)									8.55
Key Largo 5.3 SW (FL-MN-4) (25.05N 80.49W)									9.98
Key Largo 6.2 NE (FL-MN-25) (25.17N 80.37W)									6.93
Key West 1.3 ENE (FL-MN-16) (24.57N 81.76W)									9.03
LaBelle 2 WNW (FL-HY-3) (26.76N 81.48W)									10.31
Lady Lake (FL-LK-16) (28.89N 81.94W)									11.03
Lake City 7.9 SSW (FL-CB-12) (30.08N 82.69W)									8.44
Lake Wales 0.7 SE (FL-PK-59) (27.89N 81.58W)									9.84
Leesburg (FL-LK-30) (28.84N 81.91W)									10.13
Marathon 6.8 ENE (FL-MN-23) (24.74N 80.98W)									9.42
Micanopy 2.1 NNE (FL-AL-51) (29.53N 82.26W)									10.70
Micanopy 4.6 SSE (FL-MR-42) (29.44N 82.25W)									6.83
Mims (FL-VL-49) (28.69N 80.99W)									12.87
Miramar 1 WSW (FL-BW-10) (25.98N 80.37W)									9.92
North Port 2.6 E (FL-SS-34) (27.05N 82.15W)									6.55

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Ocala 1.1 SE (FL-MR-54) (29.17N 82.12W)									8.63
Ocala 10.7 WSW (FL-MR-56) (29.12N 82.29W)									9.90
Ocala 11.2 SW (FL-MR-59) (29.07N 82.26W)									9.96
Ocala 4.6 N (FL-MR-57) (29.25N 82.13W)									10.12
Ocala 9.80 SW (FL-MR-43) (29.08N 82.24W)									9.91
Ocala 14.3 S (FL-MR-36) (28.97N 82.13W)									9.65
Ocklawaha 4.9 NE (FL-MR-22) (29.09N 81.87W)									9.00
Orange (FL-OR-23) (28.59N 81.11W)									10.51
Orange Park 1.8 WSW (FL-CY-25) (30.15N 81.73W)									11.03
Orlando (FL-OR-27) (28.59N 81.11W)									10.51
Oviedo (FL-SM-12) (28.66N 81.25W)									12.14
Palm Coast 0.6 ESE (FL-FL-21) (29.56N 81.20W)									7.67
Palm Coast 1.9 S (FL-FL-26) (29.54N 81.21W)									6.72
Palm Coast 5.9 S (FL-FL-25) (29.48N 81.21W)									9.10
Palm Bay (FL-BV-1) (27.95N 80.64W)									11.10

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Palm Shores (FL-BV-2) (28.19N 80.68W)									10.01
Penney Farms (FL-CY-41) (29.98N 81.81W)									7.46
Poinciana Place 2.5 SSW (FL-PK-53) (28.12N 81.50W)									10.14
Port St. Lucie (FL-SL-19) (27.32N 80.31W)									10.36
Riverview 4.8 SSW (FL-HB-98) (27.80N 82.34W)									6.82
Ruskin 1.8 ESE (FL-HB-44) (27.71N 82.40W)									6.78
Sebring 4.7 WNW (FL-HL-13) (27.52N 81.53W)									10.54
Starke 0.9 ESE (FL-BF-2) (29.94N 82.10W)									11.74
The Villages 2.7 NNW (FL-ST-13) (28.90N 81.97W)									9.18
Titusville (FL-BV-38) (28.63N 80.86W)									11.33
Trenton 4 NW (FL-GC-8) (28.63N 80.86W)									6.53
Trenton 8.0 ENE (FL-GC-1) (29.65N 82.69W)									7.60
Union Park (FL-OR-10) (28.59N 81.22W)									13.79
Valrico 1.1 SE (FL-HB-3) (27.93N 82.23W)									6.52
Valrico 2.2 SE (FL-HB-4) (27.91N 82.23W)									6.31

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Vero Beach (FL-IR-15) (27.64N 80.42W)									10.00
Weeki Wachee 7.1 NNE (FL-HN-24) (28.61N 82.54W)									7.36
Weston 2 SSE (FL-BW-99) (26.13N 80.39W)									8.80
NWS Cooperative Observer Program (COOP) Sites									
Bahia Honda Key 1 WSW (BPNF1) (24.66N 81.28W)									7.58
Boca Raton 12 W (WBCF1) (26.36N 80.30W)									9.24
Buckhead Ridge 7 WSW (IPEF1) (27.09N 81.01W)									6.18
Buckhead Ridge 9 SW (NWLF1) (27.03N 81.00W)									7.11
Buckhead Ridge 12 WSW (BRGF1) (27.03N 81.07W)									7.30
Buckhead Ridge 14 WNW (IPIF1) (27.19N 81.13W)									6.03
Buckhead Ridge 15 W (IPRF1) (27.12N 81.16W)									6.18
Carol City 2 NW (LLUF1) (25.97N 80.30W)									8.00
Coral Springs 3 SW (CSGF1) (26.23N 80.30W)									9.72
Cutler Bay 3 NE (CTRF1) (25.61N 80.31W)									6.48
Cutler Bay 3 SSE (BCPF1) (25.54N 80.33W)									6.07

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Deerfield Beach 2 WNW (BORF1) (26.33N 80.13W)									6.76
El Portal (ELPF1) (25.85N 80.19W)									6.79
Florida City 5 SW (EVGF1) (25.40N 80.56W)									6.49
Ft. Lauderdale 4 W (FTDF1) (26.14N 80.20W)									9.90
Ft. Pierce WP (FPCF1) (27.44N 80.35W)									21.66
Juno Beach (JUBF1) (26.86N 80.06W)									6.47
Jupiter 3 W (JPTF1) (26.93N 80.14W)									6.32
Lake Harbor (SLOF1) (26.70N 80.81W)									7.75
Lakeport 2 E (LKPF1) (26.98N 81.09W)									6.60
Lauderdale Lakes 1 E (LDLF1) (26.17N 80.18W)									7.68
Leisure City 5 E (BHMF1) (25.49N 80.35W)									6.88
Melbourne WFO (MLBF1) (28.11N 80.65W)									11.82
Miami Lakes (MMLF1) (25.91N 80.32W)									6.33
Miami Springs 2 E (MINF1) (25.81N 80.26W)									6.94
Moore Haven (MHVF1) (26.84N 81.09W)									7.70

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Moore Haven 3 NW (MRHF1) (26.86N 81.14W)									6.98
Mt. Plymouth (PLTF1) (28.79N 81.53W)									11.59
Naples 7 E (NPLF1) (26.17N 81.68W)									11.46
Plantation 2 SE (PLAF1) (26.09N 80.23W)									8.10
Plantation7 W (WSTF1) (26.13N 80.37W)									10.81
Pompano Beach (PNOF1) (26.23N 80.12W)									6.39
Princeton (PRNF1) (25.54N 80.41W)									6.79
Richmond Heights 7 WNW (RHWF1) (25.66N 80.48W)									6.18
Sanford (SFNF1) (28.81N 81.28W)									11.95
South Bay 13 SSE (SWAF1) (26.48N 80.65W)									6.03
Stuart (STRF1) (27.19N 80.24W)									10.53
Sunrise (SNRF1) (26.16N 80.30W)									7.95
Sweetwater 9 W (TTLF1) (25.76N 80.50W)									6.11
Regional Observation Monitoring Program Sites (ROMP)									
Avon Park Romp 43XX (7174) (27.60N 81.48W)									8.19

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Brownsville Romp 26 (4334) (27.30N 81.82W)									8.77
Caspersen Romp TR 4-1 (8634) (27.06N 82.44W)									6.71
Cecil Webb Romp 5 (2754) (26.95N 81.81W)									8.86
Cristina Romp 62 (8414) (27.86N 82.31W)									6.06
Cumpressco Romp 89 (1834) (28.36N 82.04W)									11.34
Dade City Romp 90 (6174) (28.36N 82.14W)									8.67
Davenport Romp 74X (8094) (28.16N 81.57W)									9.64
Fort Meade Romp 45 (1354) (27.76N 81.79W)									10.11
Fort Ogden Romp 16.5 (5094) (27.06N 81.88W)									8.38
Green Swamp Romp 87 (1254) (28.22N 82.03W)									9.61
Hicoria Romp 14 (7554) (27.15N 81.35W)									8.65
Horse Creek Romp 17 (1554) (27.17N 81.96W)									8.94
Horse Lake Romp 105 (8454) (28.56N 82.40W)									7.33
Josephine Creek Romp 28 (2634) (27.37N 81.44W)									9.18

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Joshua Creek Romp 16 (1574) (27.19N 82.13W)									8.04
Kuka Romp CB-1NW (7274) (28.43N 82.48W)									6.47
Lake Medard Romp 61 (1854) (27.91N 82.16W)									6.57
Lake Placid Romp 28X (1494) (27.27N 81.34W)									7.82
Lemon Bay Romp TR 3-3 (7594) (26.93N 82.33W)									6.49
Lily Romp 25 (7954) (27.37N 81.01W)									8.40
Long Island Marsh Romp 15 (7934) (27.21N 81.66W)									8.80
Mulberry Romp 60 (1314) (27.89N 81.98W)									6.36
Murdock Romp 18 (8514) (27.19N 82.13W)									7.00
Myakka City Romp 23 (1474) (27.31N 82.18W)									6.64
Myakka Head Romp 32 (1414) (27.47N 82.06W)									7.14
North Port Romp 9 (7834) (27.08N 82.15W)									8.03
Old Polk City Romp 76 (8114) (28.18N 81.83W)									8.66
ONA Romp 31 (1434) (27.45N 81.92W)									6.34

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Ozello Romp TR 21-2 (1174) (28.85N 82.60W)									7.43
Prairie Creek Romp 12 (2834) (27.04N 81.74W)									9.51
Ringgold Romp 107 (1214) (28.66N 82.46W)									6.30
Rock Ridge Romp 88 (1874) (28.31N 81.91W)									9.62
Romp 35 (3394) (27.29N 82.04W)									6.95
Romp 39 (2594) (27.59N 82.25W)									6.37
Romp 131 (4434) (28.33N 82.56W)									7.26
Rutland Romp 112 (8434) (28.88N 82.23W)									8.48
Shell Creek Romp 11 (1614) (26.98N 81.94W)									6.79
Starling Romp 123 (1374) (27.68N 82.25W)									6.20
Tippen Bay Romp 13 (2614) (27.07N 81.62W)									8.96
Tsala Apopka Romp 116 (6734) (28.96N 82.34W)									10.19
Romp TR 1-2 (7754) (26.84N 81.98W)									7.98
Romp TR 3-1 (1594) (26.94N 82.22W)									7.33

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Romp TR 5-3 (8574) (27.16N 82.40W)									6.79
Utopia Romp 22 (7474) (27.31N 82.34W)									6.21
Warner Southern Romp 44 (8054) (27.82N 81.60W)									9.46
Waterbury Romp 33 (7694) (27.46N 82.26W)									6.62
Williston Romp 134 (6774) (28.75N 82.23W)									7.77
Winter Haven Romp 73 (8034) (28.02N 81.73W)									7.43
Zolfo Springs Romp 30 (2794) (27.46N 81.80W)									10.58
Other Sites									
Airglades FAWN Clewiston (AIRGL) (26.73N 81.05W)			11/0015	59 (15 min, 10 m)	78				
Alachua 5 SE (29.72N 82.42W)									7.51
Alva (ALVA) (26.71N 81.61W)									7.05
Apopka - FAWN (POPF1) (28.64N 81.55W)			11/0530	32	53				11.01
Arcadia – FAWN (ARCAD) (27.23N 81.84W)			11/0130	41	67				9.83
Avon Park Bomb Range (AVONPK) (27.63N 81.26W)									8.23
Bellair 4 W (29.75N 82.93W)									15.11

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Belle Glade 3 SE FAWN (BLDF1) (26.65N 80.64W)			10/2245	44	57				10.35
Belleview 3 SSW (29.01N 82.07W)									9.64
Bird Creek (4074) (29.01N 82.75W)									6.33
Bithlo - USGS (WELF1) (28.44N 81.17W)									10.54
Bonita Springs Utilities (BSUTIL) (26.34N 81.75W)									9.92
Boca Raton 2 NNW (E5514) (26.39N 80.11W)									7.36
Bowling Green (7114) (27.64N 81.84W)									8.94
Bronson - FAWN (BRZF1) (29.40N 82.59W)			11/0545	23	43				6.81
Broward County EOC (26.12N 80.27W)			10/2100	50	67				
Chinsegut Hill (9174) (28.62N 82.37W)									7.65
Christmas - Spotter (ORA-048) (28.57N 81.02W)									17.44
Clewiston 7 W (CLWF1) (26.75N 80.94W)									9.65
Coleman LP-6 (2774) (28.81N 82.09W)									9.26
Coley NR Frostproof (6070) (27.74N 81.53W)									8.45

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Collier County EOC (NPLCC) (26.11N 81.69W)			10/2000	71	106				
Coral Springs (CRLCG) (26.26N 80.30W)			10/1900	43	77				
Creek Ranch (CREEKR) (28.04N 81.46W)									7.93
Cypress Creek TMR-5 (2734) (28.26N 82.40W)									7.48
Dade City - FAWN (311) (28.35N 82.20W)			11/0615	27	42				8.67
Davie - FAWN (FDLF1) (26.09N 80.30W)			10/1900	30	57				9.68
Daytona Beach Embry Riddle (KFLDAYTO14) (29.19N 81.05W)			11/0324	61	70				
Deerfield Beach (DRFCE) (26.31N 80.15W)			10/2200	61	87				
Doral (WFORT) (25.79N 80.34W)			10/1800	41	83				
DV-1 Dover (1294) (27.99N 82.21W)									6.95
DV-2 Dover (7714) (27.97N 82.15W)									7.12
East Palatka 3.5 NNW (29.69N 81.62W)									10.96
Fernandina Beach (30.65N 81.45W)									12.70
Fernandina Beach 0.4 N (30.66N 81.45W)									9.86

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Fernandina Beach 6.3 S (30.56N 81.45W)									9.92
Floral City Pool (2014) (28.75N 82.28W)									8.52
Florence 9 N (29.86N 81.88W)									8.55
Ft. Wilderness - Reedy Creek (M) (28.41N 81.56W)									10.21
Gateway (GATEWAY) (26.57N 81.74W)									7.38
Geneva - USGS (GNEF1) (28.71N 81.04W)									11.74
Green Cove Springs 2.6 WNW (30.00N 81.72W)									10.48
Hanna Lake (7534) (28.14N 82.45W)									6.07
Hernando Pool (2054) (28.90N 82.37W)									8.13
Indian Lakes Fire (INDIANL) (27.79N 81.33W)									9.21
Indian River - FAWN (IRVF1) (27.62N 80.57W)			11/0400	31	46				14.15
Inverness Pool (2034) (28.85N 82.32W)									8.20
Island Ford Lake (1634) (28.15N 82.60W)									6.24
Jacksonville 6.7 WSW (30.30N 81.76W)									7.37

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Jacksonville 10 SW (30.24N 81.79W)									11.04
Jacksonville 12 SSE (30.18N 81.57W)									11.00
Jacksonville Heights 5 WNW (30.27N 81.86W)									7.54
Johnson Pond (2294) (29.50N 82.38W)									7.98
Joshua - FAWN (241) (27.26N 81.61W)									8.72
Lake Apopka NSRA - SJRWMD (M) (28.65N 81.57W)									10.65
Lake Arbuckle (ARBCKL_P) (27.66N 81.37W)									6.36
Lake Buena Vista - Reedy Creek (M) (28.39N 81.52W)									10.65
Lake Gibson 2 (2434) (28.10N 81.95W)									8.59
Lake Hamilton (1754) (28.04N 81.64W)									8.68
Lake Henry (1814) (28.08N 81.66W)									8.84
Lakeland L. Field (KLAL) (27.99N 82.01W)			11/0415	44	58				
Lake Lowery (6184) (28.13N 81.69W)									8.41
Lake Mary - USGS (LSPF1) (28.79N 81.41W)									12.46

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Lakes Regional Park (LAKES) (26.53N 81.89W)									9.20
Lauderhill (FRBCS) (26.12N 80.18W)			10/1300	43	70				
Lecanto - FAWN (275) (28.83N 82.50W)			11/0315	23	36				8.41
Lehigh Acres (LEHI) (26.61N 81.65W)									10.07
Leslie Heifner (6774) (28.75N 82.23W)									7.72
Lorida-McArthur (MCARTH) (27.44N 81.21W)									7.79
Lovers Key (LOVERSKE) (26.39N 81.87W)									8.78
Magic Kingdom - Reedy Creek (M) (28.43N 81.58W)									10.29
Mandarin 4 NNE (30.20N 81.61W)									7.35
Marco Island PD (25.94N 81.71W)			10/1900		113				
Marco Island – (Spotter) (25.92N 80.73W)		936.9		97	112				
Big Pine Key – (Spotter) (21.67N 81.35W)	10/1216	933.7							
Margate (PMPNB) (26.25N 80.19W)			10/1925	46	69				
McIntosh (5074) (28.07N 82.14W)									7.51
MIA - ITWS (25.80N 80.29W)			10/1646	58 (1 min, 15 m)	86				
Melbourne Shores (KFLMELBO72) (27.96N 80.51W)			11/0325	56 (10.4 m)	75				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Middleburg 8.8 E (30.04N 81.75W)									11.32
Moore Haven (MRHMG) (26.83N 81.10W)			10/2300	47	68				
N. Serv (NRESV) (26.71N 81.84W)									9.68
Naples 1 E (NPLMP) (26.15N 81.77W)			10/2000	81	123				
National Weather Service Miami (25.76N 80.38W)		989.5	10/1708		70				
Near N Perry Airport (CLWCH) (26.04N 80.22W)			10/1950	70	95				
North Kissimmee River (KREF) (27.75N 81.18W)									9.48
North Port - FAWN (NPORT) (27.14N 82.34W)			10/2330	31	51				7.44
Oakland Park (FTPCS) (26.20N 80.13W)			10/2100	43	74				
Olga (OLGA) (26.72N 81.68W)									8.81
Olustee 3 N (30.24N 82.43W)									9.76
Ortega 1 WNW (30.27N 81.72W)									11.11
Palm Bay Public Works - SJRWMD (M) (27.99N 80.70W)									10.52
Palm Bay Stp - SJRWMD (M) (28.02N 80.60W)									10.67

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Palmdale - FAWN (PALF1) (26.94N 81.31W)			11/0045	36	59				8.38
Pana Vista Lake Panasoffkee (8974) (28.81N 82.14W)									9.98
Parkland (PRKLN) (26.30N 80.27W)			10/2000	42	71				
Parrish Park - SJRWMD (M) (28.76N 80.88W)									10.07
Peace River (7394) (27.09N 82.01W)									8.43
Pembroke Park (HLLYW) (25.99N 80.16W)			10/2200	47	75				
Pembroke Pines (PBRPN) (26.01N 80.27W)			10/1520	53	95				
Pierson - USGS (LGRF1) (29.23N 81.49W)									10.03
Plant City 3 W (Spotter) (28.04N 82.16W)	11/0509	964.4	11/0142	63 (10 sec, 7 m)	71				
Raiford 0.9 NE (30.04N 82.23W)									9.62
Ransom Rd - NASA - SJRWMD (M) (28.51N 80.68W)									11.34
Rock Springs Well - SJRWMD (28.77N 81.44W)									11.16
S-161 Along Harney Rd (6614) (28.02N 82.37W)									6.52
Saddle Creek (1774) (27.94N 81.85W)									8.90

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Satsuma 4 NE (29.59N 81.61W)									10.05
Sebring - FAWN (SEBF1) (27.42N 81.40W)			11/0300		49				9.03
Sebring (SEBRNG) (27.46N 81.35W)									7.92
St. Augustine South (29.84N 81.31W)									10.22
St. George Island Bridge (Weatherstem) (29.69N 84.89W)			11/1210	47	47				
St Pete 42 (3014) (28.18N 82.52W)									7.58
Southwest Ranches (WSTNF) (26.06N 80.39W)			10/1700	47	85				
Starkey (3154) (28.25N 82.35W)									6.69
Sunrise (FTDST) (26.16N 80.25W)			10/1700	45	71				
Sunrise (SNRSC) (26.16N 80.29W)			10/2100	42	85				
SWFWMD Headquarters (7094) (28.47N 82.44W)									6.46
Tampa SVC Office (9274) (28.02N 82.35W)									6.87
Taylor 7 NNW (30.53N 82.34W)									7.79
Ten Mile Canal NR Daniel (10MILE) (26.55N 81.86W)									10.03

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
The Villages 2.8 ESE (28.90N 81.97W)									10.59
Tick Island-Kiss. River (TICK) (27.69N 81.19W)									8.38
Umatilla - FAWN (UMLF1) (28.93N 81.65W)			11/1100	29	45				10.49
University Park (MFL) (25.75N 80.38W)									6.96
Urban Estates (NPLLV) (26.27N 81.75W)			10/2100	48	97				
Venus (VENUSR) (27.08N 81.34W)									8.40
Vilano Beach 4 NNW (30.02N 81.32W)	11/0308	1005.0	10/2223	51	60				
Walt Disney World Svc Area - Reedy Creek (28.38N 81.59W)									10.21
Wasteplant (WTEP) (26.63N 81.76W)									11.59
Webster City (9074) (28.61N 82.05W)									10.60
West Miami (MMMCH) (25.74N 80.30W)			10/1540	59	81				
Wildwood II (7034) (28.86N 82.03W)									8.57
Whidden Properties (WHID) (26.95N 81.57W)									9.76
Wilton Manors 1 S (D0271) (26.14N 80.13W)									9.94

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Withlacoochee River (6082) (28.48N 82.18W)									10.31
Wolfe Nr Jumping Gully (7254) (28.38N 82.50W)									6.49
Yeehaw Junction - SJRWMD (M) (27.70N 80.90W)									12.00
Yellow Fever Creek (YELLOWFE) (26.68N 81.90W)									6.78
Georgia									
International Civil Aviation Organization (ICAO) Sites									
Atlanta International Airport (KATL) (33.64N 84.43W)	12/0200	999.0	11/1910	39 (2 min, 10 m)	56				
Bacon County Airport - GA (KAMG) (31.54N 82.51W)			11/1314		38				6.04
Brunswick/Clynco Airport (KBQK) (31.15N 81.47W)			11/0915	35 (2 min, 10 m)	52				
Hunter Army Airfield (KSVN) (32.01N 81.16W)			11/1458	33	51				6.47
Middle Georgia Regional AP (KMCN) (32.69N 83.65W)	11/2110	994.6	11/1555	37 (2 min, 10 m)	53				
Savannah Intl Airport - GA (KSAV) (32.13N 81.20W)	11/1956	997.6	11/1152	38 (2 min, 10 m)	52				
Valdosta - GA (KVLD) (30.97N 83.28W)	11/0953	996.5	11/1005	36 (2 min, 10 m)	49				
Valdosta/Moody AFB - GA (KVAD) (30.97N 83.20W)	11/1443	984.8	11/1214	38 (2 min, 10 m)	54				
Coastal-Marine Automated Network (C-MAN), and NOS Sites									
Fort Pulaski (FPKG1) (32.03N 80.90W)	11/1706	999.7	11/1218	42 (6.5 m)	61	5.63	8.18	4.7	
Weatherflow Sites									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Jeckyll Island - GA (XJEK) (31.05N 81.41W)	11/1322	988.0	11/1337	50	67				
Tybee Island North - GA (XTYB) (32.02N 80.84W)	11/1729	997.0	11/1219	43 (10 m)	56				
Tybee Island South - GA (XTYE) (31.99N 80.85W)	11/1702	997.0	11/1447	43 (9.1 m)	55				
Remote Automated Weather Stations (RAWS) and HADS Sites									
Baxley (BXTG1) (31.71N 82.39W)			11/1504		56				
Jones Island Okefenokee (JONG1) (30.82N 82.36W)			11/1801		44				
Okefenokee NWR East (TS818) (30.74N 82.13W)			11/1801		44				
Okefenokee NWR West (TT331) (30.97N 82.40W)			11/1801		48				
Sapelo Island Reserve (SAXG1) (31.42N 81.30W)	11/1415	994.0	11/2000	35 (10 m)	52				7.20
Sterling Glynn (STRG1) (31.25N 81.61W)			11/1104		48				
Waycross (OKEG1) (31.24N 82.40W)			11/1004		55				
CoCoRaHS Sites									
Reevesville 1 SSE (SC-DC-18) (33.18N 80.64W)									6.00
Richmond Hill 1 NE (GA-BR-2) (31.94N 81.30W)									6.66
Richmond Hill 7 ESE (GA-BR-5) (31.88N 81.20W)									6.67
Rincon 5 NNE (GA-EF-18) (32.36N 81.21W)									7.86

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
NWS Cooperative Observer Program (COOP) Sites									
Darien 7 NNE (MERG1) (31.45N 81.36W)									6.00
Fort Stewart (FSBG1) (31.96N 81.46W)									6.63
Richmond Hill 3 NE (RICG1) (31.97N 81.29W)									6.12
Sapelo Island (SPIG1) (31.39N 81.28W)									7.53
Other Sites									
Atkinson 1 WSW (31.21N 81.87W)									8.74
Blackshear 5 NNW (31.36N 82.28W)									8.45
Decatur (33.71N 84.24W)									6.32
Deenwood 2 W (31.25N 82.40W)			11/0604		48				
Fargo 2 NE (30.70N 82.54W)									8.66
Folkston 10 SW (30.73N 82.13W)									9.30
Homeland (30.85N 82.02W)									9.85
Jesup 4.2 NNW (31.65N 81.92W)									7.22
Jesup 10 NNW (31.73N 81.95W)									6.96

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Kingsland 2 SSE (30.75N 81.65W)			11/0511		49				
Kingsland 3 WSW (30.77N 81.71W)									6.84
Little Satilla River (31.45N 82.05W)									7.14
Nahunta 6 S (31.12N 81.98W)									10.34
Pearson 3.5 NE (31.33N 82.81W)									6.50
Satilla River HWY 158 (31.30N 82.56W)									6.49
Screven 2.3 ENE (31.49N 81.98W)									8.56
Steven Foster St Park 1 WNW (30.83N 82.36W)									7.66
Steven Foster St Park 11 NNW (30.98N 82.40W)			11/0510		42				
Sun Belt Ag Expo Weatherstem (31.13N 83.71W)		992.2	11/1214	37	41				
Suwanee River US Hwy 44 (30.68N 82.56W)									8.44
Thalmann 5 ESE (31.26N 81.61W)			11/0704		42				9.65
Waycross (31.21N 82.36W)									6.86
South Carolina									
International Civil Aviation Organization (ICAO) Sites									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Beaufort County Airport - SC (KARW) (32.41N 80.63W)	11/1355	1001.4	11/1235	35 (2 min, 10 m)	51				
Charleston Executive Airport (KJZI) (32.70N 80.01W)	11/2035	1003.4	11/1615	35 (2 min, 10 m)	51				
Charleston Intl Airport (KCHS) (32.90N 80.04W)	11/1846	1000.6	11/1609	37 (2 min, 10 m)	52				
Coastal-Marine Automated Network (C-MAN), and NOS Sites									
Charleston (CHTS1) (32.78N 79.93W)	11/1654	1002.8	11/1654	42 (8.8 m)	53	4.86	6.78	4.2	
Oyster Landing (N Inlet Estuary) (NIWS1) (33.35N 79.19W)						4.64	5.75	3.4	
Springmaid Pier (MROS1) (33.66N 78.92W)	12/0224	1006.6				3.27	5.31	2.9	
Folly Beach C-MAN (FBIS1) (32.69N 79.89W)	11/2200	1004.3	11/1620	44 (10 m)	56				
Sumter/Charleston Harbor (XSUM-FT) (32.75N 79.87W)	11/1651	1001.0	11/1656	43 (12.1 m)	56				
Weatherflow Sites									
Beaufort (XBUF) (32.34N 80.59W)	11/1351	995.0	11/1356	49 (10 m)	66				
Charleston/Battery Point (XCHA) (32.76N 79.95W)	11/1700	998.0	11/1620	42 (10 m)	57				
Folly Beach Pier (XFOL) (32.65N 79.94W)	11/2144	1001.0	11/1604	51 (12.8 m)	63				
Isle of Palms (XIOP) (32.78N 79.79W)	11/1830	1002.0	11/1645	49 (9.4 m)	59				
Sullivans Island (XSUL) (32.77N 79.82W)	11/1645	1001.0	11/1655	46 (12.8 m)	59				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
CoCoRaHS Sites									
Beaufort 4 NNE (SC-BF-35) (32.47N 80.67W)									9.07
Bluffton 7 W (SC-BF-50) (32.21N 80.98W)									6.13
Bluffton 6 WNW (SC-BF-10) (32.26N 80.96W)									7.44
Canadys (SC-CL-6) (33.05N 80.63W)									7.33
Charleston 2 S (SC-CR-88) (32.75N 80.00W)									7.26
Charleston 2 SE (SC-CR-89) (32.76N 79.98W)									7.95
Charleston 5 SSE (SC-CR-13) (32.72N 79.96W)									7.82
Charleston 2 W (SC-CR-34) (32.78N 80.03W)									6.90
Charleston 3 W (SC-CR-11) (32.78N 80.05W)									6.30
Cottageville 3 NNW (SC-CL-17) (32.77N 79.82W)									6.01
Charleston 6 NW (SC-CR-45) (32.83N 80.07W)									8.53
Charleston 5 WNW (SC-CR-97) (32.80N 80.07W)									8.86
Cottageville 6 WSW (SC-CL-16) (32.89N 80.57W)									6.01
Daniel Island 1 SE (SC-BK-48) (32.84N 79.90W)									7.29

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Goose Creek 5 WNW (SC-BK-17) (33.00N 80.08W)									6.45
Hollywood 2 S (SC-CR-10) (32.75N 80.24W)									6.38
Lodge 3 SW (SC-CL-9) (33.02N 80.99W)									6.97
Meggett 2 W (SC-CR-32) (32.70N 80.29W)									7.27
Moncks Corner 4 E (SC-BK-38) (33.19N 79.94W)									7.28
Moncks Corner 7 SW (SC-BK-25) (33.11N 80.07W)									6.33
NWS Charleston (SC-CR-49) (32.89N 80.03W)									6.30
North Charleston 3 NW (SC-CR-34) (32.92N 80.07W)									6.82
North Charleston 3 WNW (SC-DC-3) (32.92N 80.08W)									6.87
Pineville (SC-BK-29) (33.42N 80.03W)									6.10
Ravenel 2 WNW (SC-CR-92) (32.78N 80.26W)									6.48
Reevesville 1 SSE (SC-DC-18) (33.18N 80.64W)									6.00
Summerville 2 N (SC-DC-41) (33.03N 80.17W)									7.51
Summerville10 NNE (SC-BK-43) (33.12N 80.09W)									6.24

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[C]	Storm tide (ft)[D]	Estimated Inundation (ft)[E]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Summerville 5 NNW (SC-BK-46) (33.07N 80.22W)									6.43
Summerville 2 SSE (SC-DC-52) (32.97N 80.17W)									7.28
Summerville 1 SSW (SC-DC-36) (32.98N 80.18W)									7.02
NWS Cooperative Observer Program (COOP) Sites									
Edisto Island Middleton (EDSS1) (32.60N 80.33W)									6.10
Sullivans Island (SULS1) (32.76N 79.85W)									6.26
Summerville 4 W (SMVS1) (33.03N 80.23W)									6.35
Yemassee 1 N (YEMS1) (32.70N 80.85W)									7.00
Other Sites									
Bennetts Point (ACXS1) (32.55N 80.45W)									6.06
Charleston 6 NW (BEES1) (32.83N 80.07W)									8.97
Furman 1 SW (YMFS1) (32.66N 81.20W)									8.22
Mount Pleasant (MWPS1) (32.80N 79.90W)									6.44

[A] Date/time is for sustained wind when both sustained and gust are listed.
[B] Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.
[C] Storm surge is water height above normal astronomical tide level.
[D] Storm tide is water height above the North American Vertical Datum of 1988 (NAVD88) in the continental United States. Storm tide is water height above the Puerto Rico Vertical Datum of 2002 (PRVD02) in Puerto Rico and above the Virgin Islands Vertical Datum of 2009 (VIVD09) in the U.S. Virgin Islands.

[E] Estimated inundation is the maximum height of water above ground. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.
[F] Last of several occurrences.
[G] Wind speed data missing 0510-0650 UTC 3 October 2016.
[H] All wind data missing 0800-1000 UTC 6 October 2016.
[I] Record water level.
[J] Station went offline and did not transmit a peak water level during the event. Peak values represent the highest transmitted prior to outage.
[K] All wind data missing 1300 UTC 9 October – 0200 10 October 2016.
[L] Water levels within the St. Johns River are were affected by a combination of storm surge and freshwater runoff.

Table 4. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	42	78
Medium (40%-60%)	30	48
High (>60%)	12	36

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for forecasts issued for Hurricane Irma, 30 August–12 September 2017. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**14.8**	**25.5**	**37.6**	**50.5**	**73.9**	**101.8**	**135.0**
OCD5	31.2	74.3	122.2	175.8	291.7	463.2	677.1
Forecasts	49	47	45	43	39	35	31
OFCL (2012-16)	24.9	39.6	54.0	71.3	105.8	155.4	208.9
OCD5 (2012-16)	47.3	103.9	167.8	230.3	343.1	442.6	531.0

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for forecasts issued for Hurricane Irma, 30 August–12 September 2017. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	14.5	25.8	38.9	51.8	74.7	104.2	140.2
OCD5	29.9	73.8	124.2	181.0	302.0	473.4	691.0
GFSI	18.7	33.7	50.5	68.2	105.5	153.7	205.5
HMNI	18.1	31.9	45.2	63.8	110.0	156.6	213.6
HWFI	20.5	37.9	52.5	67.0	87.8	117.1	150.8
EGRI	15.2	27.1	43.7	64.2	113.8	170.3	212.5
EMXI	**14.3**	**23.3**	**33.2**	**40.3**	**54.9**	**78.2**	**119.5**
CMCI	20.6	33.2	47.8	61.5	87.8	129.5	182.1
CTCI	19.5	38.8	58.6	80.9	136.5	208.5	296.7
AEMI	18.9	32.1	46.9	62.7	94.8	138.7	188.5
HCCA	14.5	26.1	**37.7**	**47.8**	**65.1**	**84.7**	**106.8**
TVCA	15.2	27.6	40.9	55.7	89.2	129.8	176.6
TVCX	**14.1**	26.4	39.1	53.0	82.4	119.5	165.1
FSSE	14.9	**25.0**	**35.7**	**43.7**	**64.1**	**97.0**	**120.6**
GFEX	**14.2**	26.1	39.6	52.2	77.9	111.5	152.2
TABS	29.3	44.9	56.9	64.5	89.2	137.8	190.2
TABM	20.1	33.5	51.9	68.7	99.9	147.6	193.4
TABD	24.9	56.7	75.7	84.1	109.2	154.9	207.1
Forecasts	45	43	41	39	35	31	27

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Irma, 30 August–12 September 2017. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	9.0	12.4	15.8	17.4	18.7	24.9	29.7
OCD5	11.0	17.1	22.3	27.0	33.5	39.8	39.5
Forecasts	49	47	45	43	39	35	31
OFCL (2012-16)	5.5	8.2	10.5	12.0	13.4	14.0	14.5
OCD5 (2012-16)	7.1	10.5	13.0	15.1	17.4	18.2	20.6

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for forecasts issued for Hurricane Irma, 30 August–12 September 2017. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	9.0	11.6	15.1	17.3	19.4	26.1	30.2
OCD5	10.9	16.1	21.3	26.6	34.3	40.7	38.9
HMNI	**8.9**	**9.8**	**13.2**	**15.8**	19.5	**25.6**	**28.1**
HWFI	**8.7**	11.7	**13.2**	**14.1**	**15.4**	**22.1**	**30.0**
CTCI	9.3	11.9	**14.6**	**16.6**	**14.7**	**15.8**	**23.9**
DSHP	10.0	14.4	18.3	19.0	23.3	30.9	34.4
LGEM	9.6	13.6	18.1	18.4	21.8	30.1	33.5
IVCN	**8.1**	**10.4**	**13.1**	**14.1**	**16.1**	**23.8**	**28.7**
HCCA	**7.9**	**10.4**	**12.7**	**14.0**	**16.0**	**24.4**	33.1
FSSE	**8.0**	**9.9**	**11.6**	**12.5**	**17.6**	28.7	33.9
GFSI	10.4	13.8	16.6	20.6	27.3	32.7	35.0
EMXI	12.8	19.2	25.4	29.6	33.3	33.4	32.5
Forecasts	46	44	42	40	36	32	28

Table 7. Hurricane and tropical storm watch and warning summary for Hurricane Irma, 30 August–12 September 2017.

Date/Time (UTC)	Action	Location
3 / 2100	Hurricane Watch issued	Antigua, Barbuda, Anguilla, Montserrat, St. Kitts and Nevis
3 / 2100	Hurricane Watch issued	Saba, St. Eustatius, and St. Maarten
3 / 2100	Hurricane Watch issued	St. Martin and St. Barthelemy
4 / 1500	Hurricane Watch changed to Hurricane Warning	Antigua, Barbuda, Anguilla, Montserrat, St. Kitts and Nevis
4 / 1500	Hurricane Watch changed to Hurricane Warning	Saba, St. Eustatius, and St. Maarten
4 / 1500	Hurricane Watch changed to Hurricane Warning	St. Martin and St. Barthelemy
4 / 1500	Tropical Storm Watch issued	Dominica
4 / 1500	Hurricane Watch issued	Guadeloupe
4 / 1500	Hurricane Watch issued	British Virgin Islands
4 / 1500	Hurricane Watch issued	U.S. Virgin Islands
4 / 1500	Hurricane Watch issued	Puerto Rico, Vieques. and Culebra
4 / 2100	Tropical Storm Warning issued	Guadeloupe
5 / 0300	Hurricane Watch changed to Hurricane Warning	British Virgin Islands
5 / 0300	Hurricane Watch changed to Hurricane Warning	U.S. Virgin Islands
5 / 0300	Hurricane Watch changed to Hurricane Warning	Puerto Rico, Vieques. and Culebra
5 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Dominica
5 / 1200	Tropical Storm Watch issued	Cabo Engano to Isla Saona, Dominican Republic
5 / 1500	Tropical Storm Watch issued	Le Mole to Port-Au-Prince, Haiti
5 / 1500	Hurricane Watch issued	Cabo Engano, Dominican Republic to Northern Border with Haiti
5 / 1500	Hurricane Watch issued	Northern border of Haiti and Dominican Republic to Le Mole
5 / 1500	Hurricane Watch issued	Turks and Caicos Islands
5 / 1500	Hurricane Watch issued	Southeastern Bahamas

Date/Time (UTC)	Action	Location
5 / 2100	Hurricane Watch changed to Hurricane Warning	Cabo Engano to Northern Border with Haiti
5 / 2100	Tropical Storm Warning issued	Cabo Engano to Southern Border with Haiti
6 / 0000	Tropical Storm Warning changed to Hurricane Warning	Guadeloupe
6 / 0000	Hurricane Watch discontinued	Guadeloupe
6 / 0000	Hurricane Watch issued	Matanzas to Guantanamo, Cuba
6 / 0900	Hurricane Watch changed to Hurricane Warning	Turks and Caicos Islands
6 / 0900	Hurricane Watch changed to Hurricane Warning	Southeastern Bahamas
6 / 0900	Tropical Storm Warning discontinued	Dominica
6 / 0900	Hurricane Watch issued	Central Bahamas
6 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Le Mole to Port-Au-Prince
6 / 1500	Hurricane Watch changed to Hurricane Warning	Le Mole to northern border with Dominican Republic
6 / 1500	Hurricane Warning discontinued	Antigua, Barbuda, Montserrat, St. Kitts and Nevis
6 / 1500	Hurricane Warning discontinued	Guadeloupe
6 / 1600	Hurricane Warning discontinued	Saba and St. Eustatius
6 / 1800	Hurricane Warning discontinued	Anguilla
6 / 1800	Hurricane Warning discontinued	St. Maarten
6 / 2100	Hurricane Watch changed to Hurricane Warning	Central Bahamas
6 / 2100	Tropical Storm Warning issued	Las Tunas to Guantanamo
6 / 2100	Hurricane Watch issued	Northwestern Bahamas
6 / 2100	Hurricane Warning discontinued	St. Martin and St. Barthelemy
7 / 0300	Hurricane Warning discontinued	British Virgin Islands
7 / 0300	Hurricane Warning discontinued	U.S. Virgin Islands
7 / 0900	Hurricane Watch changed to Hurricane Warning	Northwestern Bahamas
7 / 0900	Hurricane Warning discontinued	Puerto Rico, Vieques, and Culebra

Date/Time (UTC)	Action	Location
7 / 1500	Tropical Storm Warning modified to	Villa Clara to Guantanamo
7 / 1500	Hurricane Watch issued	Jupiter Inlet to Bonita Beach, Florida Bay, Lake Okeechobee, and Florida Keys
7 / 2100	Tropical Storm Warning modified to	Las Tunas to Guantanamo
7 / 2100	Hurricane Watch modified to	Las Tunas to Guantanamo
7 / 2100	Hurricane Warning issued	Villa Clara to Camaguey, Cuba
8 / 0000	Tropical Storm Warning discontinued	Cabo Engano to Southern Border with Haiti
8 / 0000	Hurricane Warning modified to	Cabo Frances Viejo to Northern Border with Haiti
8 / 0300	Hurricane Watch changed to Hurricane Warning	Jupiter Inlet to Bonita Beach and Florida Bay, Lake Okeechobee, and Florida Keys
8 / 0300	Hurricane Watch issued	Jupiter Inlet to Sebastian Inlet
8 / 0300	Hurricane Warning discontinued	Cabo Frances Viejo to Northern Border with Haiti
8 / 0300	Hurricane Watch issued	Bonita Beach to Anna Maria Island
8 / 1200	Tropical Storm Warning discontinued	Le Mole to Port-Au-Prince
8 / 1200	Hurricane Warning discontinued	Northern border of Haiti and Dominican Republic to Le Mole
8 / 1500	Hurricane Watch modified to	Jupiter Inlet to Flagler/Volusia County Line
8 / 1500	Hurricane Watch modified to	Bonita Beach to Anclote River
8 / 1800	Hurricane Warning discontinued	Turks and Caicos Islands
8 / 2100	Hurricane Watch modified to	Sebastian Inlet to Flagler/Volusia County Line
8 / 2100	Hurricane Watch discontinued	Bonita Beach to Anclote River
8 / 2100	Hurricane Watch issued	Anna Maria Island to Suwannee River, Florida
8 / 2100	Hurricane Warning modified to	Sebastian Inlet to Anna Maria Island
9 / 0000	Hurricane Warning discontinued	Southeastern Bahamas

Date/Time (UTC)	Action	Location
9 / 0300	Hurricane Watch changed to Hurricane Warning	Matanzas to Camaguey
9 / 0300	Tropical Storm Warning discontinued	Las Tunas to Guantanamo
9 / 0300	Tropical Storm Warning issued	La Habana to Holguin
9 / 0300	Tropical Storm Warning issued	Ciudad de la Habana
9 / 0300	Hurricane Watch modified to	Las Tunas to Holguin
9 / 0300	Hurricane Watch issued	Volusia/Brevard County Line to Fernandina Beach
9 / 0300	Hurricane Watch issued	Anclote River to Indian Pass
9 / 0300	Hurricane Warning modified to	Matanzas to Camaguey
9 / 0300	Hurricane Warning modified to	Volusia/Brevard County Line to Anclote River, including Florida Keys, Florida Bay, Lake Okeechobee
9 / 0900	Hurricane Watch modified to	Flagler/Volusia County Line to Fernandina Beach
9 / 0900	Hurricane Watch modified to	Chassahowitzka to Indian Pass
9 / 0900	Hurricane Warning modified to	Flagler/Volusia County Line to Chassahowitzka, Florida Keys, Lake Okeechobee, Florida Bay
9 / 0900	Tropical Storm Watch issued	north of Fernandina Beach to Altamaha, Georgia
9 / 1200	Hurricane Warning discontinued	Central Bahamas
9 / 1500	Tropical Storm Warning changed to Hurricane Warning	Ciudad de la Habana
9 / 1500	Tropical Storm Watch issued	Edisto Beach to South Santee River
9 / 1500	Tropical Storm Watch issued	Indian Pass to Okaloosa/Walton County Line
9 / 1500	Tropical Storm Warning modified to	Las Tunas to Holguin
9 / 1500	Hurricane Watch modified to	Fernandina Beach to Edisto Beach
9 / 1500	Hurricane Watch modified to	Aucilla River to Indian Pass
9 / 1500	Hurricane Warning discontinued	Northwestern Bahamas
9 / 1500	Hurricane Warning modified to	La Habana to Camaguey
9 / 1500	Hurricane Warning issued	Andros Island, Bimini, and Grand Bahama Island

Date/Time (UTC)	Action	Location
9 / 1500	Hurricane Warning modified to	Fernandina Beach to Aucilla River
9 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Indian Pass to Okaloosa/Walton County Line
9 / 2100	Tropical Storm Watch discontinued	All
9 / 2100	Tropical Storm Warning discontinued	Las Tunas to Holguin
9 / 2100	Tropical Storm Warning issued	Fernandina Beach to South Santee River
9 / 2100	Hurricane Watch discontinued	Aucilla River to Indian Pass
9 / 2100	Hurricane Watch discontinued	Las Tunas to Holguin
9 / 2100	Hurricane Warning modified to	Fernandina Beach to Indian Pass
10 / 0900	Tropical Storm Watch issued	Bimini and Grand Bahamas Island
10 / 0900	Hurricane Warning discontinued	Andros Island, Bimini, and Grand Bahama Island
10 / 0900	Hurricane Warning modified to	La Habana to Ciego de Avila
10 / 1200	Hurricane Warning modified to	La Habana to Matanzas
10 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Bimini and Grand Bahamas Island
10 / 1800	Hurricane Warning discontinued	La Habana to Matanzas
10 / 1800	Hurricane Warning discontinued	Ciudad de la Habana
11 / 0300	Hurricane Warning changed to Tropical Storm Warning	Florida Bay
11 / 0300	Hurricane Warning changed to Tropical Storm Warning issued	Jupiter Inlet to Bonita Beach
11 / 0300	Hurricane Warning modified to	Jupiter Inlet to Fernandina Beach
11 / 0900	Hurricane Warning changed to Tropical Storm Warning	Lake Okeechobee
11 / 0900	Tropical Storm Warning modified to	Anclote River to Bonita Beach
11 / 0900	Tropical Storm Warning discontinued	Florida Bay
11 / 0900	Tropical Storm Warning discontinued	Bimini and Grand Bahamas Island
11 / 0900	Hurricane Warning modified to	Sebastian Inlet to Fernandina Beach
11 / 0900	Hurricane Warning modified to	Anclote River to Indian Pass

Date/Time (UTC)	Action	Location
11 / 1200	Tropical Storm Warning modified to	Bonita Beach to Okaloosa/Walton County Line
11 / 1200	Tropical Storm Warning modified to	Jupiter Inlet to South Santee River
11 / 1200	Hurricane Watch discontinued	All
11 / 1500	Tropical Storm Warning modified to	Anclote River to Okaloosa/Walton County Line
11 / 1500	Tropical Storm Warning modified to	Volusia/Brevard County Line to South Santee River
11 / 1500	Tropical Storm Warning discontinued	Lake Okeechobee
11 / 1800	Tropical Storm Warning modified to	Suwannee River to Okaloosa/Walton County Line
11 / 1800	Tropical Storm Warning modified to	Flagler/Volusia County Line to South Santee River
11 / 2100	Tropical Storm Warning discontinued	Suwannee River to Okaloosa/Walton County Line
11 / 2100	Tropical Storm Warning modified to	Fernandina Beach to South Santee River
11 / 2100	Tropical Storm Warning modified to	Altamaha Sound to South Santee River
12 / 0300	Tropical Storm Warning discontinued	All

Table 8. Storm surge watch and warning summary for Hurricane Irma, 30 August–12 September 2017.

Date/Time (UTC)	Action	Location
7 / 1500	Storm Surge Watch issued	Jupiter Inlet to Bonita Beach, including Florida Keys
8 / 0300	Storm Surge Watch changed to Storm Surge Warning	Jupiter Inlet to Bonita Beach, including Florida Keys
8 / 1500	Storm Surge Warning modified to	Sebastian Inlet to Venice, including Florida Keys
8 / 1500	Storm Surge Watch issued	North of Sebastian Inlet to Ponce Inlet
8 / 2100	Storm Surge Watch issued	north of Venice to Anclote River, including Tampa Bay
8 / 2100	Storm Surge Watch modified to	Ponce Inlet to Flagler/Volusia County Line
9 / 0300	Storm Surge Warning modified to	Volusia/Brevard County Line to Anclote River, including Florida Keys and Tampa Bay
9 / 0300	Storm Surge Watch modified to	north of Anclote Rive to Suwanee River
9 / 0900	Storm Surge Warning modified to	Volusia/Brevard County Line to Chassahowitzka, Florida Keys, Tampa Bay
9 / 1500	Storm Surge Warning modified to	Volusia/Brevard County Line to Suwanee River, Florida Keys, Tampa Bay
9 / 1500	Storm Surge Watch modified to	north of Volusia/Brevard County line to the Isle of Palms, South Carolina
9 / 1500	Storm Surge Watch modified to	north of Suwanee River to Ochlocknee River
9 / 2100	Storm Surge Warning modified to	South Santee River to Suwanee River, Florida Keys, Tampa Bay
10 / 0300	Storm Surge Warning modified to	South Santee River to Jupiter Inlet, North Miami Beach to Ochlocknee River, Florida Keys
11 / 0900	Storm Surge Warning discontinued	Florida Keys, North Miami Beach to Cape Sable
11 / 1500	Storm Surge Warning discontinued	Bonita Beach southward

Date/Time (UTC)	Action	Location
11 / 2100	Storm Surge Warning discontinued	From Fernandina Beach southward, from Aucilla River westward, from Clearwater Beach southward
12 / 0300	Storm Surge Warning discontinued	All

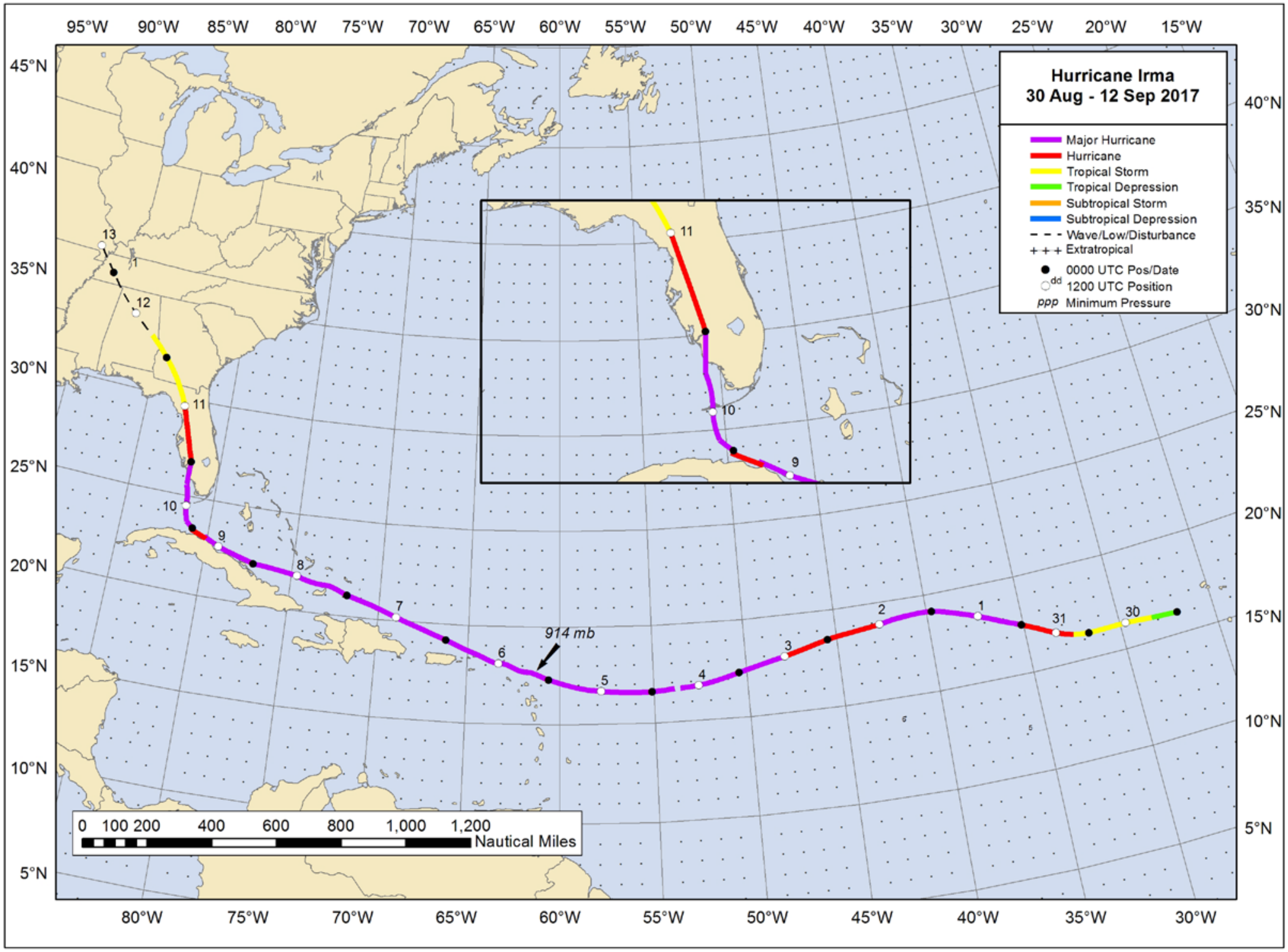


Figure 1. Best track positions for Hurricane Irma, 30 August–12 September 2017.

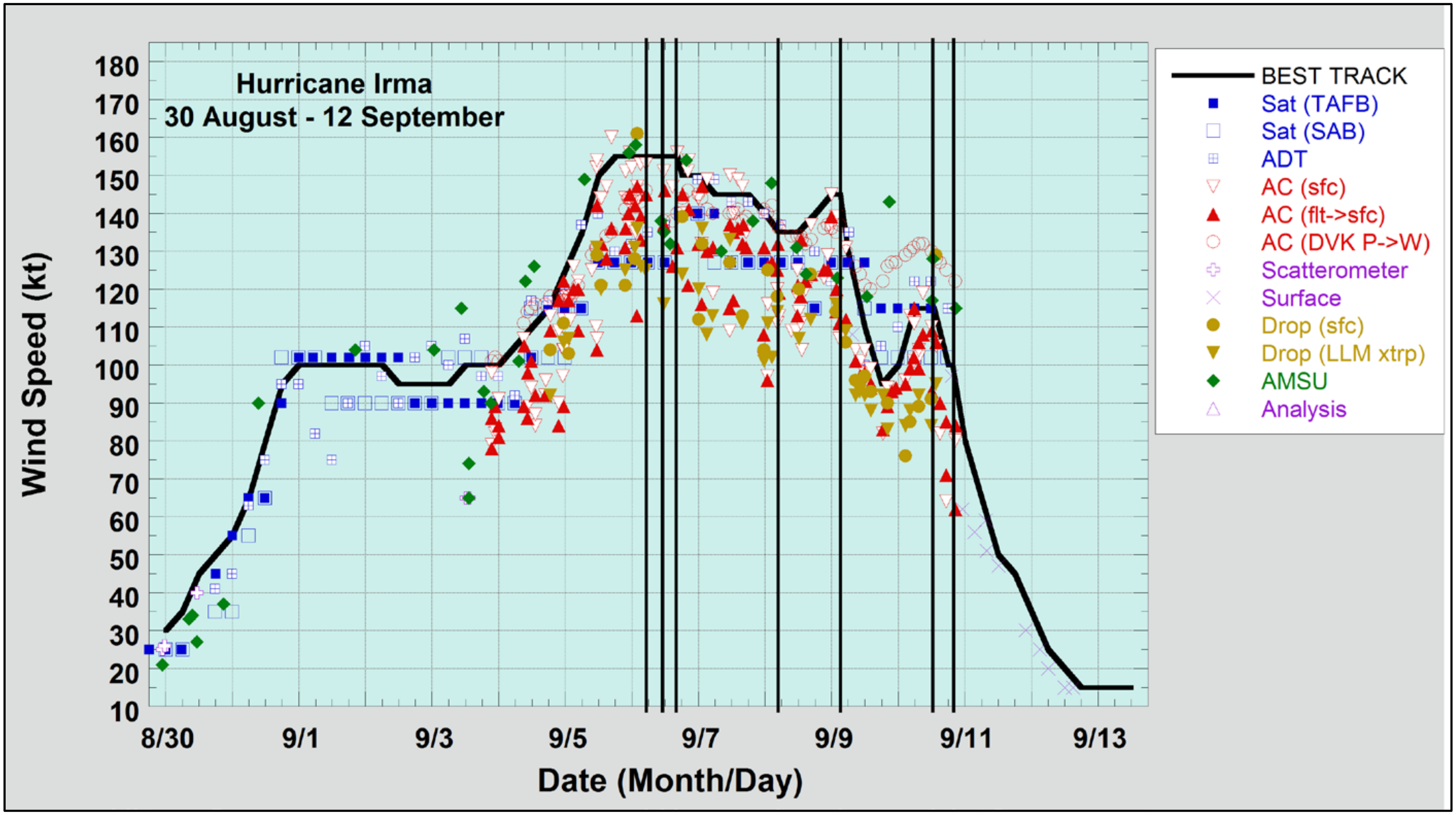
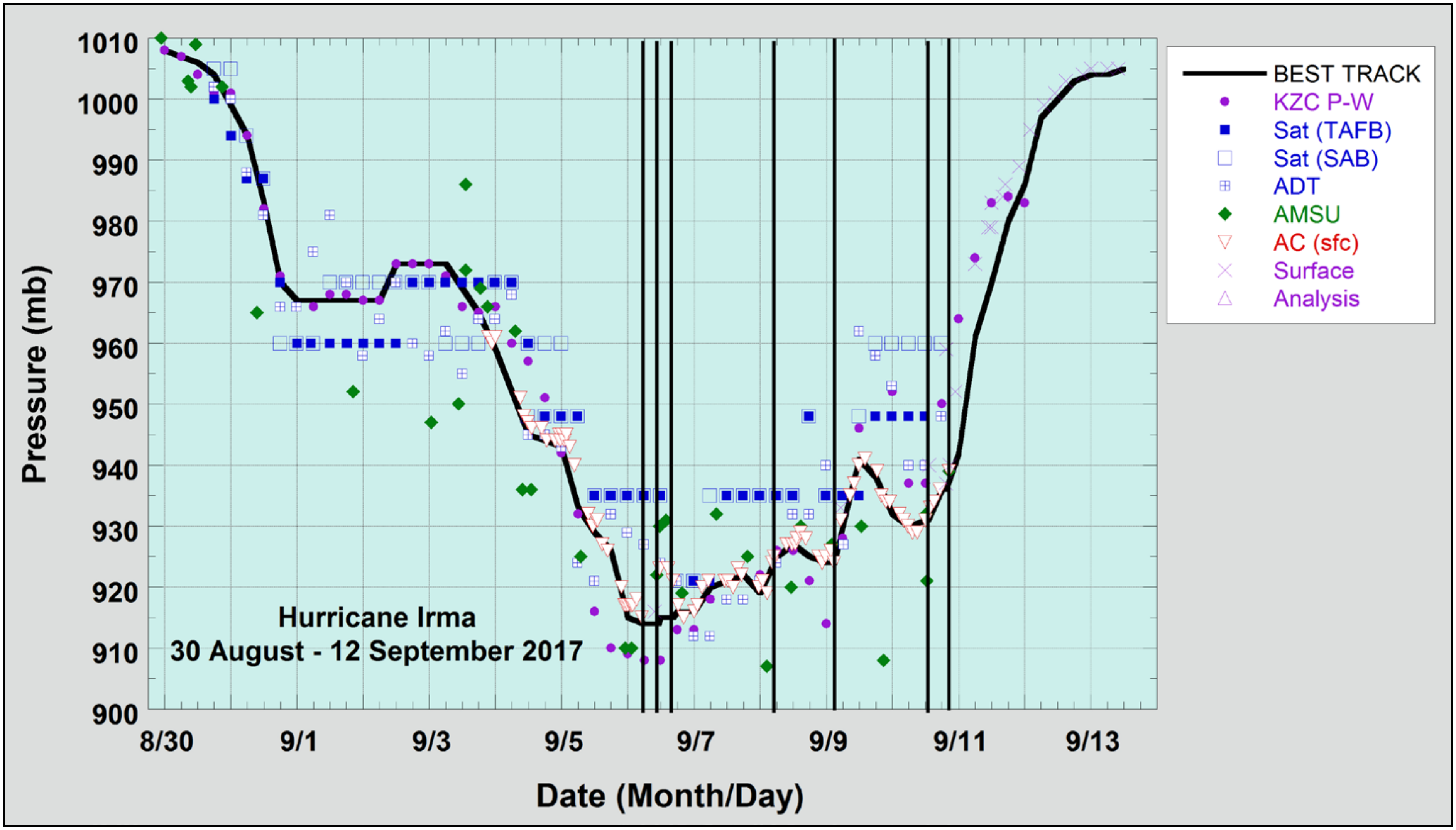


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Irma, 30 August–12 September 2017. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and the solid vertical lines correspond to landfalls.



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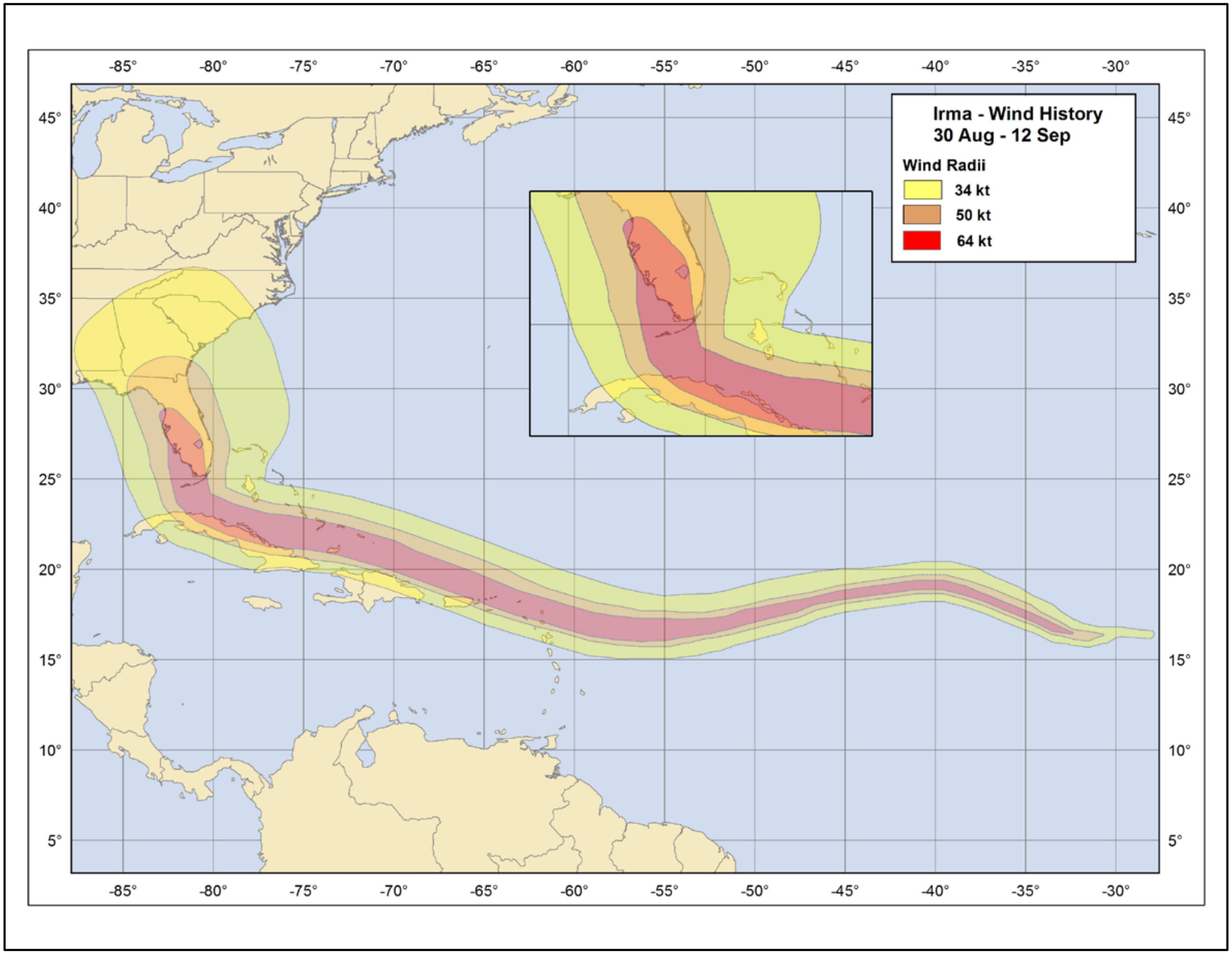

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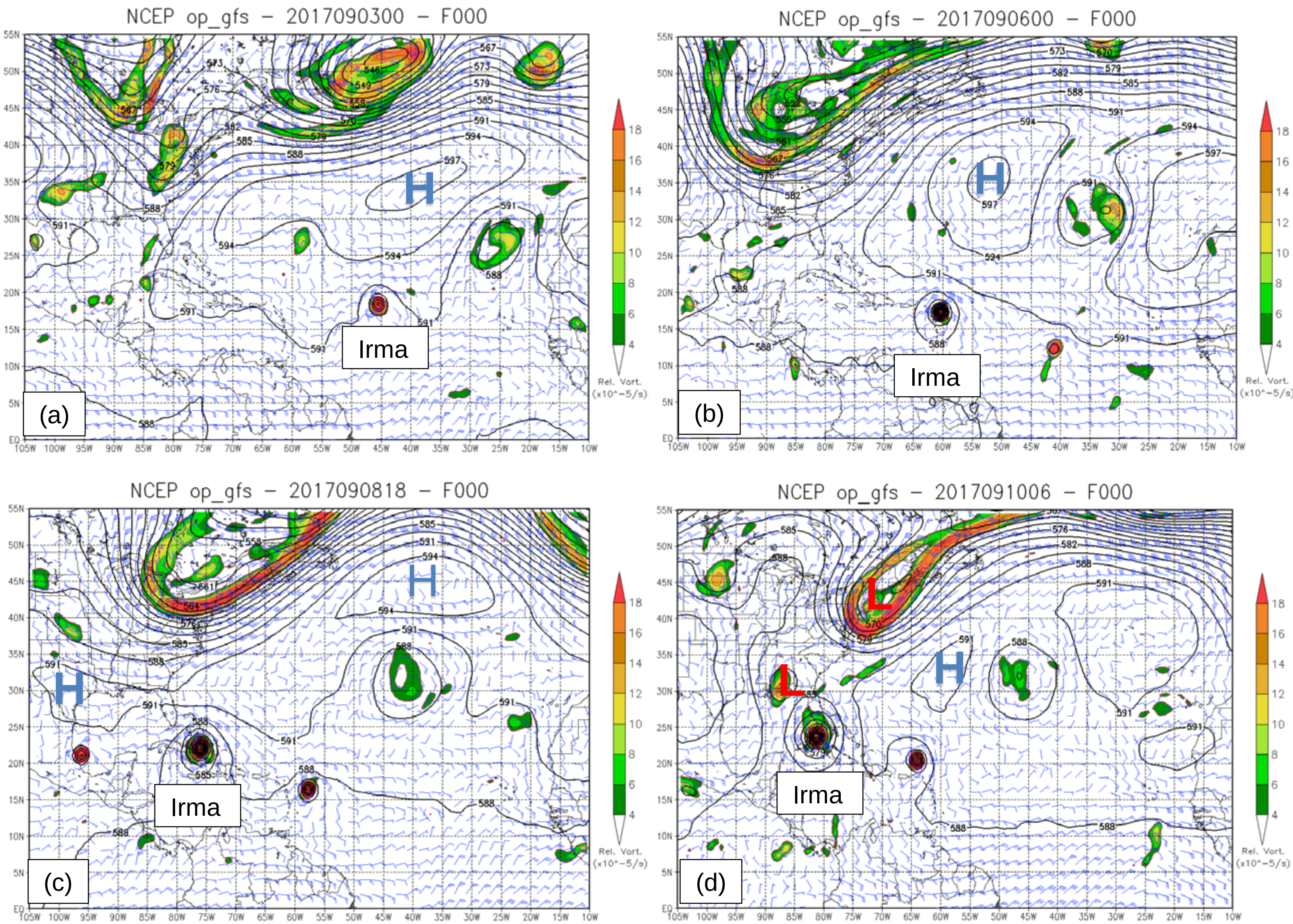

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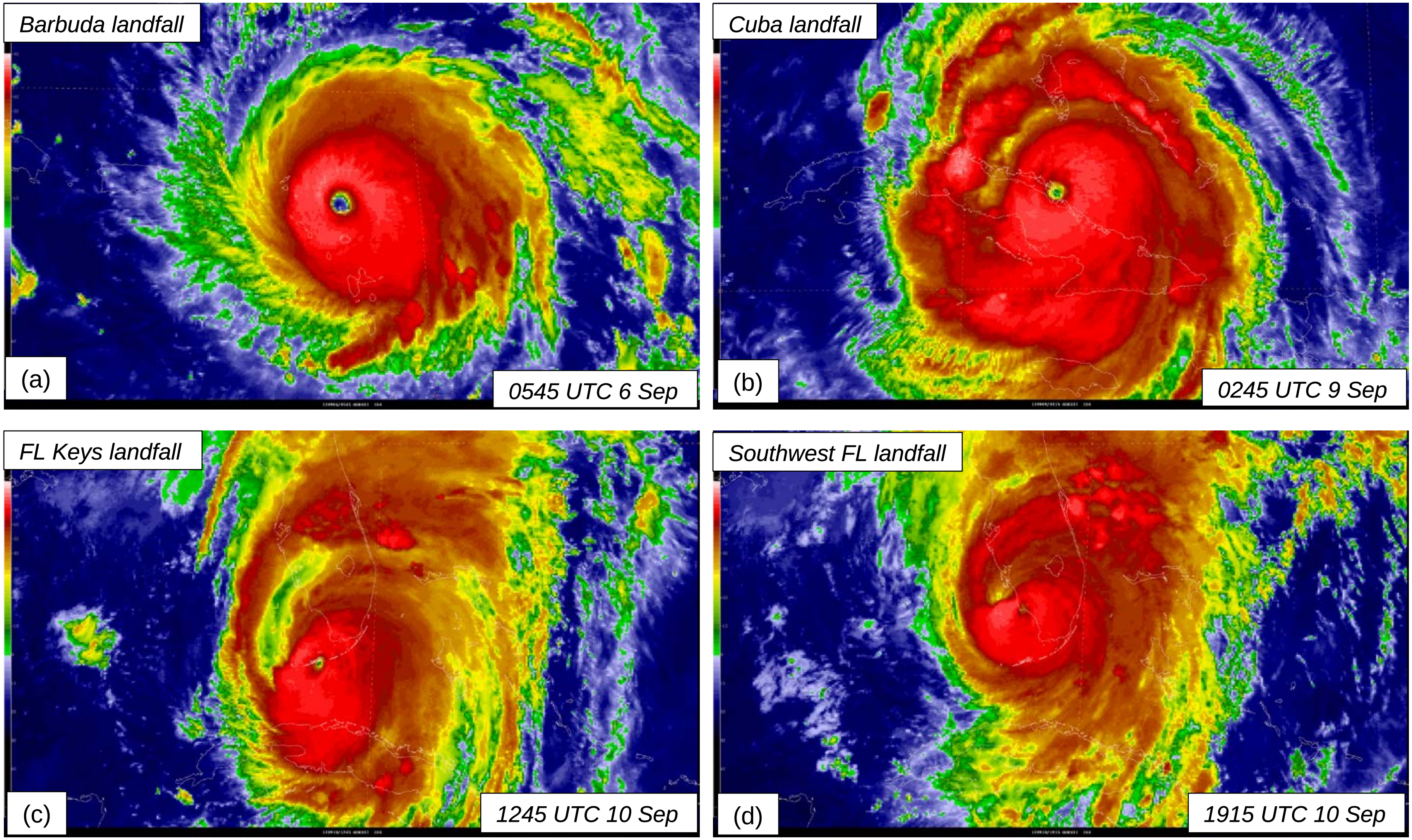

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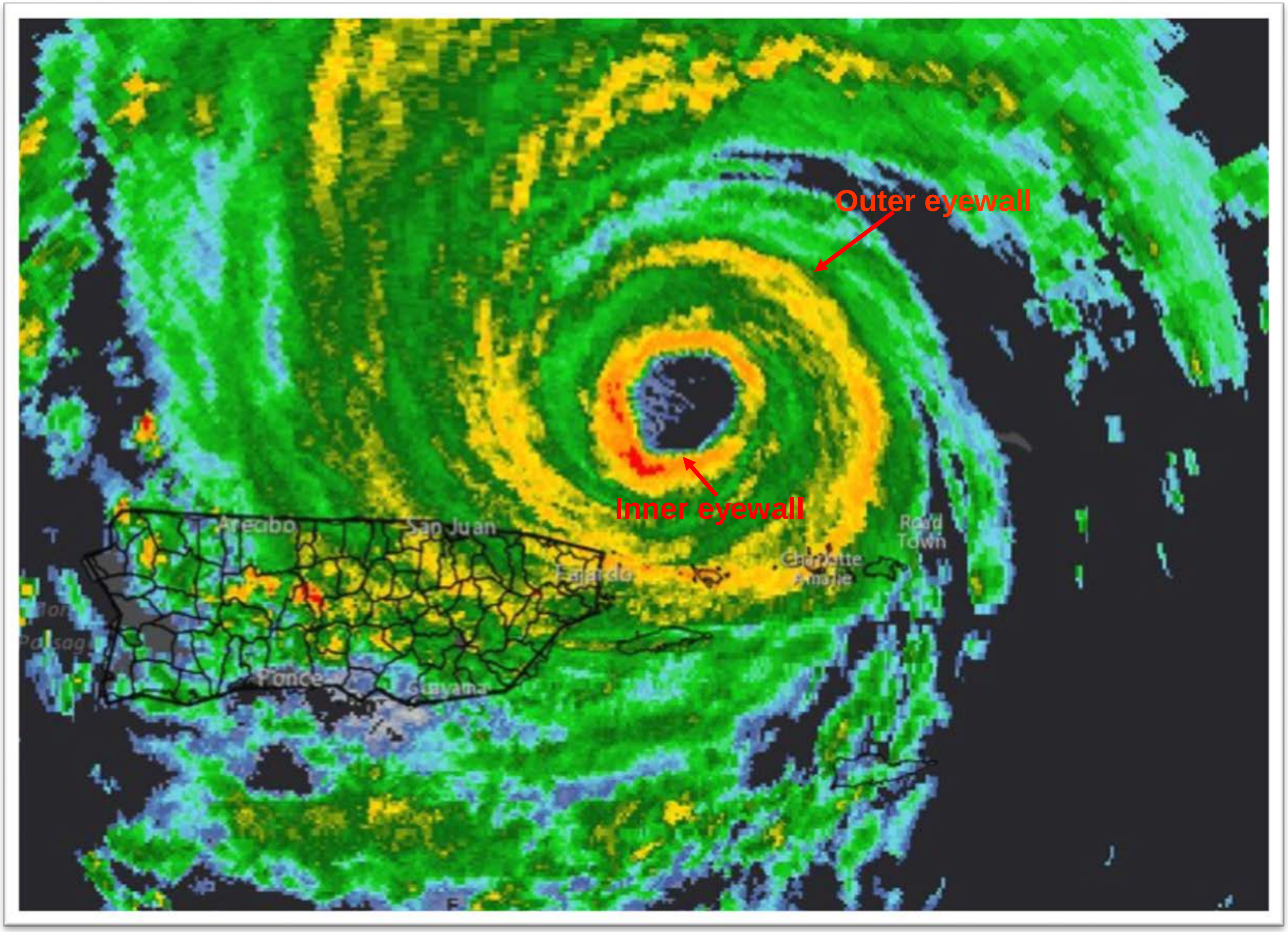

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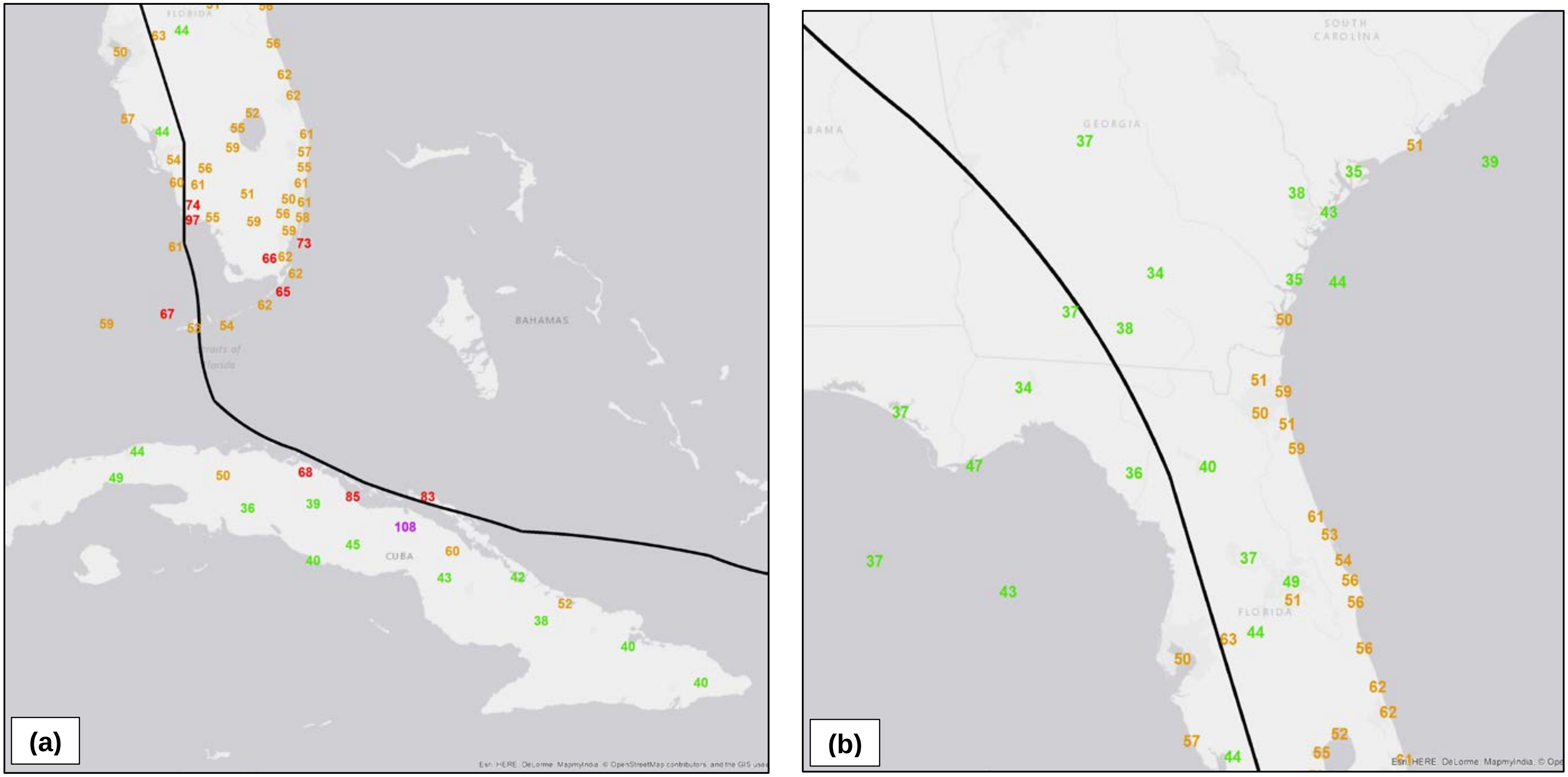

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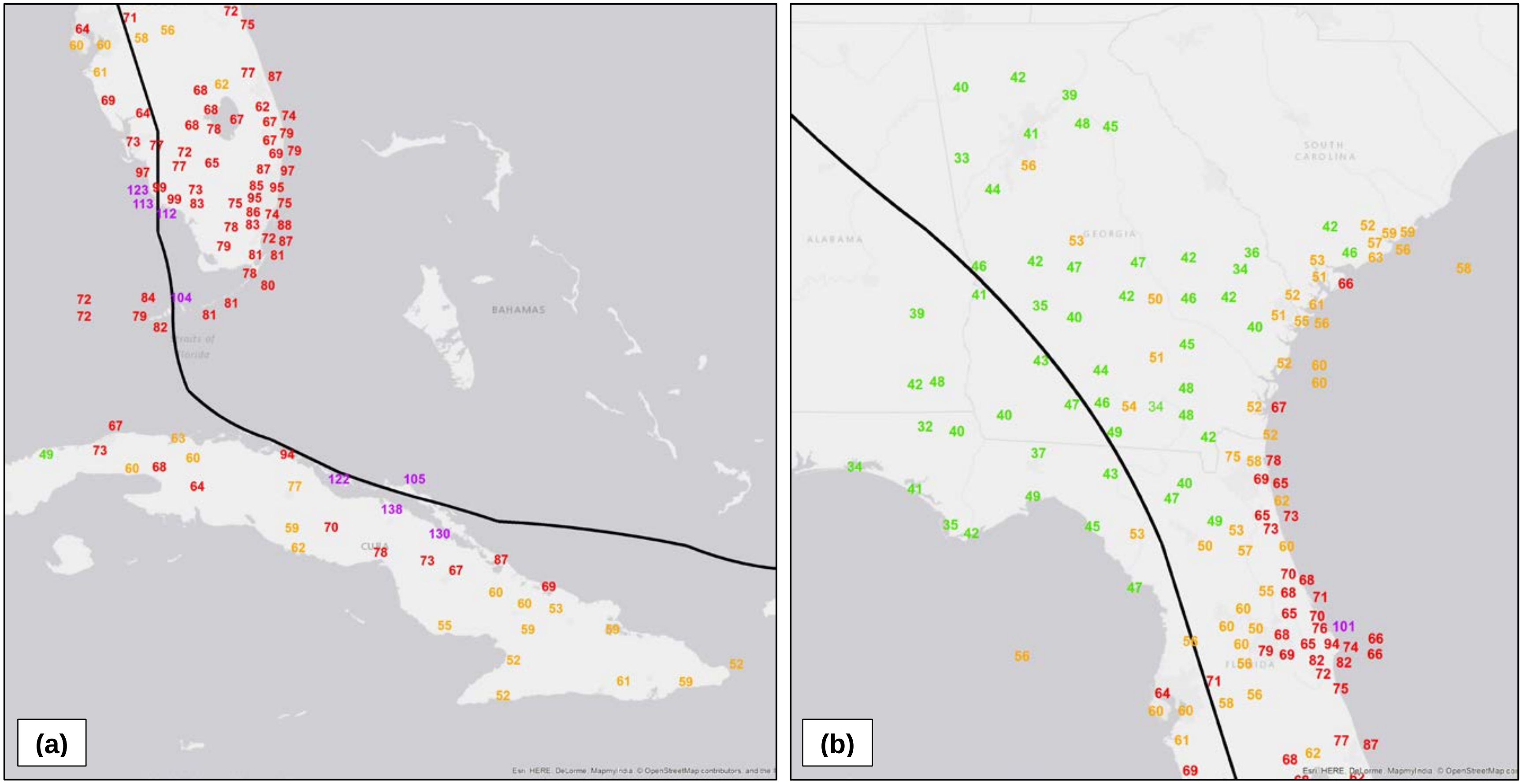

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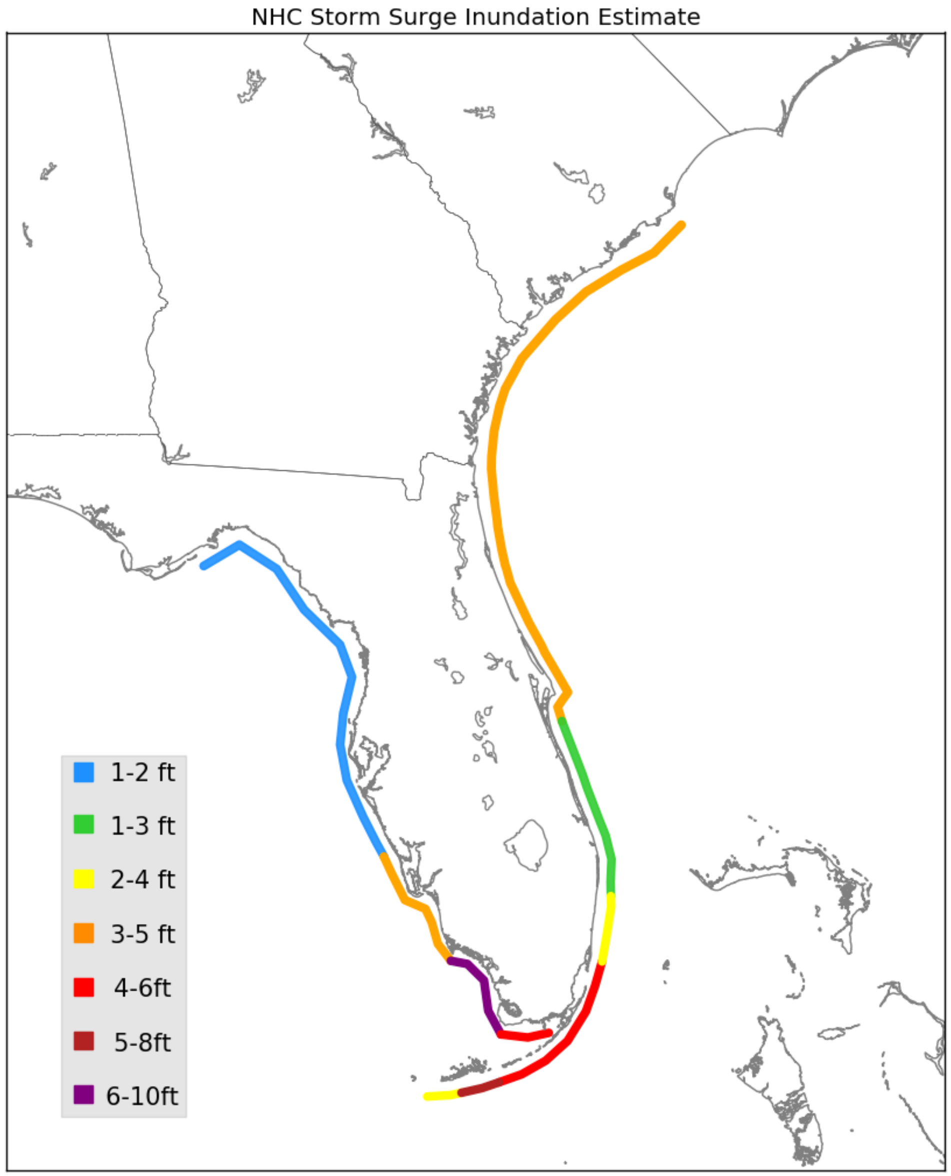

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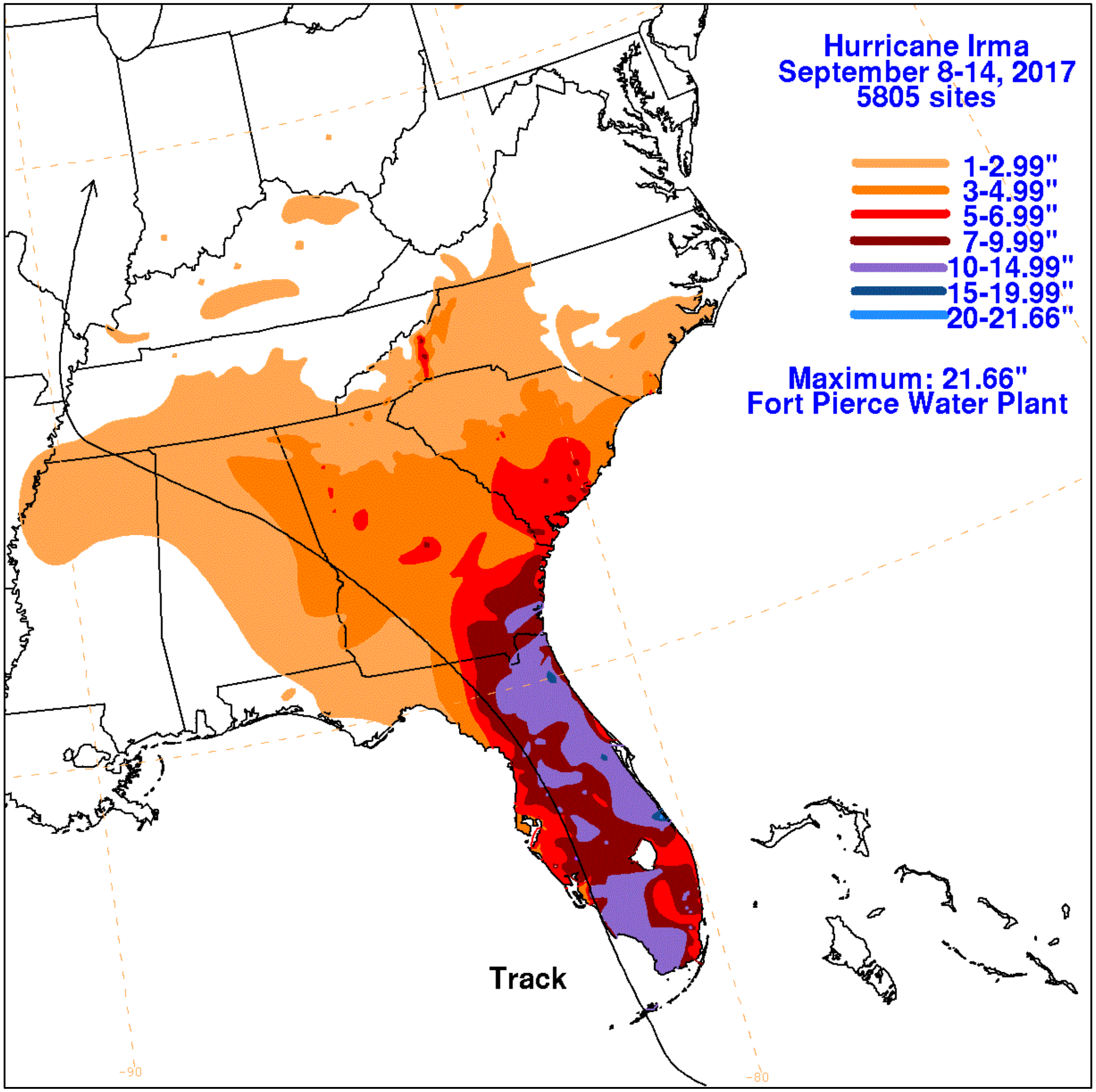

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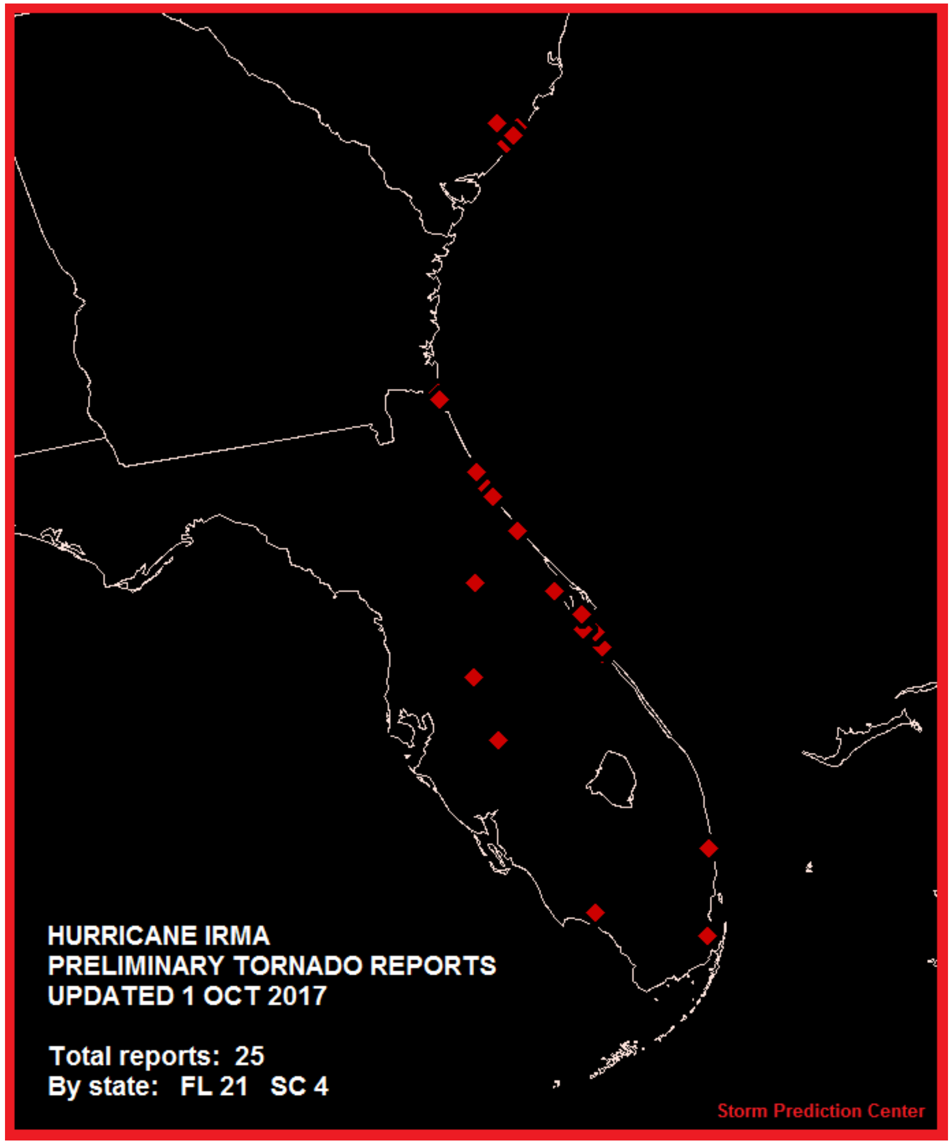

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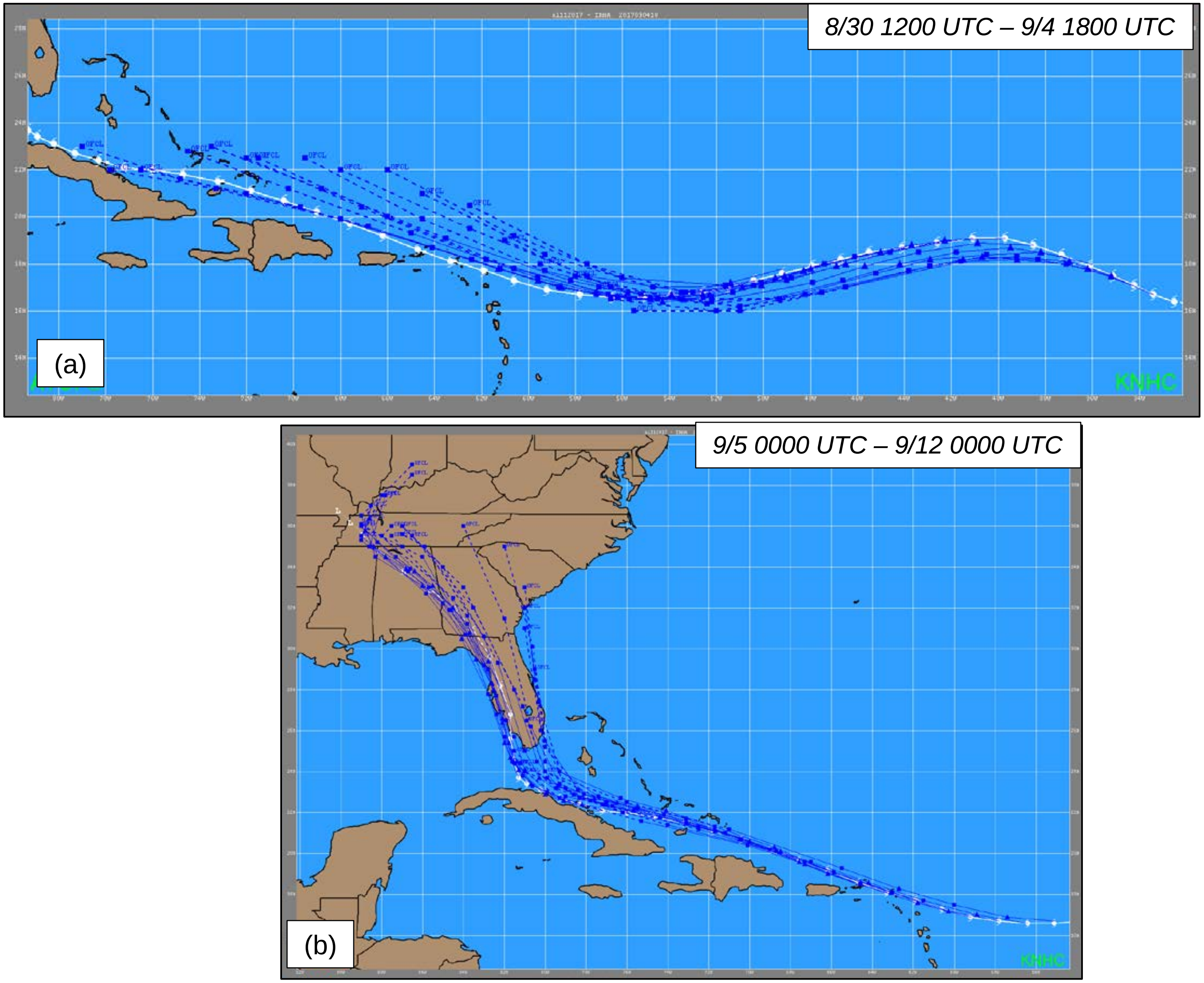

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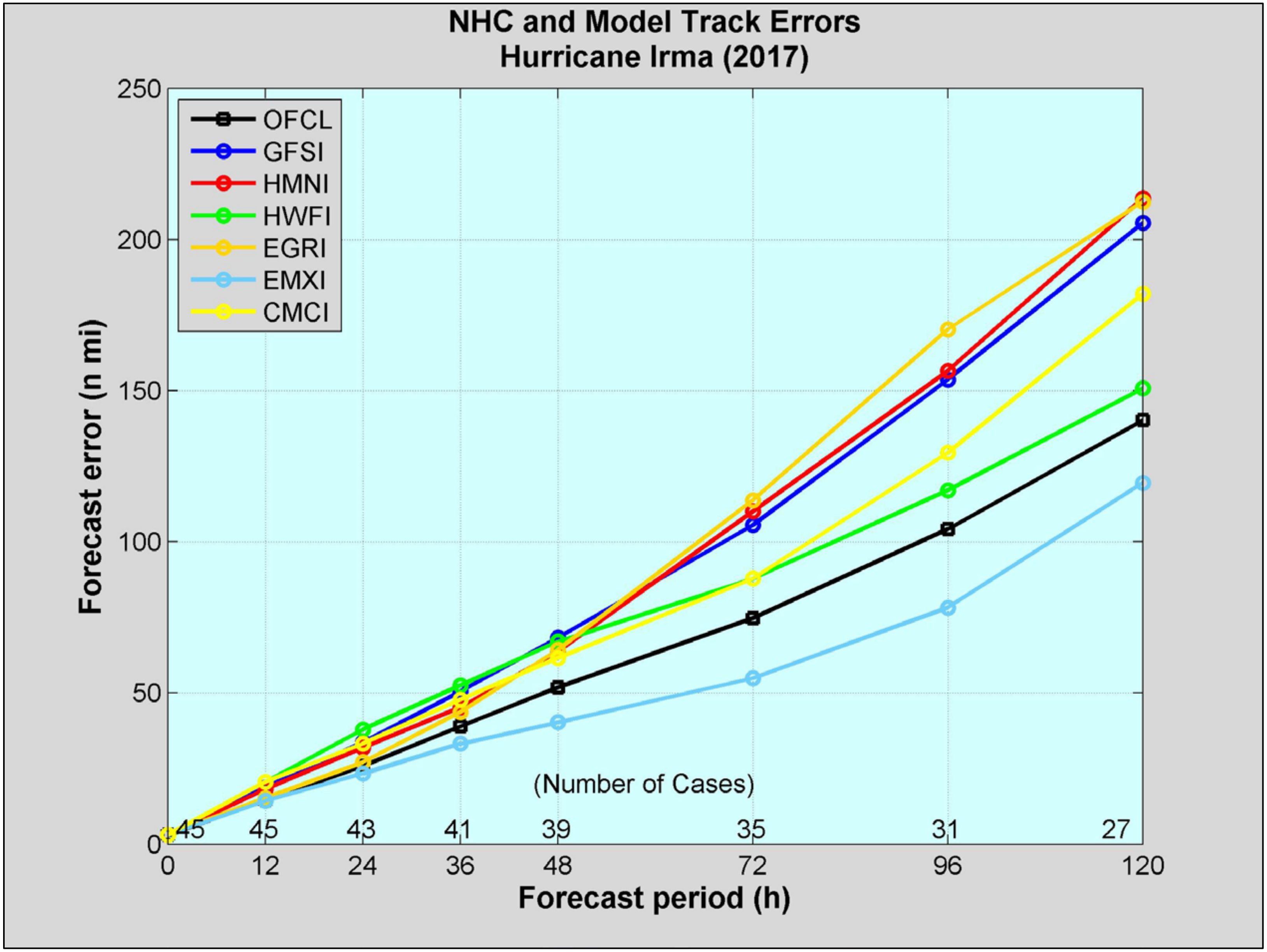

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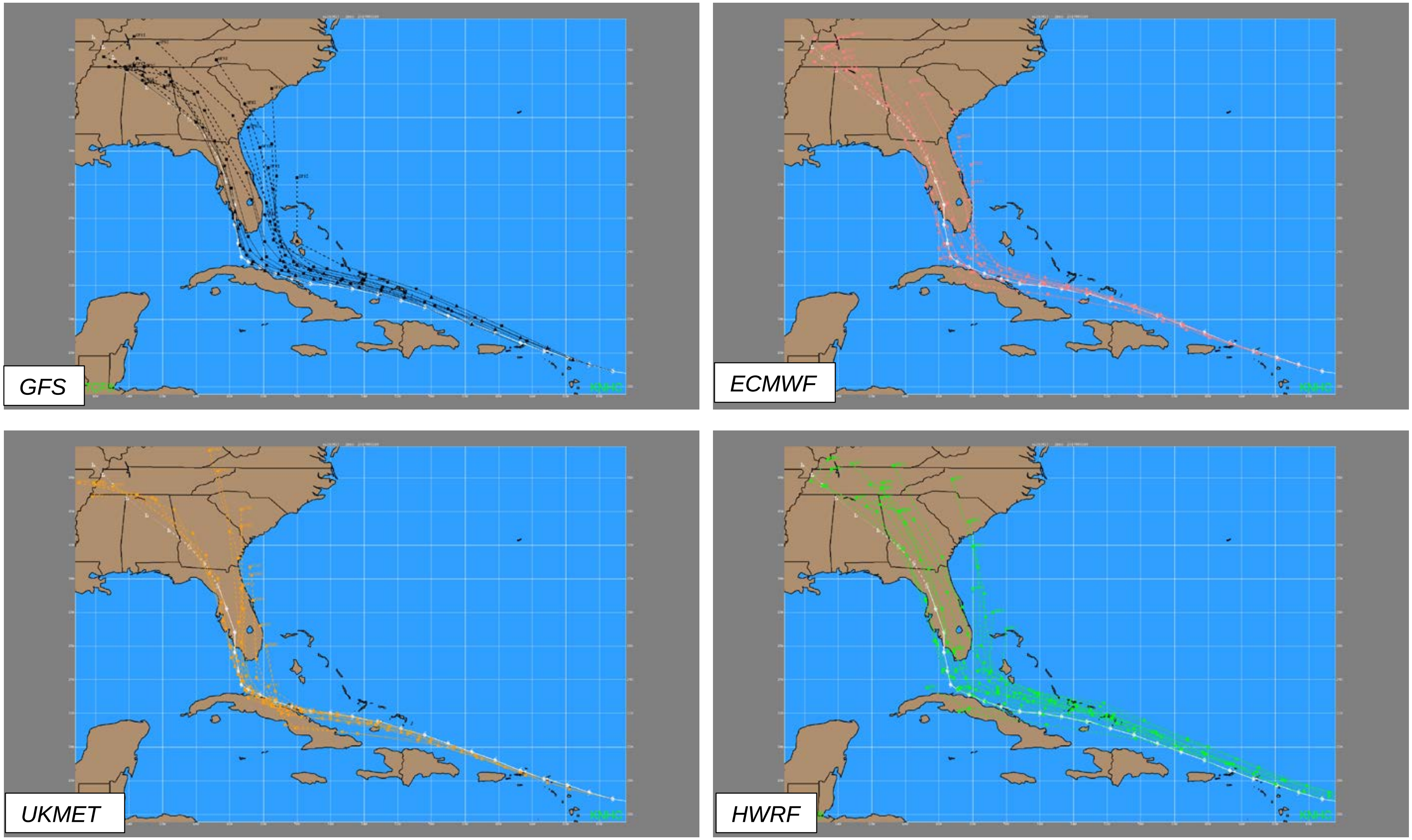

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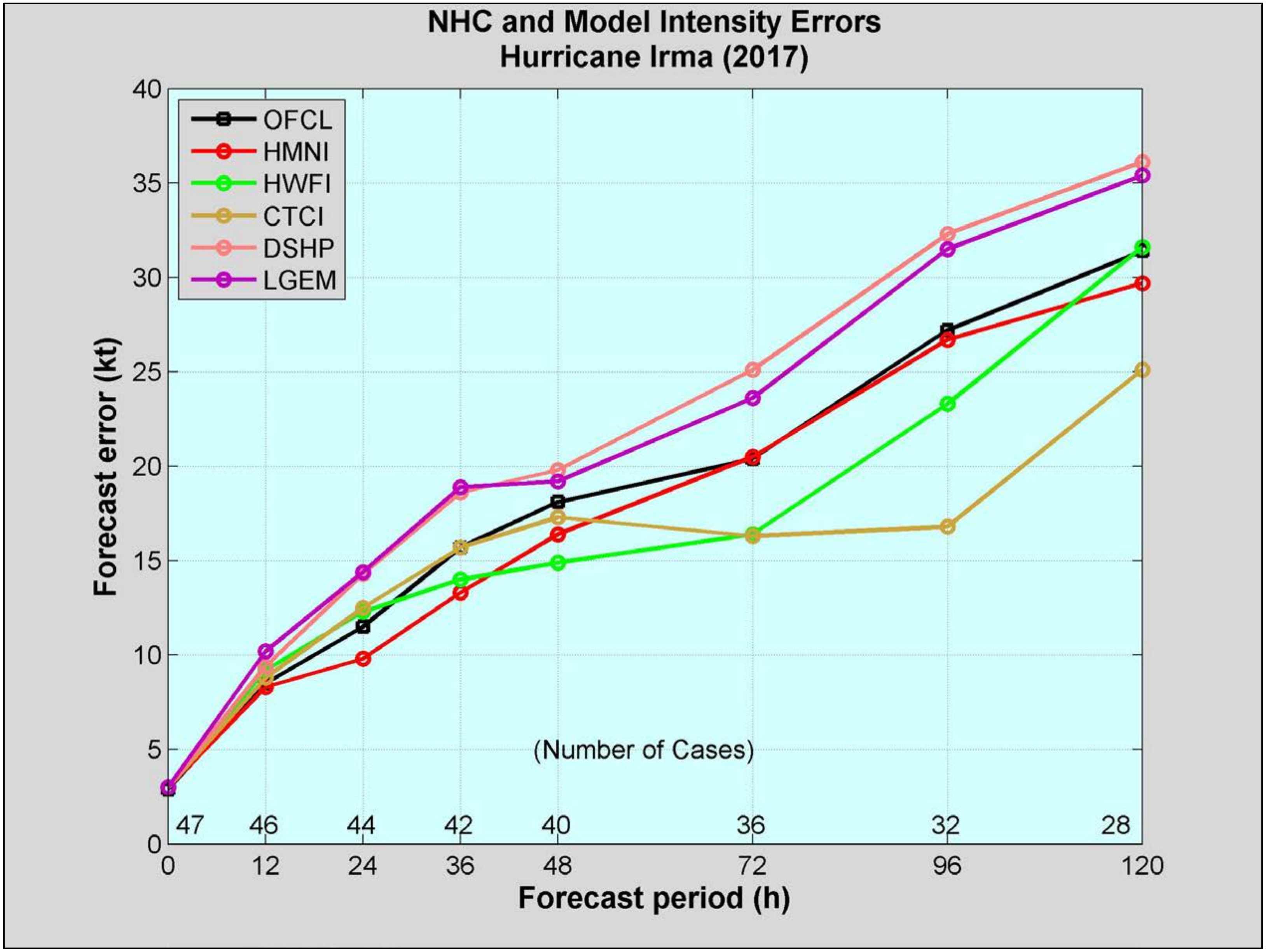

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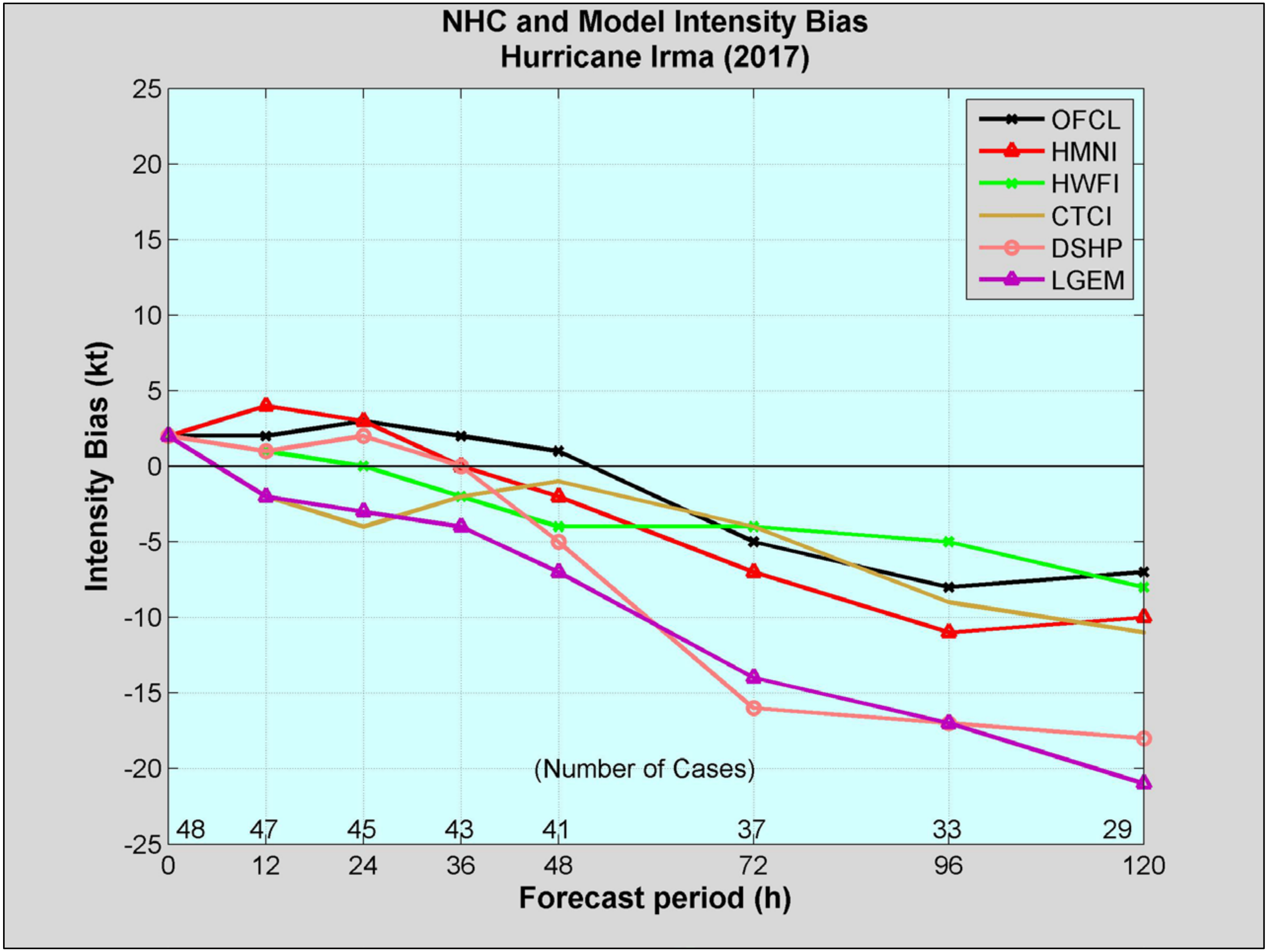

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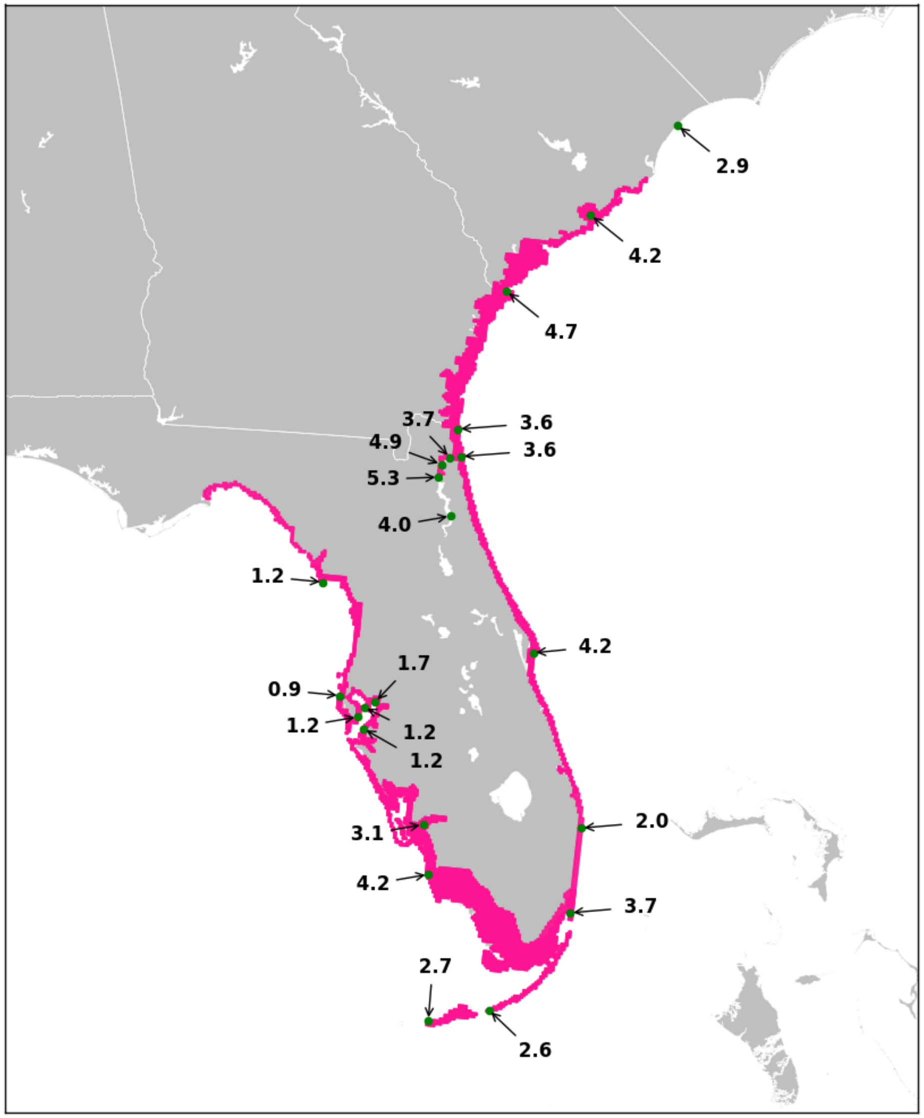

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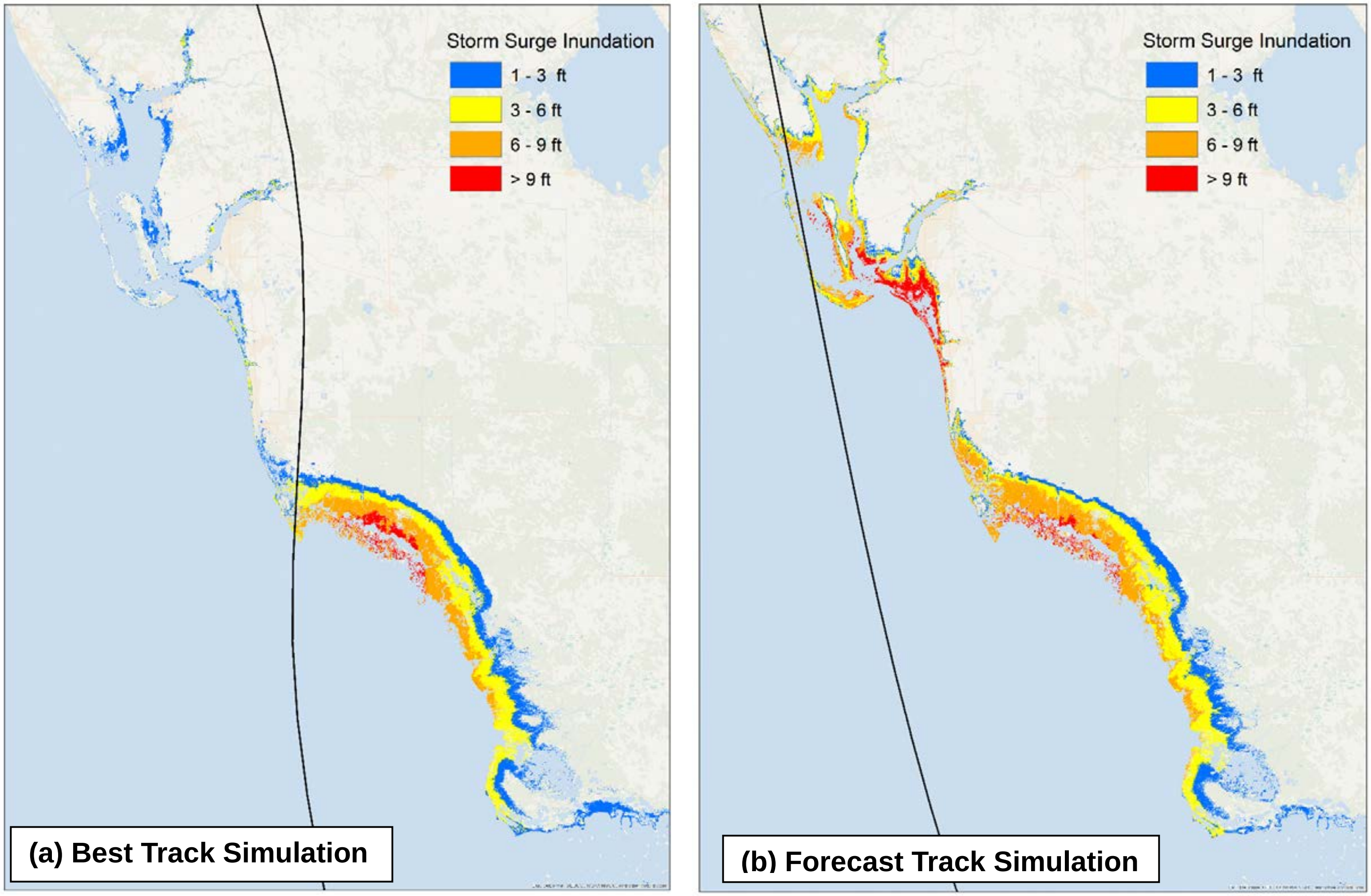

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Mitigation Assessment Team Report

Hurricane Irma in Florida

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-2023 / December 2018

U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

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FEMA

Big Pine Key, FL
FEMA / J.T. BLATTY, 2017

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HURRICANE
IRMA
IN FLORIDA

Executive Summary

Hurricane Irma struck Florida's coast on September 10, 2017, as a low Category 4 storm and caused building damage across the entire affected area.

Hurricane Irma made landfall on the East Coast of the United States at Cudjoe Key, FL, with maximum winds near 130 miles per hour (mph) and a minimum pressure of 931 millibars (mb) (NOAA NHC, 2018). Later that day, Hurricane Irma made a second landfall on Marco Island as a low Category 3 hurricane with maximum sustained winds of 115 mph and a central pressure of 936 mb before tracking up the Florida Peninsula and into Georgia on September 11 (NOAA NWS, 2017). Sustained hurricane force winds (i.e., 74 mph or greater) were reported along much of the east coast of Florida, from Jacksonville to Miami. The Naples Municipal Airport reported a wind gust of 142 mph. In addition to the long periods of heavy rain and strong winds, storm surge caused flooding along the Florida coast, particularly on the east side of the State in the Jacksonville area (NOAA NHC, 2018; NOAA NWS, 2017).

NOTEWORTHY STORM METRICS

- One of the strongest hurricanes ever observed in the open Atlantic Ocean
- One of only five hurricanes with measured sustained winds of 185 miles per hour (mph) or higher
- Maintained 185 mph sustained wind speed for 37 hours, the longest period for any tropical cyclone

Hurricane Irma resulted in one of the largest evacuations (approximately 6.5 million people) and most extensively used sheltering operations for the State of Florida (Florida House of Representatives, 2018). Presidential disaster declarations were issued for Florida, Georgia, Puerto Rico, and the U.S. Virgin Islands following the storm (FEMA, 2018c). Hurricane Irma caused damage to buildings across the entire affected area, as well as widespread power outages and interruptions in utility service.

Mitigation Assessment Team Deployment and Observations

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the Federal Emergency Management Agency (FEMA) deployed a pre-Mitigation Assessment Team (pre-MAT) to perform a preliminary field assessment of building damage in limited areas of Collier, Lee, Miami-Dade, and Monroe Counties. This pre-MAT was a small team sent in advance of the larger MAT to quickly observe and record select perishable damage data; locate damaged areas requiring further assessment; and determine the overall impact of the hurricane, scope of buildings and areas to be visited, and skillsets that would be needed for the larger, follow-on MAT. Following the pre-MAT, in response to a request for technical support from the Joint Field Office (JFO) in Florida, FEMA deployed the full MAT in December 2017 to assess the performance of buildings in Florida. A MAT conducts forensic engineering analyses of buildings and related infrastructure to determine causes of damage and success, and recommends actions that Federal, State, and local governments; the design and construction industry; and building code and standards organizations can take to mitigate damage from future natural hazard events.

The MAT deployed to Florida assessed the performance of municipal buildings, coastal residential properties, and public facilities. The MAT focused on structures in Lee, Collier, Miami-Dade, and Monroe Counties.

Summary of Damage Observed by the MAT

Although Hurricane Irma was neither a flood nor wind design-level event, the storm caused widespread damage to residential and commercial buildings and infrastructure. Other long-term damage impacts include the loss of housing in the Florida Keys, damage to wastewater and potable water infrastructure, and minor to major erosion at different locations along the coastline. The extent of the wind and/or flood damage varied depending on the nature of the building design and construction. Chapters 3 and 4, as well as Chapter 5, provide additional insight into why a below design-level event caused the damage that it did.

Flood. The storm caused moderate flooding and erosion in South Florida but was not considered a storm surge design event (i.e., exceedance of the 1-percent-annual-chance flood elevations was only observed where the combination of storm surge and rainfall caused severe flooding). Buildings in low-lying areas were damaged from inundation.

Although inundation alone was a significant source of damage, some of the more dramatic structural failures observed were a result of the added force of wave action and scour. The extent of flood damage to buildings varied with the depth of floodwater, the amount of energy in the water (waves, velocity), and the nature of building design and construction (old versus new, at-grade versus elevated, manufactured housing [MH] units / recreational vehicle versus site-built/modular). Some of the structures destroyed by the storm were MH units located in the floodplain. Very few of these houses were elevated to the base flood elevation. Buildings constructed at or near grade were subject to deeper and more damaging flooding from either storm surge or rainfall-induced flooding.

The MAT also spoke with building owners, operators, and managers of dry floodproofed non-residential buildings to understand the performance of dry floodproofing systems.

In addition, the MAT visited 15 public restroom buildings and sites on or near the shoreline in public parks in Lee, Collier, Monroe, and St. Johns Counties. For those restrooms damaged by flooding, iii the degree of damage ranged from complete destruction, to some structural damage, to damage to doors and fixtures only. The degree of damage depended on both flood conditions and building characteristics.

Wind. The MAT focused primarily on one- and two-family dwellings, but also assessed some multi-family dwellings (apartments and condominiums) and MH units. Estimated wind speeds from Hurricane Irma in Florida did not approach the design wind speeds required in the last six editions of the Florida Building Code (FBC).

Buildings designed and constructed to comply with the FBC met expectations by performing well structurally. Though not widespread, wind-induced structural damage to main wind-force resisting systems was observed in older (pre-FBC) residential construction and included roof failure and loss of exterior walls. Wind damage to roof structures appeared to have been generally initiated through loss of roof covering or breaching of the attic envelope. Framed walls of residential structures collapsed where significant portions of the roof and ceiling diaphragm were destroyed by wind.

Many buildings sustained wind-induced failures of building envelope components, connections, and systems that allowed wind-driven rain to penetrate into the interior, resulting in costly damage. While structural damage observations from Hurricane Irma winds were almost exclusively limited to pre-FBC residential buildings, envelope damage was commonly observed on both older and newer construction. The most frequently observed damage affected roof coverings, soffits, exterior wall coverings, glazed openings, and garage doors.

Most observed damage to MH units was initiated by wind acting on improperly attached appurtenances. When carports and covered porches broke away from MH units, they left openings at failed connections in the remaining roof or wall that allowed rain to enter the MH unit envelopes.

MAT Recommendations

The recommendations presented in this report are made based on the MAT's field observations. They are directed to design professionals, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners, academia, select industries and associations, and local officials, as well as FEMA.

General recommendations. The Florida Division of Emergency Management (FDEM), the Building Officials Association of Florida (BOAF), Florida Home Builders Association (FHBA), and/or other stakeholders should consider developing additional training opportunities regarding contemporary flood- and wind-related design and construction issues. The FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform building officials and local officials responsible for floodplain management about accessing resources to aid recovery through the Statewide Mutual Aid Agreement. FDEM should also consider training design professionals to assist with inspections. Furthermore, FEMA should develop a timely and effective means to deliver the Adjuster Preliminary Damage Assessment data submitted by National Flood Insurance Program (NFIP) claims adjusters to States and communities.

Building codes and floodplain management ordinances. Permitting agencies (e.g., Florida Department of Environmental Protection [DEP], Water Management Districts, local government) should evaluate permitting criteria and performance requirements for new or replacement bulkheads with respect to design conditions, including the effects of saturated backfill, wave forces, overtopping, and erosion on both water and land sides. Recommendations related to FEMA reviewing and updating its event-based erosion methodology. FDEM should expand its technical assistance for Community Rating System (CRS) communities are also provided. The Florida Department of Highway Safety and Motor Vehicles should update its Florida statutes for MH unit installation to reference the most recent edition of FEMA P-85, *Protecting Manufactured Homes from Floods and Other Hazards* (2009c), and consider incorporating additional wind- and flood-resistant construction provisions with particular emphasis on anchoring.

Flood-related building performance. Because dry floodproofing measures were found to fail under less than design flood conditions, the MAT recommends that building owners, design professionals, and local floodplain administrators follow the guidance in Florida MAT Recovery Advisory 1, *Dry Floodproofing: Operational Considerations* (2018d), and Texas MAT Recovery Advisory 1, *Dry Floodproofing: Planning and Design Considerations* (2018e), related to dry floodproofing methods and procedures. These methods and procedures were developed based on observations during and after the two storms. Facility managers should develop an emergency operations plan that outlines how to prepare the building when severe weather is expected. Facility managers should also routinely re-evaluate dry floodproofing designs and plans after deployment of their systems or training exercises, as well as instill a culture of preparedness.

Wind-related building performance. Because building envelope failures were observed on post-FBC residential structures following a below design-level wind event, industry groups should investigate the causes. In particular, the causes for the observed widespread asphalt shingle roof covering loss and the appropriate pressure equalization factor for vinyl siding should be investigated. Industry groups and/or academia should also study debris impacts to protective systems from the 2017 (and future) hurricanes to determine whether the current wind speed triggers for the wind-borne debris region (WBDR) are appropriate as defined in the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Building owners outside of the WBDR, in the hurricane-prone region, should consider protecting the glazed openings on their buildings. Contractors and inspectors should ensure roof covering repairs and replacements are in conformance with FBC requirements. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain from entering building envelopes and damaging building interiors. The FBC should require soffit and wall cladding inspections. Furthermore, as a best practice, MH appurtenances should be built as standalone units without structural connection to the MH unit.

FEMA technical publications and guidance. The FEMA Building Science Branch should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities*. FEMA should include lessons learned from the 2017 hurricane season in finishing this publication. FEMA should also consider updating or producing a supplement for its key hurricane and Risk Management Series technical guidance publications to include lessons learned from the 2017 hurricane season and to reflect updates to current building codes since the publications' latest releases. FEMA should update FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010) to incorporate new lessons learned and recommended guidance and clarifications since it was published in 2010. At the same time FEMA 213, *Answers to Questions about Substantially Damaged Buildings,* should be updated to be consistent with the updated FEMA P-758. FEMA should consider expanding existing training materials on Substantial Improvement/Substantial Damage for distribution to NFIP State Coordinators and other entities. Finally, dry floodproofing guidance should be updated and a comprehensive recommendation for dry floodproofing design, limitations, testing, and maintenance and operations requirements should be developed for inclusion in ASCE 24, *Flood Resistant Design and Construction.*

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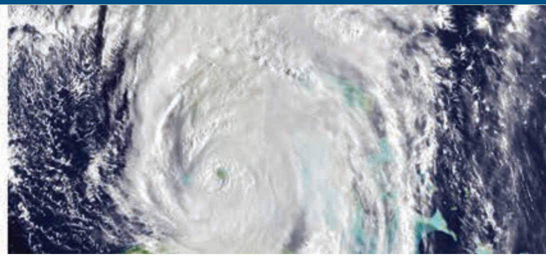
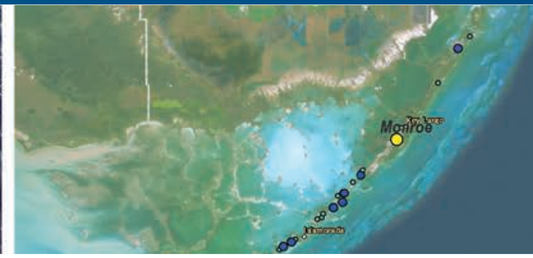
Acronyms and Abbreviations

AAMA	American Architectural Manufacturers Association
ACE	Accumulated Cyclone Energy
ACI	American Concrete Industry
ADCIRC	Advanced Circulation
AISI	American Iron and Steel Institute
ASCE	American Society of Civil Engineers
ASD	allowable stress design
ATC	Applied Technology Council
BCIS	Building Code Information System
BFE	base flood elevation
BOAF	Building Officials Association of Florida
CAC	Community Assistance Contact
CAP-SSSE	Community Assistance Program State Support Services Element
CAV	Community Assistance Visits
CERA	Coastal Emergency Risks Assessment
CFR	Code of Federal Regulations
CPCB	Community Planning and Capacity Building
CRS	Community Rating System
DBPR	Department of Business and Professional Regulation
DEP	Department of Environmental Protection (Florida)
DFE	design flood elevation
DHS	U.S. Department of Homeland Security
EDT	Eastern Daylight Time
EDWS	estimated design wind speed
EOP	emergency operations plan
EWS	estimated wind speed
FBC	Florida Building Code
FBCA	Florida Building Code, Accessibility
FBCB	Florida Building Code, Building
FBCEB	Florida Building Code, Existing Building
FBCEC	Florida Building Code, Energy Conservation
FBCFG	Florida Building Code, Fuel Gas
FBCM	Florida Building Code, Mechanical
FBCP	Florida Building Code, Plumbing
FBCR	Florida Building Code, Residential
FDEM	Florida Division of Emergency Management
FEMA	Federal Emergency Management Agency

FFMA	Florida Floodplain Managers Association
FHBA	Florida Home Builders Association
FIMA	Federal Insurance and Mitigation Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurances Study
HUD	U.S. Department of Housing and Urban Development
HVHZ	High-Velocity Hurricane Zone
IBC®	International Building Code
ICC®	International Code Council
IRC®	International Residential Code
JFO	Joint Field Office
MAT	Mitigation Assessment Team
MEP	mechanical, electrical, and plumbing
MH	manufactured housing
mph	miles per hour
MWFRS	main wind-force resisting systems
NAVD88	North American Vertical Datum of 1988
NCEI	National Center for Environmental Information
NDRF	National Disaster Recovery Framework
NFIP	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum of 1929
NHC	National Hurricane Center
NHRAP	Natural Hazard Risk Assessment Program
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWS	National Weather Service
PEF	pressure equalization factor
Risk MAP	FEMA Risk Mapping, Assessment, and Planning
RRCC	Regional Response Coordination Center
RSF	Recovery Support Function
SFHA	Special Flood Hazard Area
SFMO	State Floodplain Management Office
SMAA	Statewide Mutual Aid Agreement
SWAN	Simulating Waves Nearshore
TAC	Technical Advisory Committees
TAS	Testing Application Standards
USGS	U.S. Geological Survey
WBDR	windborne debris region





HURRICANE **IRMA** IN FLORIDA

1 Introduction

Hurricane Irma was one of the strongest hurricanes ever observed in the open Atlantic Ocean and caused 92 fatalities in five States (NOAA NHC, 2018).

On September 10, 2017, Hurricane Irma made landfall on the East Coast of the United States. As part of the response to the disaster, the Federal Insurance and Mitigation Administration (FIMA) of the U.S. Department of Homeland Security's (DHS's) Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) composed of national and regional building science and other types of experts to assess the damage in Florida.

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the MAT performed a preliminary field assessment of building damage in limited areas in Collier, Lee, Miami-Dade, and Monroe Counties. This pre-MAT was a small team sent in advance tasked to quickly observe and record select perishable damage data; locate damaged areas requiring further assessment; and determine overall impact of the hurricane, scope of buildings and areas to be visited, and skillsets that would be needed for a larger, follow-on MAT. The MAT was then deployed from December 10 to 16, 2017 to Collier, Lee, Miami-Dade, and Monroe Counties. Investigative field work to evaluate erosion impacts in St. Johns County was conducted on February 14 and 15, 2018. Its mission was to assess the performance of buildings affected by Hurricane Irma and their associated utility systems.

The primary purpose of a MAT is to improve the natural hazard resistance of buildings by evaluating the key causes of building damage, failure, and success, and developing strategic recommendations for improving short-term recovery and long-term disaster resilience to future natural hazard events. The MAT report provides information that will help communities, businesses, design professionals, and other interested stakeholders to rebuild and design more robust and resilient buildings, structures, and their associated utility systems, thereby minimizing loss of life and injuries, and reducing property damage resulting from future natural hazard events. This report describes the MAT's observations during field assessments in Florida and presents conclusions and recommendations based on those observations.

This MAT report focuses on several construction and floodplain management issues observed after Hurricane Irma that were not observed in former MAT damage assessments or that were addressed in lesser detail in those MAT reports. These issues include, but are not limited to:

- The lack of planning and operations associated with deploying active dry floodproofing systems
- The effect of preferential scour pathways
- Damage to structures due to improperly secured fastening of breakaway walls
- Damage to asphalt shingles, vinyl soffits, and vinyl siding from wind and wind-borne debris

1.1 Organization of the Report

This MAT report is divided into five chapters and three appendices. This chapter describes Hurricane Irma, regional preparedness activities and the MAT background and process. Chapter 2 discusses building codes, standards, and regulations in effect in Florida. Chapter 3 describes MAT observations related to the performance of residential and non-residential buildings under flood conditions. Chapter 4 describes MAT observations related to damage sustained by residential and non-residential buildings from high winds and evaluates the effect building codes have had on building performance for those buildings exposed to high winds. Chapter 5 presents the MAT's conclusions and recommendations and is intended to help guide reconstruction for flood- and hurricane-prone communities. In addition, the report includes the following appendices:

- Appendix A: Acknowledgements
- Appendix B: Glossary
- Appendix C: Links to Recovery Advisories for Hurricane Irma in Florida
    - Recovery Advisory 1 (2018d), *Dry Floodproofing: Operational Considerations*
    - Recovery Advisory 2 (2018h), *Soffit Installation in Florida*
    - Recovery Advisory 3 (2018f), *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) of the Florida Building Code*

1.2 Hurricane Irma: The Event

Irma began as a weak wave of low pressure accompanied by disorganized showers and thunderstorms that emerged off the West African coast on August 27. Tropical Storm Irma formed in the far eastern Atlantic Ocean, just west of the Cape Verde Islands, on the morning of August 30. Over the next 30 hours, the storm intensified into a major hurricane with highest sustained winds of 115 miles per hour (mph), a Category 3 storm on the Saffir-Simpson Hurricane Wind Scale. The storm became a Category 5 hurricane on September 5, with maximum sustained winds of 185 mph, and was located north of the islands of Puerto Rico and Hispaniola. This made Hurricane Irma one of the strongest observed hurricanes in the open Atlantic Ocean. Table 1-1 shows a comparison of Hurricane Irma's wind speeds with other major Atlantic hurricanes.

THE SIGNIFICANCE OF HURRICANE IRMA

- Hurricane Irma became a Category 5 hurricane on September 5, 2017. Hurricane Irma's 185 mph winds were the strongest 1-minute maximum sustained winds recorded for an Atlantic hurricane outside of the Gulf of Mexico and the Caribbean.
- Hurricane Irma maintained an intensity of 185 mph for 37 hours—the longest any cyclone on record has maintained that intensity—breaking the old record of 24 hours set by Typhoon Haiyan in 2013.
- As a measure of the storm's intensity, the Accumulated Cyclone Energy (ACE) index of 67.5 generated by Irma was the second highest in the satellite era (since 1966) for an Atlantic hurricane, trailing only Hurricane Ivan (2004), which had an ACE index of 70.4.
- As Hurricane Irma hit Florida, tropical storm force winds extended outward up to 400 miles from the center.
- Approximately 6.5 million residents in Florida were evacuated from coastal areas.

SOURCES: NOAA NWS, 2017; KLOTZBACH AND BELL, 2017

Table 1-1: Comparison of Hurricane Irma Wind Speed to Other Major Atlantic Hurricanes

Year	Hurricane	Maximum Sustained Winds (mph)
1992	**Andrew**	173
2004	**Ivan**	167
2005	**Katrina**	173
2005	**Wilma**	184
2017	**Irma**	185

SOURCES: NOAA, N.D.; NOAA NHC, 2004; NOAA NHC, 2005; NOAA NHC, 2006; NOAA NCEI, 2018b

The storm weakened to a Category 4 on September 8 and then re-intensified while crossing the open waters of the Straits of Florida. On September 10 at 9:10 a.m. EDT, Hurricane Irma made landfall on Cudjoe Key, FL, as a Category 4 storm with maximum sustained winds near 130 mph and a minimum pressure of 931 millibars (mb) (NOAA NHC, 2018). Later that day, Hurricane Irma made a second landfall near Marco Island as a Category 3 hurricane with maximum sustained winds of 115 mph and a central pressure of 940 mb before tracking up the Floridian Peninsula (Figure 1-1) and into Georgia on September 11 (NOAA NWS, 2017). Sustained hurricane force wind (i.e., 74 mph or greater) extended well inland over the southern Florida peninsula. The Marco Island Police Department reported a wind gust of 130 mph, and a wind gust of 142 mph was reported at the Naples Municipal Airport (NOAA NWS, 2017; NOAA NHC, 2018).

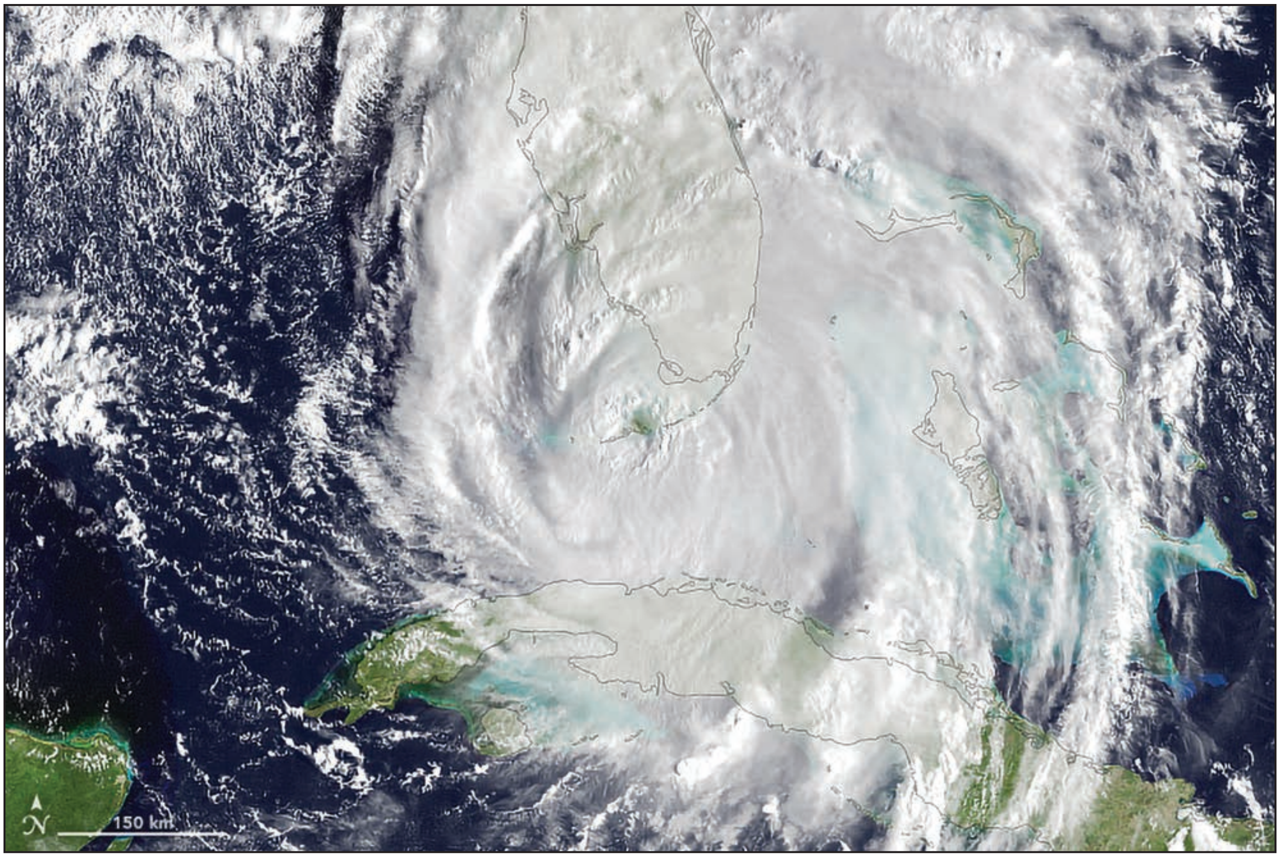


Figure 1-1: Composite satellite image from the GOES-13 weather satellite of landfall near the Florida Keys (left) on September 10, 2017 8:15 AM

SOURCE: NASA, 2017

As Hurricane Irma hit Florida, tropical storm force winds extended up to 400 miles from the center, and hurricane force winds extended outward 80 miles. Figure 1-2 shows the cone of the probable track that was forecast on Thursday, September 7, enveloping the entire State of Florida, and the most likely arrival time of tropical storm force winds on Sunday, September 10. In addition to the long periods of heavy rain and strong winds, storm surge flooding also pummeled the coasts well away from the storm center. In the Jacksonville area, strong and persistent onshore winds blew for days before Irma's center made its closest approach.

The National Oceanic and Atmospheric Administration (NOAA) measures the power of hurricanes using the estimated maximum sustained surface wind velocity for each 6-hour period of their existence. This measurement, the ACE, was 67.5 for Hurricane Irma, which is the second most powerful storm in the satellite era (since 1966) (Klotzbach and Bell, 2017). Irma's power was the result of the duration of sustained hurricane force winds as the storm approached the U.S. coast. As it approached southern Florida, the storm weakened to a Category 3 hurricane. For a detailed discussion of the timeline and formation history of Hurricane Irma, see the NOAA National Hurricane Center's (NHC's) Hurricane Irma Tropical Cyclone Report (NOAA NHC, 2018).

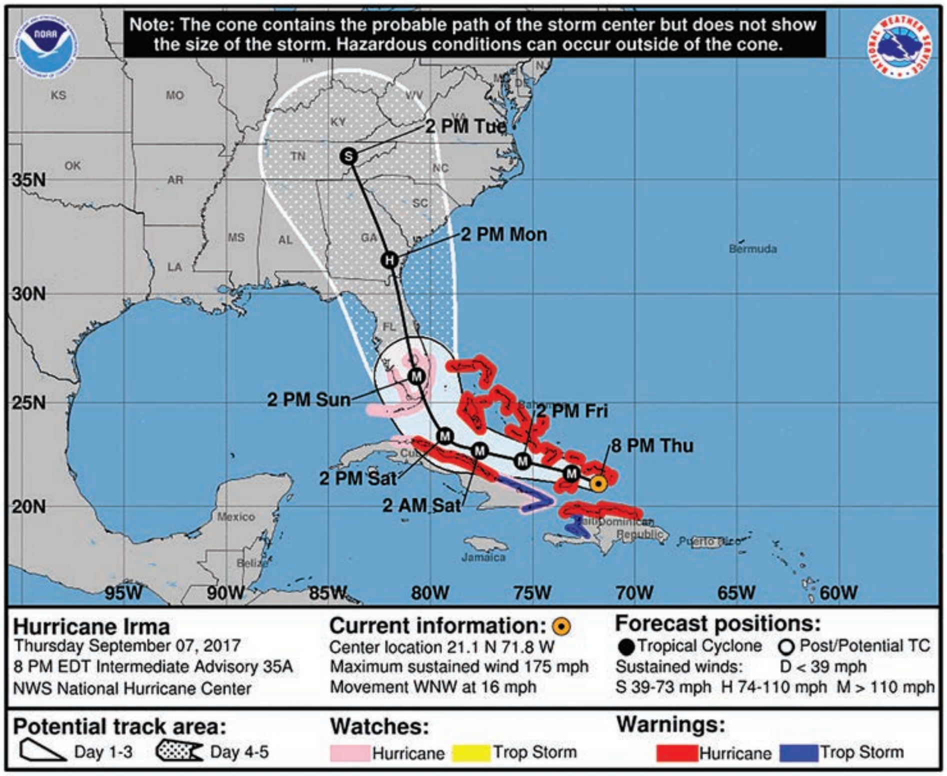
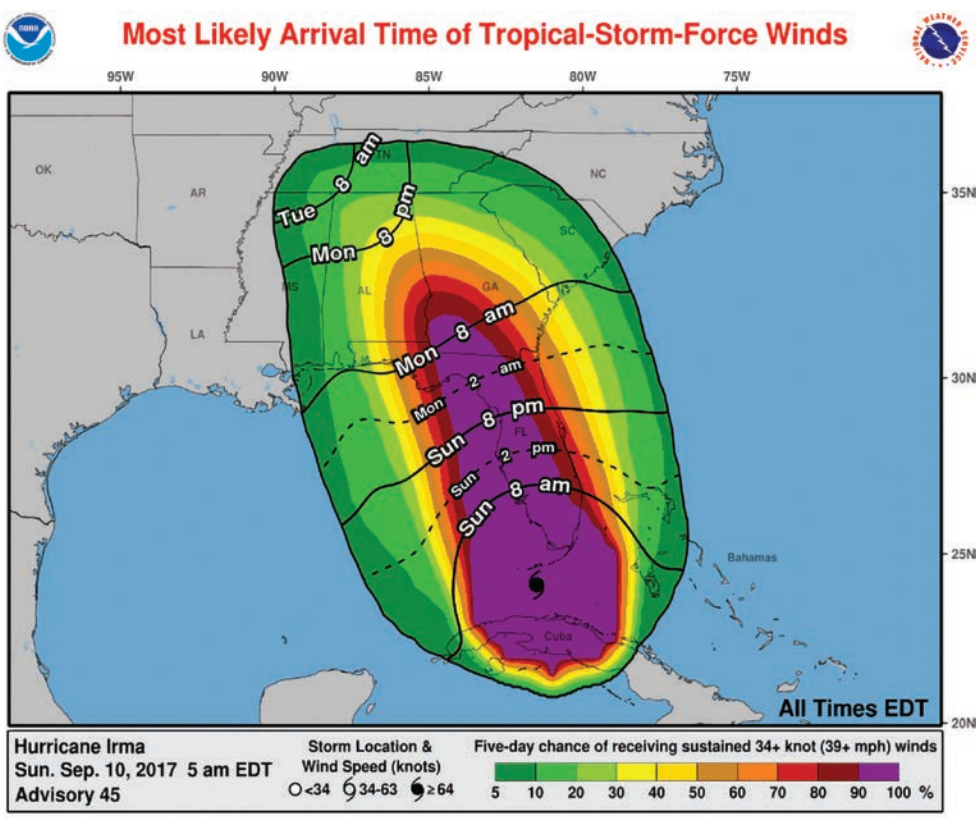


Figure 1-2: Hurricane Irma cone of probable track forecast on Thursday, September 7 (upper) and most likely arrival of tropical storm force winds on Sunday, September 10 (lower)

SOURCE: NOAA NHC, 2017A AND 2017B



1.2.1 Storm Surge Flooding

Hurricane Irma was the first major (Category 3 or higher) hurricane to make landfall in South Florida since Hurricane Wilma of 2005, bringing with it high winds and predicted storm surge inundation. Figure 1-3 to Figure 1-6 show the locations of high water marks surveyed by the U.S. Geological Survey (USGS) after the event. Significant flooding occurred where the combination of storm surge and riverine flooding from rainfall-runoff overflowed streams and riverbanks and related infrastructure in the City of Jacksonville (Note: the MAT did not visit this area). This phenomenon probably occurred in locations where rivers flow into tidal areas that experienced storm surge, although the timing of the runoff and storm surge peaks seldom coincide (NOAA NHC, 2018).

To characterize the storm surge flooding from Hurricane Irma, two datasets from FEMA's Flood Map Service Center[1] were queried and compared: tide gage data at locations in South Florida and the 10-, 2-, 1-, and 0.1-percent-annual-chance stillwater elevations from the counties' Flood Insurance Studies (FISs). The results of this comparison are reported in Table 1-2.

The FISs for Lee, Collier, Miami-Dade, and Monroe County are currently in the process of being updated. The revised Flood Insurance Rate Maps (FIRMs) are estimated to be completed in 2019–2021. Thus, the effective FISs (circa 2009–2012) were used to determine the annual percent chance stillwater elevations. Although the effective studies are dated 2009–2012, the storm surge elevations are based on studies from the 1970–1980 timeframe. As reported at these five gages, Hurricane Irma was below the 1-percent-annual-chance event (or 100-year flood).

1-PERCENT-ANNUAL-CHANCE EVENT

FEMA FIRMs delineate flood hazard areas and zone designations (e.g., Zone VE, Zone AE) that reflect the nature of the flood conditions expected during the base flood. The base flood is the flood that has a 1 percent annual chance of occurrence (frequently referred to as the 100-year flood). FIRMs show the base flood elevation, or BFE. The area designated as subject to inundation from the 1-percent-annual-chance flood is called the Special Flood Hazard Area (SFHA).

Locations within the SFHA can be exposed to flooding at a greater frequency (i.e., more often) than the 1-percent-annual chance event. The water surface elevation at these locations may be less than the BFE, but may still cause minor damage. Subsurface areas and infrastructure at ground level are subject to flooding at a water surface elevation below the BFE.

1 The FEMA Flood Map Service Center can be accessed here: msc.fema.gov/portal/home.

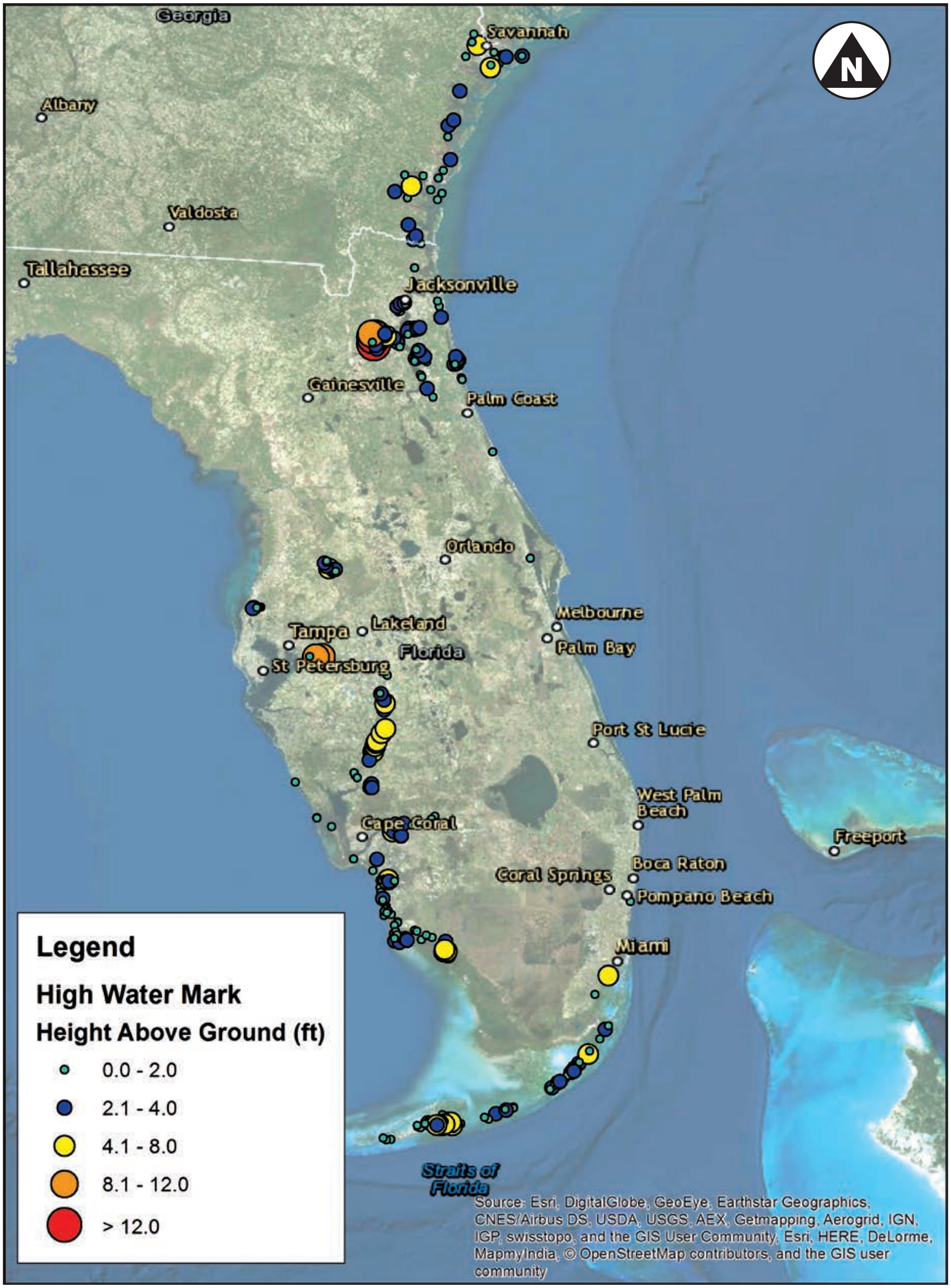


Figure 1-3: Surveyed locations of Hurricane Irma's high water marks

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

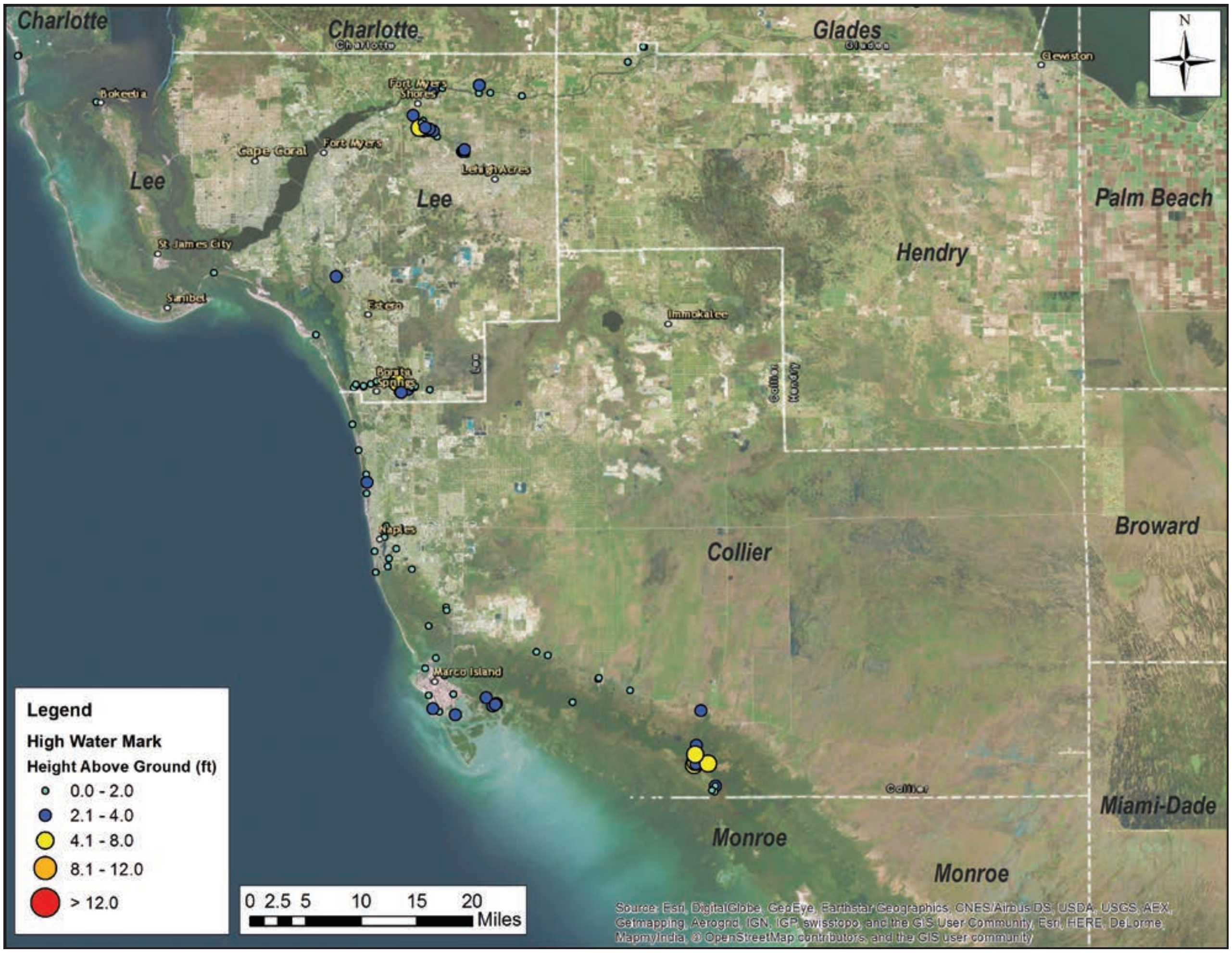


Figure 1-4: Surveyed locations of Hurricane Irma's high water marks in Lee and Collier Counties

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

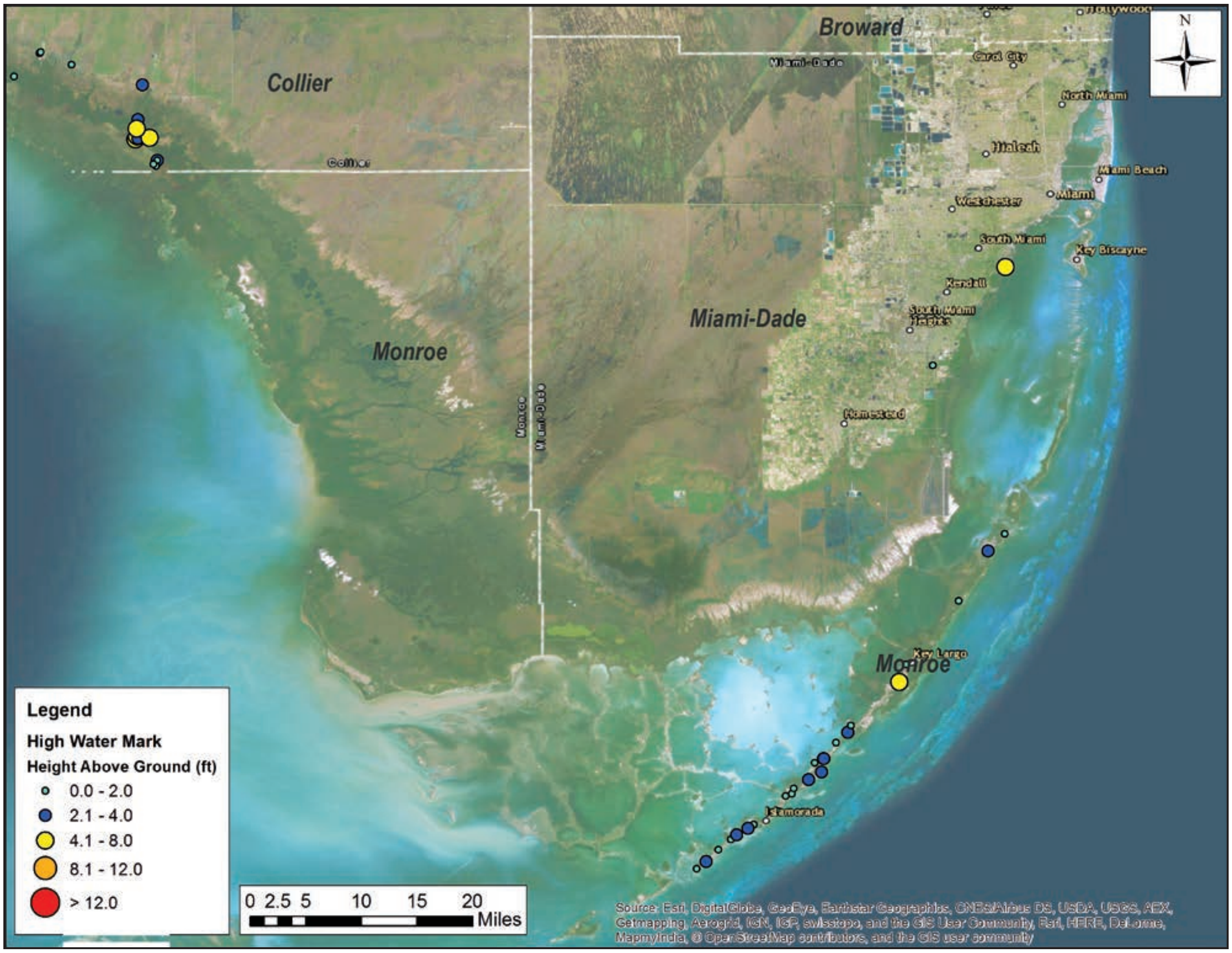


Figure 1-5: Surveyed locations of Hurricane Irma's high water marks in Miami-Dade County

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

The combined effect of storm surge and tide produced maximum inundation levels between 5 and 8 feet above ground level for small portions of the Lower Florida Keys from Cudjoe Key eastward to Big Pine Key and Bahia Honda Key. Several high water marks of at least 4 feet above ground level were also surveyed by USGS in this area, with the highest mark being 5.45 feet above ground level on Little Torch Key (NOAA NHC, 2018).

In Collier County at Chokoloskee, inundation levels were as high as 6 to 8 feet near the waterfront. Inland areas of the island had inundation levels of 3 to 5 feet. At the Everglades National Park Gulf Visitor Center in Everglades City, the USGS measured a high water mark greater than 5 feet above ground. Flooding in other areas in Everglades City ranged from 2 feet to a maximum of 6 feet of inundation. Marco Island had up to 3 feet of inundation above ground (NOAA NWS, 2017). Strong offshore winds initially blew away from the coast causing water to recede along the southwestern coast of Florida. As the center of the storm moved past this area, the winds shifted onshore, and the water level at the NOAA tide gage at Naples increased by 6 feet within the first hour and 9 feet in 3 hours (NOAA NHC, 2018).

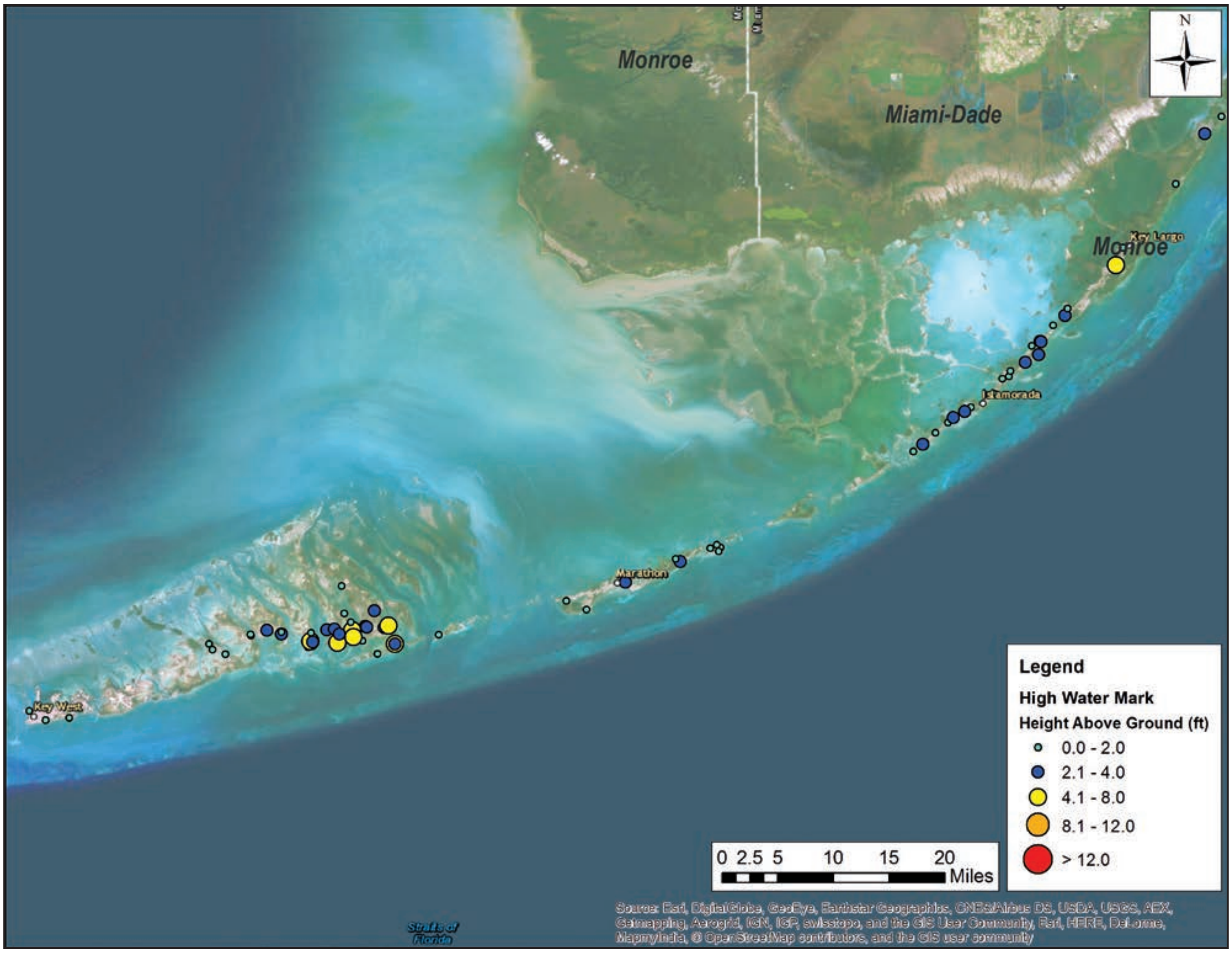


Figure 1-6: Surveyed locations of Hurricane Irma's high water marks in Monroe County

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

In Miami-Dade County along the shoreline of Biscayne Bay, the USGS measured 4 to 6 feet of inundation, with the highest estimated depth of more than 5 feet in Matheson Hammock Park. Downtown Miami was flooded, likely due to the combination of rainfall and runoff, wave overwash, and backflow through the city's drainage system (NOAA NHC, 2018). Inundation depths were shallower in the communities north of downtown Miami. In Broward County, the highest inundation was 2 to 3 feet from Ft. Lauderdale Beach southward. In Palm Beach County, inundation was not significant (NOAA NWS, 2017).

The combined effect of storm surge and the tide produced maximum inundation levels of 1 to 2 feet above ground level along the west coast of Florida north of Charlotte Harbor to Apalachee Bay. Similar to what occurred near Naples, offshore winds on the northern side of Irma's circulation initially caused water levels to recede below normal levels along much of the west coast of Florida, including Tampa Bay. In Tampa Bay at St. Petersburg, the water level was 5 feet below normal (NOAA NWS, 2017).

Table 1-2: Water Surface Elevations and Estimated Return Periods in South Florida Counties

County	NOAA ID	NOAA Station Name	Maximum Water Surface Elevation (feet NAVD88)	Estimated Return Period[a]	Annual-Chance Stillwater Elevation (feet NAVD88)			
					10% (10-Year)	2% (50-Year)	1% (100-Year)	0.2% (500-Year)
Lee	8725520	Fort Myers, Caloosahatchee River, FL	3.33	10 year	3.3[b]	N/A[b]	7.0[b]	8.1[b]
Collier	8725110	Naples, Gulf of Mexico, FL	4.60	<20 year	3.9[c]	7.3[c]	8.4[c]	10.4[c]
Miami-Dade	8723214	Virginia Key, Biscayne Bay, FL	3.84	<10 year	4.3[d]	5.6[d]	6.2[d]	7.2[d]
Monroe	8723970	Vaca Key, Florida Bay, FL	2.14	<10 year	3.2[e]	5.4[e]	6.3[e]	7.6[e]
Monroe	8724580	Key West, FL	2.64	<20 year	1.9[e]	4.2[e]	5.5[e]	6.0[e]

NAVD88 = North American Vertical Datum of 1988; NGVD29 = National Geodetic Vertical Datum of 1929; NOAA = National Oceanic and Atmospheric Administration

(a) Prior to Hurricane Irma, FEMA initiated a coastal flood risk study for the South Florida Study Area (Broward, Miami-Dade, Monroe, and Palm Beach Counties) and the Southwest Florida Study Area (Charlotte, Collier, Desoto, Hendry, Lee, and Sarasota Counties). Hurricane Irma impacted the coast in the middle of the coastal flood mapping update process.

(b) The Lee County FIS is preliminary (dated February 2018). The stillwater values do not include wave setup.

(c) The effective Collier County FIS (dated May 2012) is in the process of being updated by the Southwest Florida Study. The return period results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup.

(d) The effective Miami-Dade County FIS (dated September 2009) is in the process of being updated by the South Florida Study. The results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup. The stillwater values were converted from NGVD29 to NAVD88.

(e) The effective Monroe County FIS (dated February 2005) is in the process of being updated by the South Florida Study. The results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup. The stillwater values were converted from NGVD29 to NAVD88.

1.2.2 Rainfall

Rainfall totals of 10 to 15 inches were common for Hurricane Irma across the peninsula and the Florida Keys. The maximum reported total rainfall for the storm was near the Fort Pierce Water Plant in St. Lucie County, where 21.66 inches of rain was measured between September 9 and 12. Most rivers in northern Florida were flooded, and major or record flood stages were reported at rivers in Alachua, Bradford, Clay, Duval, Flagler, Marion, Nassau, Putnam, and St. Johns Counties (Note: the MAT did not visit riverine areas in these counties). The St. Johns River set record flood stages at many locations in Duval County, causing major flooding in the Jacksonville metropolitan area (NOAA NHC, 2018). Figure 1-7 shows the total estimated rainfall from Hurricane Irma for the southeastern United States.

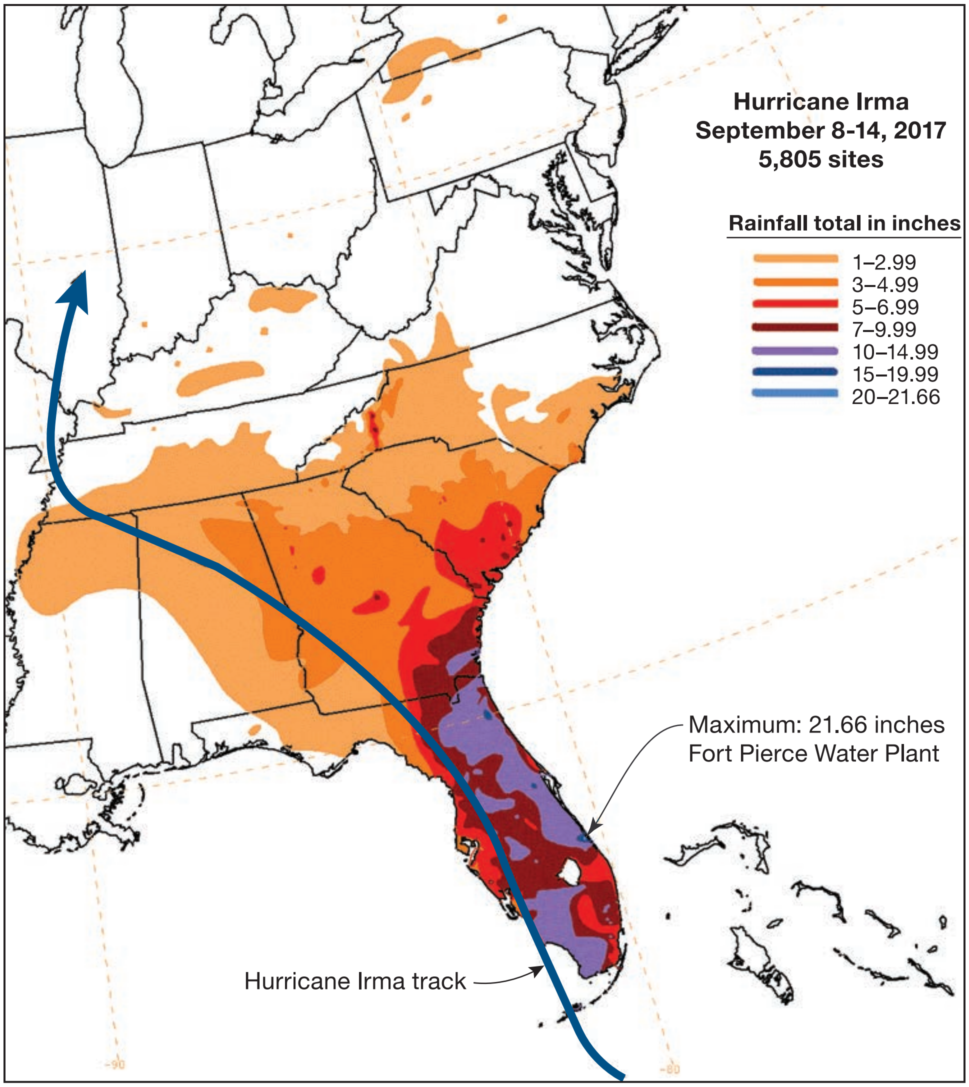


Figure 1-7: Map of rainfall totals associated with Hurricane Irma (or its remnants)
SOURCE: NOAA NCEP, 2017

1.2.3 Wind

On September 10 at 9:10 a.m. EDT, Hurricane Irma made landfall on Cudjoe Key, FL, as a Category 4 storm with maximum sustained winds near 130 mph. Later that day as Hurricane Irma approached the mainland, sustained Category 3 winds of 111 to 115 mph were confined to a small area of the eye that touched Marco Island, FL, and a small part of the immediate coastline of Collier County. Sustained Category 2 winds (96 to 110 mph) occurred in portions of the Naples area. The highest wind gust recorded on land in South Florida was 142 mph at a monitoring site at the Naples Municipal Airport (ID: NPLMP). The maximum sustained wind speed on Marco Island was recorded at 112 mph (NOAA NWS, 2017).

Many locations in Broward and Miami-Dade Counties reported sustained winds below hurricane force (between 50 and 73 mph). Isolated locations (immediate coastal areas of Broward and Miami-Dade Counties within 1 mile of the coast and southern Miami-Dade) may have experienced sustained winds that reached the low end of Category 1 hurricane strength (around 75 mph). Wind gusts in Broward, Miami-Dade, and Palm Beach Counties likely peaked in the 80 to 100 mph range (see Figure 1-8). For comparison, the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* basic wind speeds[2] for Risk Category II building design are shown on the right (ASCE 7-10).

ASCE 7 RISK CATEGORIES

The ASCE classifies buildings as Risk Category I, II, III, or IV depending on the risk posed to human life if the structure were to fail. Almost all residential buildings fall into Category II. Category II includes buildings that do not fall into Category I (those that pose a low risk to human life in the event of failure), Category III (those that pose substantial risk to human life in the event of failure), or Category IV (those designated as essential facilities, which pose substantial hazard to the community in the event of failure).

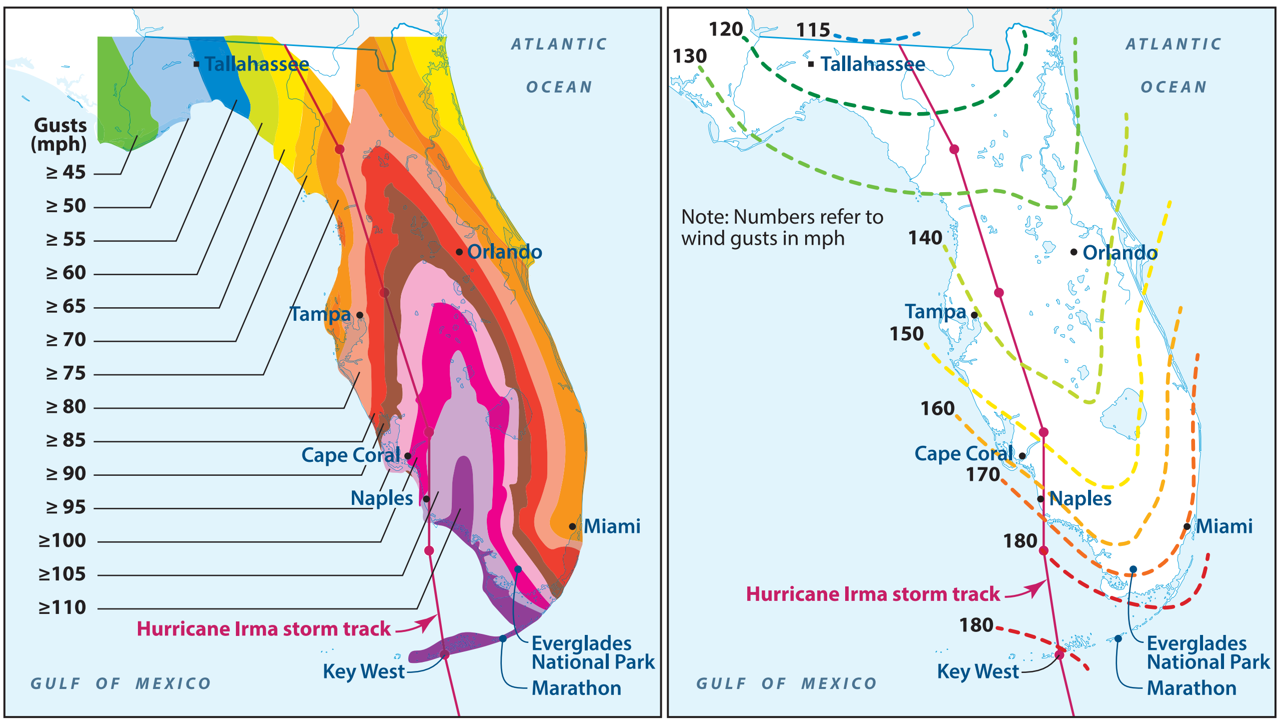


Figure 1-8: Comparison of gusts experienced during Hurricane Irma (left) with ASCE 7-10 design 3-second wind gusts (right)

SOURCES: LEFT MAP MODIFIED FROM ARA/FEMA GEOSPATIAL WORKING GROUP, 2017. RIGHT MAP MODIFIED FROM ASCE, 2010

2 Basic wind speed is defined as the 3-second gust speed at 33 feet (10 meters) above the ground in Exposure Category C.

1.2.4 Tornadoes

Hurricane Irma produced 25 confirmed tornadoes, 21 of which occurred in Florida. There were three EF-2 (on the Enhanced Fujita Scale[3]), 15 EF-1, and 7 EF-0 tornadoes (NOAA NHC, 2018). The majority of the tornadoes developed along the east coast of central and northern Florida. The tornado in Miami-Dade County struck near Homestead Motor Speedway. In Broward County, two of the tornadoes were EF-1 and the other was EF-0. One of the EF-1 tornadoes occurred 4 miles west of Miramar along 172nd Avenue between Memorial Hospital and Miramar Regional Park, where sections of trees were ripped apart. The other EF-1 tornado formed 4 miles west-northwest of Miramar in the Chapel Trail Neighborhood near NW 196th Avenue, north of Pines Boulevard. Several trees were ripped apart in a localized area, with some damage to roof tiles and screened-in patios. The damage pattern suggested rotation from a tornado vortex. The EF-0 tornado briefly touched down near Oakland Park (NOAA NWS, 2017).

1.3 Hurricane Irma: The Impact

The Tropical Cyclone Report for Hurricane Irma published by NOAA's NHC on May 30, 2018, indicates that Hurricane Irma was directly responsible for 47 fatalities across the Caribbean Islands and the southeastern United States as a result of strong winds, heavy rains, and high surf. In the United States, 10 direct fatalities were reported and an additional 82 indirect fatalities occurred, 77 of which were in Florida. These include the fatalities of elderly residents in a nursing home when the facility lost power to its central air conditioning, causing the facility to become overheated. Hundreds more were injured as a result of the storm (NOAA NHC, 2018). Approximately 6.5 million residents in Florida were evacuated from coastal areas (Florida House of Representatives, 2018).

NOAA's National Center for Environmental Information (NCEI) estimates that wind and water damage caused by Irma in the United States totaled approximately $50.5 billion (NOAA NCEI, 2018a). This estimate is based on a variety of public and private data sources, including FEMA, the Insurance Services Office, the U.S. Department of Agriculture, the Energy Information Administration, the U.S. Army Corps of Engineers, and State and other agencies. The data sources provide key pieces of information that capture the total, direct costs (both insured and uninsured) of weather and climate events. The estimated costs were adjusted for inflation and reported in dollars in terms of damages avoided had the event not taken place. The damage costs incorporate estimates based on physical damage to residential, commercial, and government or municipal buildings; material assets within a building; time element losses such as business interruption; vehicles and boats; offshore energy platforms; public infrastructure such as roads, bridges, and buildings; and agricultural assets such as crops, livestock, and timber. Insured loss data were scaled up to account for uninsured and underinsured losses. This is specific by peril, geography, and asset class. In addition, the estimated damage costs do not include losses related to health care, injury and loss of life, and natural capital.

In the Florida Keys, more than 1,300 boats were damaged or destroyed (NOAA NHC, 2018). Other long-term damage impacts include the loss of housing in the Florida Keys, damage to wastewater and potable water infrastructure, and minor to major erosion at different locations along the coastline. In addition, the estimate of Hurricane Irma's impact on Florida's agriculture industry is $2.5 billion

3 For more information about the Enhanced Fujita scale, refer to www.spc.noaa.gov/faq/tornado/ef-scale.html.

in total losses (Florida House of Representatives, 2018). The insurance industry estimated $8.6 billion in insured losses (Florida Office of Insurance Regulation, 2018).

For a detailed discussion on the assessment of the storm's impact on beach and dune erosion and structural damage to coastal regions of Florida, refer to the Florida Department of Environmental Protection's report titled, *Hurricane Irma Post-Storm Beach Conditions and Coastal Impact in Florida Report* (Florida DEP, 2018).

1.4 Regional Preparedness Actions

On September 4, Florida Governor Rick Scott declared a state of emergency for Florida and placed 100 members of the Florida National Guard on duty to assist in preparations. According to a report prepared for the Florida House of Representatives (2018), all 7,000 National Guard troops were ordered to be on duty by September 8. State and local emergency management officials advised residents to stock their hurricane kits. Governor Scott suspended tolls on all toll roads in the State starting at 5:00 p.m. on September 5. All State offices in Florida were closed on September 8. Schools and colleges were closed in 44 of the State's 67 counties before Governor Scott ordered all State colleges, universities, schools, and offices to be closed from September 8 to 11.

Fifty-four of Florida's 67 counties issued both voluntary and mandatory evacuation orders to a record 6.8 million people. Nearly 700 shelters were opened throughout the State, housing a record 190,000 people. A record 6.5 million people evacuated, all while the State Emergency Operations Center and local emergency management officials adjusted to 10 different scenarios over the course of Irma's track (Florida House of Representatives, 2018).

1.5 FEMA Mitigation Assessment Team

FEMA conducts building performance studies after unique or nationally significant disasters to better understand how natural and manmade events affect the built environment. A MAT is deployed when FEMA believes the findings and recommendations derived from field observations will result in design and construction guidance that will improve the disaster resistance of the built environment in the affected State or region and will be of national significance to other disaster-prone regions. FEMA bases its decision to deploy a MAT on preliminary information, such as:

- Magnitude of event
- Type and severity of damage in the affected areas
- Pre-storm site conditions in the impacted areas, such as the presence of older housing, newer housing, non-residential and critical facility stock, and building utility infrastructure
- Potential value of study results to the recovery effort
- Strategic lessons that can be learned and applied, potentially on a national level, related to improving building codes, standards, industry practices or guidance, code enforcement, research needs, knowledge gaps, or others
- Possibility of the field assessment gathering and analyzing pertinent information regarding the effectiveness of (1) certain FEMA grants and (2) key engineering principles and practices that FEMA promotes in published guidance and best practice documents

- Value of providing FEMA guidance in discipline topics currently not addressed or updating existing FEMA guidance on select topics as needed

The MAT studies the adequacy of current building codes and floodplain management regulations, local practices, and building materials in light of the damage observed after a disaster. Lessons learned from the MAT's observations are communicated through recovery advisories, fact sheets, and a comprehensive MAT report, all of which are made available to communities and the general public to aid their rebuilding efforts and enhance the disaster resistance of building improvements and new construction.

1.5.1 Hurricane Irma MAT

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the pre-MAT performed a preliminary field assessment of building damage in limited areas in Collier, Lee, Miami-Dade, and Monroe Counties. The full Irma MAT was deployed on December 10, 2017, to the areas initially surveilled by the pre-MAT and completed its field assessment work in February 2018. The MAT's mission was to assess the performance of residential and non-residential buildings affected by Hurricane Irma in Florida. To assess the effectiveness of flood and wind mitigation efforts previously undertaken, the MAT evaluated buildings that had previously undergone mitigation to improve their resistance to hurricane conditions (either wind or flood), as well as residential and non-residential buildings that had not been mitigated. The MAT focused on buildings located in the area of Hurricane Irma's landfall in Collier, Lee, Miami-Dade, and Monroe Counties.

1.5.2 Team Composition

The Irma MAT was composed of 17 subject matter experts, including:

- FEMA Headquarters and Regional office staff
- A representative from the State of Florida Division of Emergency Management (FDEM) Floodplain Management Office
- Building code, construction, and manufacturing industry staff from the Asphalt Roofing Manufacturers Association and PGT Industries
- Design professionals and technical consultants

Team members have backgrounds in structural, civil, and coastal engineering; floodplain management and mapping; building codes; critical facility protection; flood and wind damage-resistant materials; and urban floodproofing. The members of the MAT are listed in the front matter of this report.

1.5.3 Methodology

The Hurricane Irma MAT was divided into two specialty units: Flood and Wind. The Flood Unit focused on flood damage related to inundation, scour, and wave forces, as well as the performance of dry floodproofing and facility planning. The Wind Unit focused on wind-related damage and roof and soffit performance. Each unit visited several locations in Florida to assess the performance of different building and facility types.

Involvement of State and Local Agencies

FEMA encouraged State, county, and local government officials and locally based experts to participate in the assessment process. Their involvement was critical and helped improve the MAT's understanding of local construction and enforcement practices; encouraged the MAT to develop recommendations that were both economically and technically feasible for the communities involved; facilitated communications among Federal, State, and local governments and the private sector; and improved the State and local understanding of the MAT's observations, conclusions, and recommendations, which should enable them to bring about changes in their communities.

The MAT members met with local emergency management and government officials in many of the areas they visited. The officials gave an overview of the damage in their area and helped identify key sites to visit. The MAT also coordinated with the FEMA Joint Field Offices (JFOs) that had been set up in the area shortly after Hurricane Irma. Individuals who assisted the MAT in its field operations and report development are listed in Appendix A.

Pre-MAT Deployment and Site Selection

The pre-MAT was deployed shortly after Hurricane Irma's landfall and was tasked to quickly observe and record select perishable damage data, locate damaged areas requiring further assessment, and help determine the size and scope of areas and buildings to be visited, as well as the skillsets that would be needed for a larger follow-on MAT. The pre-MAT conducted ground surveillance in the areas shown in Figure 1-9. The members of the pre-MAT developed a list of select locations and specific building sites they considered important for the MAT to observe to better understand performance, vulnerabilities, and gaps or strengths in building planning, design, construction, enforcement, or other practices.

FEMA, State and local government agencies, and the MAT members also identified additional potential sites for the MAT to visit. To produce the final site list, the MAT assessed whether data were sufficient to evaluate building damage at each site. Specifically, the availability of the following data sources was considered for each site:

- Wind field maps, wind contour maps, and grids showing flood depths and extents produced by the FEMA Natural Hazard Risk Assessment Program (NHRAP)
- Water surface elevation data compiled from USGS, recorded high water marks, and surge sensor data
- Data on FEMA Hazard Mitigation Assistance grant projects
- Claims from the FEMA National Flood Insurance Program (NFIP)
- Data from the effective FEMA National Flood Hazard Layer and preliminary/ongoing FEMA Risk Mapping, Assessment, and Planning (Risk MAP) coastal studies in South Florida
- Damage information received from the FEMA Regional Response Coordination Center (RRCC) and JFO through Federal, State, and local governments and academic and private sector sources from which buildings of interest were selected
- Orthophotographs and data from NOAA and the Civil Air Patrol

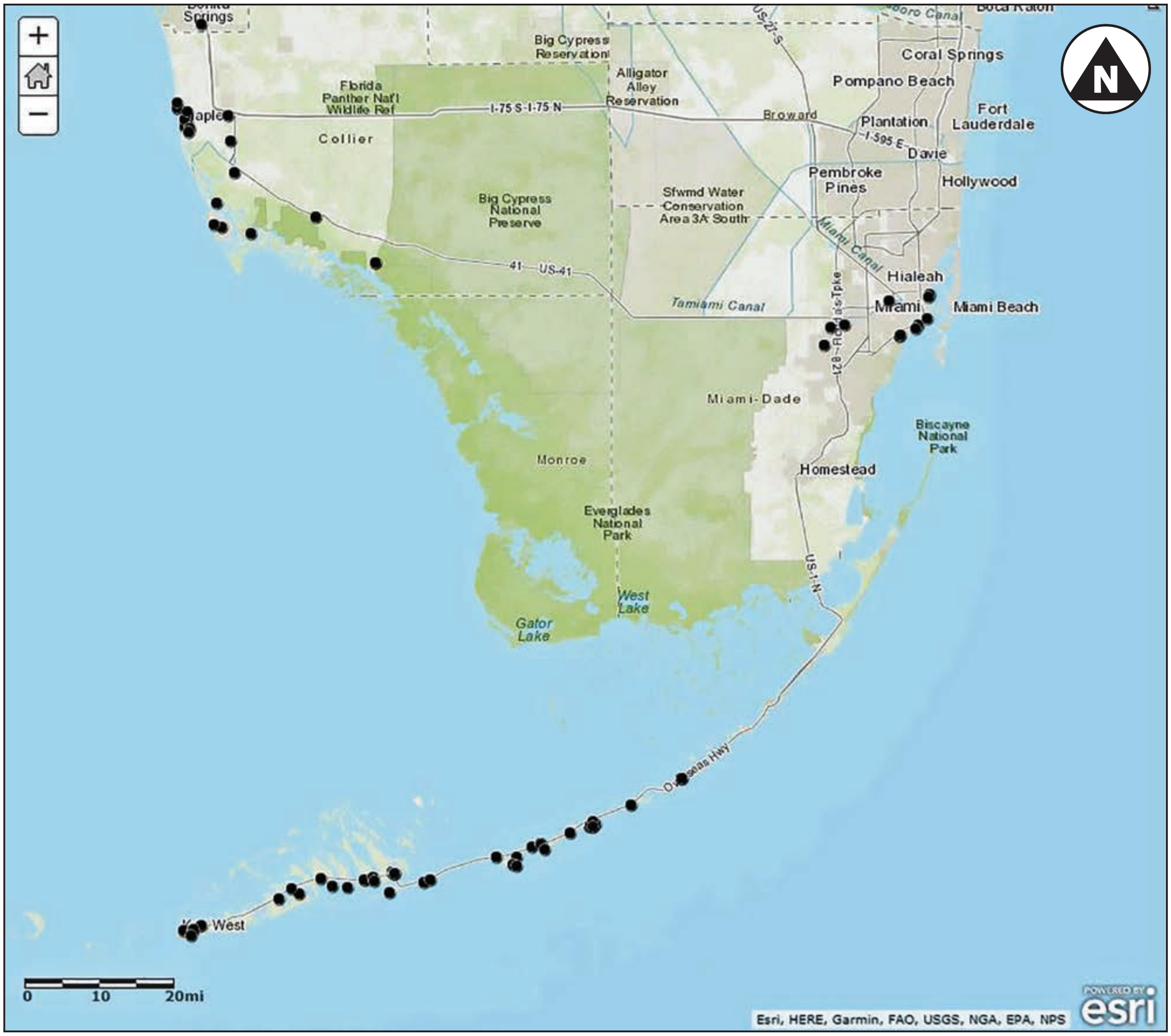


Figure 1-9: Field locations visited by the pre-MAT

- Data from the Fulcrum Community Data National Science Foundation (NSF) Rapid Response Research for the 2017 hurricanes[4]
- Estimates of storm surge and wave heights from the Coastal Emergency Risks Assessment's (CERA's) Advanced Circulation (ADCIRC) Storm Surge and Simulating Waves Nearshore (SWAN) models webcast[5]
- Press/social media stories and photographs of post-disaster damage

4 Fulcrum Community is a crowdsourced data collection solution for qualified humanitarian projects. For the 2017 disaster season, the NSF funded teams from universities across the United States and coordinated a response with the objective of collecting perishable data on the performance of U.S. civil infrastructure. The data collected are accessible here: web.fulcrumapp.com/communities/nsf-rapid.

5 The CERA group delivers storm surge and wave predictions for impending or active tropical cyclones in the United States. Based on the ADCIRC model, the CERA web mapping application provides an easy-to-use interactive web interface, which is accessible here: nc-cera.renci.org.

Based on the results of the pre-MAT, buildings were selected as examples of wind or flood effects for the full MAT damage assessment. The buildings selected for damage assessment included residential, non-residential, and mixed-use low-rise buildings; mid- and high-rise buildings; critical facilities and key assets; and public facilities, specifically public restrooms. Buildings were located in both coastal and riverine floodplains, as well as in urban areas, as described in the section that follows.

Field Deployment

Two MAT units were deployed on December 10, 2017, for 1 week. The 3-month delay in deployment after the storm resulted in the loss of perishable damage data (some sites and buildings were demolished; many buildings, roofs, windows and doors, and wall or other systems were already repaired or being repaired; and debris fields were cleaned up by the time the MAT arrived). When speaking with individuals about specific buildings, some were hesitant to discuss damage repairs affecting insurance claims.

To assess the performance of specific building and facility types, the MAT Flood and Wind units visited different locations depending on the type of damage—wind or flood—that occurred during Hurricane Irma. Both units conducted site visits and recorded observations along the coast of Florida at the locations shown in Figure 1-10.

The locations were based on those previously visited by the pre-MAT and on FEMA, State, and local input. For specific locations, outreach was conducted before and during the MAT deployment via telephone and email with site visit representatives to coordinate access. Some attempts were successful, while others were not. If a site of interest was identified in a conversation with the local contact, the contact was included as part of the field reconnaissance team.

When possible, building or facility owners were interviewed to gain insight into how well their buildings and facilities withstood Hurricane Irma and how their recovery efforts were progressing. The MAT spent considerable time assessing partially damaged buildings to determine why certain buildings performed better than others. The MAT members documented any observed best practices.

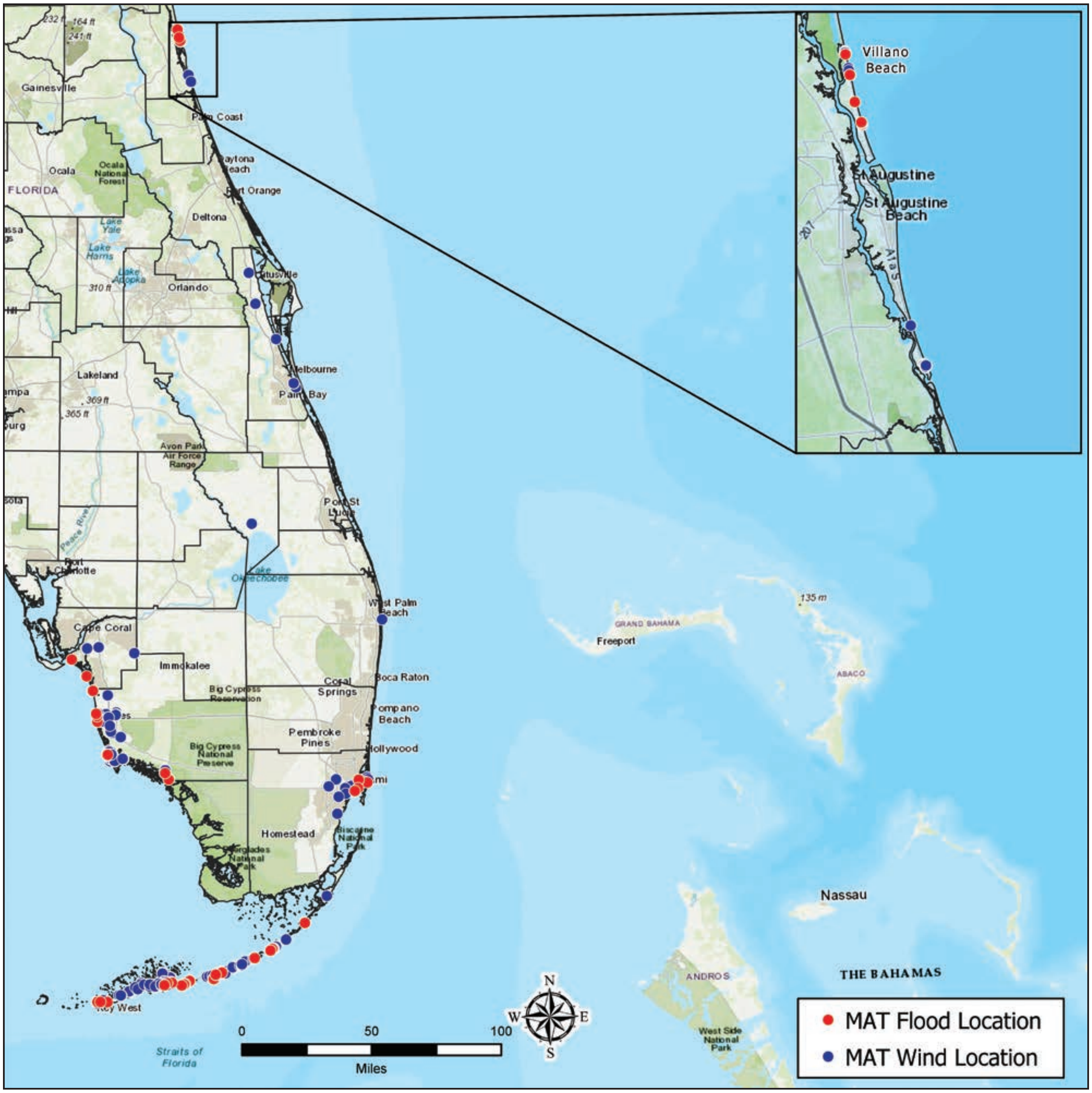
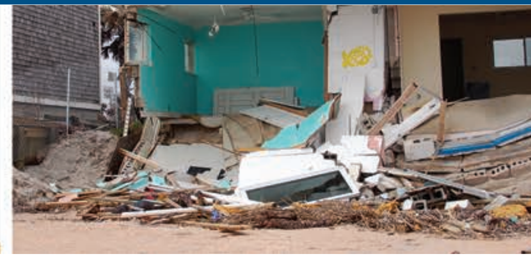


Figure 1-10: Field locations visited by the MAT Wind and Flood Units after Hurricane Irma. The inset map shows the locations of field visits in St. Johns County to evaluate erosion impacts.



HURRICANE
IRMA
IN FLORIDA

2 Building Codes, Standards, and Regulations

Building codes that include requirements to address flooding and high winds can help buildings resist damage.

This chapter presents an overview of Florida's building codes, the wind and flood provisions in those codes, and floodplain management in Florida. Section 2.1 describes the Florida Building Code (FBC), the process used by the Florida Building Commission to adopt and modify the International Codes® (I-Codes®), the model codes on which the FBC is based, and how local jurisdictions can amend the FBC.

Section 2.2 highlights recent initiatives of the Florida Division of Emergency Management (FDEM) to support communities that participate in the NFIP and summarizes the history of flood provisions in the FBC. Florida-specific amendments to the flood provisions of the I-Codes are described, including requirements specific to hospitals, nursing homes, and public education relocatable units. This section also lists the most common local amendments to the flood provisions in the FBC adopted by many Florida communities to incorporate higher and more restrictive standards. Section 2.3 summarizes the wind requirements in the FBC, including Florida-specific amendments for wind and water intrusion. Section 2.4 discusses Florida manufactured housing (MH) installation standards.

FEMA, the State of Florida, and others have documented how buildings are better able to resist damage from high winds and flooding when designed and constructed in compliance with building codes that contain requirements to address those hazards. As with other post-disaster MAT reports, observations after Hurricane Irma reinforce the value of the wind and flood provisions of the FBC, and the importance of trained plan reviewers and inspectors. Observations also identify the critical importance of builders paying attention to details during construction.

2.1 Building Codes in Florida

The FBC is part of the Florida Administrative Code adopted through Rulemaking as governed by Chapter 120 of the Florida Statutes. The adoption of the FBC by the Florida Building Commission as a Rule is mandated by the Florida Legislature (the code is not adopted statutorily). Local jurisdictions are required to enforce the FBC, but do not need to adopt it locally.

When Hurricane Irma made landfall in the State of Florida, the 5th Edition (2014) FBC was in effect. The 6th Edition (2017) FBC was adopted on June 13, 2017 through Rulemaking with an effective date of December 31, 2017. The term "Florida Building Code" refers to all of the codes administered by the Florida Building Commission, which include:

- Florida Building Code, Building (FBCB)
- Florida Building Code, Residential (FBCR)
- Florida Building Code, Existing Building (FBCEB)
- Florida Building Code, Mechanical (FBCM)
- Florida Building Code, Plumbing (FBCP)
- Florida Building Code, Energy Conservation (FBCEC)
- Florida Building Code, Accessibility (FBCA)
- Florida Building Code, Fuel Gas (FBCFG)
- Florida Building Code, Test Protocols (High-Velocity Hurricane Zone [HVHZ] Test Protocols)

SCOPE OF THE FLORIDA BUILDING CODE

For new construction, the FBCB applies to all buildings and structures except detached one- and two-family dwellings and townhouses not more than three stories above grade plane, which are within the scope of the FBCR. One- and two-family dwellings and townhouses outside the scope of the FBCR are required to comply with the FBCB. The FBCEB applies to the repair, alteration, change of occupancy, addition to, and relocation of buildings, including historic structures.

The 5th Edition (2014) FBC is based on the 2012 Edition of the applicable I-Codes published by the International Code Council (ICC). The 6th Edition (2017) FBC is based on the applicable 2015 I-Codes. The base codes are revised by Florida-specific amendments through Florida's code development process to create the FBC.

2.1.1 Florida Building Commission

The FBC is maintained and updated by the Florida Building Commission with administrative support and technical assistance from the Florida Department of Business and Professional Regulation (DBPR). The Commission is a 27-member stakeholder group that strives for consensus decisions on changes and updates to the FBC. Although the FBC is required to be updated every 3 years, the Commission may revise the code annually to incorporate Declaratory Statements (interpretations), clarifications, and standard updates.

Code Development Process

The development processes for the 5th Edition (2014) and 6th Edition (2017) FBC were essentially the same. The first step was to select the base code that would serve as the starting point. The 2015 I-Codes were selected as the base code for the 6th Edition (2017) FBC. For each update, all Florida-specific amendments expire except for the minimum requirements for State agencies (schools, nursing homes, swimming pools, etc.), statutory requirements, and the provisions of the HVHZ. The public is invited to propose code changes (Florida-specific amendments) to the base codes through the online Building Code Information System (BCIS) portal. Before the Florida Building Commission reviews the proposed code changes, they are first reviewed by Technical Advisory Committees (TACs). Eleven TACs review the proposed changes to the base code and make recommendations to the Florida Building Commission.

Previously, for a proposed code change to be recommended for approval by a TAC, three-fourths of the TAC members in attendance were required to be in support of the change. The recommendations of the TAC were then forwarded to the Florida Building Commission; incorporating the code change in the next edition of the FBC required three-fourths of the Commission members present to support the proposal. Once the code development process was completed, the Rulemaking process began, and the updated FBC became effective at a predetermined date.

However, as a result of 2017 changes to Section 553.73 of the Florida Statutes, the process for developing the 7th Edition (2020) FBC will change rather significantly. The Commission must use the 6th Edition (2017) FBC as the base code or starting point. The first phase of the process requires the Commission and TACs to review the 2018 I-Codes to examine changes from the 2015 I-Codes and determine whether to incorporate those changes into the 7th Edition (2020) FBC. The second phase will involve the TACs and Commission reviewing proposals submitted by the public to determine whether to incorporate those changes into the 7th Edition (2020) FBC. Additionally, the threshold for a TAC recommendation of approval of a code change has been reduced from three-fourths of the TAC members present at the meeting to two-thirds.

The 2017 statutory change also limits the Commission to only approving amendments to the code that are “needed to accommodate the specific needs of this state.” The statute further specifies that, at a minimum, the Commission must “adopt any updates to such codes or any other code necessary to maintain eligibility for federal funding and discounts from the National Flood Insurance Program, the Federal Emergency Management Agency, and the United States Department of Housing and Urban Development.” Any amendments or modifications made to the FBC will be carried forward until the next edition of the FBC.

The statute also prohibits any weakening of the wind resistance or prevention of water intrusion requirements in the FBC, including those contained in referenced standards, though this is not part of the 2017 changes.

2.1.2 Local Amendments

Local jurisdictions in Florida are permitted to amend the FBC provided such amendments do not weaken the code. Amendments must be submitted to the Florida Building Commission, which makes them available online. As part of the triennial code development process, the Commission reviews local amendments for consideration and inclusion in the FBC. However, the Commission does not have authority to approve or disapprove local amendments.

Local amendments expire with the effective date of each new edition of the codes, which means communities must re-adopt local amendments every 3 years. There are several other limitations on local technical amendments, but they can be challenged. As a result, there are very few local technical amendments of the code except for those related to flood, which, by statute, do not expire (refer to Section 2.3.3). The most common technical amendments related to the wind provisions of the code clarify the specific location of the wind speed contours.

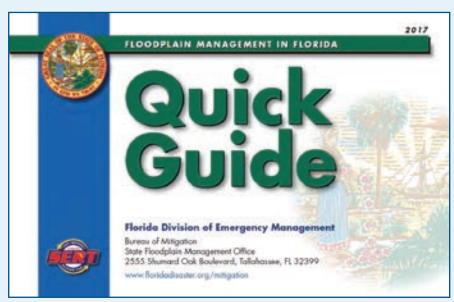
2.2 Floodplain Management in Florida

Communities that participate in the NFIP agree to adopt and enforce floodplain management regulations that meet or exceed the minimum requirements of the NFIP (44 CFR Parts 59 and 60). The State Floodplain Management Office (SFMO) of the FDEM is designated by the Governor as the NFIP State Coordinating Agency. In this capacity, the SFMO serves as a liaison between Florida's 467 NFIP communities and FEMA, helping communities implement sound land use development in floodplain areas to promote public health and safety, minimize loss of life, and reduce economic losses caused by flooding. Communities achieve those objectives by enforcing local floodplain management ordinances and the flood provisions of the FBC.

Supported by FEMA Community Assistance Program State Support Services Element (CAP-SSSE) funding, the SFMO conducts Community Assistance Visits (CAV) and Community Assistance Contact (CAC) interviews, provides one-on-one assistance for ordinance development and amendments, offers general technical assistance to Florida communities, supports FEMA's Map Modernization and Risk MAP processes, and provides training for local officials. The training is

QUICK GUIDE FOR FLOODPLAIN MANAGEMENT

The SFMO produced an illustrated overview of floodplain management for non-technical local staff and refresher for floodplain administrators. The guide is useful for informing elected officials, appointed citizen boards, and the public.



The Quick Guide is available online at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

conducted primarily through an agreement with the Florida Floodplain Managers Association (FFMA).

The SFMO also supports communities that participate in the NFIP Community Rating System (CRS), a program that recognizes activities undertaken by communities to reduce flood risk by providing premium discounts to citizens who have NFIP flood insurance policies. As of April 2018, 236 of the 467 Florida NFIP communities are in the CRS. Charged by FDEM leadership in early 2015 to increase participation in the CRS, the SFMO worked with FEMA to develop an initiative to visit more than 200 communities. Depending on the results and resolution of any identified concerns, the reports produced for each community can be used by FEMA to qualify communities for the CRS.

A central element of the initiative was development of “Seven Performance Measures” that, in effect, form a recommitment to the NFIP. The measures include conducting annual inspections of Special Flood Hazard Areas (SFHAs), having permit procedures and checklists in place, having procedures for making Substantial Improvement/Substantial Damage determinations, and communicating with utility companies and service providers regarding equipment and tank requirements. As of mid-2018, 26 of the visited communities have received FEMA approval for CRS entry. Other benefits of the initiative include increased awareness of the SFMO’s availability to provide technical support and acceleration of communities transitioning to floodplain management ordinances written explicitly to rely on the flood provisions of the FBC (refer to Section 2.2.4).

In May 2018, the SFMO released the *Florida Post-Disaster Toolkit for Floodplain Administrators* (see text box on the right). The toolkit describes six key actions, including planning ahead to communicate, assessing post-disaster needs, documenting high water marks, making Substantial Improvement/Substantial Damage determinations, understanding the NFIP claims and Increased Cost of Compliance coverage, and identifying post-disaster and mitigation funding assistance.

To facilitate insurance company access to elevation certificates, in the 2016 legislative session, the Governor signed a bill amending Section 472.0366 of the Florida Statutes to require professionals authorized to prepare land surveys to submit elevation certificates to FDEM using the form developed by FEMA. Communities report that having access to elevation certificates for buildings is beneficial when owners elect to have certificates prepared as part of obtaining flood insurance policies.

TOOLKIT FOR FLOODPLAIN MANAGERS

The toolkit is available online at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

ELEVATION CERTIFICATES

The web application for submitting elevation certificates and accessing submitted documents is available at www.floridadisaster.org/elevation-certificates.

2.2.1 History of Flood Provisions in the Florida Building Code

> **FLORIDA BUILDING CODE AND THE NFIP**
>
> The Florida SFMO compiles excerpts of the flood provisions of the 6th Edition FBC and a summary of the differences between the 6th Edition and the 5th Edition, online at www.floridadisaster.org/dem/mitigation/floodplain.
>
> FDEM refers users to FEMA's *Highlights of ASCE 24-14 Flood Resistant Design and Construction* (2015), online at www.fema.gov/building-code-resources.

The flood provisions in the FBC are based on the flood provisions in the I-Codes, which in turn are related to the floodplain management regulations of the NFIP. Since 1998, FEMA has participated in the code development process for the I-Codes. Every 3 years, the family of I-Codes is modified through a formal, public consensus process. Starting with the 2010 FBC, the flood provisions in the I-Codes are retained as the Florida Building Commission undertakes the code development process every 3 years.

FEMA deems the flood provisions in the 2018, 2015, 2012, and 2009 I-Codes to meet or exceed the minimum NFIP requirements for buildings and structures. Because the 6th Edition (2017) FBC is based on the 2015 I-Codes and the Florida Building Commission has not weakened any flood provision below the NFIP minimums, the flood provisions of the 6th Edition (2017) FBC also meet or exceed the minimum NFIP requirements for buildings and structures. In conjunction with floodplain management ordinances, Florida communities rely on the FBC to fulfill the requirements for participation in the NFIP. FEMA makes the same statement about the flood provisions of the 2012 and 2009 I-Codes, which formed the basis of the 2010 FBC and 5th Edition (2014) FBC, respectively.

In 2007 and 2008, with technical and funding support from FEMA Headquarters and FEMA Region IV, FDEM made a commitment to re-establish the NFIP State Coordinating Agency function and build capacity to become a premier State partner in floodplain management. In mid-2008, FDEM asked the Florida Building Commission to appoint a flood standards workgroup to develop recommendations for integrating the flood damage-resistant provisions in the I-Codes into the FBC. In mid-2009, the Commission adopted the workgroup recommendations. As a result, the 2010 FBC included those provisions, with some Florida-specific amendments.

Many Florida communities, through local floodplain management regulations, have adopted and enforced provisions that exceed the NFIP minimum requirements for buildings. However, as dictated by Florida Statutes, only the FBC governs the design and construction of buildings. Thus, to address the potential for conflict and challenge to locally adopted higher standards, the SFMO developed a companion model ordinance written explicitly to rely on the FBC for design and construction of buildings in SFHAs. The ordinance, described in Section 2.2.4, includes administrative provisions and requirements for development other than buildings within the scope of the FBC. Together, the FBC and the model ordinance meet or exceed the NFIP requirements (Figure 2-1).

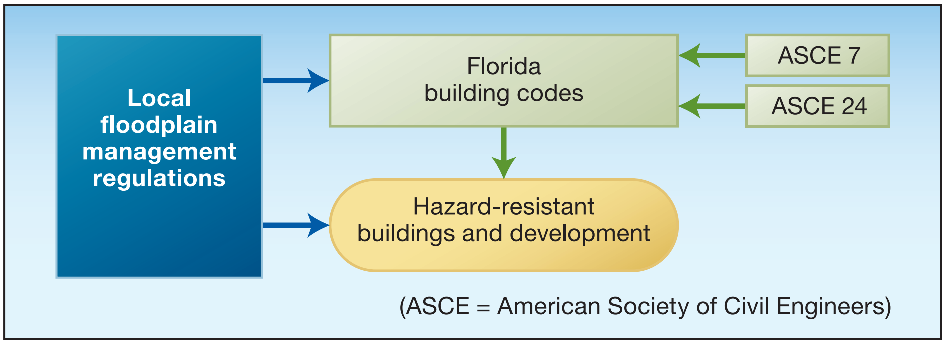


Figure 2-1: FBC and local regulations meet or exceed the NFIP requirements

2.2.2 Flood Provisions in the Florida Building Code

International Building Code (IBC) Chapter 1, Administration, forms the basis for Chapter 1 of the FBC, which is used to administer all volumes in the FBC family of codes. For each triennial code development cycle, the Florida Building Commission makes numerous amendments to tailor Chapter 1 of the IBC according to statutory requirements and State-specific needs. The 5th Edition (2014) FBC, which was in effect when Hurricane Irma made landfall, and the 6th Edition (2017) FBC, effective December 31, 2017, contain the following Chapter 1 amendments specific to buildings and structures in flood hazard areas:

- Section 102.7 adds a provision that relocated manufactured buildings (not manufactured housing) shall comply with flood hazard area requirements (e.g., if moved into or within flood hazard areas).
- Sections 104.2.1 and 104.10.1 are not retained. Local floodplain management regulations incorporate equivalent provisions for Substantial Improvement and Substantial Damage determinations and requests for modification of flood provisions (refer to Section 2.2.4 of this report).
- Sections 105.14 and 107.6.1 add provisions to restrict the building official's authority to issue permits based on affidavits by stating it does not extend to flood load and flood resistance requirements. This limitation is necessary because of the NFIP requirement that communities review development for compliance.
- Section 107.3.5 adds a section to specify examination of documents, including minimum plan review criteria for "Building" and "Residential." These review criteria include flood hazard area requirements, lowest floor elevations, enclosures, and flood damage-resistant materials. Plan review criteria for mechanical, electrical, and plumbing (MEP) and fuel gas include design flood elevations (DFE).
- Section 110.3 replaces the I-Code section for inspections. It requires two inspections specific to flood hazard areas: a foundation inspection and a final inspection. As part of the foundation inspection, elevation certification must be submitted upon placement of the lowest floor and prior to further vertical construction. As part of the final inspection, final certification of the lowest floor elevation must be submitted.

- Section 111.2 adds a new requirement that certificates of occupancy for buildings in flood hazard areas must include a statement that documentation of the as-built lowest floor elevation has been provided and is retained in the community's records.
- Section 117 refers to local floodplain management ordinances for procedures when requests for variances to the flood provisions (Section 1612 or R322) are requested. This section does not apply to Section 3109, Coastal Construction Control Line.

Through the triennial code development process, the Florida Building Commission considers Florida-specific amendments, including several sections in Chapter 4 that outline requirements for specific occupancies. Provisions in those sections are considered "agency amendments" and are carried forward from edition to edition. Specific to flood hazard areas, agency amendments include:

- Sections 449 and 450 require, for new construction and Substantial Improvements of hospitals and nursing homes, elevation or dry floodproofing to the higher of the base flood elevation (BFE) plus 2 feet or "the height of hurricane Category 3 (Saffir-Simpson scale) surge inundation elevation." The sections also specify that for all additions, patient support areas, including food service, and patient support utilities for the additions shall be at or above the elevation of the existing building, unless otherwise required by Section 1612.
- Section 454 requires initial and subsequent installation of public education relocatable units to comply with floodplain standards, including setting the "finished floor" 12 inches above the BFE and anchoring the units to resist "buoyant forces."
- Section 1612.3 and Table R301.2(1) specify the establishment of flood hazard areas, which is accomplished by local floodplain management ordinances that adopt flood hazard maps and supporting data.
- Section 1612.4.1 modifies ASCE 24 Table 6-1 and Section 6.2.1 to permit dry floodproofing of non-residential buildings located in Coastal A Zones provided "wave loads and the potential for erosion and local scour are accounted for in the design." The FBC references ASCE 24, *Flood Resistant Design and Construction*, for specific requirements for buildings and related components in flood hazard areas.
- Section 3109 contains requirements applicable to most structures located seaward of the Coastal Construction Control Line, a line established by Florida Statute. In the 6th Edition (2017) FBC, this section is completely revised to bring the Coastal Construction Control Line requirements more in line with the Section 1612 requirements for Coastal High Hazard Areas (Zone V), while retaining certain requirements of statute and declaration statements (interpretations) issued by the Commission. At many locations around Florida's coast, the "100-year storm elevation" used in the Coastal Construction Control Line requirements is higher than the BFE shown on FIRMs.

2.2.3 Local Amendments to the Flood Provisions of the FBC

A statutory provision was added in 2010 specifically for local amendments to the FBC flood provisions. Under three circumstances, these amendments do not expire every 3 years as other local amendments do (refer to Section 2.1.2): (1) if they are locally adopted before July 1, 2010; (2) if the higher standard is freeboard; and (3) if the higher standard is adopted for the purpose of participating in the NFIP CRS.

As of mid-2018, 80 percent of Florida's NFIP communities had adopted FBC-coordinated floodplain management regulations (refer to Section 2.2.4), with the remainder expected to do so by the end of 2019. The SFMO maintains a database of the most common locally adopted higher standards. The most common higher standards that affect the design and construction of buildings in flood hazard areas include:

SFMO INSTRUCTIONS FOR HIGHER STANDARDS

The SFMO provides instructions for local adoption of common higher standards, including local technical amendments to the flood provisions of the FBC. The instructions can be accessed at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

- **Additional elevation (freeboard).** Freeboard specifies how high lowest floors and dry floodproofing are above the minimum required elevation. More than 30 communities have adopted freeboard of 2 or 3 feet above the BFE, more than 10 have adopted 1.5 feet above the BFE, and many have adopted a minimum elevation above the crown of the road (typically 12 to 18 inches). Prior to the 6th Edition FBCR, which now requires a minimum BFE plus 1 foot, nearly 125 communities had individually adopted 1 foot of freeboard.

- **Enclosure limits (prohibition, size limits, access, no partitions).** Eighty communities have adopted some form of enclosure limits. A small number prohibit walls (other than insect screening or lattice). Some communities limit the size to less than 299 square feet (primarily in Zone V), while many others limit the size and number of doors and do not allow partitions (except crawlspace if required for fire safety).

- **Cumulative Substantial Improvement.** More than 80 communities have adopted requirements to accumulate costs of improvements and repairs over specific periods of time. The most common period of time is 5 years, followed by 10 years, 2 years, and life of structures. Shorter periods are typically selected when the objective is to discourage deliberate phasing of improvements that, if taken together, would trigger the Substantial Improvement requirement to bring structures into compliance with the flood provisions.

- **Repetitive flood loss.** About 40 communities modified the definition of "Substantial Damage" to include repetitive flood damage, such that the term includes "flood-related damage sustained by a structure on two separate occasions during a 10-year period for which the cost of repairs at the time of each such flood event, on average, equals or exceeds 25 percent of the market value of the structure before the damage occurred." Thus, buildings that are determined to be substantially damaged by repetitive flooding must be brought into compliance with the flood requirements of the FBC. Owners of those buildings, if covered by NFIP flood insurance policies, may qualify for Increased Cost of Compliance claims that pay up to $30,000 toward the cost of bringing the buildings into compliance.

- **Critical facilities.** More than 30 communities have adopted some form of regulation pertaining to critical facilities. A common amendment is to define critical facilities to include Flood Design Class 3 and 4 structures (see ASCE 24-14 for the Flood Design Class descriptions). Many have adopted higher elevation requirements, which may now be superseded by the Flood Design

Class 4 requirement that specifies lowest floors and dry floodproofing be at or above the BFE plus 2 feet or the 500-year flood elevation (elevation of the 0.2-percent-annual-chance flood), whichever is higher. A number of communities do not permit critical facilities in all or part of the SFHA or have adopted language requiring alternative locations to be considered.

FLOOD DESIGN CLASS

FEMA's *Highlights of ASCE 24-14 Flood Resistant Design and Construction* (2015) includes Table 1-1, "Flood Design Class of Buildings and Structures," available online at www.fema.gov/building-code-resources.

2.2.4 Floodplain Management Ordinances Coordinated with the FBC

In 2009, concurrent with the work of the Florida Building Commission's flood standards workgroup, FDEM began developing a model floodplain management ordinance written explicitly to rely on the FBC for NFIP-consistent requirements for buildings and structures. The ordinance contains administrative provisions, duties and responsibilities of the Floodplain Administrator, provisions for determining BFEs and floodways when not specified on Flood Insurance Rate Maps (FIRMs), records retention, and other provisions. FEMA supported this work with technical and financial assistance. Final approval of the model ordinance was received in January 2013. A major benefit of the close collaboration with FEMA is the FEMA Region IV office relies on FDEM's recommendations for approval when communities are required to demonstrate that their ordinances comply with the NFIP as part of the flood map revision process.

The FBC-coordinated model ordinance is intended to be administered by the community Floodplain Administrator and Building Official and contains direct links with the FBC as follows:

- **Buildings, structures, and facilities that are exempt from the FBC**. The NFIP requires communities to regulate all development. Thus, the scope of the ordinance specifically includes such buildings and structures and requires conformance with the flood load and flood-resistant provisions of ASCE 24. The Floodplain Administrator is responsible for inspecting these buildings and structures.
- **Substantial Improvement and Substantial Damage determinations**. The Floodplain Administrator and Building Official coordinate on these determinations, which are spelled out in the ordinance. In addition, the ordinance defines "market value."
- **Variances**. Restrictions on variances and conditions and issues that must be examined when considering requests for variances are specified. FBC Section 117 refers to local ordinances when variances to the flood provisions of the FBC are requested.

ADOPTION OF FBC-COORDINATED ORDINANCE

As of mid-2018, more than 80 percent of Florida's NFIP communities have adopted local ordinances based on the FBC-coordinated floodplain management ordinance. The remaining communities are expected to make the transition by the end of 2019.

FDEM anticipated a significant level of effort to work with the 467 NFIP-participating communities in Florida to transition to the FBC-coordinated ordinance. To meet the demand and facilitate adoption, the agency procured professional services to review draft ordinances and work with communities to incorporate community-specific amendments and higher standards. Considerable attention was paid to preparing higher standards that affect the design of buildings in the format required for local technical amendments of the FBC (refer to Section 2.2.3).

The SFMO database of higher standards adopted by communities includes common higher standards that do not affect the design and construction of buildings in flood hazard areas. As of mid-2018, the most common non-building higher standards:

- **Manufactured home restrictions.** Nearly 50 communities adopt restrictions on the installation of manufactured homes. While some prohibit manufactured homes in SFHAs, most limit the prohibition to the installation of new manufactured homes in Zone V or floodways unless they are in existing manufactured home parks or subdivisions that were established before the communities joined the NFIP.
- **Compensatory storage.** More than 15 communities have adopted some form of compensatory storage, most commonly requiring excavation of a volume equivalent to the volume of fill brought into flood hazard areas. Some require analyses to demonstrate compensation is hydraulically equivalent.

2.3 Wind Provisions of the Florida Building Code

The design of buildings for wind loads in the State of Florida is governed primarily by the FBCB, FBCR, and FBCEB. The 5th and 6th Editions of the FBC reference the 2010 Edition of ASCE Standard 7, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10). However, the FBCB, FBCR, and FBCEB also contain numerous Florida-specific, wind-related amendments that exceed the minimum criteria in the I-Codes.

The FBC also contains separate wind, structural, and testing requirements for a special zone called the "High-Velocity Hurricane Zone." The HVHZ, specifically defined as Miami-Dade and Broward Counties, was created for the inaugural version of the FBC (2001) as a way to maintain certain wind-related provisions from the South Florida Building Code. The wind criteria applicable in the HVHZ have historically been more stringent than the criteria applied in the rest of the State. However, more recent versions of the code have been minimizing the differences.

WIND REQUIREMENTS FOR EXISTING BUILDINGS

The FBCEB contains several mitigation "triggers" for roof repairs and reroofing. These triggers and mandated mitigation of existing buildings are discussed in Hurricane Irma in Florida Recovery Advisory No. 3 (see Appendix C).

2.3.1 Wind Loads and Wind Design in the FBC

The wind load and wind design requirements of the 5th Edition (2014) and the 6th Edition (2017) FBCB and FBCR are similar. Both editions reference ASCE 7-10, and the definition of wind-borne debris regions, protection of glazed openings, and classification of exposure categories are also consistent with ASCE 7. Exceptions permit the use of certain prescriptive high-wind design standards primarily for one- and two-family dwellings, although ICC 600 is permitted for Group R2 buildings (apartments, hotels, dormitories, etc.). These prescriptive standards include:

- *Wood-Frame Construction Manual for One- and Two-Family Dwellings*, American Wood Council, 2015
- *Standard for Residential Construction in High-Wind Regions* (ICC 600), International Code Council, 2014
- *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings, 2007, with Supplement 3, dated 2012* (AISI S230), 2012

Florida-specific design wind speed maps are contained in the 6th Edition (2017) FBCB and FBCR; the maps are consistent with ASCE 7-10. The wind speed maps for Risk Category II, III, and IV buildings (FBCB) are shown in Figure 2-2 and Figure 2-3, and the wind speed map in the FBCR is shown in Figure 2-4.

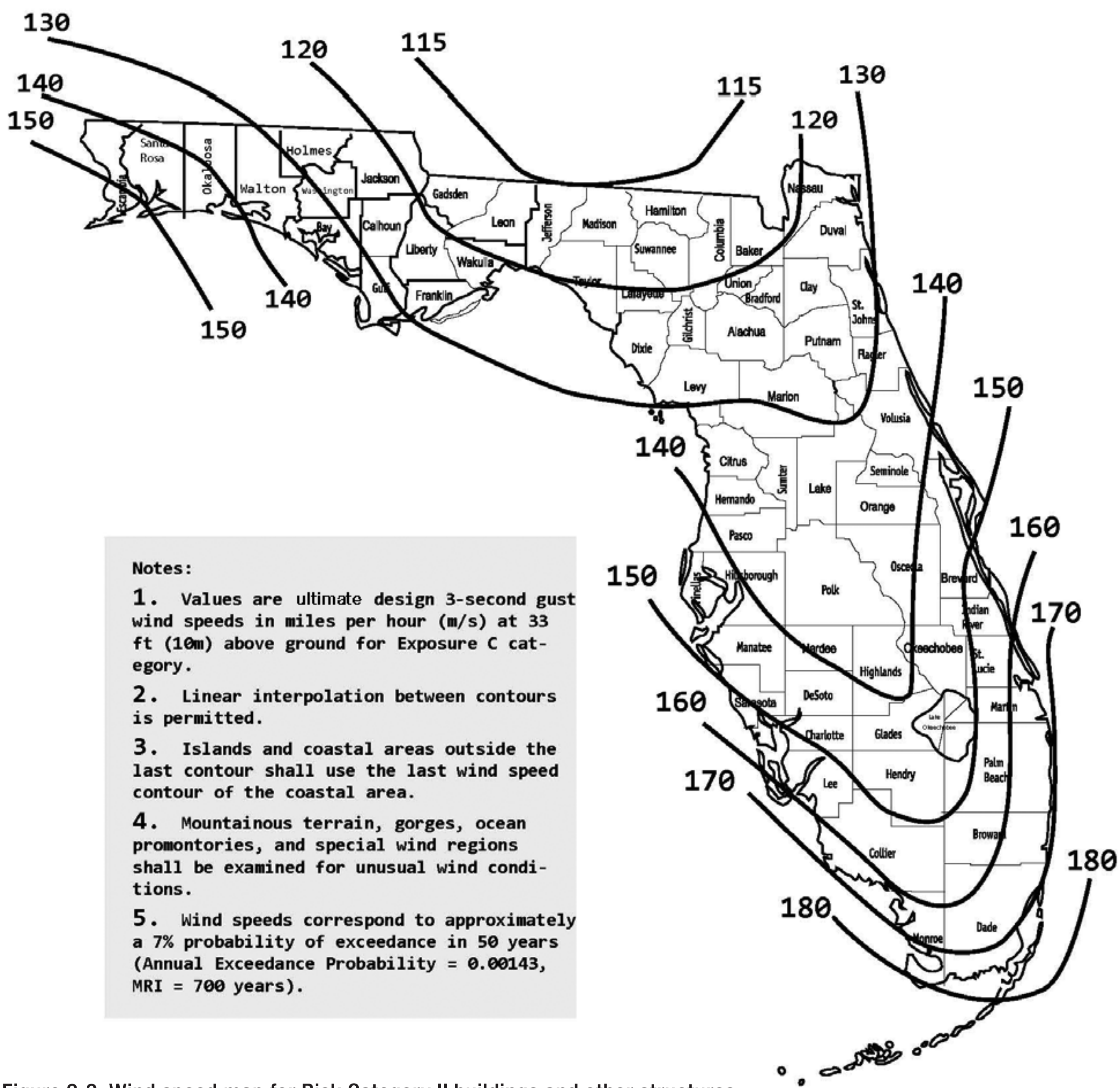


Figure 2-2: Wind speed map for Risk Category II buildings and other structures
SOURCE: 6TH EDITION [2017] FBCB

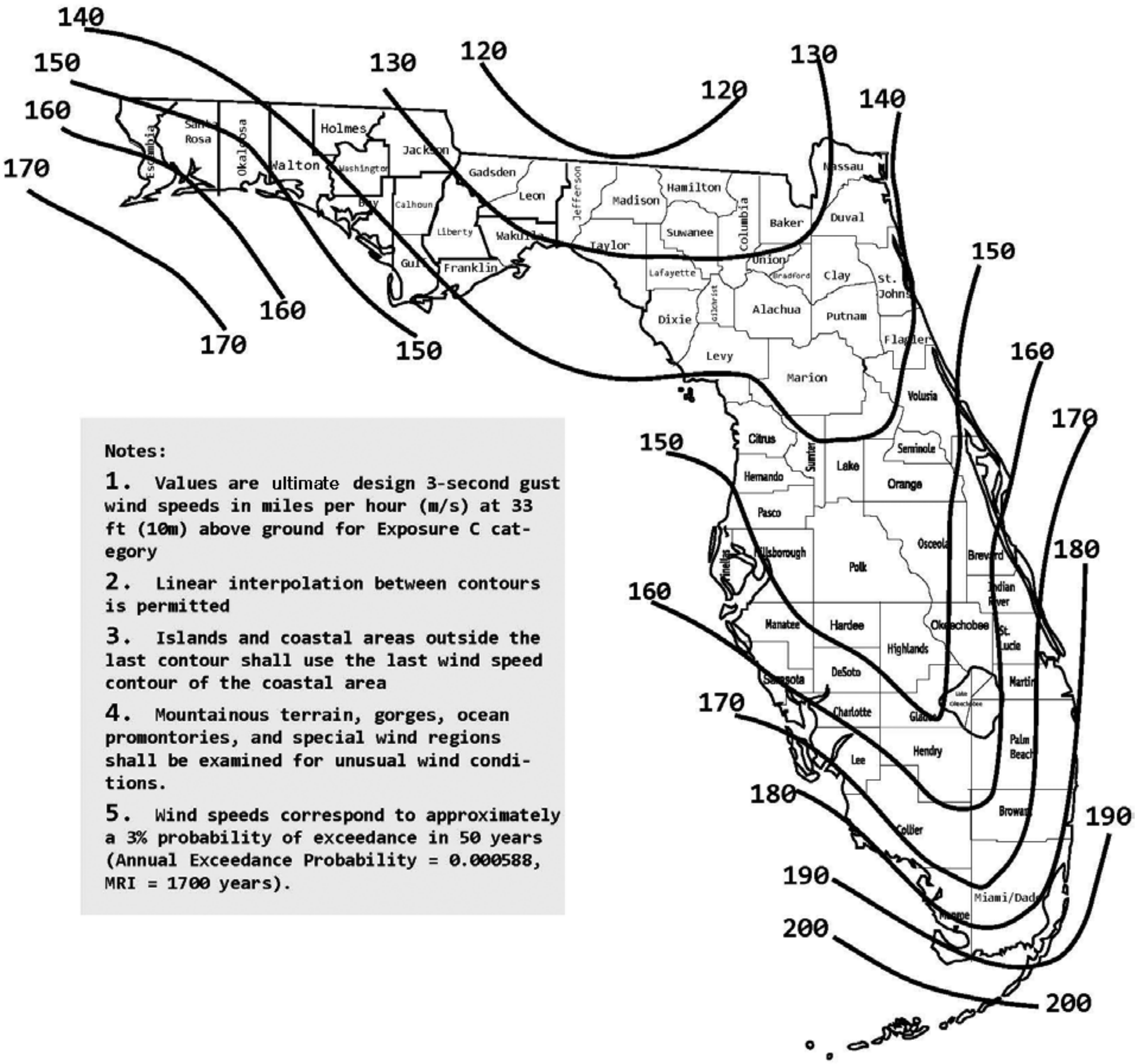


Figure 2-3: Wind speed map for Risk Category III and IV buildings and other structures

SOURCE: 6TH EDITION [2017] FBCB

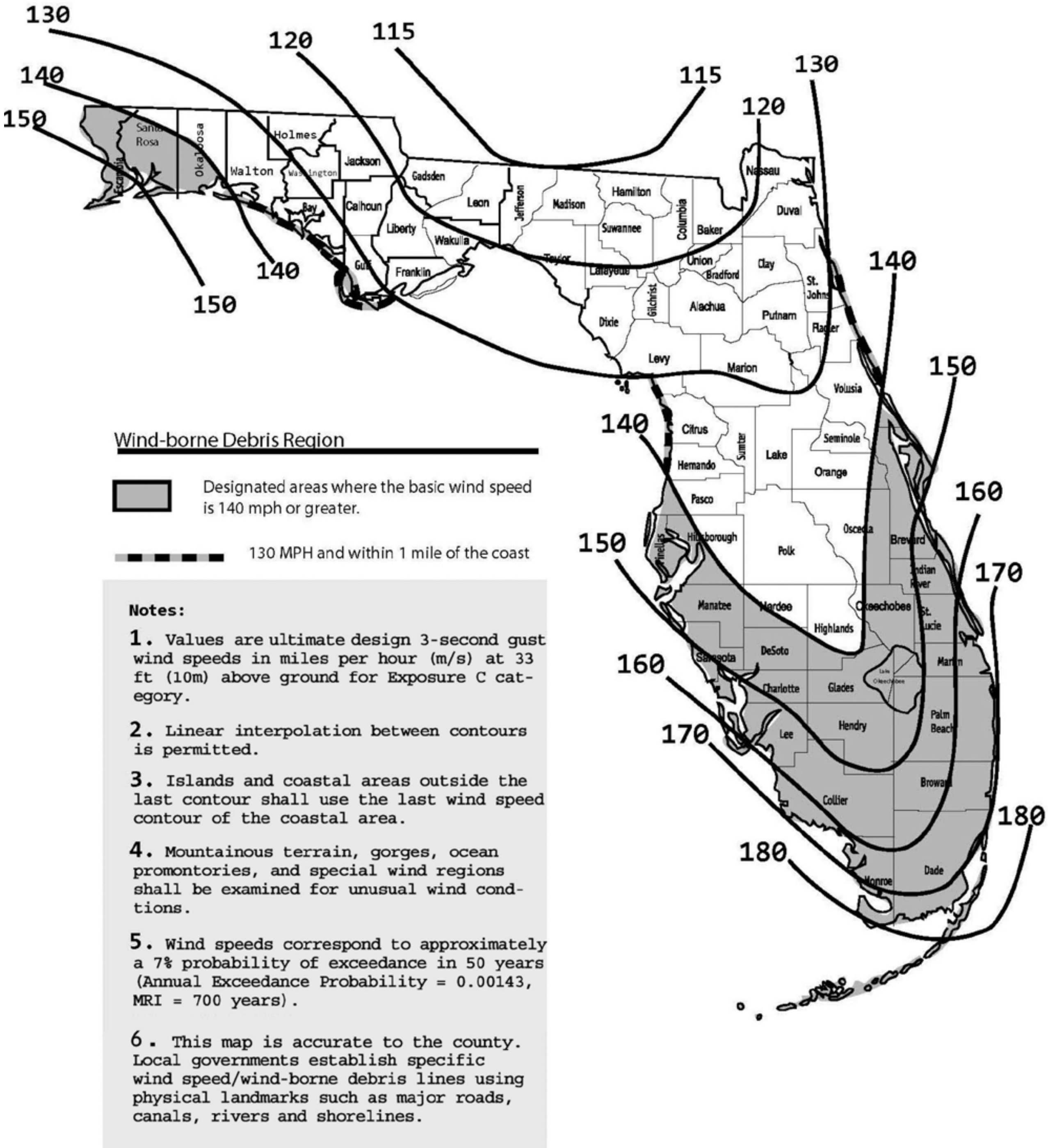


Figure 2-4: Wind speed map for FBCR buildings

SOURCE: 6TH EDITION [2017] FBCR

2.3.2 Florida-Specific Amendments for Wind and Water Intrusion

As previously stated, the FBC contains numerous Florida-specific amendments related to wind and water intrusion, including the requirements in the HVHZ that exceed the minimum requirements in the 2015 I-Codes. Table 2-1 lists some notable Florida-specific amendments related to wind and water intrusion prevention.

Table 2-1: Notable Florida-Specific Amendments for Wind and Water Intrusion

	Non-HVHZ	HVHZ
6th Edition (2017) FBCB	• Specifically requires soffits to be designed for wall component and cladding loads • Limits the span of wood structural panels used for opening protection to 44 inches • Enhanced roofing underlayment provisions for high-wind areas apply throughout the entire State • Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating	• Requires all buildings to be designed for wind loads; prescriptive high-wind standards are not permitted • Requires a single wind speed to be used for each county – Miami-Dade County – Risk Category II = 175 mph – Risk Categories III and IV = 186 mph – Broward County – Risk Category II = 170 mph – Risk Categories III and IV = 180 mph • The entire building envelope is required to be impact resistant (some deemed-to-comply assemblies are provided) • All areas are required to be designed for Exposure Category C unless Exposure Category D applies • Enhanced roofing underlayment provisions apply throughout • Requires the use of plywood sheathing; oriented strand board is not permitted
6th Edition (2017) FBCR	• Establishes the entire State as requiring wind design – Prescriptive high-wind standards are permitted – Prescriptive construction provisions in the 2015 IRC are not permitted • Exposure category definitions have been revised to be consistent with ASCE 7 • Specifically requires soffits to be designed for wall component and cladding loads • Limits the span of wood structural panels used for opening protection to 44 inches • Enhanced roofing underlayment provisions for high-wind areas apply throughout the entire State • Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating • References to the use of staples for wall covering attachment methods have been removed	• Refers to the HVHZ provisions in the FBCB

ASCE = American Society of Civil Engineers; FBCB = Florida Building Code, Building; FBCR = Florida Building Code, Residential; HVHZ = High-Velocity Hurricane Zone; IRC = International Residential Code; mph = miles per hour

2.4 Florida Manufactured Housing Installation Standards

The Florida Department of Highway Safety and Motor Vehicles has jurisdiction over the installation of MH units. Requirements for installation, setup, tie-downs, and anchoring foundations, with specific provisions related to wind loads, are contained in Chapter 15C of the Florida Administrative Code. With respect to installation in floodprone areas, the regulations refer to and incorporate by reference the 1985 edition of FEMA 85, *Manufactured Home Installation in Flood Hazard Areas*.

MANUFACTURED HOMES CONSTRUCTION

The Manufactured Home Construction and Safety Standards, 24 CFR Part 3280, developed by the U.S. Department of Housing and Urban Development, cover the design and construction of manufactured homes.

HURRICANE
IRMA
IN FLORIDA

3 Flood-Related Observations

The Irma MAT made general flood-related observations as well as examined specific building performance issues.

This chapter describes the MAT's observations, which focused on the following:

- General flood damage
- Performance of dry floodproofing measures
- Performance of public restrooms in coastal flood hazard areas

> **MAT OBSERVATIONS**
>
> **Deployments**
>
> Pre-MAT: September 22 to 25, 2017
> MAT: December 10 to 15, 2017
> MAT: February 14 to 15, 2018
>
> **Locations**
>
> - Southwest Florida (Fort Myers to Marco Island to Everglades City)
> - Southeast Florida (Miami and Miami Beach)
> - The Florida Keys (Tavernier to Key West)
> - St. Johns County (Vilano Beach and South Ponte Vedra Beach)

The Irma MAT deployed on three occasions: September 2017 (pre-MAT), December 2017, and February 2018; see text box for additional information. The pre-MAT performed a cursory review of flood damage to buildings at approximately 150 locations in the Florida Keys, Southwest Florida, and Southeast

Florida. For the second deployment, the MAT conducted more detailed evaluations of flood conditions and flood damage to buildings in the same geographic areas of the pre-MAT visit, at approximately 25 general damage sites, 25 floodproofing sites, and 15 public restroom sites. For, the third deployment, the MAT visited approximately 20 general damage sites and one public restroom site in St. Johns County, FL.

Figure 3-1 shows locations for selected September 2017 observations, and Figure 3-2 shows selected locations of flood-related observations made during the December 2017 and February 2018 deployments.

Hurricane Irma was a large storm that traveled northward over the entire Florida peninsula. It resulted in storm surge and heavy rain in many areas not visited by the MAT. However, the MAT observations included in this chapter capture the type and range of effects produced by Hurricane Irma.

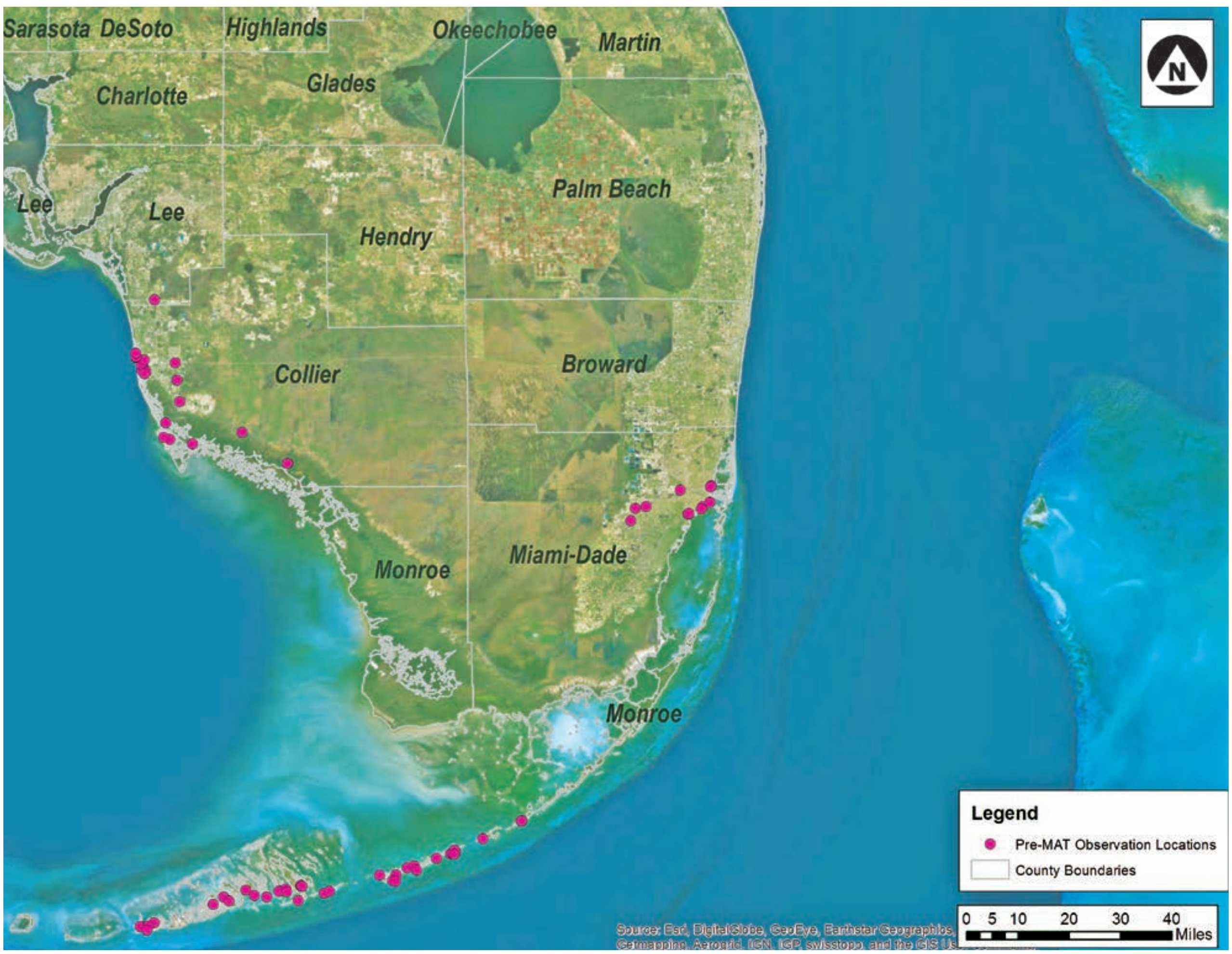


Figure 3-1: Locations of selected September 22–25, 2017 (pre-MAT) observations for Hurricane Irma

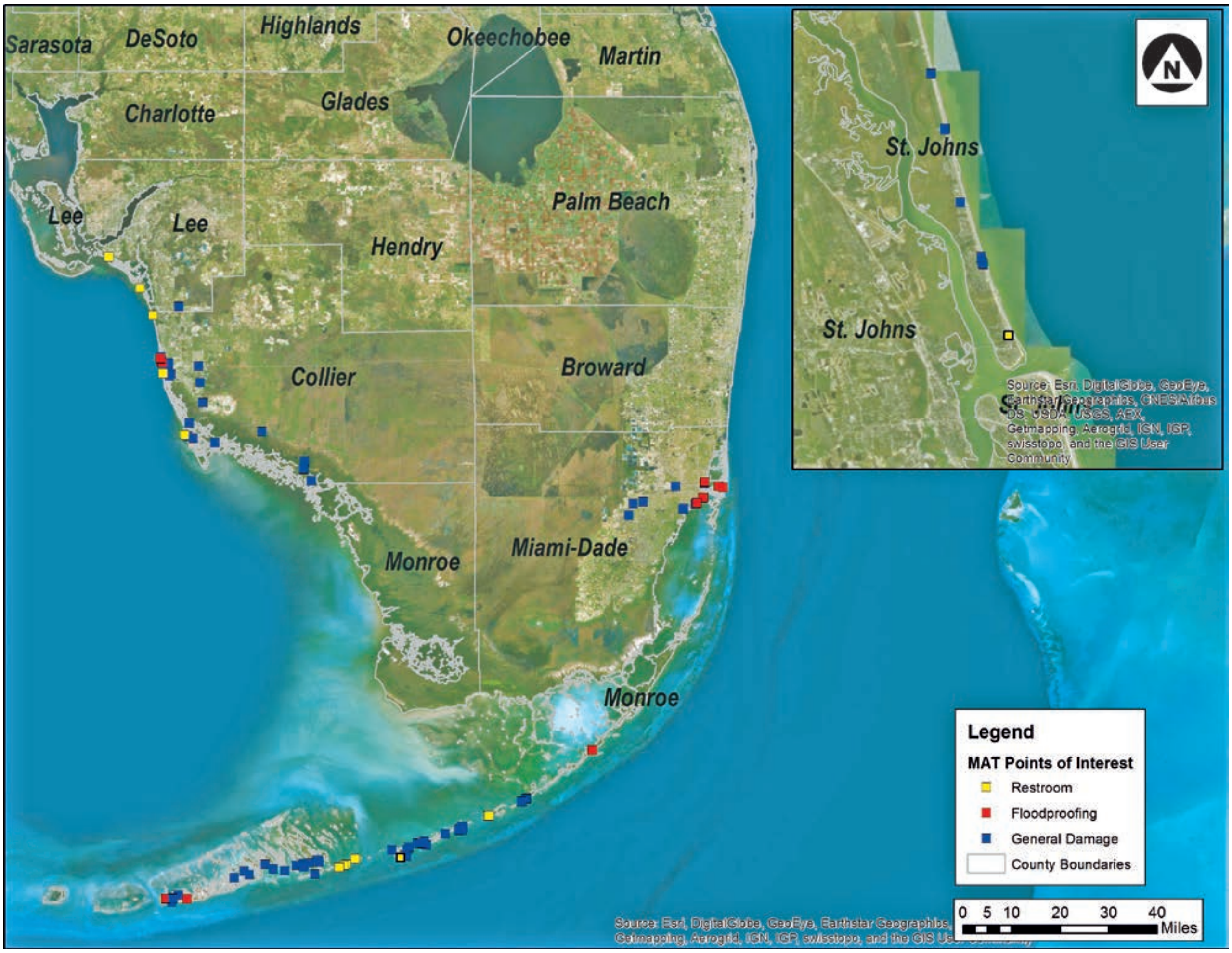


Figure 3-2: Locations of selected December 10–15, 2017 and February 14–15, 2018 (MAT) observations for Hurricane Irma

3.1 General Flood Damage Observations

The Irma MAT, like other post-Hurricane MATs, planned for and made general observations of building performance under a variety of flood conditions. Observations of building performance under a variety of flood conditions are summarized in this section. The MAT observed many cases of erosion and scour, along with variable performance of erosion control structures. Sections 3.1.1 and 3.1.2 summarize observations made related to these topics.

The extent of flood damage to buildings observed by the MAT varied with the depth of floodwater, the amount of energy in the water column (waves, velocity), and type of building design and construction (old versus new, at-grade versus elevated, MH unit/recreational vehicle versus site-built/modular). Buildings constructed at or near grade were subject to deeper and more damaging flooding. This applied to buildings subject to storm surge and to buildings subject to rainfall-induced flooding.

Figure 3-3 shows how flood damage varied along one street on Big Pine Key. Figure 3-4 shows long-duration flooding in the Bonita Springs area. Figure 3-5 and Figure 3-6 show damage to adjacent elevated and non-elevated homes on the Atlantic Ocean shoreline of Big Pine Key.

House near shoreline and subject to wave action/ high water velocity was washed off its foundation and destroyed.

Inundation, water velocity, and debris damage to buildings situated farther from the shoreline.

Inundation, water velocity, and debris damage to buildings situated farther from the shoreline.

Minor enclosure damage to newer, elevated house situated away from the shoreline.

Figure 3-3: Typical range in flood damage observed along Avenue D, in order along the street as indicated (Big Pine Key, FL)

**Figure 3-4:
Long-duration flooding in the Bonita Springs area (Lee County, FL)**

View looking north across Bonita Beach Road SE on September 15, 2017 (photograph courtesy of Civil Air Patrol).

Part of Bonita Springs still flooded on September 23, 2017, nearly 2 weeks after Irma.

Figure 3-5:
Elevated house with unreinforced masonry breakaway walls that performed as intended (Big Pine Key, FL)

Figure 3-6:
House constructed at grade where the masonry walls parallel to the shoreline were destroyed; this house was near the house shown in Figure 3-5 (Big Pine Key, FL)

Performance of breakaway walls below elevated buildings varied. Some walls broke away cleanly without damaging the main structure (see Figure 3-7), while others did not. Of those that did not break away cleanly, some appeared to cause no damage to the structure (see Figure 3-8), while others appeared to cause damage to the columns to which they were attached (see Figure 3-9).

Figure 3-7:
Example of a breakaway wall that was reported by a local code official to have performed as intended (Lower Matecumbe Key, FL)

Figure 3-8:
Example of partial failure of breakaway wall, with no associated damage to main structure observed (Cudjoe Key, FL)

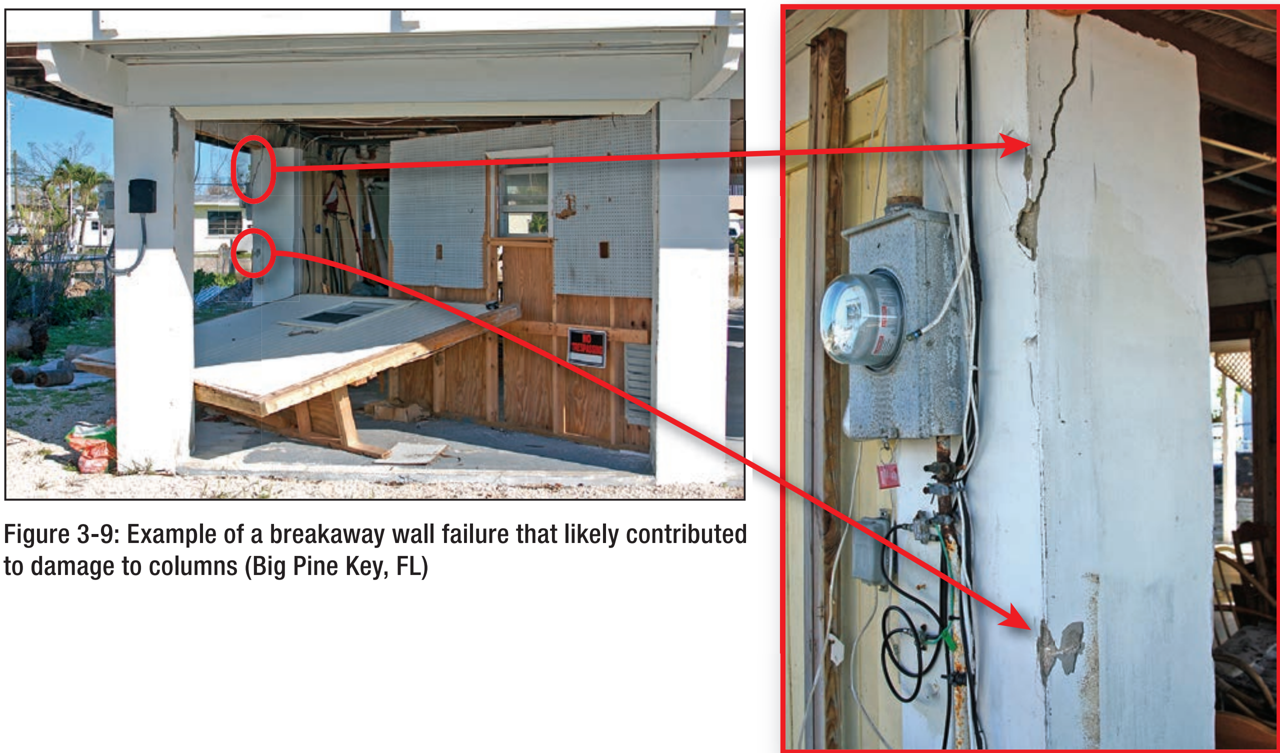


Figure 3-9: Example of a breakaway wall failure that likely contributed to damage to columns (Big Pine Key, FL)

The MAT observed considerable debris that had washed around and into buildings in the Florida Keys. Debris was composed of building materials and furnishings from damaged and destroyed buildings, displaced sheds, automobiles, boats, and recreational vehicles, as illustrated in Figure 3-10 through Figure 3-13.

Figure 3-10: Building debris and recreational vehicles washed into a canal on 61st Street Ocean (Marathon, FL)

Figure 3-11:
Boat and small debris that washed across a canal and onto houses
(Big Pine Key, FL)

Note the wind damage to the elevated portion of the house.

Figure 3-12:
Car and debris that washed into a house
(Big Pine Key, FL)

Figure 3-13: Shed that washed across Highway US 1 (Grassy Key, FL)

3.1.1 Erosion and Scour

The MAT observed a few instances of erosion and scour in Monroe County and widespread dune and bluff erosion in St. Johns County. In both counties, buildings with deep foundations performed better than buildings with shallow foundations.

Monroe County

The Monroe County erosion the MAT observed was likely due to a combination of waves and high-velocity flow across low-lying areas along the Atlantic shoreline of the Florida Keys. In some cases, the flow could have been affected by development practices that channeled or confined flow (e.g., privacy walls, driveways, utility installations), which contributed to the erosion (see Figure 3-14).

EROSION AND SCOUR

Erosion: Loss of soil over a large area.

Scour: Localized loss of soil due to interaction of flow and building components.

Most building foundations constructed in the last few decades in the Florida Keys are reinforced concrete piles that are augered into the soil and underlying rock. These foundations were resistant to scour and erosion (see Figure 3-14, Figure 3-15, and Figure 3-16).

The MAT observed one instance of building collapse in the Florida Keys (Figure 3-17). The building was a two-story multi-family structure elevated on an open concrete column foundation, with ground-level parking below (this building is 600 feet from the undermined building shown in Figure 3-14).

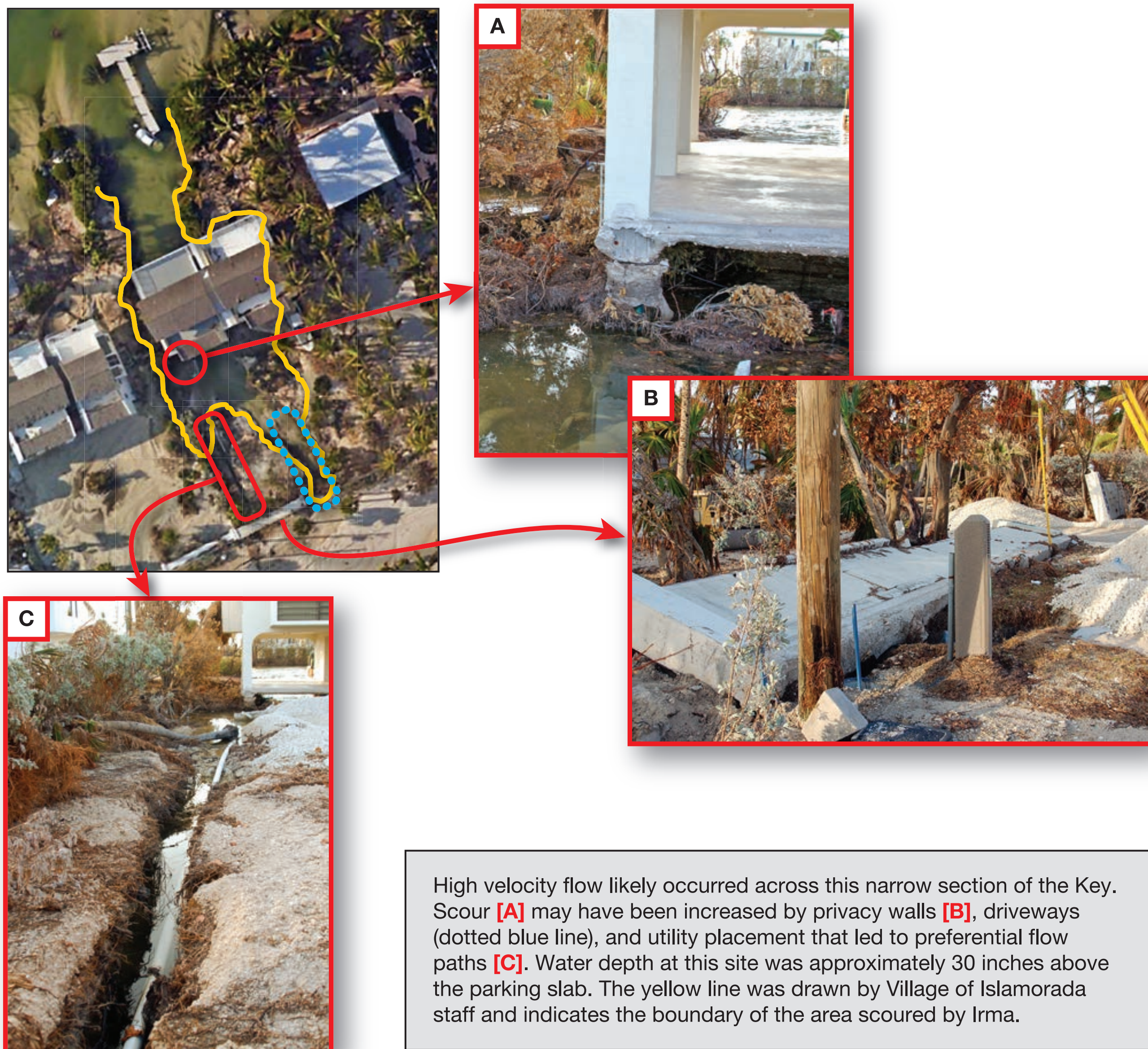
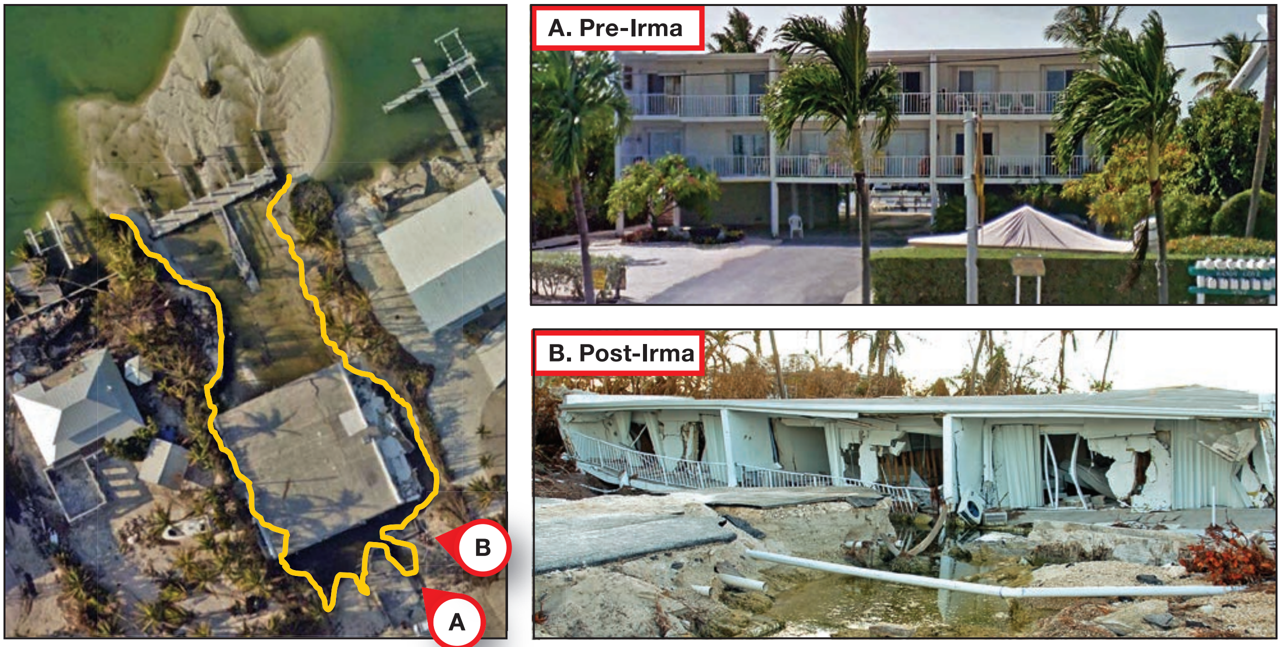


Figure 3-14: Scour near and around building foundation (Lower Matecumbe Key, FL)

Figure 3-15:
Scour was likely due to waves and high-velocity flow at this house on Long Beach Drive (same house is shown in Figure 3-6) (Big Pine Key, FL)

Figure 3-16:
Erosion was likely due to wave attack around the foundation of this house on Sombrero Beach Road (Marathon, FL)



The yellow line in the aerial image was drawn by Village of Islamorada staff and indicates the boundary of the area scoured by Irma. The MAT did not determine whether scour contributed to the collapse.

Figure 3-17: Collapsed building (Lower Matecumbe Key, FL)

St. Johns County

Erosion observed by the MAT in St. Johns County was a result of storm surge and waves attacking oceanfront dunes and bluffs. The same shoreline was also battered by storm surge and waves during Hurricane Matthew (2016) and various northeast storms before and after Irma.

Many undermined buildings were on deep pile foundations and survived the erosion (Figure 3-18 and Figure 3-19), but many were rendered uninhabitable pending repairs to buildings and utilities (and in some cases, replacement of soil). Some houses were on shallow foundations and collapsed (Figure 3-20).

Figure 3-18:
Undermined house on deep piles that survived erosion (Vilano Beach, FL)

Figure 3-19:
Undermined houses constructed on top of the dune (Vilano Beach, FL)

These houses survived the undermining, even though approximately 10 to 15 feet of dune height was lost beneath the houses. The pilings farther seaward are for a seawall under construction at the time of the MAT visit (February 2018).

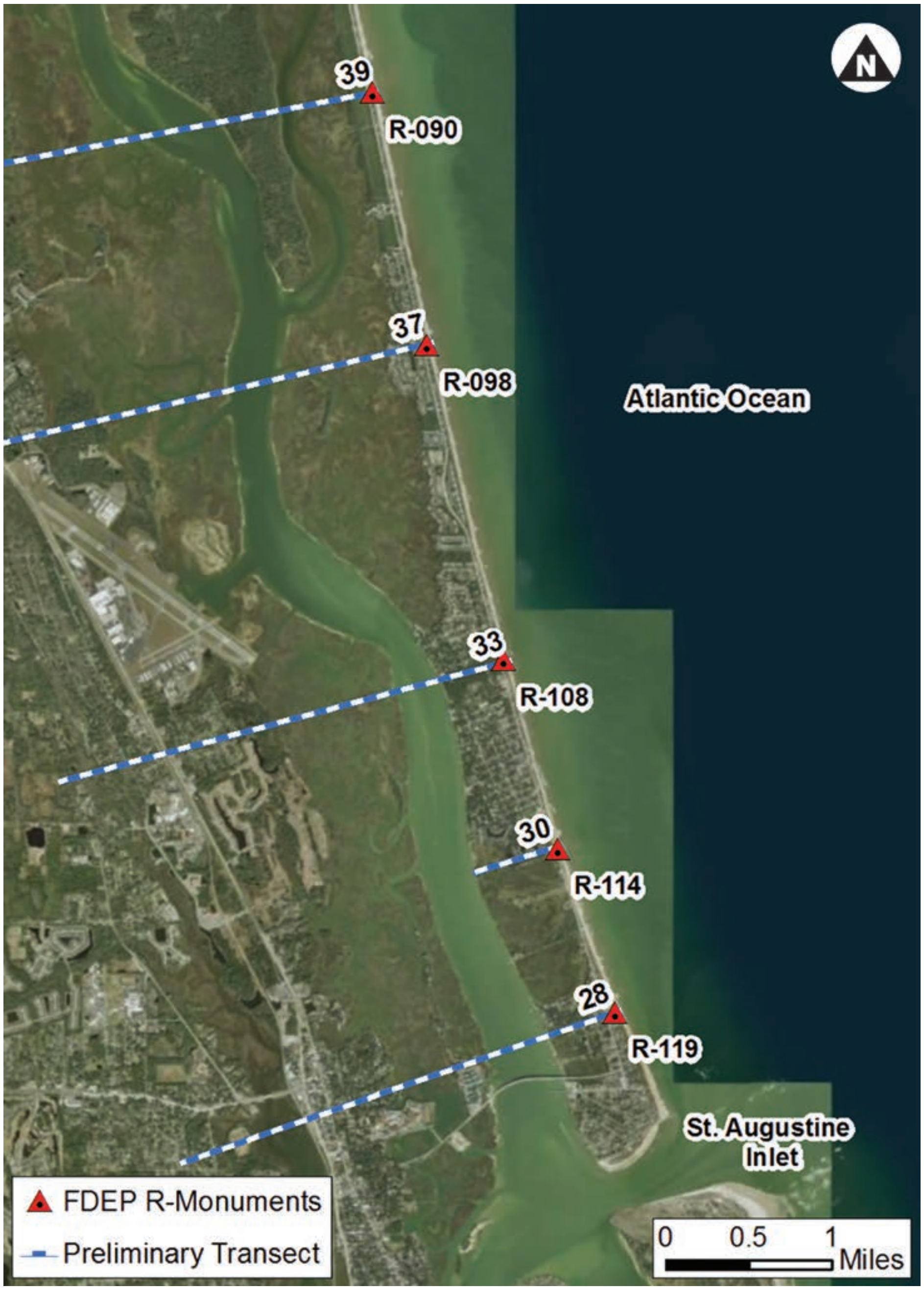
Figure 3-20: Collapsed house on shallow foundation that was undermined by erosion induced by Hurricane Irma (Vilano Beach, FL)

SOURCE: UPPER PHOTOGRAPH COURTESY OF CIVIL AIR PATROL (SEPTEMBER 20, 2017); LOWER PHOTOGRAPH COURTESY OF ST. JOHNS COUNTY (SEPTEMBER 12, 2017).

Figure 3-21 through Figure 3-26 illustrate dune erosion that occurred at selected FIS transect locations during Hurricane Matthew and Hurricane Irma.[1] The "preliminary transect" lines represent pre-Matthew ground elevations. The "preliminary modeled" lines represent the FIS estimation of dune erosion during a base flood. In some cases, Hurricane Matthew erosion was greater than Hurricane Irma erosion, while in others Hurricane Irma erosion was greater. In some cases, the modeled erosion understated actual erosion, while in others it overstated actual erosion. This information indicates high longshore variability in dune erosion may occur in any given storm. It also demonstrates that building foundations in high dune areas may sustain 5 to 10 feet or more of vertical erosion during a severe storm event.

1 Post-Matthew and pre-Irma beach nourishment was implemented in some locations, and the profiles in Figure 3 22 through Figure 3 26 reflect this. Details on volumes and locations of nourishment are unknown.

Figure 3-21:
Locations of FIS transects 28–39, where comparative beach and dune profiles are shown in Figure 3-22 through Figure 3-26 (R-numbers are survey monuments established by the State of Florida)



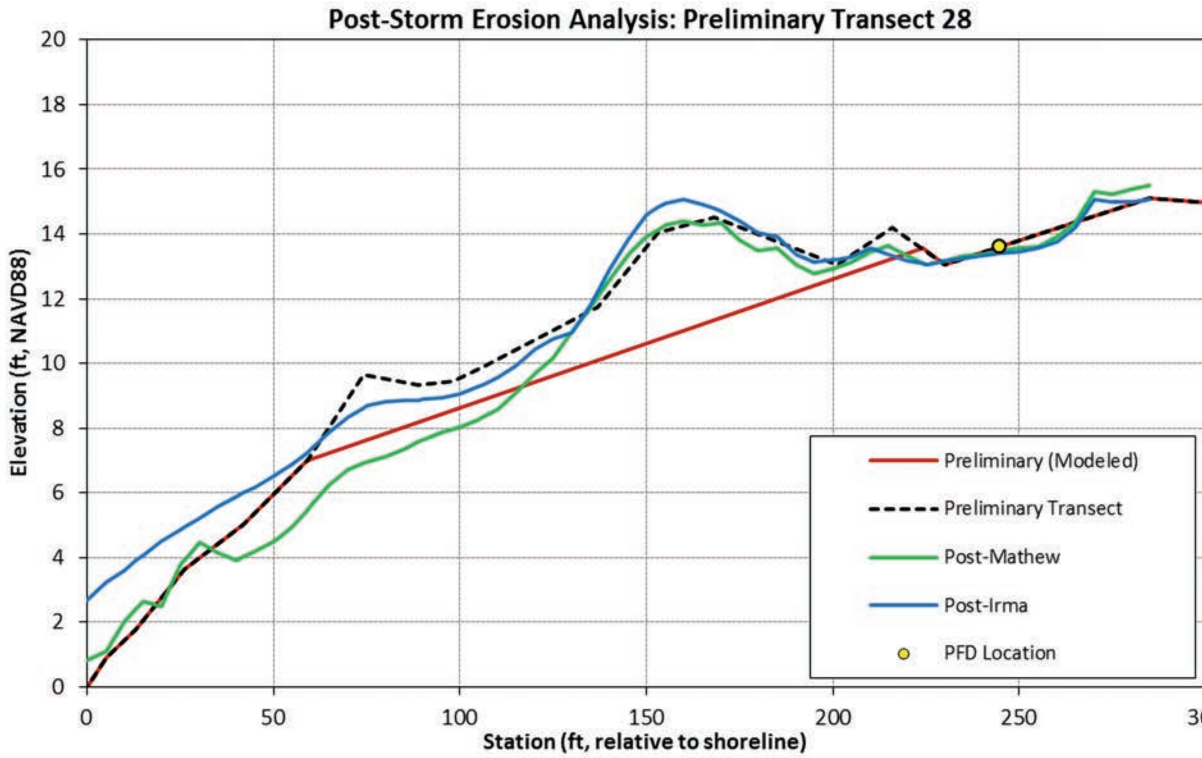


Figure 3-22: Beach and dune profiles at Transect 28

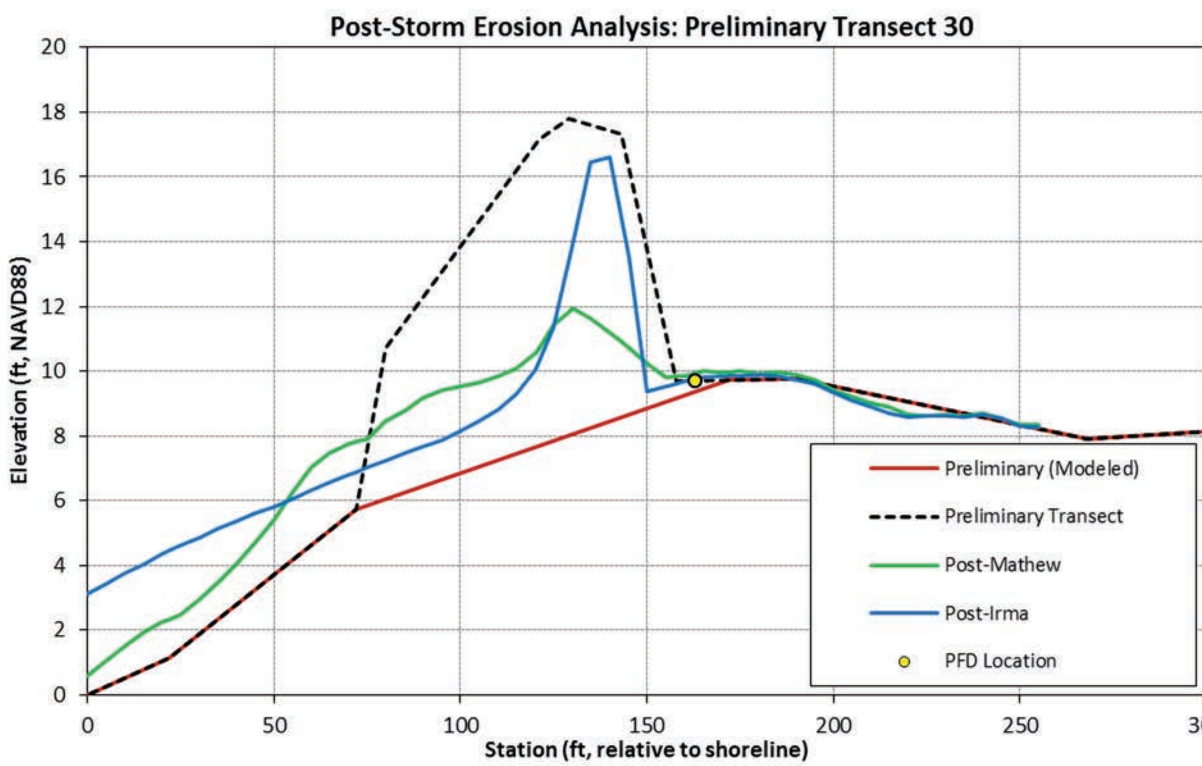


Figure 3-23: Beach and dune profiles at Transect 30

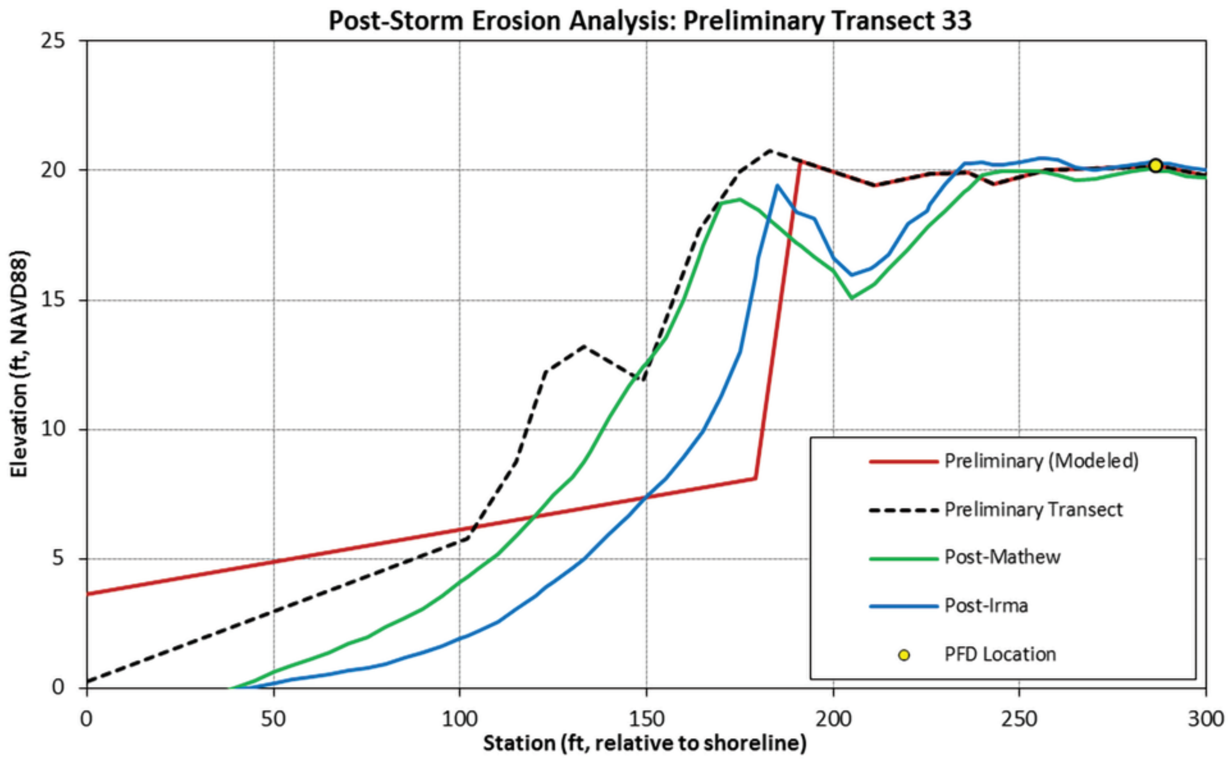


Figure 3-24: Beach and dune profiles at Transect 33

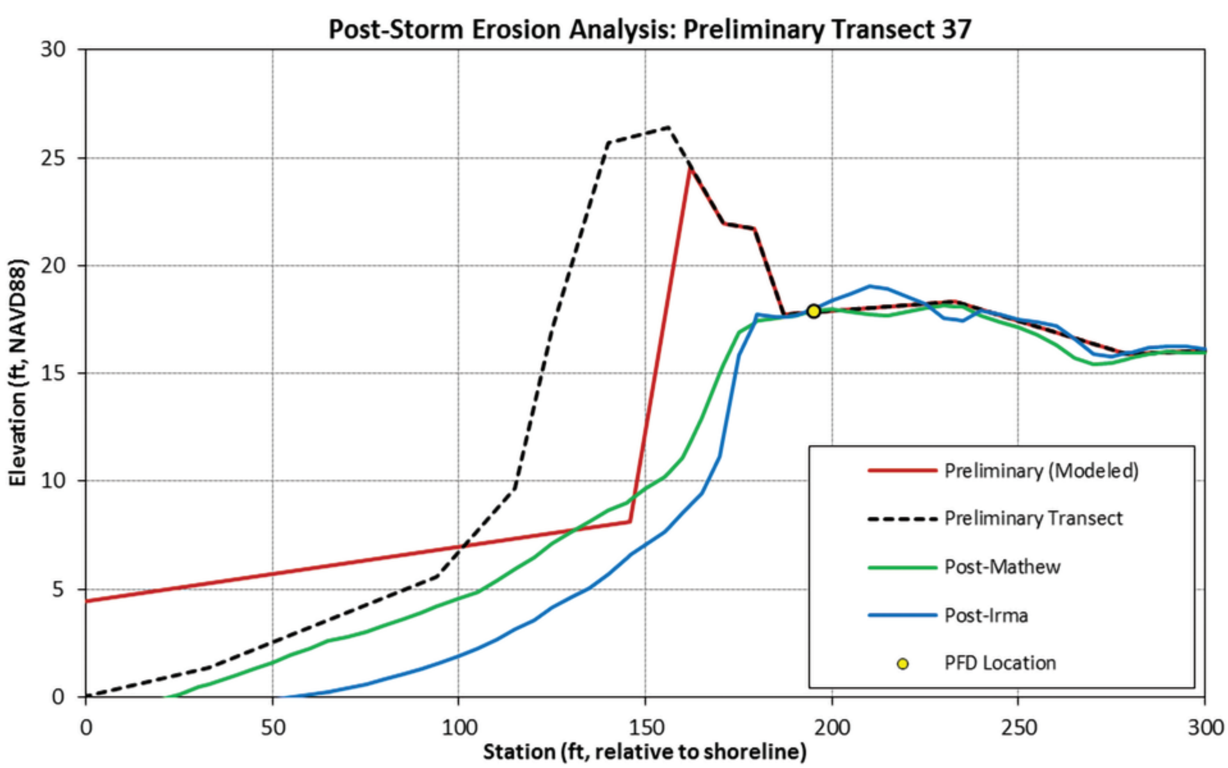


Figure 3-25: Beach and dune profiles at Transect 37

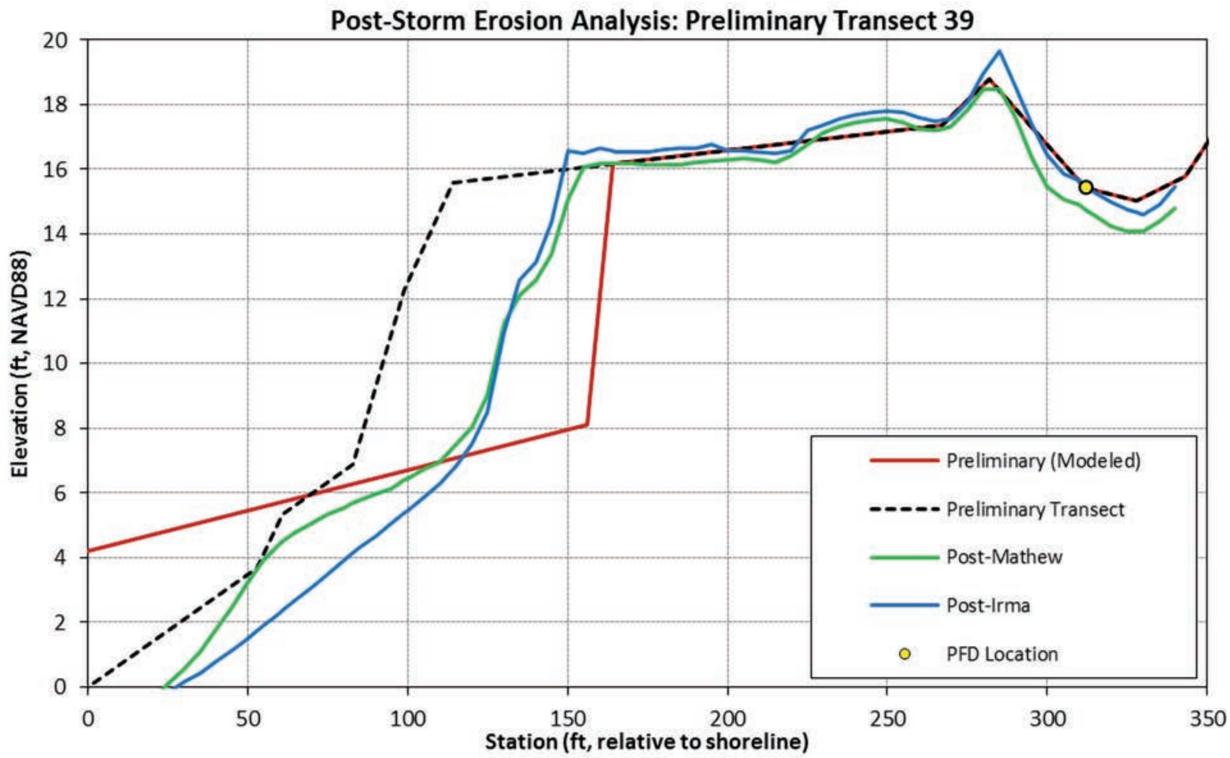


Figure 3-26: Beach and dune profiles at Transect 39

3.1.2 Erosion Control Structures

The pre-MAT and MAT observed many erosion control structures during field visits in canal, bay, and estuarine areas (Southwest Florida, Southeast Florida, and the Florida Keys) and along the oceanfront (St. Johns County). Many of these structures survived Hurricane Irma and protected land behind them, but some showed signs of damage or failure.

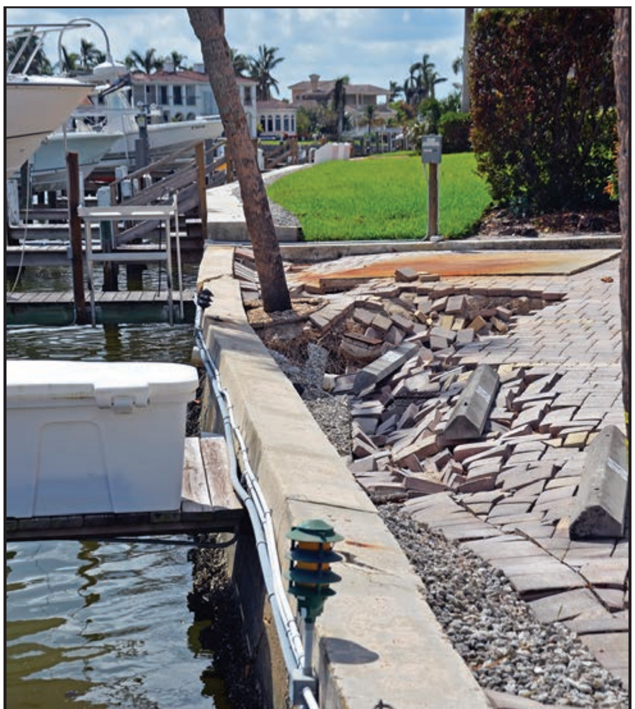
Numerous instances of canal or estuarine bulkhead failures were observed in Southwest and Southeast Florida. Failures were typically associated with saturated soil behind bulkheads exerting loads that exceeded the capacity of anchor systems or insufficient embedment of the bulkhead into the ground. Anchor system failure likely caused the top of the bulkhead to rotate toward the water, as shown in Figure 3-27. Failures of bulkheads that were insufficiently embedded into the ground likely resulted in the toe of the bulkheads moving toward the water, as shown in Figure 3-28.

Similar anchor system and toe embedment failures have occurred for decades during periods of heavy rain when backfill becomes heavily saturated, and the failures observed after Hurricane Irma are not new or different. The canal and estuarine bulkhead failures that the MAT observed did not lead to undermining and failure of buildings, but bulkhead failures could be a concern where buildings are located close to bulkheads or where bulkheads are constructed close to buildings.

Figure 3-27: Failure of bulkhead (anchor system) (Naples, FL)

The failure of this bulkhead likely originated at its anchor system. This type of failure allows the top of a bulkhead to rotate toward the water.

Figure 3-28: Bulkhead toe failure (insufficient embedment) (Naples, FL)



The failure of this bulkhead was likely due to insufficient embedment of the bulkhead toe into the ground. This type of failure allows the bottom of a bulkhead to rotate toward the water.

Oceanfront bulkheads that were supposed to prevent loss of soil under buildings did not always perform as intended to protect the buildings. Some oceanfront bulkhead failures were observed in St. Johns County, and such failures exposed the foundations and septic systems of homes to undermining. Homes on very deep foundations withstood the loss of soil, while homes on shallow foundations did not. Figure 3-29 shows one such bulkhead failure and the resulting collapse of a building with a shallow foundation.

ADDITIONAL INFORMATION

Additional information pertaining to dry floodproofing for areas affected by Hurricanes Irma and Harvey in 2017 can be found in the following recovery advisories:

- *Dry Floodproofing: Operational Considerations* (Hurricane Irma in Florida, Recovery Advisory 1, 2018d)
- *Dry Floodproofing: Planning and Design Considerations* (Hurricane Harvey in Texas, Recovery Advisory 1, 2018e)

Figure 3-29: House on a shallow foundation that collapsed after it was undermined following failure of the bulkhead during Hurricane Irma (St. Johns County, FL)

3.2 Performance of Dry Floodproofing Measures

The MAT was tasked with evaluating how dry floodproofing systems had performed during Hurricane Irma. Approximately 25 sites with dry floodproofing systems were investigated. Not all of the systems were deployed prior to Irma, and only some of those deployed were "tested" by Irma (i.e., in many cases, the flood level did not reach the flood barrier or closure). In cases where floodproofing was tested by floodwater, most buildings sustained at least minor flooding, and some sustained more serious flooding.

Evaluations of dry floodproofing performance were sometimes hampered by a reluctance of building owners and managers to discuss their dry floodproofing. Based on discussions, this reluctance appears to be related to concerns that comments made to the FEMA MAT might somehow affect the floodproofing credit for their NFIP flood insurance policy. However, the MAT was able to obtain enough information to make general observations about dry floodproofing performance, owner/manager understanding of dry floodproofing requirements, deployment successes and failures, implementation issues, and availability and scope of floodproofing plans. One designer interviewed by the MAT indicated that he specifies dry floodproofing on all his projects, but his two main worries are gasket degradation and the time required to deploy dry floodproofing systems.

Based on interviews conducted by the MAT, building managers and owners understand dry floodproofing concepts and understand that floodproofing can lead to NFIP flood insurance premium credit, but may not appreciate the importance of design and deployment details necessary to achieve successful floodproofing systems. In many cases, deployment is handled by contractors, so owners and managers may not understand installation and maintenance procedures, and they may not conduct annual testing.

Finally, there appears to be a need for guidance on maintaining and deploying dry floodproofing systems, as well as on developing emergency operations and maintenance plans that meet the requirements of Chapter 6 of ASCE 24 (the standard referenced by the FBC and specified by FEMA Form 086-0-34, *NFIP Floodproofing Certificate for Non-Residential Structures*).

3.2.1 Failure Modes

Some dry floodproofing systems were not subject to flooding, but still sustained some minor water accumulation behind them due to rainwater between the floodproofing system and the building face (see Figure 3-30). In one case, significant flooding infiltrated a building as a result of building envelope failure that allowed large quantities of rainwater to enter and become trapped behind the floodproofing system.

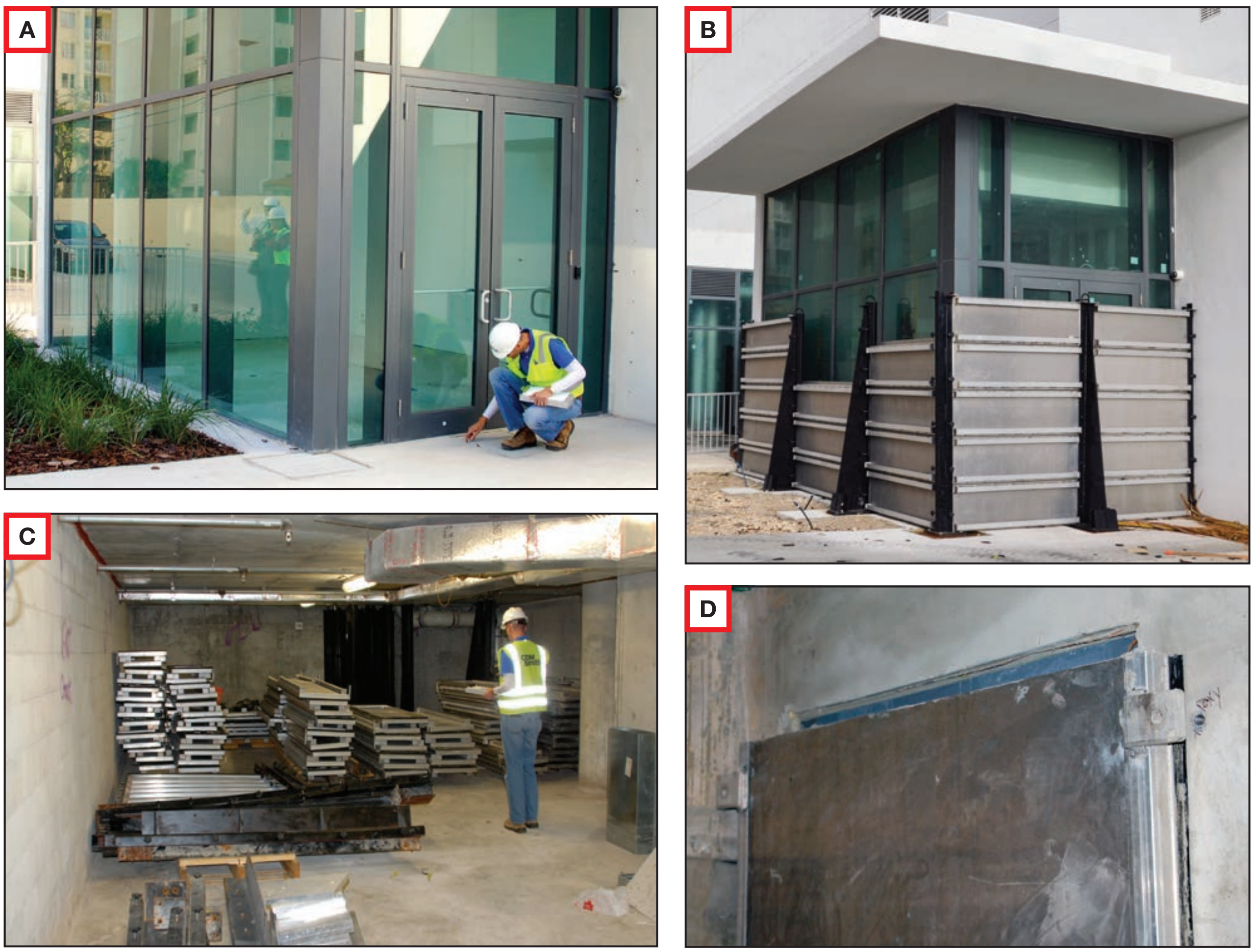
Five door openings were covered by flood planks. Hurricane Irma floodwater did not reach the planks; however, wind-driven rain accumulated and entered the building behind one of the barriers deployed at a door without a canopy overhead (the amount of water entry was minor but still a nuisance). System components were lightweight and stored on site. It took two workers 2 hours to deploy. The system was deployed 2 days prior to Irma landfall.

Inset shows the labels on planks that indicate the correct installation location.

Figure 3-30: Flood plank system deployed at utility company building (Key West, FL)

Of those dry floodproofing systems that were deployed and tested, a few worked as intended (see Figure 3-31), but most were reported to have leaked (minor quantities of water) or failed (major quantities of water; see Figure 3-32). Failure modes described by those responsible for implementing floodproofing or observed by the MAT at many floodproofing locations included lack of gaskets, failure of gaskets due to physical damage or degradation over time, gasket compression during storage, and leaking valves (air gasket systems).

More significant floodproofing failures were likely associated with human intervention aspects of floodproofing (installation and maintenance). In one case, a contractor failed to properly install the complete floodproofing system, allowing floodwater to enter the building through the unprotected area.

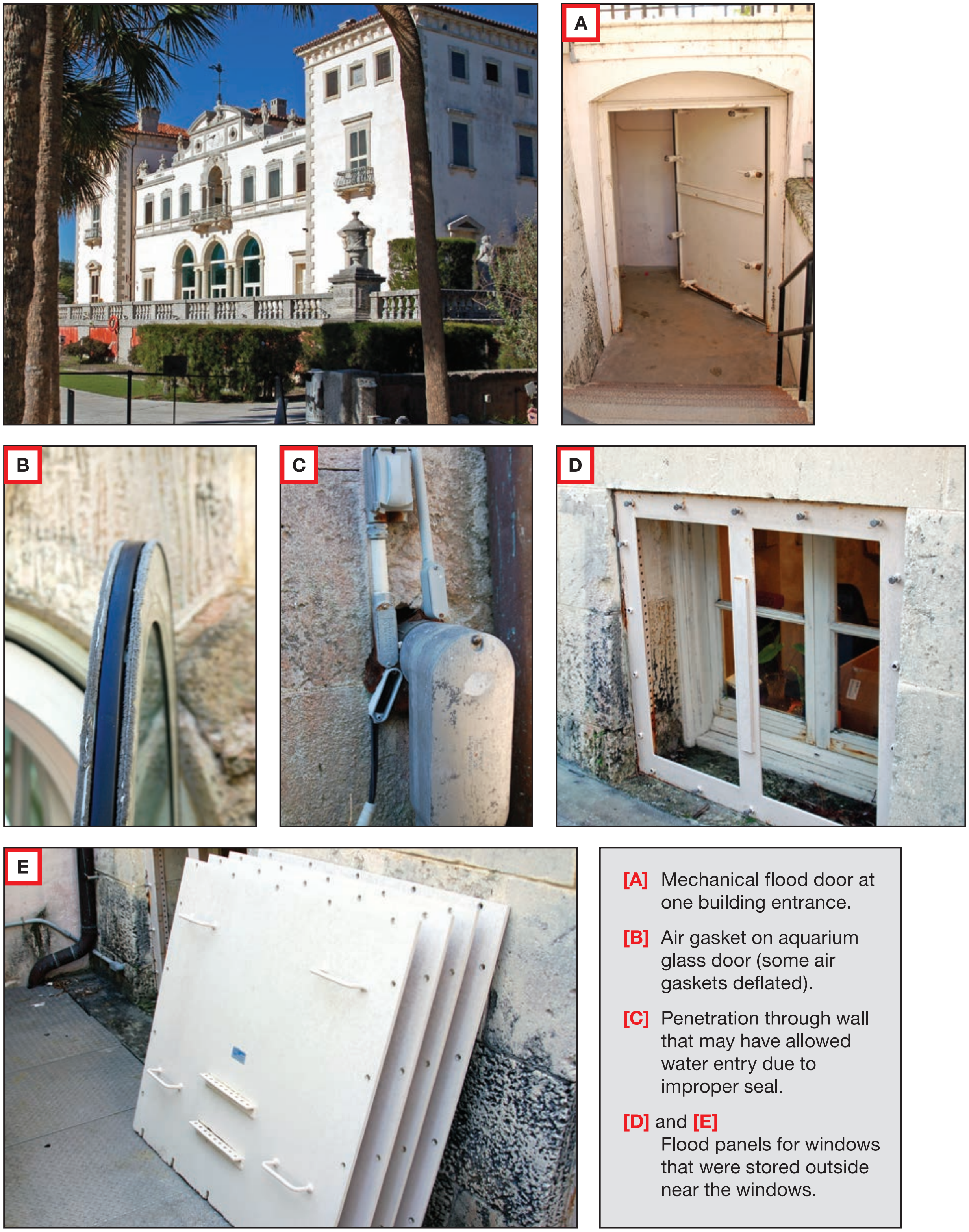


The doors without **[A]** and with **[B]** the floodproofing system deployed. The system took 10 workers with heavy equipment 2 full days to install prior to Hurricane Irma.

[C] shows the panel and post storage room.

[D] shows a gap at the top of a doorway flood shield.

Figure 3-31: A high-rise residential building under construction was successfully protected by a dry floodproofing method that used flood panels and doors; the floodproofing was installed by the building contractor (Miami, FL)



[A] Mechanical flood door at one building entrance.

[B] Air gasket on aquarium glass door (some air gaskets deflated).

[C] Penetration through wall that may have allowed water entry due to improper seal.

[D] and **[E]** Flood panels for windows that were stored outside near the windows.

Figure 3-32: Floodproofing system components at a historic building (top); parts of the system failed and approximately 3 feet of flooding infiltrated part of the building (Miami, FL)

3.2.2 Implementation Considerations

One of the MAT's concerns is the time necessary to implement some of the observed dry floodproofing systems. While some systems can be (and were) deployed in 2 hours or less by just two workers (see Figure 3-30), other complex systems likely required many workers using material handling equipment to lift and position heavy flood posts and panels over 2 or more days (see Figure 3-31). Small panels and planks are relatively easy to handle and install and do not require equipment. Single, large, heavy panels require more workers and equipment to install and can be difficult to lift, hold, align, and secure. As one architect interviewed by the MAT said, "simpler is better" when it comes to floodproofing systems.

Lengthy deployment times not only increase the likelihood of flooding when systems are installed, but they leave insufficient time to install the dry floodproofing measure before rapid-onset, intense rainfall events ("rain bombs").

The MAT observed that flood protection components often were not stored in a secure and dedicated location. If components are not stored securely in a designated area, they can be misplaced or stolen. In many cases, the storage arrangements did not facilitate component inventory, making it hard to identify missing parts.

3.2.3 Operations and Maintenance Plans

The MAT obtained written plans for deployment of dry floodproofing systems for some floodproofed sites, but for other sites, plans either were not obtained or may not exist. Plans that were reviewed varied in scope and complexity, and some did not include all necessary information for successful installations. The required installation knowledge may reside with current staff, but staff members change over time, and institutional floodproofing knowledge may be lost if it is not documented.

3.3 Performance of Public Restrooms

The MAT visited 15 public restroom buildings and sites on or near the shoreline in public parks in Lee, Collier, Monroe, and St. Johns Counties.

The restrooms visited were of varying ages and construction and were subject to a variety of flood conditions during Hurricane Irma, depending on building location and elevation. Some restrooms were likely exposed to Zone V conditions during Irma (wave heights of 3 feet or higher), while others were likely exposed to shallow flooding and small waves (or no waves).

Table 3-1 summarizes the MAT restroom observations.

Table 3-1: Summary of Public Restrooms Visited

Site Identifier	Name/Location	MAT Observations
1	**Bunche Beach Preserve** (Lee County)	• Zone VE[(a)] • Intact and in use, December 2017 • Elevated on masonry foundation walls • Owner reported possible shallow flooding in grade-level enclosure • See Figure 3-33
2	**Lovers Key State Park** (Lee County)	• Zone VE[(a)] • Intact and in use, December 2017 • Timber pile foundation • Owner reported shallow flooding in enclosure below building • See Figure 3-34
3	**Barefoot Beach Preserve County Park** (Collier County)	• Zone VE[(a)] • Intact and in use, December 2017 • Timber pile foundation • Flooding was likely shallow and passed beneath building • There may have been wind damage to building • See Figure 3-35
4	**City of Naples Pier – two buildings** (Naples)	• Zone VE[(a)] • Intact and in use, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • See Figure 3-36
5	**Tigertail Beach Park** (Marco Island)	• Zone AE[(a)] • Intact and in use, December 2017 • Timber pile foundation • Flooding was likely shallow and passed beneath elevated building • See Figure 3-37
6	**Tigertail Beach Park** (Marco Island)	• Zone AE[(a)] • Intact and in use, December 2017 • At-grade building • Likely shallow flooding inside restroom building • See Figure 3-38
7	**Sombrero Beach City Park** (Marathon)	• Zone AE[(a)] • Intact and closed, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • See Figure 3-39
8	**Sombrero Beach City Park** (Marathon)	• Zone AE[(a)] • Intact and closed, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • Construction identical to site 7; see Figure 3-39
9	**Long Key State Park** (Monroe County)	• Zone AE[(a)] • Damaged by flood, September 2017 • At-grade masonry building • Building demolished by owner and site cleared between September 2017 and December 2017 • See Figure 3-40

(a) Flood zone at time of Hurricane Irma, not necessarily at time of restroom construction.

(continued on page 3-28)

Table 3-1: Summary of Public Restrooms Visited (concluded)

Site Identifier	Name/Location	MAT Observations
10	**Long Key State Park** (Monroe County)	• Zone AE[(a)] • Intact and closed (park closed), December 2017 • Concrete column foundation • Flooding was likely shallow and passed beneath building • See Figure 3-41
11	**Bahia Honda State Park, Sandspur Day Use** (Monroe County)	• Zone AE[(a)] • Washed away by Hurricane Irma, September 2017
12	**Bahia Honda State Park, Sandspur Camping Restroom** (Monroe County)	• Zone AE[(a)] • Intact and closed (park closed), December 2017 • Elevated on high masonry foundation walls with louvers • Flooding in enclosure below elevated building was approximately 5 feet deep (approximately 1 foot below floor of restroom) • See Figure 3-42
13	**Bahia Honda State Park, Loggerhead Restroom** (Monroe County)	• Zone AE[(a)] • Damaged by wind and closed (park closed), September 2017 • Wood frame building elevated on timber pile foundation • Building demolished by owner between September 2017 and December 2017 • Replaced with temporary (mobile) toilet building • See Figure 3-43
14	**Veterans Memorial Park** (Monroe County)	• Zone AE[(a)] • Damaged by flood, September 2017 • At-grade masonry building • See Figure 3-44
15	**Surfside Park, Vilano Beach** (St. Johns County)	• Zone VE[(a)] • Intact and functional, February 2018 • Wood frame, at-grade building (walls do not extend to slab) • See Figure 3-45

(a) Flood zone at time of Hurricane Irma, not necessarily at time of restroom construction.

For those restrooms damaged by flooding, the degree of damage ranged from complete destruction, to some structural damage, to damage to doors and fixtures only. The degree of damage depended on both flood conditions (flood depth, flood velocity, wave conditions) and building characteristics (floor elevation, robustness of construction, features allowing flow-through). Figure 3-33 through Figure 3-45 show the restrooms that the MAT observed (site numbering refers to Table 3-1). For the following observations, see Table 3-1.

- One restroom was destroyed by Hurricane Irma and nothing remained to evaluate (Bahia Honda State Park – Sandspur Day Use, Site 11). This restroom was likely exposed to Zone V conditions.
- Two restrooms were heavily damaged and observed by the pre-MAT in September 2017, but were demolished by the Florida Division of Recreation and Parks before the December 2017 return visit to the sites (Long Key, Site 9; Bahia Honda – Loggerhead, Site 13). The Long Key restroom was likely exposed to Zone V conditions.
- One flooded restroom that did not sustain structural damage, Veterans Memorial Park (Site 14), was likely subject to Zone V flood conditions.

- Two restrooms were at grade and were flooded (Tigertail, Site 6; Veterans, Site 14). The Tigertail restroom was far from the shoreline, sheltered by 200 feet of dense vegetation, and subject to storm surge only. The Veterans restroom was close to the shoreline and subject to storm surge and wave action.
- One restroom was constructed with at-grade enclosures and partial-height walls (Surfside Park, Site 15). Whether the floor slab was flooded as a result of Hurricane Irma is unclear, but if it was, the flood depth would have been shallow (inches).
- Three restrooms were elevated above the Hurricane Irma flood level and had ground-level enclosures that were or may have been flooded (Bunche Beach Preserve, Site 1; Lovers Key, Site 2; and Bahia Honda, Site 12).
- Six restrooms were elevated above the Hurricane Irma flood level and had no ground-level enclosure (Barefoot Beach, Site 3; City of Naples Pier, Site 4; Tigertail, Site 5; Sombrero Beach, Sites 7 and 8; and Long Key, Site 10).

Figure 3-33: Elevated restrooms with ground-level enclosure. Bunche Beach Preserve restroom (Site 1; Lee County), where the degree of flooding in the enclosure, if any, would have been shallow.

Figure 3-34: Elevated restrooms with ground-level enclosure. Lovers Key State Park restroom (Site 2; Lee County) enclosure sustained shallow flooding but no damage during Hurricane Irma.

Figure 3-35: Elevated restroom at Barefoot Beach Preserve County Park (Site 3; Collier County)

[A] Photo taken from land side

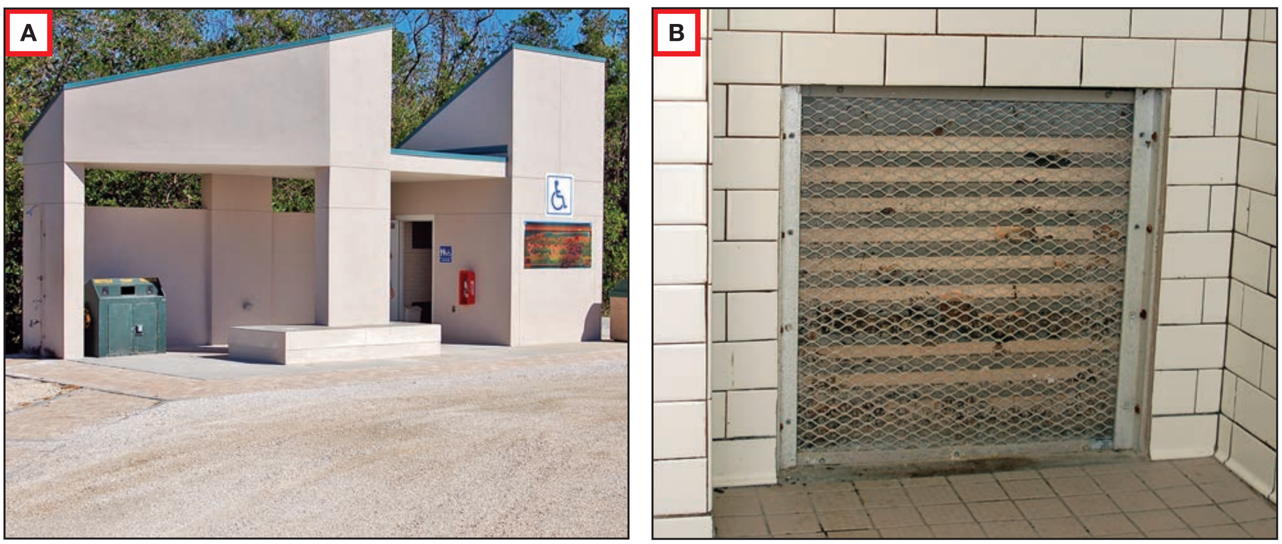
[B] Photo taken from beach

[C] Finished floor is below BFE but restroom walls are wet floodproofed to 1 foot above BFE

[D] Flood openings have been installed

Figure 3-36: Elevated restrooms (Site 4; City of Naples Pier)

Figure 3-37: Elevated restroom at Tigertail Beach Park (Site 5; Marco Island, Collier County)



[A] Restroom at Tigertail Beach, Marco Island. The estimated flood depth was 1 to 2 feet, and stormwater and surge from Hurricane Irma carried enough velocity to drive parking lot gravel around the restroom.

[B] Flood debris in a vent

Figure 3-38: Grade-level restrooms at Marco Island (Site 6; Collier County)

Figure 3-39:
Elevated restrooms at Sombrero Beach Park without ground-level enclosure and that sustained no flood damage during Hurricane Irma (Site 7; Marathon)

Figure 3-40:
Elevated Long Key State Park restroom without ground-level enclosure and that sustained no flood damage during Hurricane Irma (Site 9; Monroe County)

The bottom photos show damage to fixtures, partitions, and walls that was likely caused by waves and high-velocity flow. The restroom was demolished between the pre-MAT and MAT visits.

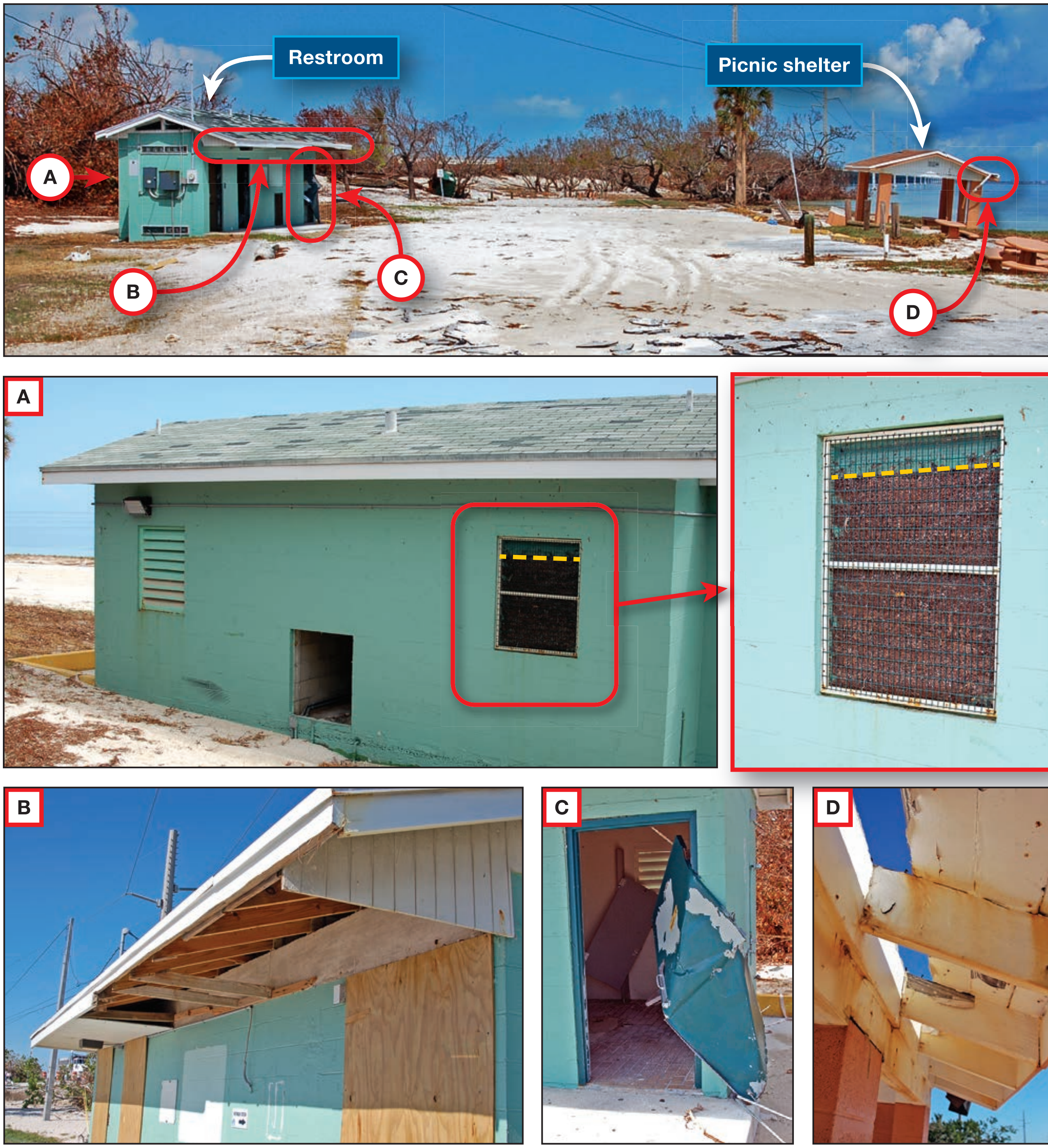
Figure 3-41: Restroom in Long Key State Park that sustained structural flood damage (Site 10; Monroe County)

Figure 3-42: Elevated restroom with ground-level enclosure at Bahia Honda State Park, Sandspur Campground; Hurricane Irma flood depth in enclosure was 5 feet (Site 12; Monroe County)

Figure 3-43: Elevated restroom at Bahia Honda State Park, Loggerhead (Site 13; Monroe County)

The elevated restroom sustained wind damage.

The same site after building demolition, showing temporary mobile restroom building installed for public use (photo taken in December 2017).



[A] Rear of restroom showing debris trapped inside vent—debris level was approximately 7 feet above grade and would have accounted for stillwater plus sloshing waves trapped inside restrooms

[B] Wave splash against seaward restroom wall likely damaged soffit

[C] Exterior door damaged by waves

[D] Wave crests were likely just below the shelter soffit and lifted the roof deck off

Figure 3-44: Grade-level Veterans Memorial Park restroom that was likely exposed to Zone V conditions (Site 14; Monroe County)

Exterior and interior photos of a restroom building at Surfside Park, St. Johns County. The wood frame outer walls do not extend to the floor slab (red arrows), and gable ends are open, allowing light and air to enter the restrooms. There is no electric service to the restrooms. The building likely sustained no flood damage during Irma.

Figure 3-45: Grade-level Vilano Beach Surfside Park restrooms (Site 15; St. Johns County)

HURRICANE
IRMA
IN FLORIDA

4 Wind-Related Observations

The MAT Wind team assessed one- and two-family dwellings in the vicinity of the first and second Florida landfall locations.

Building assessments also included some multi-family dwellings (apartments and condominiums) and MH units and also covered Key West eastward to Duck Key and throughout Collier County, as well as the Miami area.

Estimated wind speeds from Hurricane Irma did not approach the design wind speeds required by the last six editions of the FBC. Each photograph caption in this chapter includes both the estimated wind speed for the photograph location during the storm and estimated design wind speed for comparison. Estimated event wind speeds were taken from Applied Research Associates data, and ASCE 7-10 design wind speeds, which are referenced in the current edition of the FBC, were taken from the Applied Technology Council (ATC) Hazards by Location website.[1] Wind speeds provided are 3-second peak gust for Risk Category II buildings. Wind speed is not the only factor for determining wind pressures or levels of damage; however, wind speeds provide a good basis for comparing event conditions and design requirements. In addition to high wind pressures, damage to buildings may be caused by wind-borne debris. However, wind speeds were used to more easily compare event conditions and design requirements.

1 The ATC Hazards by Location website is available at hazards.atcouncil.org/.

In addition to estimated wind speed and estimated design wind speed in each photograph caption, the text describing each figure identifies the year the building was constructed. The date built is provided to offer some context with respect to the wind provisions that were in effect when the building was permitted for construction. The estimated design wind speed may not be correlated with the wind requirements of the codes that were in effect when the building was built. Further, damaged components shown in the photographs may have been replaced since the original date of construction. Where the property appraisal databases indicated that work permits were issued after the original date of construction, the date of the permitted work is noted for damaged components identified in the photographs.

Although failures of the main wind-force resisting systems (MWFRSs) were observed in some buildings, as described in Section 4.1, most buildings designed and constructed to comply with the FBC performed well structurally. However, many of these same buildings sustained wind-induced failures of building envelope components that allowed wind-driven rain to penetrate, resulting in costly damage, as described in Section 4.2.

Section 4.3 describes performance assessments of MH units and includes observations on anchorage (tie-downs) and damage resulting from failure of attached appurtenances.

4.1 Main Wind-Force Resisting System Performance

The MWFRS is defined in ASCE 7-10 as an assemblage of structural elements assigned to provide support and stability for the overall structure. Examples of MWFRS elements include shear walls, roof diaphragms, and structural frames. Wind-induced structural damage to MWFRS was not widespread and, where observed, mostly occurred in older (pre-FBC) buildings. Damage observations did include roof failure and loss of exterior walls.

4.1.1 Roof Failure

Wind damage to roof structures was often found to have initiated through loss of the roof covering or breaching of the attic envelope, though the cause of the initial failure cannot always be determined after the event. Once wind enters a building, failures can progress to other components and connections along numerous load paths.

Figure 4-1 shows an elevated, single-story, wood-framed house (built in 1988) that lost nearly all its roof sheathing, most likely due to withdrawal of the roof decking-to-framing fasteners. Numerous roof truss top chords located near the roof ridge were also damaged or missing, but roof framing adjacent to the front wall and the roof-to-front wall connections remained intact (see bottom photo in Figure 4-1). The roof truss bottom chords remained in place, providing lateral support that prevented wall collapse.

Another example of roof damage on a pre-FBC dwelling (built in 1923) in Miami is shown in Figure 4-2, where large sections of roof were picked up by Irma's winds and dropped onto the neighboring house. As shown in the red circle, where connected, the conventional wood frame roof and bond beam separated from the masonry wall.

The close-up shows severed truss upper top chords (blue circles) and intact connection of lower top chord and top of wall (yellow circles).

Figure 4-1:
House with structural damage to roof system (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The failed connection resulted in large sections of roof being blown atop an adjacent structure. The red circle shows a portion of the bond beam attached to the displaced roof section.

Figure 4-2:
Residence where a roof-to-wall connection failed (EWS = 78 mph; EDWS = 169 mph) (Miami)

4.1.2 Wall Failure

Framed walls of residential structures collapsed where significant portions of the roof and ceiling diaphragm were destroyed by wind and the lateral support for the walls was compromised.

Figure 4-3 shows the south end of an elevated one-story, wood-framed residence (built in 1986) on Cudjoe Key where roof-to-wall connections failed to prevent large portions of the conventionally framed roof from lifting away. The rafters separated from the connectors, which are visible along the top of the wall everywhere the roof is missing. The MAT could not determine why the connection failed; the connectors may not have been adequate to resist uplift forces associated with Irma's winds on Cudjoe Key, or they may not have been installed according to the manufacturer's instructions. Pre-damage images show the north end of the house had a screened porch; all that remains of the porch is shown on Figure 4-4 and Figure 4-5, where the remaining post and header are visible along the right side of Figure 4-4 and left side of Figure 4-5. An exterior wall section adjacent to the screened porch also collapsed and is also shown in the images. One possible scenario is that the overhang portion of the screened porch began failing and created a breach in the envelope, allowing wind to enter the interior of the building and create high internal pressures.

Another example of wall failure was observed on Ramrod Key, as shown in Figure 4-6. The two-story, wood-framed residence (built in 1990) lost roof trusses above the east-facing (ocean-facing) second floor area; two exterior walls were lost from the room below the missing roof trusses, and the adjacent deck floor collapsed onto the porch floor below.

Figure 4-3: South end of east-facing wall; the south end of the roof remained in place (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

One section of the north-facing exterior wall (painted orange, indicated with the red arrow) adjacent to screened porch remained in place. Same house as Figure 4-3.

Figure 4-4:
North end of east-facing wall where the roof was (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

The screened porch and portion of the exterior wall, which is painted orange and indicated with the red arrow, remained standing. There is a missing wall section between it and the west-facing exterior wall. Same house as Figure 4-3.

Figure 4-5:
Remainder of the screened porch and exterior wall (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

Figure 4-6:
House with roof structure loss and collapse of the second floor exterior wall and adjacent deck (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

4.2 Envelope

Although MAT observations of structural damage from Hurricane Irma winds were almost exclusively limited to pre-FBC (prior to March 1, 2002, the date the first edition FBC went into effect) residential buildings, the MAT observed envelope damage on both older and newer construction. The building envelope includes exterior doors, windows, skylights, exterior wall coverings, soffits, roof systems, and attic vents. In buildings elevated on open foundations, the floor is also considered a part of the envelope. The most frequently damaged elements of these envelope systems observed by the MAT were roof coverings, soffits, and exterior wall coverings. While less frequent, damage to glazed openings, impact-protection systems, and garage doors was also noted.

4.2.1 Roof Coverings

MAT wind observations of roof covering loss are grouped according to common material types present in South Florida: asphalt shingles, tile, and metal. In many cases, the reason for the damage could not be determined because damaged roofs were under repair or covered by tarps.

4.2.1.1 Asphalt Shingles

Asphalt shingle loss was observed to be widespread, especially in the Florida Keys. Asphalt shingle failure was observed on both older dwellings and those built after adoption of the FBC.

The roof of the Big Coppitt Key house (built in 2005) shown in Figure 4-7 and Figure 4-8 was mostly hidden under a tarp, but the uncovered slope reveals shingle loss near the eaves and ridge. Figure 4-9 shows another post-FBC dwelling (built in 2007) with significant asphalt shingle loss that was observed in Marathon.

Figure 4-7:
The MAT could not observe much of the asphalt roof damage on this house because it was covered by a tarp (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

Figure 4-8:
Asphalt shingle loss shown inside yellow ovals for house shown in Figure 4-7 (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

Figure 4-9:
House with asphalt shingle loss as evidenced by tarp (EWS = 120 mph; EDWS = 180 mph) (Marathon)

Asphalt shingle loss was limited on the Sugarloaf Key house (built in 1997) shown in Figure 4-10, but the pattern of loss near the ridge remains evident in the inset photo where shingle-to-roof deck nails remain in place. The Figure 4-10 inset photo indicates the shingles were likely installed incorrectly, because the shingle-to-roof deck nails were positioned too close to the top edge of the shingle. As shown in Figure 4-11, asphalt shingle nails in high-wind regions should be positioned close to the centerline of the shingle to secure the shingle underneath and decrease the moment arm of the uniform wind pressure acting on the shingle.

Figure 4-10:
Residence that lost shingles near the ridge (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

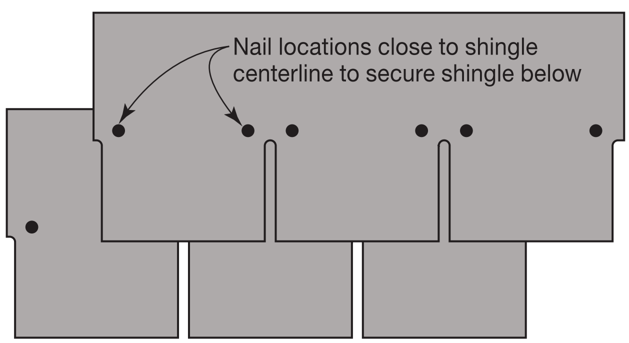


Figure 4-11:
Recommended asphalt shingle nail locations for high wind regions

As the MAT anticipated, older asphalt shingle roofs on pre-FBC dwellings were more vulnerable to wind damage than newer roofs on post-FBC buildings. Figure 4-12 shows a typical example from Marco Island (built in 1971) where asphalt shingle loss is visible near the main ridge and between the hips above the garage.

Figure 4-12:
House with shingle loss near main ridge and between roof hips (yellow oval) (EWS = 109 mph; EDWS = 170 mph) (Marco Island)

4.2.1.2 Roof Tile

Based on MAT observations, damage to roof tile was limited and generally minor. However, the MAT observed failure of several older, pre-FBC roofs with mortar-set roof tiles as described below. The Cudjoe Key house (built in 1989), shown in Figure 4-13, lost a significant number of tiles, particularly at the hips and garage ridge. The Florida's Association of Roofing Professionals / Tile Roofing Institute (FRSA/TRI) *Florida High Wind Concrete and Clay Roof Tile Installation Manual*, Fifth Edition (2012) (FRSA/TRI Manual) requires mortar-set hip and ridge tiles to be fully embedded in mortar. The hip tiles shown in 4-13 were not fully embedded in mortar.

Figure 4-13:
Roof tile failure (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

The top image shows damaged hip tiles in the red circle; the inset is a close-up of the same area. Damage to hip and ridge tiles was the most commonly observed damage, but other types of damage in the field area were also noted.

Similar damage was observed along the front eaves, ridge, and area along and adjacent to the left hip over the front porch of the roof on the Duck Key house (built in 1984) shown in Figure 4-14. Although no measurements could be taken, the first course of tile appears to project too far over the eave. The FRSA/TRI Manual specifies that tiles must overhang the eave at least ¾ inch but not more than 2 inches. Additionally, the first course near the eave does not appear to be set in mortar, as the first row of mortar patties are beyond the first course of tile.

Inset shows close-up of mortar-set roof tile loss around ridge and between left hip and front porch eaves.

Figure 4-14:
House lost roof tiles across most of its front eaves (red arrows) (EWS = 111 mph; EDWS = 180 mph) (Duck Key)

4.2.1.3 Metal Roof Systems

Residential metal roof systems performed well overall, with a few isolated instances of damage. The damage to metal roof systems that the MAT observed was generally limited to roof edges. For example, the metal fascia cover separated from the fascia board along the front- and side-facing gables of the Sugarloaf Key house (built in 2003) shown in Figure 4-15. The metal roof trim directly above the missing fascia covers had also peeled back, but the edge of the metal roof system itself appeared to be intact where visible along the right side of the front-facing gable.

The metal roof system damage shown in Figure 4-16 appears to be limited to the hip caps of the Sugarloaf Key residence (built in 1992). Monroe County property appraisal data indicate that the roof was installed in 1999.

Figure 4-15: House with separated metal roof trim and missing fascia cover (red ovals) along gable end. (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

Damaged hip cover components are shown from both visible hips (red oval and circle). Yellow arrows indicate exposed sections of hip joint.

Figure 4-16: House with damaged metal roof system (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

4.2.2 Soffits

The MAT observed widespread damage to soffits in the Florida Keys, particularly vinyl soffits. MAT wind observations of soffit loss are grouped according to common material types present in South Florida: vinyl and metal (aluminum and steel).

In some cases, vinyl soffit failure was also associated with fascia cover loss. While further study is needed, the loss of the fascia cover could have resulted in more wind exposure on the edges of soffits, affecting their performance. Information on soffit installation in Florida is available in Florida Recovery Advisory 2, *Soffit Installation in Florida* (2018h) (Appendix C).

4.2.2.1 Vinyl

Vinyl soffit panel assemblies were the most common soffit variety observed by the MAT. Wind damage to vinyl soffit assemblies was widespread, especially in the Florida Keys.

The Summerland Key dwelling (built in 2008) in Figure 4-17 shows an example of soffit failure associated with fascia cover loss. Interrelated fascia cover/soffit damage was also observed in a house built in 2001 on Little Torch Key, shown in Figure 4-18.

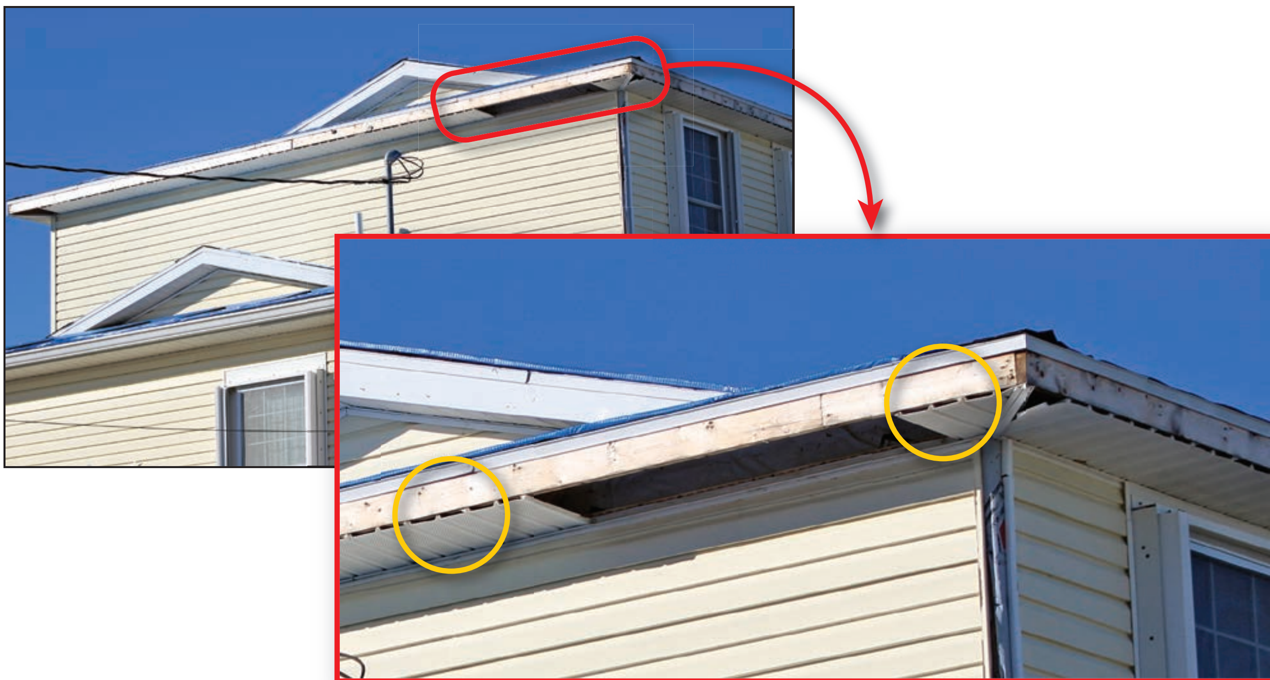


Figure 4-17: House that lost its vinyl soffit panel (EWS = 113 mph; EDWS = 180 mph) (Summerland Key)

The inset shows how the ends of the adjacent remaining panels are exposed where the fascia cover has pulled away, allowing wind to enter the closed soffit (yellow circles) and increase outward pressure, facilitating soffit blow-out.

Not all observed vinyl soffit damage was associated with fascia cover loss. The Sugarloaf Key house in Figure 4-19 (built in 1995) lost its vinyl soffit in several areas; the red outline shows where the soffit panel was stripped from the assembly's J-channel, which remains attached along the exterior wall. The soffit appears to have been attached to only a single nailing strip across the midpoint of the framing above.

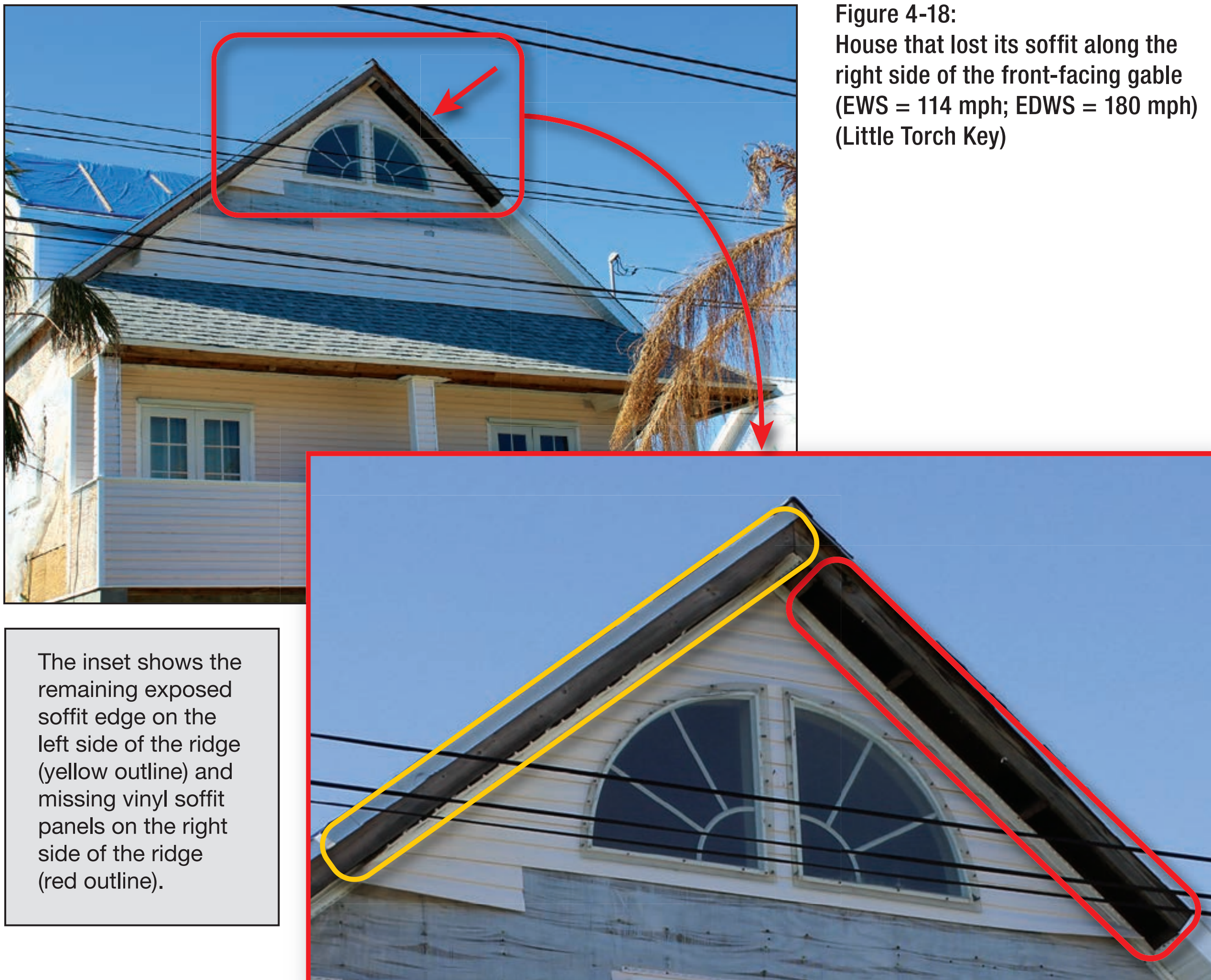


Figure 4-18:
House that lost its soffit along the right side of the front-facing gable (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

The inset shows the remaining exposed soffit edge on the left side of the ridge (yellow outline) and missing vinyl soffit panels on the right side of the ridge (red outline).

Figure 4-19:
House with vinyl soffit damage not caused by fascia loss (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The red outline shows where the soffit panel was stripped from the assembly's J-channel, which remains attached (yellow arrows).

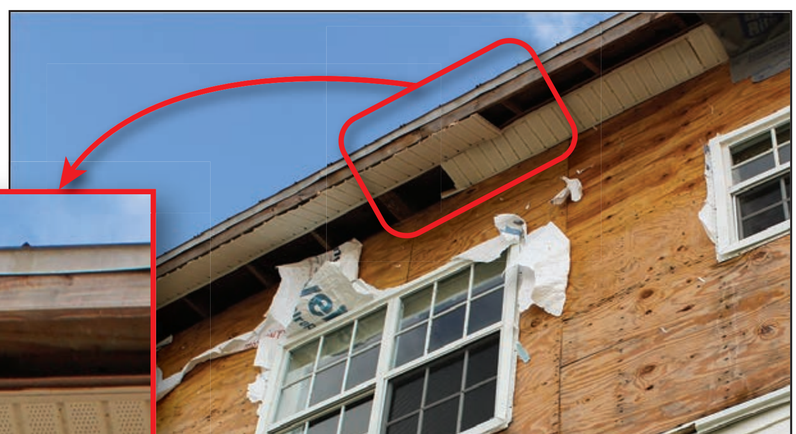
Figure 4-20 shows similar soffit panel attachment and loss on a Sugarloaf Key dwelling (built in 1999). The wider eaves included a second nailing strip to attach the vinyl soffit panels, but the attachment did not prove adequate for wind pressures experienced during Hurricane Irma.

The MAT also observed post-FBC construction with vinyl soffit damage outside the Florida Keys, as demonstrated by a house in Goodland (Collier County) as shown in Figure 4-21. The dwelling (built in 2005) is part of a development described in detail in the text box "Vinyl Siding/Soffit Failure Example" in Section 4.2.3 and is another example of soffit failure associated with fascia cover loss. Although the missing fascia cover played a role by elevating wind pressures within the closed soffit system shown in Figure 4-21, the unconventional installation provided inadequate support for the soffit panels. The two parallel runs of soffit appear to be joined at the eave's midpoint with back-to-back J-channels. With no nailing strip along the exterior wall, the inside edge of the soffit system could only be attached directly to framing at 24 inches on center.

Figure 4-20: Dwelling with similar soffit panel attachment and loss as shown in Figure 4-19 (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The wider eaves on this dwelling (in comparison to Figure 4-19) included a second nailing strip (red arrows), though the attachment did not resist the wind loads.

Figure 4-21: House with soffit loss (EWS = 110 mph; EDWS = 169 mph) (Goodland)



The inset (area inside red outline) shows exposed edge of soffit panels adjacent to missing soffit panels.

4.2.2.2 Metal

Metal soffit assemblies were not as common as vinyl soffit assemblies in areas visited by the MAT. However, the MAT did observe wind damage to metal soffits in the Florida Keys and Collier County.

Figure 4-22 shows metal soffit panel loss along the corner of a Ramrod Key front porch (house built in 2005). The remains of the soffit attachment, which were fastened directly to the nailing strip along the outside edge and held in place by a channel above the porch opening, are indicated by the red arrow. Similar to the damage pattern noted in the previous discussion on vinyl soffits, some metal soffit panels were missing; an example is shown in Figure 4-23, where soffits were missing below the Big Pine Key house's (house built in 1989) screened porch gable end outlooker rafters, directly below an area where the fascia cover had blown away (compare with Figure 4-17).

The red arrow shows direct attachment of soffit to framing along the outside edge of eaves only; panels are secured by a channel only above the porch opening.

Figure 4-22:
Metal soffit loss on house (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

Figure 4-23:
House with metal soffit loss below missing fascia cover (EWS = 114 mph; EDWS = 180 mph) (Big Pine Key)

ROOF VENTILATION/SOFFIT VENTS

Refer to Section R806 of the 6th Edition (2017) Florida Building Code, Residential (FBCR) for roof ventilation requirements. To avoid water entry at soffit vents, options include eliminating soffit vents and providing an alternate method for roof ventilation, or designing for an unvented attic. For additional guidance on mitigating water intrusion through attic vents and strengthening soffits, refer to Technical Fact Sheet No. 7.5, "Minimizing Water Intrusion through Roof Vents in High-Wind Regions" in FEMA P-499, *Homebuilder's Guide to Coastal Construction* (2010).

In Naples, the MAT observed two apartment buildings with metal soffit panel loss patterns similar to the single-family Florida Keys dwellings shown above. On the left side of Figure 4-24, metal fascia covering can still be seen hanging from the eaves near the corner of the hip-roofed building (built in 1983). Soffit panels remain in place toward the center of the building, but are missing closer to the corner. The right side image of Figure 4-24 shows the adjacent side of the building where fascia covering is completely gone along with most of the metal soffit panels. On a nearby Naples apartment building (built in 1980), metal soffit panels were lost below the front porch gable end outlooker rafters. As shown in Figure 4-25, no damage is apparent along the adjacent fascia of the building.

Dangling fascia cover (red outline) is shown adjacent to missing metal soffit panels near the corner of a Naples apartment building (yellow outline indicates intact soffit panels).

Missing metal soffit panels are shown below damaged fascia; located on the other side of the corner shown in left image.

Figure 4-24: Apartment building with metal soffit panel loss (EWS = 104 mph; EDWS = 166 mph) (Naples)

Figure 4-25: Metal soffit panel loss apartment gable end overhang (EWS = 104 mph; EDWS = 166 mph) (Naples)

4.2.3 Exterior Wall Coverings

The MAT observed exterior wall covering damage and loss resulting from Hurricane Irma winds. Aside from a few isolated instances of damage to wood siding, most of the exterior wall covering damage observed by the MAT was to vinyl siding. Damage to vinyl siding was widespread in the Florida Keys, but was also observed in Collier County. In most cases, the Irma MAT could not determine the design pressure rating of the failed vinyl siding. However, most of the observations indicated that the vinyl siding did not appear to be "high-wind" siding. The vinyl siding text box on the next page describes a failed vinyl siding installation that did not appear to be rated for South Florida application. The subsequent high wind-rated vinyl siding text box describes differences between vinyl siding rated for high-wind regions and standard vinyl siding.

For a few other sites, such as the Sugarloaf Key house shown in Figure 4-26, the MAT was able to record product identification numbers that allowed them to compare product-specific wind ratings to the FBC requirements. The house (built in 2014) lost siding along its back; based on the product identification shown in the inset, the MAT determined that the product had a negative design wind pressure rating of –74 psf (refer to Section 4.2.3.2). This vinyl siding product had a rolled-over nail hem, which is characteristic of higher-rated vinyl siding. Using the Risk Category II design wind speed of 180 mph, Exposure Category D, an effective wind area of 10 square feet for Zone 5 (corner zone), enclosed building classification, and an approximate mean roof height of 20 feet, the required design pressures (ASD) are +54 psf and –72 psf. Therefore, based on the required design pressure, the design pressure rating, and the estimated wind speeds at this site, the vinyl siding, if installed properly, should have resisted wind pressures sustained during Hurricane Irma. The State of Florida also requires building envelope products to be approved as described in the text box on the next page.

VINYL SIDING/SOFFIT FAILURE EXAMPLE

The MAT visited a subdivision of 24 elevated single-family dwellings in Goodland that sustained significant damage to vinyl siding and soffit assemblies on nearly all houses. Typical construction featured combinations of masonry and wood-framed exterior walls with a wood-framed roof.

Maximum estimated 3-second gusts for Goodland during Irma were estimated to be 110 mph. The design wind speed for this site is approximately 169 mph, so vinyl siding and soffit assemblies rated for the site-specific conditions and installed per manufacturer's instructions should not have failed. According to Collier County Property Appraisal information, the houses were all built between 2005 and 2006, when the 2004 FBC was in effect statewide.

The top left photo shows typical siding damage in the area. The bottom left photo shows where siding was attached with staples to masonry wall furring strips at 16 inches on center. Additionally, there is no evidence of utility trim in the J-channel above, which would have been needed to secure the trimmed top course. Similarly, it does not appear that starter strips were used at the bottom of the first (lowest) course of siding, nor at the division between first and second floor siding sections. The photo on the right shows an aerial view of the neighborhood for perspective.

HIGH WIND-RATED VINYL SIDING VS. STANDARD VINYL SIDING

Much of the failed vinyl siding that the Irma MAT observed in Florida did not appear to be rated for high-wind regions. Technical Fact Sheet 5.3, “Siding Installation in High-Wind Regions,” in FEMA P-499, *Homebuilders Guide to Coastal Construction* (2010), includes guidance on vinyl siding installation. The left-side graphic below from Technical Fact Sheet 5.3 demonstrates the basic differences between vinyl siding rated for high-wind regions and standard vinyl siding. The right-side image is siding from one of the damaged houses in Goodland described in the previous text box. Note how the detached siding has a standard (single) hem and locking area depicted in left image (rather than the high-wind siding required by the FBC in this area).

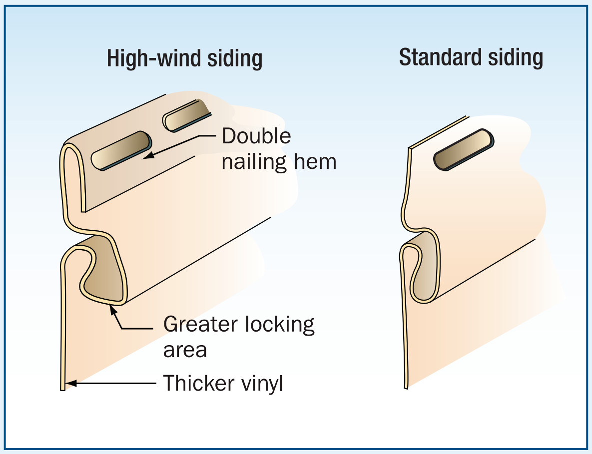


Figure 4-26: Vinyl siding lost along the back of a house (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

FLORIDA-PRODUCT APPROVAL

Rule 61G20-3 of the Florida Administrative Code applies to products and systems that compose the building envelope and structural frame. The rule requires the following products to have product approval for compliance with the structural requirements of the Florida Building Code:

- Panel walls (subcategories include soffits and siding)
- Exterior doors
- Roofing products
- Skylights
- Windows
- Shutters
- Structural components
- Impact protective systems

Products may be approved using either the optional statewide product approval system or local product approval. Regardless of the method used, products have to be evaluated for compliance (evaluation report, certification, test report, etc.), be validated for compliance with the evaluation, and approved by the Florida Building Commission. For additional information on product approval in the State of Florida, see Rule 61G20-3 of the Florida Administrative Code or the Building Code Information System at www.floridabuilding.org administered by the Florida Department of Business and Professional Regulation. A database of products approved using the statewide product approval system can be found under the "Product Approval" tab at www.floridabuilding.org.

The Marathon Key house (built in 2009) shown in Figure 4-27 lost siding across a significant portion of one gable end wall; based on the product identification shown in the inset, the MAT determined that the product had a design wind pressure rating of –55 psf (refer to Section 4.2.3.2). Using the Risk Category II design wind speed of 180 mph, Exposure Category D, an effective wind area of 10 square feet for Zone 5 (corner zone), enclosed building classification, and approximate mean roof height of 25 feet, the required design pressures are +56 psf and –75 psf. While the design pressure rating is about 27 percent less than the required design pressure, considering the estimated wind speeds at this site, the siding should have resisted wind pressures experienced during Hurricane Irma if it was properly installed. There is no evidence of utility trim under the window, which left the siding vulnerable at that location.

The red oval on left image shows the area magnified in the inset.

Figure 4-27:
House that lost vinyl siding on its gable end wall (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

4.2.3.1 Vinyl Siding Installation Issues

In addition to concerns about the use of vinyl siding with inadequate pressure ratings, the MAT observed several instances of vinyl siding wind damage on buildings that may have been due to installation issues. Figure 4-28 shows a Marathon Key duplex building (built 2017) with vinyl siding loss across the front and left exterior walls. The Vinyl Sinding Institute's 2015 *Vinyl Siding Installation Manual* recommends that the head of the fastener not be driven tightly against the nail hem to allow for expansion.[2] A clearance of 1/32 inch is recommended between the nail head and nail hem. The clearance shown in Figure 4-28 appears to exceed 1/32 inch. Further, vinyl siding loss above the front-facing wall above the front porch may have been initiated where a J-channel was installed instead of the manufacturer's specified starter strip.

The houses in Figure 4-29 (built in 2000), Figure 4-30 (built in 1977), and Figure 4-31 (built in 2000) show representative installation issues where vinyl siding failed. The house in Figure 4-29 was permitted to have its vinyl siding replaced in 2015, with work completed in 2016. The Little Torch Key house in Figure 4-31 was permitted to repair damage to its vinyl siding due to Hurricane Wilma in 2006, with the work completed the same year.

2 The Vinyl Siding Institute's 2018 *Vinyl Siding Installation Manual* makes this same recommendation.

Figure 4-28: Duplex where vinyl siding above the front porch did not comply with manufacturer's installation instructions (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

Figure 4-29: House appeared to lack utility trim under the windows, as shown in the red outline (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

Figure 4-30:
House that lacked a proper starter strip, as shown in the red outline (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Figure 4-31:
House with irregular fastener pattern and apparent lack of a proper starter strip (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

4.2.3.2 Vinyl Siding Design Pressure Ratings and the Pressure Equalization Factor

Vinyl siding is required to be certified and labeled as conforming to ASTM D 3679, *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding*. The 6th Edition (2017) FBC refers to the 2011 edition of ASTM D 3679, and the 5th Edition (2014) refers to the 2009 edition of ASTM D 3679. For determining the design wind pressure rating of vinyl siding, ASTM D 3679 permits test pressures to be adjusted to account for pressure equalization across the vinyl siding due to leakage paths (gaps). Pressure equalization refers to the reduction in net wind forces across cladding layers caused by external pressures being transferred to an interior air space. Pressure equalization of vinyl siding is accounted for by using a pressure equalization factor (PEF). ASTM D 3679 permits the PEF for vinyl siding to be taken as 0.36, which has the net effect of reducing the required test pressure to 36 percent of the design pressure rating of the vinyl siding times a Factor of Safety of 1.5. To clarify, the applicable equation is shown below:

$$P_t = D_p \times PEF \times 1.5$$

Where:

P_t = test pressure

D_p = design pressure rating of vinyl siding

PEF = Pressure Equalization Factor, 0.36

1.5 = Factor of Safety

For example, if a vinyl siding product had a design pressure rating (D_p) of 60 psf, that product was tested to a pressure of 32.4 psf (60 psf x 0.36 x 1.5).

Recent research (refer to the Insurance Institute for Business & Home Safety report *Wind Loads on Components of Multi-Layered Wall Systems with Air-Permeable Cladding* [2012]) has indicated that the PEF for vinyl siding should be higher. As a result, the 2017 edition of ASTM D 3679 increases the PEF to 0.5. Therefore, in the example above, the test pressure in ASTM D 3679-17 for a vinyl siding product with a design pressure rating (D_p) of 60 psf will be 45 psf. Debate continues about whether the PEF should be even higher than 0.5.

4.2.4 Glazed Openings and Opening Protection Systems

All sites that the MAT visited are located within the FBC's Wind-Borne Debris Region (WBDR) (see text box "FBC Wind-Borne Debris Region"). These sites have been included in the WBDR since the first edition of the FBC went into effect. The FBCR requires protection of all exterior glazed openings in the WBDR with products meeting the Large Missile Test of ASTM E 1886 and ASTM E 1996, Testing Application Standards (TAS) 201, 202, and 203 (HVHZ Test Protocols), AAMA 506, or ANSI/DASMA 115 (garage doors). The FBCR also provides a prescriptive solution for wood structural panels to serve as opening protection with limitations (the prescriptive solution for wood structural panels is not permitted in the HVHZ). While there are several limitations when using wood structural panels as opening protection, key limitations include:

- They must be a minimum of 7/16 inch thick
- Their span is limited to 44 inches
- Permanent corrosion-resistant attachment hardware must be provided, and anchors must be permanently installed on the building

The MAT observed the impact-resistant glazing and covering damage described in the following subsections.

FBC WIND-BORNE DEBRIS REGION

Wind-Borne Debris Regions are defined in Chapter 2 of the FBCR as follows:

> **Wind-Borne Debris Region.** Areas within *hurricane-prone regions* located in accordance with one of the following:
>
> - Within 1 mile (1.61 km) of the coastal mean high water line where the ultimate design wind speed, V_{ult}, is 130 mph (58 m/s) or greater.
> - In areas where the ultimate design wind speed, V_{ult}, is 140 mph (63.6 m/s) or greater; or Hawaii.

See Figure 2-4 of this MAT report for the Wind-Borne Debris Region for FBCR buildings.

The following excerpt from the FBCR applies to exterior glazed openings in the WBDR:

> **R301.2.1.2 Protection of openings.** Exterior glazed openings in buildings located in windborne debris regions shall be protected from wind-borne debris. Glazed opening protection for windborne debris shall meet the requirements of the Large Missile Test of ASTM E1996 and ASTM E1886 as modified in Section 301.2.1.2.1, TAS 201, 202 and 203, or AAMA 506, as applicable. Garage door glazed opening protection for windborne debris shall meet the requirements of an *approved* impact-resisting standard or ANSI/DASMA 115.

4.2.4.1 Impact-Resistant Glazing

The MAT observed damage to at least three double-paned glazed openings along one side of the Ramrod Key house (built in 2017) shown in Figure 4-32. However, the damaged openings appear to have resisted penetration, because in each case the inner panes were intact. The MAT could not determine with certainty that the glazed openings in Figure 4-32 were impact-resistant products without closer product inspection and research. But given the date of construction and concurrent FBCR requirements, the openings were likely protected with impact-resistant glazing to comply with building code requirements.

Figure 4-32: Residence with two windows where the outer panes were broken (see red arrows) but the inner panes stayed intact (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

The MAT visited the Little Torch Key house shown in Figure 4-33 and Figure 4-34 (built in 1985) to observe extensive wind-borne debris damage. The dwelling was struck repeatedly by construction materials blown from a nearby structure that was destroyed during Hurricane Irma. Figure 4-33 shows where the impact-resistant glazing did not prevent a wind-borne, 12-foot-long, 2x10 rafter from penetrating the interior of the house. This missile in particular is more massive than the D test missile (9-pound, 2x4 lumber) required by ASTM E1996. According to the homeowners, after penetrating the French door side light panel, the missile still had enough energy to reach and damage a television on the other side of the room. A second piece of wind-borne lumber penetrated the frame of an upper floor door unit on the same (east-facing) side of the house (see Figure 4-34).

Figure 4-33: House damaged by wind-borne debris (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

The right image shows east-facing, first floor door that was penetrated by a 12-foot-long, 2x10 rafter (indicated by the red outline). The left image is a close-up of damage to impact-resistant glazing that failed to resist the impact of a large rafter.

Figure 4-34: Wind-borne driven missile damaged second floor door at the same house as shown in Figure 4-33 (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Red arrow indicates a piece of lumber that was driven partially through an east-facing second floor door frame.

4.2.4.2 Impact-Resistant Coverings

In addition to damaged impact-resistant glazing, the MAT observed some damage to impact-resistant covering systems. The shutter and shutter system frame on the Little Torch Key dwelling (built in 2008) shown in Figure 4-35 was significantly damaged when struck by wind-borne debris. Also, note the damage to the railing in the foreground of Figure 4-35.

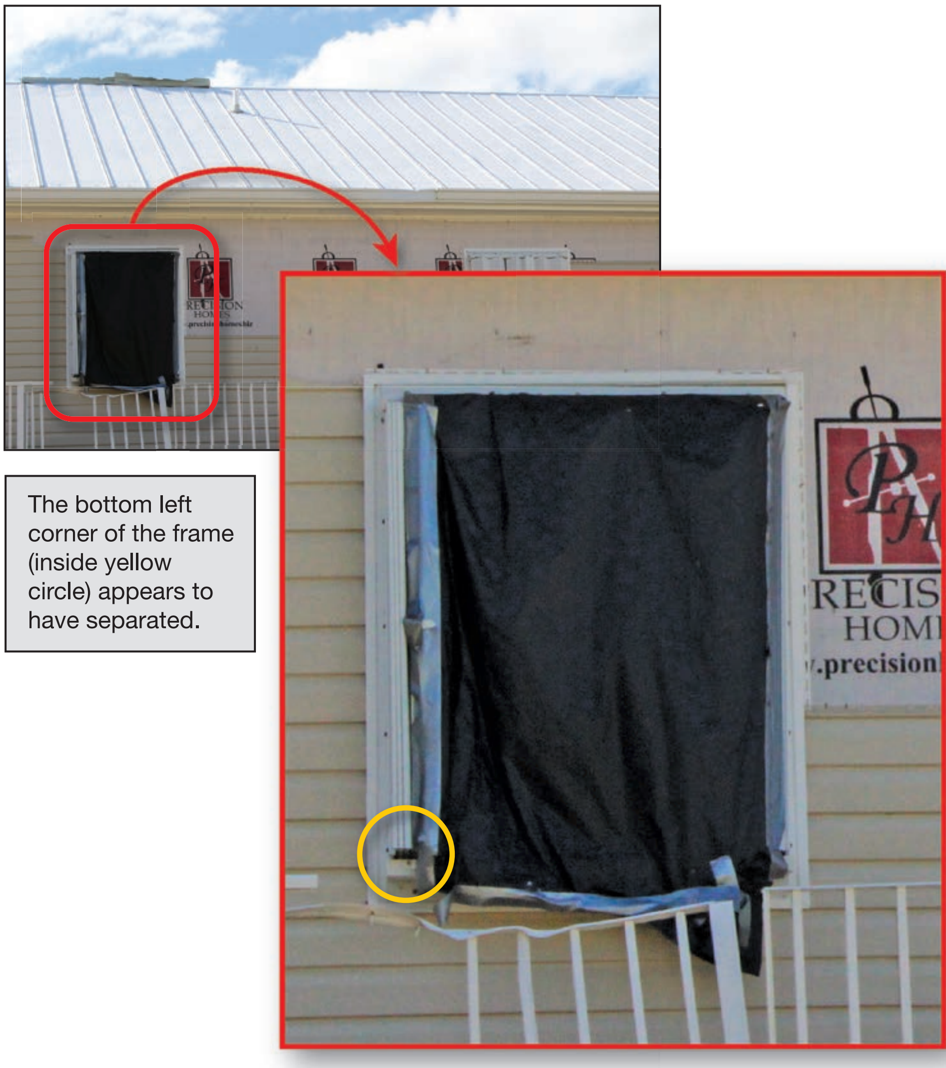
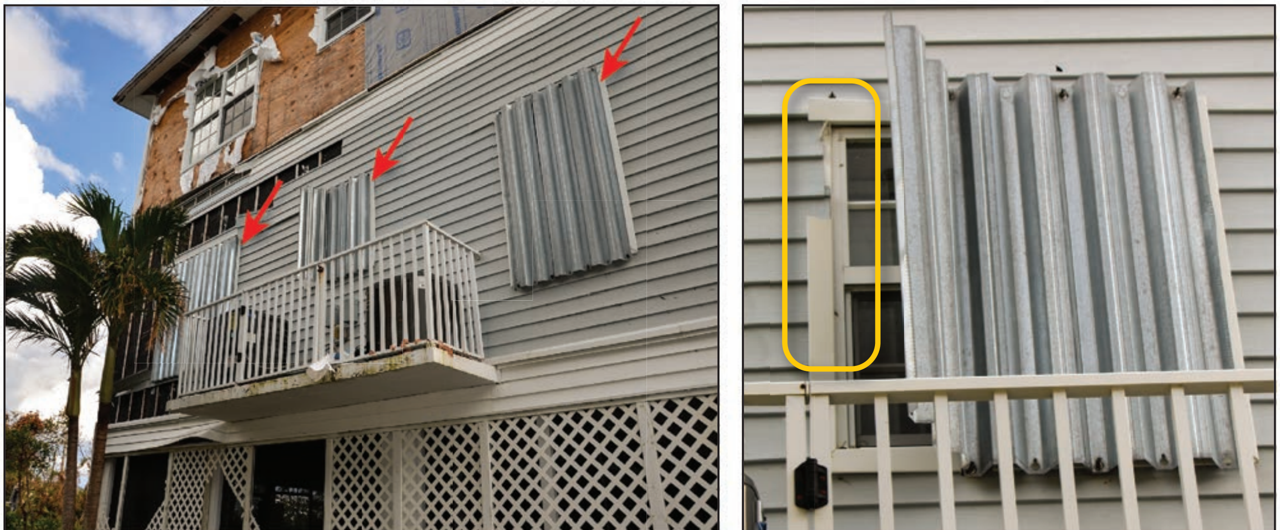


Figure 4-35:
House with impact-resistant shutter system damaged by wind-borne debris; opening was covered at the time the MAT visited (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Another example of damage to impact-resistant covering systems is shown in Figure 4-36, where a portion of the system's frame supporting the left end of the corrugated metal shutter is missing (see yellow outline). Shutters were still in place on the elevated first floor of the Goodland residence (built in 2005), but the damaged frame (see right image of Figure 4-36) rendered the glazed opening beneath it vulnerable to impact, as the metal shutter peeled toward the right side support.



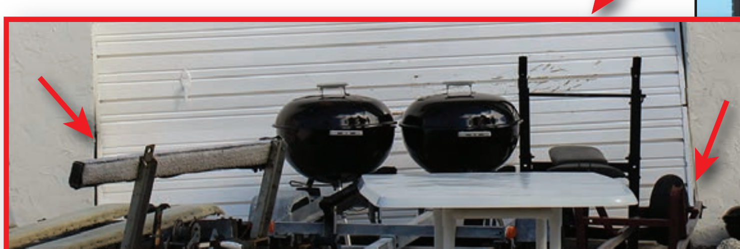
Shutters are shown in place over first-floor glazed openings (red arrows).

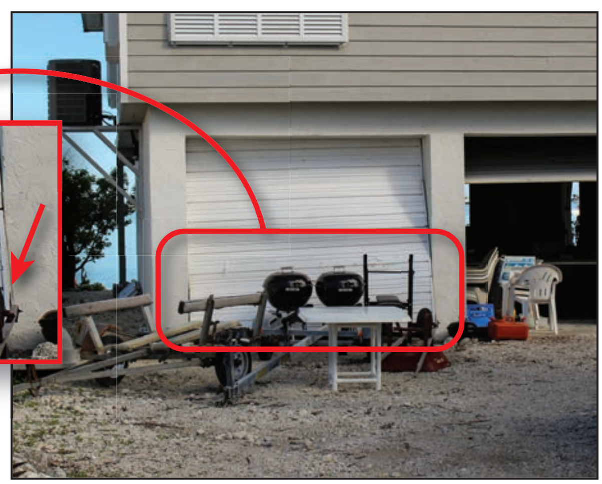
A close-up of a shutter above the air conditioning unit platform where the upper left frame is missing (yellow outline).

Figure 4-36: House with corrugated metal shutters (EWS = 110 mph; EDWS = 169 mph) (Goodland)

4.2.5 Garage Doors

The MAT observed a few instances of garage door failure on older, pre-FBC dwellings in the wake of Hurricane Irma. The failure mode for each was generally buckling near the base and failure at the track, as shown in Figure 4-37 and Figure 4-38. Both single-car overhead garage doors on the Little Torch Key house (built in 1980) shown in Figure 4-37 were damaged, but the right side opening could not be assessed in its partially open position. The left side door appears to have been pulled away from the track (evidenced by the greatest deflection present at the base of the door) by outward-acting negative wind pressure. A similar example of a single-width overhead garage door that buckled and pulled away from its track at the base is shown in Figure 4-38 for a Duck Key house (built in 1985).





The base of the door deflected outward beyond the exterior wall in the lower corners (red arrows).

Figure 4-37: Damaged overhead garage doors (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

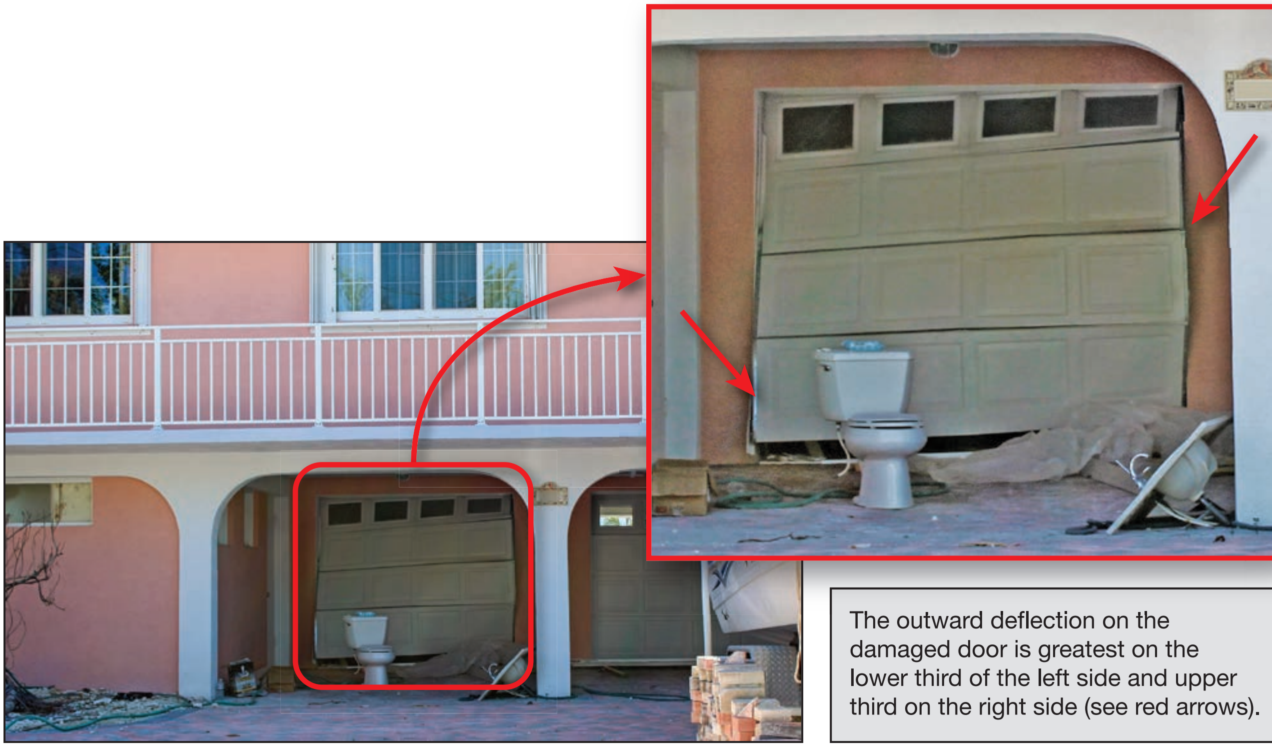


Figure 4-38: Damaged overhead garage door on a house (EWS = 111 mph; EDWS = 180 mph) (Duck Key)

4.3 Manufactured Housing Units

The MAT observed MH units in Collier County and the Florida Keys. Although some examples of MH anchorage techniques used in the Florida Keys are included below, inland observations from Collier County are primarily discussed because many installations in the Florida Keys were destroyed by storm surge. In Collier County, many more MH units than site-built houses were destroyed by Hurricane Irma's winds. Collier County building officials shared district-specific damage assessment information indicating that in three districts, 45 MH units were destroyed, while only three single-family dwellings and one multi-family dwelling were destroyed. Almost all destroyed units were inland of Irma's storm surge and were therefore destroyed by wind effects.

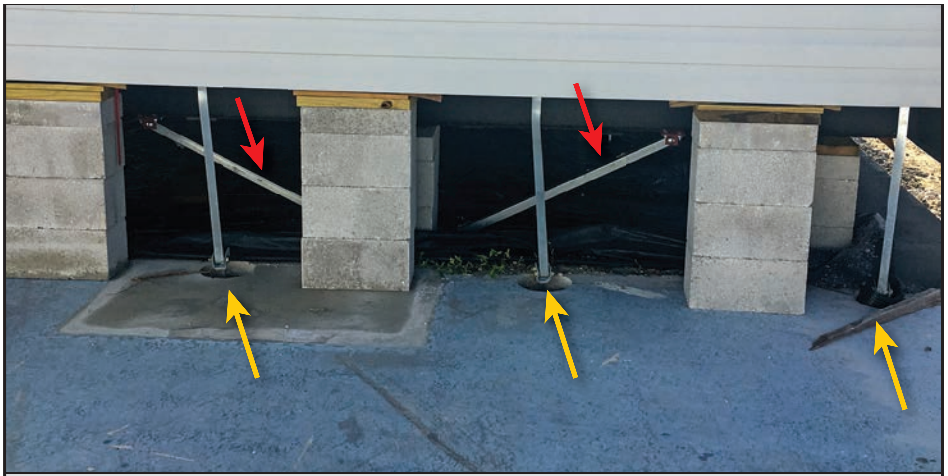
Date built and/or date manufactured information was not as readily available for the MH units as it was for site-built dwellings, which made it difficult for the MAT to determine the applicable construction criteria for observed units. When MH units were included on property appraisal websites maintained by counties and municipalities, the date listed was the date that units were installed in the referenced location, and not the date they were constructed in the factory. The date of manufacture should be included on identification plates required by the Department of Housing and Urban Development (HUD) as of June 15, 1976. However, the only observed MH units with HUD identification plates were newly installed to replace units destroyed by Irma, so the age of damaged and destroyed MH units is largely unknown.[3] Absent HUD tags could have been destroyed, removed, or located inside the MH units where the MAT did not have access.

3 For the purposes of this report, the MH units presented in this section were likely built after June 15, 1976, and are therefore referred to as MH units and are not differentiated as "Early Code" MH units (built after June 15, 1976 but before July 13, 1994) or "New" MH units (built July 13, 1994 to present).

4.3.1 Anchoring

New MH units installed after Irma and observed by the MAT appeared to be anchored much more consistently than older installations. Figure 4-39 and Figure 4-40 show two examples of post-Irma anchorage. Note both units' metal anchor straps are tight, aligned at the top and bottom, spaced 3 feet or less on center, and attached to the base of the wall. One exception to post-Irma anchorage consistency is shown in Figure 4-41, where straps are misaligned from top to bottom.

Figure 4-39: Anchorage on a new MH unit installation (EWS = 105 mph; EDWS = 164 mph) (Collier County)



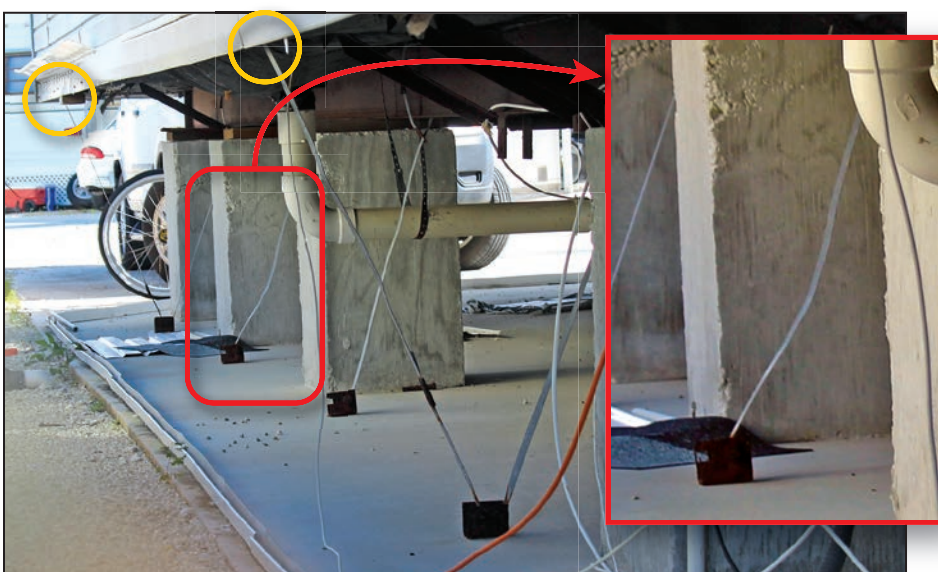
Yellow arrows show the consistent anchorage pattern and the red arrows show cross bracing behind piers.

Figure 4-40: Consistent anchorage pattern observed on a new MH unit installation (EWS = 105 mph; EDWS = 164 mph) (Collier County)

Figure 4-41:
New MH unit installation with misaligned anchor strap installation (red outline) was otherwise anchored consistently with other post-Irma examples (EWS = 105 mph; EDWS = 164 mph) (Collier County)

Aside from the newly installed units described above, the MAT observed significant variation across MH installations with respect to the spacing of anchors and where they were connected to the unit. Loose anchor straps were also commonplace. Without adequate tension, the anchor straps are ineffective at resisting the lateral and uplift effects of high wind.

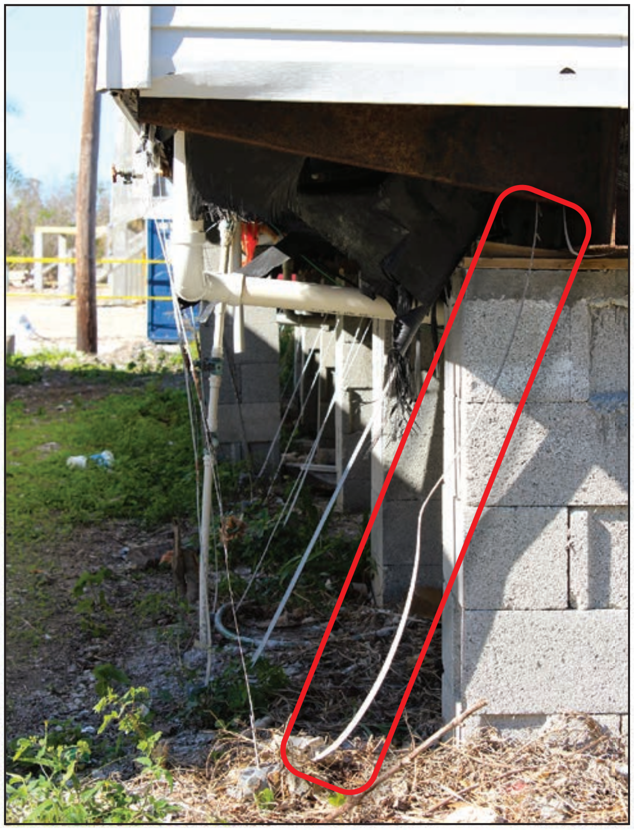
Figure 4-42 shows a unit in Big Coppitt Key that illustrates typical anchorage variations observed in older installations. The unit anchors are spaced at approximately 3 feet on center, but only every third strap is attached to the base of the exterior wall, and one of the anchors is not tight (see figure caption and inset). Another example from Marathon Key shows all straps spaced at approximately 3 feet on center and attached to the exterior wall base, but with a visibly loose anchor strap (see Figure 4-43).



Yellow circles show where straps are attached to the base of the unit wall.
The inset shows close-up of loose strap inside red outline.

Figure 4-42:
MH unit installation where only the first and fourth straps are attached to the exterior wall base (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

Figure 4-43:
MH unit installation with straps spaced at approximately 3 feet on center and attached to the exterior wall base, but with loose anchor strap shown in red outline (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)



4.3.2 Other Observations

Carports, decks, porches, and awnings are often attached after the MH unit has been installed. Chapter 15C of the Florida Administrative Code requires that additions "shall be free-standing and self-supporting with only the flashing attached to the main unit unless the added unit has been designed to be married to the existing unit (15C-2.0081)."

As observed in the Hurricane Charley MAT report (FEMA, 2005: Section 7.4), and in FEMA Recovery Advisories 4 and 5 for the 2007 tornado outbreak in central Florida, "Understanding and Improving Performance of Older Manufactured Homes During High-Wind Events" (2007d), and "Understanding and Improving Performance of New Manufactured Homes During High-Wind Events" (2007c), respectively, wind damage to MH units is frequently initiated when improperly attached appurtenances are blown off or damaged. Specifically, when carports and covered porches—which are particularly vulnerable to wind loads—break away from the MH unit, they leave openings at failed connections in the remaining roof and/or wall that allow rain to enter the MH unit envelope. In some cases, damage progresses from the initial point of failure. The MAT observations confirm this progressive failure pattern occurred in Florida during Hurricane Irma.

The following examples of MH unit damage initiated by improperly attached appurtenances were observed during the Hurricane Irma MAT site visits (before damage was cleared away) and are representative of many more failures. In the MH unit shown in Figure 4-44, loss of vinyl siding across the top and left end of the exterior wall was initiated by loss of the screened porch. The red tag on the front-facing window of the Everglades City installation means that the damage resulted in condemnation by local officials. Furthermore, the unit appears to be half of a double-wide MH unit, as evidenced by the exposed wall section (inside yellow oval) where there is no sheathing and no insulation in the exposed stud bays. The lack of wood structural sheathing on the wall may have contributed to the loss of the vinyl siding. Figure 4-45 shows another example of Collier County MH unit damage initiated by an attached screened porch, where the top of a wall opened up along the entire length of the unit and the adjacent roof section peeled back. Figure 4-46 shows a unit from the same neighborhood where the top of a wall was stripped away by the (formerly) connected carport. This MH unit also received a red tag from local officials.)

A remnant of the porch is shown in the red outline, and the red tag indicating condemnation by local officials is shown in the blue circle. The yellow oval shows missing sheathing and insulation characteristic of interior walls.

Figure 4-44:
This MH unit sustained exterior wall damage that was initiated by the loss of the attached screened porch (EWS = 115 mph; EDWS = 164 mph) (Everglades City)

The screened porch (remnants shown with blue arrows) opened the top of an exterior wall (red outline) and peeled back the adjacent roof section (red arrows) when the porch was lost to high winds.

Figure 4-45:
MH unit that was damaged when its screened porch was lost to high winds (EWS = 105 mph; EDWS = 166 mph) (Collier County)

Figure 4-46:
MH unit where carport detached from the unit, opening the building envelope across the top of a wall (EWS = 105 mph; EDWS = 166 mph) (Collier County)

The inset is a close-up of the area inside the red outline, and the red tag indicating condemnation by local officials is shown in the yellow circle.

5 Recommendations and Conclusions

The conclusions and recommendations are intended to help reduce future damage and impacts from flood and wind events such as Hurricane Irma.

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 local officials, facility representatives, design professionals, and contractors.

The recommendations are intended to assist the State of Florida, communities, design professionals, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners, academia, select industries and associations, local officials, and individuals in the reconstruction process, and to help reduce future damage and impacts from flood and wind events such as Hurricane Irma. The recommendations will also help FEMA assess the adequacy of building codes and standards as they relate to dry floodproofing and floodplain management requirements and determine whether changes are needed or additional guidance is required to reduce hurricane damage.

Section 5.1 is a summary of the conclusions and recommendations based on the MAT's observations. Section 5.2 discusses general conclusions and recommendations. Section 5.3 discusses conclusions and recommendations related to building codes, standards, and regulations. Section 5.4 includes flood-related building performance conclusions and recommendations. Section 5.5 includes wind-related building performance conclusions and recommendations. Section 5.6 provides conclusions and recommendations on FEMA Technical Publications and Guidance. Section 5.7 provides a summary of the conclusions and recommendations in a tabular format.

5.1 Overview of Conclusions and Recommendations

The recommendations are presented as guidance to the State of Florida and those who are involved with the design, construction, and maintenance of the built environment in the State. The entities involved in the reconstruction and mitigation efforts should consider these recommendations in conjunction with their existing priorities and resources when determining how they can or will be implemented.

Overall, newer construction generally sustained much less damage than older construction, so the requirements incorporated in the FBC, along with floodplain management regulations, appear to be working as intended. The extent of flood damage to buildings varied with the depth of floodwater, the amount of energy in the water (waves, velocity), and the nature of building design and construction (old versus new, at-grade versus elevated, MH units/recreational vehicles versus site-built/modular). Although inundation alone was a significant source of damage, some of the more dramatic structural failures observed were a result of wave action and scour. Wind-related damage was observed for both pre- and post-FBC buildings. While structural damage observations were almost exclusively limited to pre-FBC residential buildings, envelope damage was commonly observed on both older and newer construction. This envelope damage allowed wind-driven rain to penetrate to the interior, resulting in costly damage.

The MAT Conclusions and Recommendations are prioritized within each subsection as those that may be most important to implement by the State, community, or interested party. Specifically, recommendations of note from each section include:

Recommendation FL-1a (Section 5.2). FDEM should develop/modify training on the flood provisions in the FBC and local floodplain management ordinances.

Recommendation FL-4a (Section 5.3). Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.

Recommendation FL-7 (Section 5.4). Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).

Recommendation FL-9a (Section 5.5). Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.

Recommendation FL-14a (Section 5.6). FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities.*

5.2 General Conclusions and Recommendations

Conclusion FL-1

Building codes and floodplain management requirements were inconsistently enforced. The MAT observed inconsistencies in local code enforcement, as well as noncompliance by builders, throughout the sites visited (e.g., improper load path and not requiring or using products that are on the approved and tested list). Some observed damage is associated with use of non-flood damage-resistant materials.

Recommendation FL-1a. **FDEM should consider developing/modifying training on the flood provisions in the FBC and local floodplain management ordinances.** FDEM, in conjunction with FFMA and the Building Officials Association of Florida (BOAF), should develop a webinar on the flood provisions in the FBC and local floodplain management ordinances, specifically about enclosures, with emphasis on the use of flood damage-resistant materials below the required floor elevation. This training should be for builders, developers, floodplain administrators, building officials, plan reviewers, and building inspectors.

Recommendation FL-1b. **BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on building envelope components.** BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on the use of appropriate building envelope products that have been designed or tested for high wind locations. This topic could be addressed in conjunction with continuing education courses on the building code.

Conclusion FL-2

Building officials expressed concerns about having adequate resources. Some building officials did not feel they had adequate resources to properly inspect damaged buildings for life-safety, conduct Substantial Damage determinations, verify Substantial Improvement projects, review permit applications for repairs, and enforce FBC requirements during the post-disaster recovery period when extensive numbers of work projects are proposed in a short time.

Recommendation FL-2. **FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through the Statewide Mutual Aid Agreement (SMAA).** FDEM should inform building officials and local officials responsible for floodplain management about accessing resources to aid recovery through the SMAA signed by all Florida counties, or the inter-state Emergency Aid Compact. Although the agreement may be accessed at any time, when events are declared major disasters, some costs of aid provided under the agreement may be eligible for reimbursement by FEMA. FDEM should encourage the BOAF and the Florida Floodplain Managers Association (FFMA) to develop strategies under their SMAA and FDEM to recruit professional assistance to support communities in need. FDEM should also consider training design professionals to assist with inspections. The Florida Post-Disaster Toolkit for Floodplain Administrators should be distributed to all communities. FDEM should also continue to encourage pre-event evaluation of post-disaster needs.

Conclusion FL-3

The State and communities did not receive (or did not receive in a timely manner) data on buildings that appeared to have incurred Substantial Damage. When buildings appeared to have incurred Substantial Damage, the State and communities either did not receive requested data submitted by NFIP claims adjusters, or did not receive the information in a timely manner.

Recommendation FL-3. **FEMA should develop an effective and timely means to deliver the Adjuster Preliminary Damage Assessment data.** When NFIP claims adjusters identify claims that, based on available data, appear to have incurred Substantial Damage, the adjusters submit data using FEMA Form 086-0-20, *Adjuster Preliminary Damage Assessment* (2018a). The form indicates FEMA and communities can use the data to identify potentially Substantially Damaged buildings. FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010e) (Section 7.4.1), describes using the data for screening purposes only, especially after flood events that damage large numbers of buildings. FEMA should develop an effective and timely means to deliver data submitted by NFIP claims adjusters to States and communities.

5.3 Building Codes, Standards, and Regulations

Conclusion FL-4

The MAT observed damaged buildings that illustrate the problems associated with siting buildings on erodible shorelines. The Florida DEP report (*Hurricane Irma Post-Storm Beach Conditions and Coastal Impact in Florida* [2018]) identified numerous examples of dune/bluff erosion and building damage in these areas. Foundation design in these areas is particularly challenging. The MAT also observed numerous instances of erosion and damage to buildings and many areas where erosion control structures (bulkheads, seawalls, etc.) failed on open coast and estuarine shorelines, in many cases under less than base flood conditions. Bulkheads and other erosion control structures may not offer the intended level of protection.

Recommendation FL-4a. **Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.** Permitting agencies (e.g., Florida DEP, Water Management Districts, local government) should review public materials, emphasize the importance of evaluating existing bulkheads before relying on them for protection, and encourage communities to avoid siting buildings close to bulkheads. Permitting criteria and performance requirements for new or replacement bulkheads should be evaluated with respect to design conditions, including the effects of saturated backfill, wave forces, overtopping, and erosion on both water and land sides.

Recommendation FL-4b. FEMA should review and update their event-based erosion methodology. FEMA should review and update the methodology used to estimate dune and bluff erosion. FEMA should also improve existing siting and foundation design guidance for coastal dune and bluff areas in FEMA P-55, *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas* (2011, 4th Edition), FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010b), and other publications. In consultation with the Florida DEP and other coastal States, FEMA should evaluate siting criteria and consider recommending revisions to ASCE 24 Chapter 3 on how best to consider erosion in design and construction.

Conclusion FL-5

FDEM documented the successful completion of its multi-year CRS initiative. During the initiative, which extended into post-Irma recovery, FDEM visited and offered technical assistance to more than 200 communities with emphasis on eligibility for the CRS.

Recommendation FL-5. FDEM should expand its technical assistance for CRS communities. FDEM should review activities undertaken by CRS communities and higher standards adopted in floodplain management ordinances by CRS communities to identify activities and standards not widely employed. Future technical assistance for CRS communities should focus on encouraging consideration of those activities and standards, such as performing stormwater master plan studies; establishing compensatory storage requirements; identifying BFEs in Approximate Zone A; conducting public outreach for design professionals, surveyors, and mappers; and adopting the construction industry Coastal A Zone requirements in the FBC.

Conclusion FL-6

Florida's installation requirements for MH units do not reference the current edition of FEMA 85. Florida's installation requirements for MH units reference the 1985 edition of FEMA 85, *Protecting Manufactured Homes from Floods and Other Hazards*. The current edition, FEMA P-85, was published in 2009 and includes updated guidance for installation to address resistance to both flood and wind conditions. The 2009 edition includes some pre-engineered foundation specifications that minimize the need for site-specific engineered solutions for many locations.

Recommendation FL-6. The Florida Department of Highway Safety and Motor Vehicles should reference the most recent edition of FEMA P-85. The Florida Department of Highway Safety and Motor Vehicles should update Chapter 15C, Florida Statues (Manufactured home installation) to reference the most recent edition of FEMA P-85 (the 2009 edition, or "as revised by FEMA") in Chapter 15C. The State agency should also consider incorporating additional wind- and flood-resistant construction provisions with particular emphasis on anchoring, as well as develop a training unit for manufactured home installers, with specific focus on requirements for wind resistance and installation in SFHAs. This training should be designed to satisfy continuing education requirements for manufactured home installers.

5.4 Flood-Related Building Performance

Conclusion FL-7

Dry floodproofing measures often failed under less than design flood conditions. The MAT visited approximately 25 dry floodproofed sites following Hurricane Irma and identified several lessons to be learned from dry floodproofing failures under less than design flood conditions. The MAT also identified best practices from successfully implemented dry floodproofing measures.

Recommendation FL-7. **Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).** Texas Recovery Advisory 1, *Dry Floodproofing: Planning and Design Considerations* (2018e), and Florida Recovery Advisory 1, *Dry Floodproofing: Operational Considerations* (2018d), have guidance related to dry floodproofing methods and procedures developed based on observations made during and after Hurricanes Irma and Harvey. The MAT observations illustrate that designing and implementing dry floodproofing for buildings is complicated. Therefore, guidance based on recent events should be incorporated into the design and implementation of new and existing dry floodproofing. Specific considerations from the Recovery Advisories include:

- Conduct a thorough vulnerability assessment, including a survey of all potential water entry points, as part of the design process.
- Incorporate freeboard into the design flood elevation based on the building use.
- Treat flood barriers like fire wall assemblies—label them and minimize modifications and penetrations.
- Evaluate utility components and penetrations through walls and floors as potential water entry points.
- Install check valves in floor drain systems and require ejector systems with check valves/ backflow preventers for stormwater and sanitary sewers.
- Provide waterstops at the seals in foundation walls and floor slabs where those spaces are intended to remain dry and are located below the design flood elevation.

Conclusion FL-8

Dry floodproofed buildings where building managers had instilled a culture of preparedness sustained less damage than other dry floodproofed buildings. The scope and detail of operations, maintenance, and testing plans was an indicator of the dry floodproofing system performance.

Recommendation FL-8a. **Facility managers should develop an emergency operations plan (EOP) for severe weather.** An EOP that outlines how to prepare the building when severe weather events are expected should be developed by facility managers. Each dry floodproofed facility should have an EOP with action items or an implementation checklist based on a timeline keyed to official severe weather warnings and watches. ASCE 24 Chapter 6 contains requirements for and discussion of EOPs.

Recommendation FL-8b. Facility managers should routinely re-evaluate dry floodproofing designs and plans as required by codes and standards. After each deployment of a dry floodproofing system, including training exercises, the overall design of dry floodproofing systems and EOPs for severe weather should be revisited to resolve any deficiencies identified while systems were being tested, installed, or subjected to floodwater. ASCE 24 Chapter 6 requires periodic practice of installing shields as well as testing of sump pumps and other drainage measures.

Recommendation FL-8c. Facility managers should take reasonable measures to instill a culture of preparedness. Facility managers should conduct annual training exercises during which dry floodproofing measures are installed, taking note of the time to install each portion of the system and the total time to install the entire dry floodproofing system. The commentary in ASCE 24 indicates persons responsible for installing or implementing the measures must be familiar with the procedures and equipment. Therefore, training exercises should include building maintenance and engineering staff along with other building staff that may be needed to install dry floodproofing systems with little warning time. Maintenance of dry floodproofing system components should be conducted annually, as well as during training exercises and following deployment for a flood event. To ensure system functionality, periodic maintenance should include checking gaskets and seals, installation hardware and fasteners, and the condition of building elements to which dry floodproofing components will be attached. Consider creating a video recording of manual dry floodproofing installations, especially the complex steps, so the video can be referenced later if untrained staff are required to assist.

5.5 Wind-Related Building Performance

Conclusion FL-9

The MAT observed evidence of inadequate resistance to wind loads for roof coverings of residential buildings. In particular, the MAT observed widespread damage to asphalt roof coverings on post-FBC residential structures; the reason(s) for this damage was not determined by the MAT.

Recommendation FL-9a. Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT. More research needs to be done by industry groups (e.g., manufacturers, insurances, builders) to explain why post-FBC asphalt shingle damage was observed to be widespread following a below design-level event and whether these failures were the result of design, installation, testing, inspection, or other issues. Appropriate mitigating actions should then be taken.

Recommendation FL-9b. Contractors and inspectors must ensure roof covering repairs and replacements are in conformance with FBC requirements. When more than 25 percent of the total roof area or roof section has to be repaired, provisions of the FBC must be met. Contractors and inspectors should ensure roof covering repairs and replacements meet FBC requirements. Refer to Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (2018f) for additional guidance.

Conclusion FL-10

The MAT observed evidence of inadequate resistance to wind pressures and improper installation of soffits on residential buildings. Widespread loss of soffits was observed in residential construction, and wind-driven rain infiltrated some areas where soffits were displaced or lost.

Recommendation FL-10a. **Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.** Proper soffit installation should be emphasized by designers, contractors, and inspectors in order to limit wind-driven rain from entering building envelopes and damaging building interiors. Florida Recovery Advisory 2, *Soffit Installation in Florida* (2018h), provides soffit installation guidance and resources to meet or exceed minimum provisions of the FBC.

Recommendation FL-10b. **The FBC should require soffit inspections.** Soffit inspections will help to ensure compliant products are used and the soffit is securely attached.

Conclusion FL-11

The MAT observed evidence of inadequate resistance to wind pressures for certain wall coverings of residential buildings. In particular, failure of vinyl siding on post-FBC residential structures was widespread. Instances of improper installation and concerns about appropriate design pressure ratings are addressed in Chapter 4 and were probable factors in the damage observed.

Recommendation FL-11a. **Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding.** The MAT's observations of the amount of damage to vinyl siding and its unique sensitivity to proper installation suggests vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding. Considering that maximum peak gusts in the Florida Keys were approximately 120 mph (well below the design wind speed), better performance would have been expected.

Recommendation FL-11b. **The FBC should require wall cladding inspections.** Most MAT-observed wall cladding failures demonstrated one or more examples of non-compliant installation, which can be mitigated through field inspections. Common examples of wall cladding failures for vinyl siding include missing utility trim and starter strips.

Conclusion FL-12

The MAT observed evidence of wind-borne debris, but very few instances of glazed openings being breached. ASCE 7-required protection of windows and glazed doors in the wind-borne debris region appears to have been widely applied. However, the few instances of observed damage to protected glazed openings occurred in areas where estimated wind speeds during Hurricane Irma were well below the 130 mph wind-borne debris trigger for which ASCE 7 requires glazed opening protection. This suggests that wind-borne debris was generated at wind speeds well below the 130 mph trigger.

Recommendation FL-12a. **Industry groups and/or academia should study debris generation and strikes to protective systems during hurricanes to determine whether the wind speed triggers for the ASCE 7 wind-borne debris region are appropriate.** Industry groups and/or academia should study debris generation and associated debris strikes to protective systems from the 2017 hurricane, as well as for future storms, to determine whether the current wind speed triggers for the wind-borne debris region as defined in ASCE 7 are appropriate. Data collected and analyzed during the study can be used to make recommendations on ASCE 7-required protection of windows and glazed doors.

Recommendation FL-12b. **Building owners outside the wind-borne debris region should consider protecting the glazed openings on their buildings.** Although not required by codes and standards, owners of buildings in the hurricane-prone region should consider protecting glazed window systems and doors with rated opening protection systems (i.e., storm shutters) or retrofitting the building with impact-resistant glazing when located anywhere in the hurricane-prone region.

Conclusion FL-13

Failures of appurtenance attachments to MH units increase the units' vulnerability to wind and rain damage. Wind damage to MH units is frequently initiated when improperly attached appurtenances (such as carports and screened porches) are blown off or damaged leaving openings at failed connections that allow rain to enter the MH unit envelope. In some cases, damage progresses from the initial point of failure. This damage increases the unit's vulnerability to wind and rain damage.

Recommendation FL-13. **As a best practice, MH appurtenances should be built as stand-alone units without structural connection to the MH unit.** If the appurtenance is not free-standing and is connected to the manufactured home for structural support, plans should be prepared that clearly detail the connection between the unit and the structure being attached. The design and construction should be approved, permitted, and inspected by building officials.

5.6 FEMA Technical Publications and Guidance

Conclusion FL-14

Select FEMA Building Science technical guidance publications are becoming increasingly incongruent with current building codes and do not include lessons learned from recent MATs. The Building Science Branch at FEMA Headquarters develops and maintains over 200 publications and resources that provide technical guidance on how to assess risk; identify vulnerabilities; better understand the NFIP and the regulatory environment with respect to building codes and standards; and provide best practices and mitigation measures that can be taken to reduce vulnerabilities to flood, wind, and seismic hazards. Some of the FEMA Building Science technical guidance publications do not reflect advanced requirements in current building codes nor do they include new lessons learned from recent MAT reports.

The 2017 hurricane season brought landfalling hurricanes on the island territories and the continental United States. There are many valuable and important damage observations and lessons learned from this and other events, and the observed damage might have been avoided if the guidance from these documents had been incorporated at different building locations. However, while the approaches and theories in these publications are still accurate, many of the building codes have been updated in the last 8 to 10 years and may impact the current approaches outlined in these documents.

Recommendation FL-14a. **FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities.*** FEMA's Building Science Branch has been developing guidance to assess wind vulnerabilities of critical facilities. FEMA should include lessons learned from the 2017 hurricane season in finishing this publication, which would greatly benefit many stakeholders in the U.S.

Recommendation FL-14b. **FEMA should update select FEMA Building Science publications that affect coastal construction.** The FEMA Building Science Branch should consider updating or producing a supplement for its key hurricane technical guidance publications to include lessons learned from the 2017 hurricane season and to reflect updates to building codes since the publications' latest releases. These publications might include, but are not necessarily limited to, the following:

- FEMA P-55, *Coastal Construction Manual* (2011)
- FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010d)
- FEMA P-762, *Local Officials Guide for Coastal Construction* (2009b)
- FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (2010f)

Recommendation FL-14c. **FEMA should update the FEMA Risk Management Series guidance publications for natural hazards.** The FEMA Building Science Branch, working with other FEMA and DHS entities, should consider updating or producing a supplement to select technical documents from the FEMA Natural Hazard Risk Management Series to include lessons learned from the 2017 hurricane season and to reflect updates to building codes since the publications' latest releases. These publications might include, but are not limited to, the following:

- FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010a)
- FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007a)
- FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings* (2007b)

Conclusion FL-15

Many communities have difficulty implementing the Substantial Improvement/Substantial Damage requirements, especially after major disasters. Many buildings damaged by flooding were designed and built before communities joined the NFIP and began regulating development in SFHAs. Enforcing the NFIP and FBC requirements to bring Substantially Improved and Substantially Damaged buildings into compliance continues to be one of the more difficult challenges for floodplain administrators and building officials.

Recommendation FL-15a. **FEMA should update FEMA P-758; at the same time, FEMA 213 should be updated to be consistent with the updated FEMA P-758.** FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010e) should be updated. Updates should include lessons learned, and recommended guidance and clairifcations since it was published in 2010. At the same time, FEMA 213, *Answers to Questions about Substantially Improved/Substantially Damaged Buildings* (2018b) should be updated to be consistent with the updated FEMA P-758. Outreach material should be developed as part of the publication updates.

Recommendation FL-15b. **FEMA should consider expanding existing training materials related to Substantial Improvement/Substantial Damage.** FEMA should consider developing a webinar format training for distribution to NFIP State Coordinators and other entities related to Substantial Improvement/Substantial Damage. The materials should incorporate lessons learned after Hurricane Irma and other recent flood events and should include a unit focused on the local official's role in helping insured property owners satisfy requirements to qualify for Increased Cost of Compliance claims and in issuing permits for mitigation measures eligible for use of those claim payments.

Conclusion FL-16

Future dry floodproofing design and construction can benefit from observed failures and successes. The MAT visited about 25 dry floodproofed sites following Hurricane Irma and observed several lessons learned from dry floodproofing failures under less than design flood conditions, as well as best practices from successes.

Recommendation FL-16a. **FEMA should update dry floodproofing guidance.** Based on the varying performance of dry floodproofing measures observed, FEMA should revise existing dry floodproofing guidance to include data and observations from recent events. In particular, FEMA Technical Bulletin 3, *Non-Residential Floodproofing—Requirements and Certification* (1993), should be updated to improve guidance on planning, design and construction, and emergency operations, as well as maintenance planning requirements. Specific points of emphasis include:

- For new construction, recommend using ACI 350 for designing concrete that will be constructed below the required dry floodproofing elevation (ACI 350 concrete design reduces the crack width in concrete and increases the fineness of the concrete matrix to reduce concrete permeability rates).

- Consider limiting the amount of openings below the required dry floodproofing elevation, i.e., the portion of the building envelope that is not permanently substantially impermeable. As a result, the amount of temporary protective measures would be limited to the length of the perimeter required for egress (pedestrian and vehicular).

FEMA should also consider updating FEMA P-936, *Floodproofing for Non-Residential Buildings* (2013a), with relevant lessons learned from the 2017 hurricane season as well.

Recommendation FL-16b. **FEMA should evaluate existing dry floodproofing guidance and post-flood investigations to develop a recommendation for inclusion in ASCE 24.** FEMA should review recommendations, fact sheets, and recovery advisories related to dry floodproofing included in other MAT reports to develop a comprehensive recommendation for dry floodproofing design, limitations, testing, and maintenance and operations requirements for consideration by the ASCE 24 committee charged with revising Chapter 6, "Dry Floodproofing and Wet Floodproofing."

5.7 Summary of Conclusions and Recommendations

Table 5-1 is a matrix listing the conclusions and recommendations cross-referenced to the sections of the report that describe the supporting observations. The recommendations provided in the table have also been cross-referenced to Recovery Support Functions (RSFs) supported by FEMA through the National Disaster Recovery Framework (NDRF). FEMA developed the RSFs with the objective of facilitating the identification, coordination, and delivery of Federal assistance needed to supplement recovery resources and efforts by local, State, tribal, and territorial governments, as well as private and nonprofit sectors. The MAT has identified RSFs for the recommendations provided in this report to assist Florida with accelerating the process of recovery, redevelopment, and revitalization.

NATIONAL DISASTER RECOVERY FRAMEWORK AND RECOVERY SUPPORT FUNCTIONS

FEMA has developed the NDRF to create a common platform and forum for how the whole community builds, sustains, and coordinates delivery of recovery capabilities. FEMA guidance states:

> Resilient and sustainable recovery encompasses more than the restoration of a community's physical structures to pre-disaster conditions. The primary value of the NDRF is its emphasis on preparing for recovery in advance of disaster. The ability of a community to accelerate the recovery process begins with its efforts in pre-disaster preparedness, including coordinating with whole community partners, mitigating risks, incorporating continuity planning, identifying resources, and developing capacity to effectively manage the recovery process, and through collaborative and inclusive planning processes. Collaboration across the whole community provides an opportunity to integrate mitigation, resilience, and sustainability into the community's short- and long-term recovery goals.

The RSFs compose the coordinating structure for key functional areas of assistance in the NDRF. Their purpose is to support local governments by facilitating problem solving, improving access to resources and by fostering coordination among State and Federal agencies, nongovernmental partners, and stakeholders.

The list of RSFs and the leading coordinating agencies is presented below (and available on line at www.fema.gov/recovery-support-functions):

- Community Planning and Capacity Building (CPCB) RSF (U.S. Department of Homeland Security/FEMA)
- Economic RSF (U.S. Department of Commerce)
- Health and Social Services RSF (U.S. Department of Health and Human Services)
- Housing RSF (U.S. Department of Housing and Urban Development)
- Infrastructure Systems RSF (U.S. Army Corps of Engineers)
- Natural and Cultural RSF (U.S. Department of the Interior)

Table 5-1: Summary of Conclusions and Recommendations

Observations	Conclusions	Recommendations	Recovery Support Function
General MAT Field Observation	**FL-1** Building codes and floodplain management requirements were inconsistently enforced.	**FL-1a.** FDEM should develop/modify training on the flood provisions in the FBC and local floodplain management ordinances.	CPCB, Economic
		FL-1b. BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on building envelope components.	CPCB, Economic
	FL-2 Building officials expressed concerns about having adequate resources.	**FL-2.** FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through the SMAA.	CPCB, Economic, Housing
	FL-3 The State and communities did not receive (or did not receive in a timely manner) data on buildings that appeared to have incurred Substantial Damage.	**FL-3**. FEMA should develop an effective and timely means to deliver the Adjuster Preliminary Damage Assessment data.	CPCB, Economic, Housing
Chapter 3 (Section 3.1)	**FL-4** The MAT observed damaged buildings that illustrate the problems associated with siting buildings on erodible shorelines.	**FL-4a.** Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.	CPCB, Economic, Housing, Infrastructure
		FL-4b. FEMA should review and update their event-based erosion methodology.	CPCB, Economic, Housing, Infrastructure
Chapter 2 (Section 2.3)	**FL-5** FDEM documented the successful completion of its multi-year CRS initiative.	**FL-5**. FDEM should expand its technical assistance for CRS communities.	CPCB, Economic, Housing
Chapter 2 (Section 2.4) and Chapter 4 (Section 4.3)	**FL-6** Florida's installation requirements for MH units do not reference the current edition of FEMA 85.	**FL-6**. The Florida Department of Highway Safety and Motor Vehicles should reference the most recent edition of FEMA P-85.	CPCB, Economic, Housing

Table 5-1: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Recovery Support Function
Chapter 3 (Section 3.2)	**FL-7** Dry floodproofing measures often failed under less than design flood conditions.	**FL-7.** Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).	CPCB, Economic
	FL-8 Dry floodproofed buildings where building managers had instilled a culture of preparedness sustained less damage than other dry floodproofed buildings.	**FL-8a.** Facility managers should develop an EOP for severe weather.	CPCB, Health and Social Services, Economic
		FL-8b. Facility managers should routinely re-evaluate dry floodproofing designs and plans as required by codes and standards.	CPCB, Health and Social Services, Economic
		FL-8c. Facility managers should take reasonable measures to instill a culture of preparedness.	CPCB, Health and Social Services, Economic
Chapter 4 (Section 4.2.1)	**FL-9** The MAT observed evidence of inadequate resistance to wind loads for roof coverings of residential buildings.	**FL-9a.** Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.	Housing, Economic
		FL-9b. Contractors and inspectors must ensure roof covering repairs and replacements are in conformance with FBC requirements.	Housing, Health and Social Services, Economic
Chapter 4 (Section 4.2.2)	**FL-10** The MAT observed evidence of inadequate resistance to wind pressures and improper installation of soffits on residential buildings.	**FL-10a.** Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.	Housing, CPCB, Economic
		FL-10b. The FBC should require soffit inspections.	Housing, CPCB, Economic
Chapter 4 (Section 4.2.3)	**FL-11** The MAT observed evidence of inadequate resistance to wind pressures for certain wall coverings of residential buildings.	**FL-11a**. Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding.	Housing, Economic
		FL-11b. The FBC should require wall cladding inspections.	Housing, CPCB, Economic

Table 5-1: Summary of Conclusions and Recommendations (concluded)

Observations	Conclusions	Recommendations	Recovery Support Function
Chapter 4 (Section 4.2.4)	**FL-12** The MAT observed evidence of wind-borne debris, but very few instances of glazed openings being breached.	**FL-12a**. Industry groups and/or academia should study debris generation and strikes to protective systems during hurricanes to determine whether the wind speed triggers for the ASCE 7 wind-borne debris region are appropriate.	Housing, CPCB, Economic
		FL-12b. Building owners outside the wind-borne debris region should consider protecting the glazed openings on their buildings.	Housing, CPCB, Economic
Chapter 4 (Section 4.3)	**FL-13** Failures of appurtenance attachments to MH units increase the units' vulnerability to wind and rain damage.	**FL-13.** As a best practice, MH appurtenances should be built as stand-alone units without structural connection to the MH unit.	Housing, Economic
General MAT Field Observation	**FL-14** Select FEMA Building Science technical guidance publications are becoming increasingly incongruent with current building codes and do not include lessons learned from recent MATs.	**FL-14a.** FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities*.	CPCB, Health and Social Services, Economic
		FL-14b. FEMA should update select FEMA Building Science publications that affect coastal construction.	Housing, CPCB, Economic
		FL-14c. FEMA should update the FEMA Risk Management Series guidance publications for natural hazards.	Housing, CPCB, Health and Social Services, Economic
	FL-15 Many communities have difficulty implementing the Substantial Improvement/Substantial Damage requirements, especially after major disasters.	**FL-15a.** FEMA should update FEMA P-758; at the same time, FEMA 213 should be updated to be consistent with the updated FEMA P-758.	Housing, CPCB, Economic
General MAT Field Observation		**FL-15b**. FEMA should consider expanding existing training materials related to Substantial Improvement/Substantial Damage.	CPCB, Economic
Chapter 3 (Section 3.2)	**FL-16** Future dry floodproofing design and construction can benefit from observed failures and successes.	**FL-16a.** FEMA should update dry floodproofing guidance.	CPCB, Economic
		FL-16b. FEMA should evaluate existing dry floodproofing guidance and post-flood investigations to develop a recommendation for inclusion in ASCE 24.	CPCB, Economic

ASCE = American Society of Civil Engineers
BOAF = Building Officials Association of Florida
CPCB = Community Planning and Capacity Building
CRS = Community Rating System (NFIP)
EOP = emergency operations plan
FBC = Florida Building Code
FDEM = Florida Division of Emergency Management
FEMA = Federal Emergency Management Agency
FHBA = Florida Home Builders Association
MAT = Mitigation Assessment Team
MH = manufactured housing
PEF = pressure equalization factor
SMAA = Statewide Mutual Aid Agreement

Appendix A: Acknowledgments

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Appendix C: Recovery Advisories

Dry Floodproofing: Operational Considerations

FEMA

HURRICANE IRMA IN FLORIDA *Recovery Advisory 1, May 2018*

Purpose and Intended Audience

The purpose of this advisory is to provide guidance on how to effectively implement dry floodproofing mitigation measures for non-residential structures. This Recovery 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 practices and lessons learned about planning, preparation, and operations of dry floodproofing systems that can make facilities more resistant to disruption in future flood events. The information in this advisory is directed toward existing and new, non-residential facilities.

The guidance in this advisory, along with other FEMA publications related to dry floodproofing, should be used by building owners and design professionals to take action to limit the interruption of building services and flood damage to buildings. 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.

The primary audience for this advisory includes building owners, operators, and managers; installers; and contractors, but may also be helpful for architects, engineers, various planners, as well as local government and building code officials involved with building planning, design, enforcement, operations, or maintenance. It will also be useful to communities and building owners preparing designs and proposals for FEMA hazard mitigation funding.

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).

Key Issues

- Some dry floodproofing systems were not regularly tested or properly maintained. When the systems were installed prior to the storm, several systems did not provide the intended level of protection.
- Some facilities lacked formal or written documentation on who, how, when, and where to deploy floodproofing systems, which resulted in time and energy wasted on a disorderly or partial deployment prior to the event.

This Recovery Advisory Addresses

- Observations related to dry floodproofing system operations
- Operations, maintenance, and testing plans for dry floodproofing systems
- Deployment considerations for active dry floodproofing
- Floodproofing considerations for a facility Emergency Operations Plan

A companion advisory, titled *Dry Floodproofing: Planning and Design Considerations* (Hurricane Harvey in Texas, TX-RA1, 2018), describes observations of system failures; flood vulnerability assessments; and planning and design considerations for dry floodproofing.

Observations Related to Dry Floodproofing System Operations

The floodwaters of Hurricanes Harvey and Irma tested passive and active dry floodproofing systems. Dry floodproofing involves using passive and active measures to seal a structure or area so floodwater cannot enter (see text box).

With the uncertainty surrounding the tracks of both storms and amount of flooding predicted from rainfall and storm surge, the planning, preparation, and installation of dry floodproofing systems was a timing and logistical challenge.

After Hurricanes Harvey and Irma, the MATs deployed by FEMA to evaluate building performance observed some best practices that enhanced response, such as the use of passive floodproofing systems that operated automatically with the rise of floodwater. However, the MATs observed other active measures that created significant challenges, such as systems that required a sizeable crew with heavy and specialized equipment to mobilize over a period of several days in advance of the storm to properly install the system.

The damage observed by the MATs illustrate that planning for dry floodproofing deployment is inconsistent, installation of dry floodproofing is not always effective, and even when installed, the level of effectiveness of the operation and implementation of dry floodproofing systems is variable.

Dry Floodproofing Systems

Active: Dry floodproofing systems that require human intervention to deploy the physical barrier and are effective only if there is enough warning time to mobilize the labor and equipment necessary to implement them and safely evacuate.

Passive: Dry floodproofing systems that do not require human intervention to deploy the physical barrier.

The image below (from Delaware, 2007) shows an example of an active dry floodproofing barrier installed at a commercial property.

Key Terminology

Flood Barrier: The physical barrier, composed of opening protection, floor slab, and wall system, that separates floodwater from the dry floodproofed portion of the building.

Opening Protection: A cover, shield, or door that covers a window, doorway, loading dock access, or other opening in a building wall or floor. Sometimes called a "closure device."

Floodwall: A constructed barrier of flood damage-resistant materials to keep water away from or out of a specific area. Floodwalls surround a building and are typically offset from the exterior walls of the building; some floodwalls can be integrated into the building envelope. Floodwalls are considered a component of the overall flood barrier.

Flood Entry Point: Any opening, joint, gap, crack, low point, or other location through or over which floodwater can enter.

Operations, Maintenance, and Testing Plans for Dry Floodproofing Systems

Both the American Society of Civil Engineers, *Standard for Flood Resistant Design and Construction* (ASCE 2014), and the National Flood Insurance Policy (NFIP) guidelines require that the operations, maintenance, and testing[1] plan of a dry floodproofing system be developed during the design of the system and regularly updated throughout the life of the building.

The procedures described in the operations, maintenance, and testing plan should be conducted annually and considered part of the long-term approach to maintaining the effectiveness of the building's flood protection system. The floodproofing components at installation locations should be inspected to evaluate system performance following any flood event and after any construction or demolition project in the building's vicinity. Periodic deployment drills (at least annually) should also be specified in the operations, maintenance, and testing plan. FEMA recommends that the operations, maintenance, and testing plan include the following items:

- A decision tree identifying responsible parties, a sequence and timeline by which various components will be installed, including identified triggers or benchmarks to initiate procedures
- A list of personnel, equipment, and supplies needed to deploy all system components
- A map of the equipment storage location and component deployment locations
- A record of the manufacturer or designer and their contact information for expediting replacement parts and support as needed
- A copy of the NFIP Floodproofing Certificate

In addition to the above-described elements of the operations, maintenance, and testing plan, the following should be considered. These are based on MAT observations of damage and interviews with building owners and managers after Hurricanes Harvey and Irma.

Size and weight. Consider the size and weight of individual dry floodproofing panels when choosing or designing a system and the openings they will cover

1 The terms "testing" and "exercising" are used interchangeably in this advisory although they may have different definitions for design professionals and emergency managers. Regular evaluation of how the dry floodproofing system performs (under practice and design flood conditions) can improve a facility's response to disruption in future flood events.

Applicable Codes

ASCE 24 (Section 6.2.3) describes implementation requirements and restrictions for dry floodproofing new buildings and when Substantial Improvements are made to existing buildings. Owners who want to dry floodproof existing buildings may also benefit from following the guidelines in this standard.

NFIP Floodproofing Certificate

The requirements of the NFIP Floodproofing Certificate are described in FEMA P-936 (1993) and should be understood before starting design. The NFIP Floodproofing Certificate requires compliance with ASCE 24 and is both a design and construction certification. Professional engineers and architects should read the Floodproofing Certificate in its entirety and the applicable sections of ASCE 24, FEMA P-936, and Technical Bulletin 3, "Non-Residential Floodproofing" (FEMA 1993), prior to signing it.

Responsible Parties

Deployment of dry floodproofing systems is a shared responsibility of the building owner or manager, installer (i.e., contracted or on-site staff), and possibly building occupants.

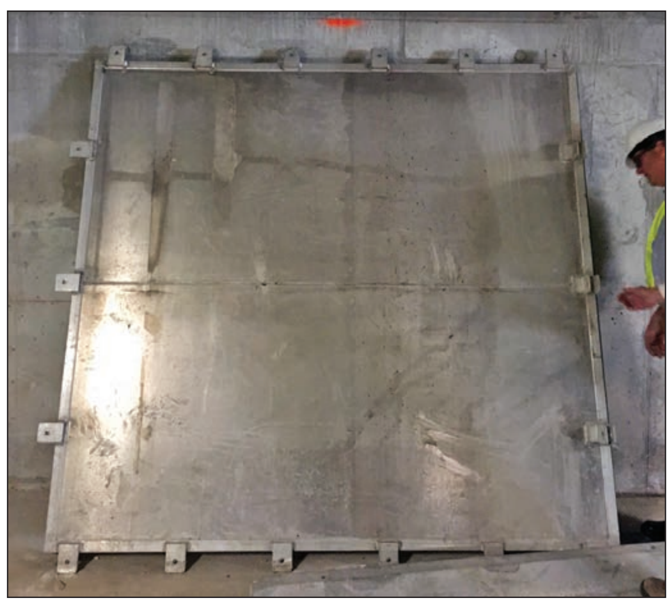

Figure 1: Large (6 feet high x 6 feet wide) metal flood panel requiring special equipment for installation

(Figure 1). If there are difficulties in installing large panels, consider approaches to improve the installation process. This may entail replacing the panel type with a passive floodproofing component or with a component that is easier to install.

System manufacturer. Flood protection systems should come from a reputable manufacturer and be consistent with a testing standard such as ANSI/FM 2510 that includes performance standards for hydrostatic test strength, system leakage, corrosion, and resistance to impact, wear, abrasion, tear, and puncture.

Storage. Determine an appropriate storage location for the dry floodproofing components, supplies, and equipment. Ensure the location is not open to the elements, as ultraviolet radiation and temperature extremes degrade rubber seals, gaskets, and component identification labels (Figure 2). Ensure this location is secure to prevent theft and vandalism, but is also accessible and labeled for the installer in case of deployment. On-site storage of floodproofing components is preferable. A separate location should be provided for spare parts.

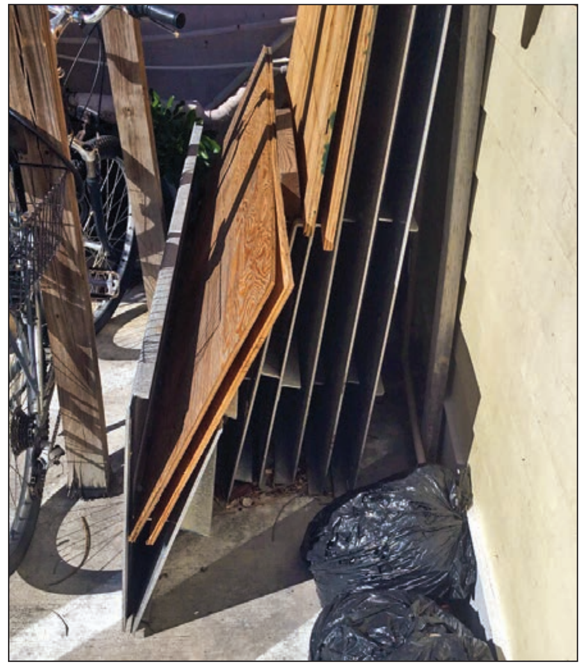

Figure 2: Flood panels (metal) and window shutters (plywood) were stored together outside a building. Panels and rubber gaskets were exposed to the elements; this storage practice is not recommended.

All parts should be clearly labelled with permanent marker and a unique identification label that signifies its location when installed.

In-house versus contract staff. Assess the pros and cons of using contracted installers versus in-house staff. Ensure sufficient, trained staff will be available to implement the system prior to a flood event. Some dry floodproofing systems are installed by hired contractors who may be responsible for deploying systems at many sites across a city or region. Contract laborers may be limited in availability and timing in the days before an event.

Deployment drills. Conduct a deployment drill of the floodproofing system annually, or more frequently, as prescribed by the operations, maintenance, and testing plan, including testing all valves, sump pumps, power generators, and other drainage measures. An important task is to ensure that all valves or other drainage measures are clear of debris.

Figure 3: Torn gasket on metal flood panel after panel was removed. Gasket must be replaced before the next deployment.

During drills and tests, building operators should record the number of workers, the equipment needed, and the time it takes to install part or all of the system, and any perceived system deficiencies should be identified. Ensure that any staff member who may be called upon to install specific floodproofing measures participates in drills and is familiar with and able to implement the floodproofing system. Ensure that the deployment drill considers egress requirements for personnel who remain inside the building.

Regular inspection. Regularly inspect and maintain shields, doors, gates, pumps, equipment, gaskets, seals, brackets, panels, hardware, etc., and replace immediately if needed, to ensure system performance (Figure 3). Use the equipment list in the operations, maintenance, and testing plan to perform an annual accounting of all component and installation equipment.

Perform a building-wide inspection of all areas below the design flood elevation to check for penetrations in walls, floors, and ceilings, which are common sources of leakage during flood events. If not properly designed with seals able to withstand hydrostatic loads for their given locations, such penetrations can negate flood protection benefits afforded by any floodproofing systems.

Wet-testing. Perform wet-testing of the floodproofing system every 5 years or after gasket replacement.

Penetrations Below Design Flood Elevation

If any pipes, conduits, or ducts that penetrate below the design flood elevation cannot resist flood loads, a mitigation solution should be immediately identified and implemented. Refer to Hurricane Harvey Recovery Advisory TX-RA1 for more information about penetrations.

Water leak detection system. Install a water leak detection system behind the dry floodproofing system to allow remote monitoring to determine when passive systems are deployed and whether measures are performing as expected.

Provide labels. To discourage unnecessary penetrations, consider labeling the walls and slabs of a dry floodproofed area, including any flood barriers that are part of a building design (e.g., foundation walls) with "Dry Floodproofed: No Penetrations Below This Level;" the sign should indicate the design flood elevation on the wall (Figure 4). For any existing penetrations that are sealed with watertight components or assemblies, consider a similar marking or designation.

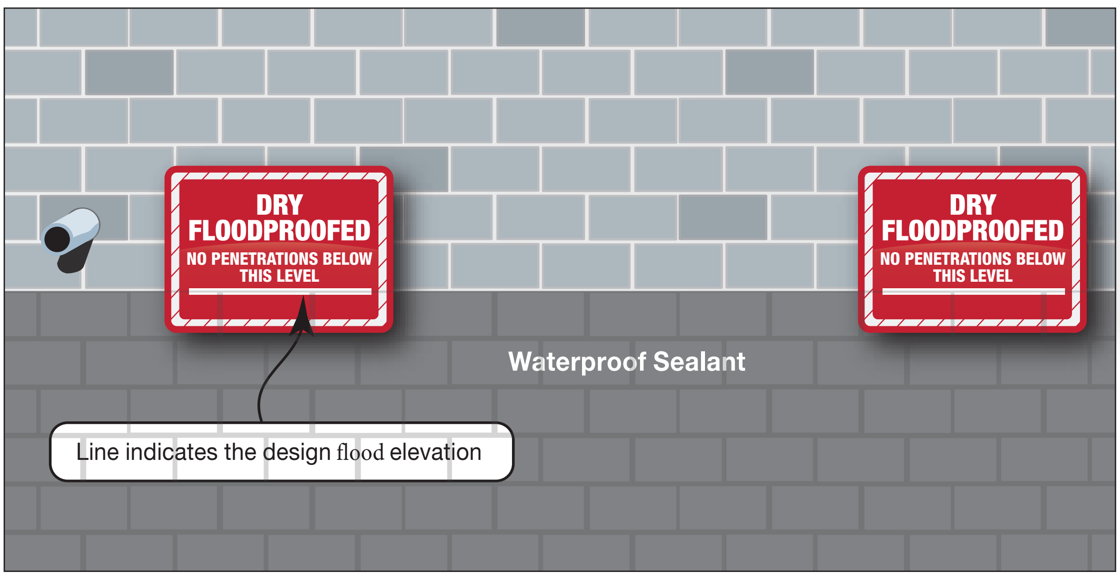

Figure 4: Example signage on a dry floodproofed wall spaced appropriately to maintain awareness

Deployment Considerations for Active Dry Floodproofing

Dry floodproofing measures should be activated once specifically identified triggers or benchmarks occur per the facility Emergency Operations Plan (refer to the following section). The following list includes common considerations to help building owners and operators effectively deploy their active dry floodproofing systems.

- Ensure that the appropriate building operations staff, installer, or municipality officials, if required, have copies of the operations, maintenance, and testing plan and the facility Emergency Operations Plan.
- Deploy all components specified by the operations, maintenance, and testing plan.
- Deploy in the order and at the locations specified in the operations, maintenance, and testing plan. Consider prioritizing locations that are more vulnerable or critical.
- Ensure that the dry floodproofing systems are installed correctly. Failure to install and tighten bolts, or repair/replace gaskets and seals as needed, can lead to leaks or floodproofing system failure.

- Verify that the system components required to install the dry floodproofing systems are stored together, as outlined in the operations, maintenance, and testing plan, with a separate area for spare parts (Figure 5).
- For individual flood components, verify that each component has retained its marking with its unique identification label that signifies its location when installed (Figure 6). Stickers and ink have a tendency to degrade over time, potentially leaving installers unsure of the proper sequence or location of the panels. Some manufacturers make flood panels with installation directions directly on the panel rather than in a separate document.
- The map showing where the dry floodproofing components will be installed should be reviewed and made available, as needed.
- If the flood panel requires a gasket to be inflated with air to ensure a watertight seal, provide redundant methods to maintain inflation, such as a portable air tank or pump (Figure 7).

Figure 5: Enclosed storage space for multiple flood panels, stanchions, and hardware

Figure 6: Installed flood panels. Each flood panel has a unique ID number. Also note the tightener bracket at top.

Figure 7: Flood gate with an air tank and a hand pump as a redundancy measure to inflate gaskets

Floodproofing Considerations for a Facility Emergency Operations Plan

Floodproofing considerations should be included in the facility's Emergency Operations Plan regardless of the size, scope, and complexity of the building(s). The scope and complexity of the floodproofing system and dry floodproofing measures will dictate the level of detail, phasing, and sequencing specified in the Emergency Operations Plan. It will also affect the equipment needed, number of personnel and time needed to install the system, maintenance requirements, appropriate training and exercising, and other issues. Flood-related considerations should address the process and timeline leading up to and during deployment, specific storm conditions that trigger deployment of floodproofing measures, and whether and how the system will be operated during the storm event. Specific additional emergency procedures should be developed for events larger than the design event.

Hurricane Irma Floodproofing Example

A building manager stated that a contractor had installed parts of the dry floodproofing system at one entrance of a building, but had not installed the required components at another building entrance. The result was that the first floor of the building flooded.

Pertinent information from the floodproofing system's operations, maintenance, and testing plan should be included in the floodproofing portion of the facility Emergency Operations Plan, as well as deployment considerations for active dry floodproofing measures (see previous subsections). Refer to Table 1 for details to evaluate when preparing the facility Emergency Operations Plan.

Building owners and operators should review and update the floodproofing portions of their facility Emergency Operations Plan on an annual basis (e.g., after hurricane or rainy season), and after each time the facility's floodproofing system is deployed. Pertinent information related to storm observations, system performance, damage to the floodproofing system, or any perceived system weaknesses or deficiencies should be recorded in both the facility Emergency Operations Plan and the operations, maintenance, and testing plan.

The building owners and operators should ensure that the facility Emergency Operations Plan and operations, maintenance, and testing plan are accessible to appropriate building operations staff, installer, or municipality, if required, and are forwarded as part of any workplace transition to maintain institutional continuity.

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan

Considerations	Details to Evaluate
Standby Power	• How long will emergency generators supply power for the sump pump system and other building systems without an off-site fuel delivery? • Will emergency generators be accessible during the flood event and equipped to operate during a flood event? • Will fuel delivery be hindered by the implemented dry floodproofing? • Are redundancy measures such as backup connections to other generators needed?
Prior to Event	• Who makes the decision to initiate mobilization and deployment of the floodproofing system? When will it occur based on warning time and expected flood conditions? • Is the facility Emergency Operations Plan permanently posted in at least two conspicuous locations? • What staff or contractors will be needed (e.g., maintenance staff, building engineer, contractors, installers) to retrieve and install active dry floodproofing components? • How many days prior to an event will personnel be mobilized? • How will personnel, equipment, and components be staged or phased? • Where are the storage location(s) and deployment location(s) of all necessary equipment? • How long will it take to deploy or activate the floodproofing system? • What is the system's design flood elevation? What is the expected flood depth?

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan (concluded)

Considerations	Details to Evaluate
Evacuation*	• Under what conditions will the building be evacuated? • Who will make the decision to evacuate the building in advance of or during a flood event? • Which points are designated as egresses or emergency openings and are they clearly marked? • Does the means of egress allow the floodproofing measures to remain in place? • How does the facility Emergency Operations Plan account for building evacuation timing and sequencing?
Building Occupancy During Event*	• Will the building be occupied during a flood event? If yes, then by whom (e.g., maintenance staff, employees, tenants)? What will their role be, if any, in deploying and operating the dry floodproofing system? • What will the occupants require in the event of an emergency (e.g., food, water, shelter)? How will supplies be stockpiled and how will operations continue during the event? • Will implemented dry floodproofing measures disrupt operations?
After the Event	• What staff or contractors will be needed for cleanup, debris management, removal of floodproofing equipment, and inspection of floodproofing equipment performance? • How long will it take to resume normal operations?

* FEMA recommends evacuating a building before a flood event whenever possible. Building owners and operators should evacuate in accordance with state and local government orders or notices. For unique situations that may require critical personnel to remain behind, advanced coordination and planning should occur with the local government so that emergency and government personnel can plan accordingly for their jurisdictional emergency operations plan.

References and Resources

References

ASCE (American Society of Civil Engineers). 2014. *Standard for Flood Resistant Design and Construction.* ASCE Standard ASCE 24-14.

American National Standards Institute and FM Approvals. 2014. *Approval Standard for Flood Abatement Equipment.* ANSI/FM 2510. http://www.fmapprovals.com/products-we-certify/products-we-certify/flood-mitigation-products.

FEMA (Federal Emergency Management Agency). 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93. https://www.fema.gov/media-library/assets/documents/3473.

FEMA 2013. *Floodproofing Non-Residential Structures.* FEMA P-936. https://www.fema.gov/media-library/assets/documents/34270.

Resources

ASCE. 2016. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-16.

ASFPM (Association of State Floodplain Managers). n.d. "National Flood Barrier Testing & Certification Program." http://www.nationalfloodbarrier.org.

FEMA. 2017. *Protecting Building Utility Systems from Flood Damage.* FEMA P-348. https://www.fema.gov/media-library/assets/documents/3729.

Risk Management Series publications listed below are available at https://www.fema.gov/security-risk-management-series-publications.

- FEMA. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds.* FEMA P-543.

- FEMA. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds.* FEMA P-577.
- FEMA. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds.* FEMA P-424.

Technical Bulletins listed below are available at https://www.fema.gov/media-library/collections/4.

- FEMA. 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93.
- FEMA. 1993. *Wet Floodproofing Requirements.* Technical Bulletin 7-93.
- FEMA. 2008. *Flood Damage-Resistant Materials Requirements.* Technical Bulletin 2.

Recovery Advisories for Hurricane Sandy listed below are available at https://www.fema.gov/media-library/assets/documents/30966.

- FEMA. 2013. *Reducing Flood Effects in Critical Facilities.* Hurricane Sandy RA2.
- FEMA. 2013. *Reducing Interruptions to Mid- and High-Rise Buildings During Floods.* Hurricane Sandy RA4.
- FEMA. 2013. *Designing for Flood Levels Above the BFE After Hurricane Sandy.* Hurricane Sandy RA5.

Recovery Advisories from the 2016 Fall Flooding in Iowa listed below are available at https://www.fema.gov/media-library/assets/documents/130555.

- FEMA. 2017. *Flood Protection for Critical and Essential Facilities.* 2016 Fall Flooding in Iowa RA3.
- FEMA. 2017. *Flood Protection and Elevation of Building Utilities.* 2016 Fall Flooding in Iowa RA4.
- FEMA. 2017. *Flood Protection for Backup and Emergency Power Fuel Systems.* 2016 Fall Flooding in Iowa RA5.

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions-building-science.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

You may also sign up for the FEMA Building Science email subscription, which is updated with publication releases and FEMA Building Science activities. Subscribe at https://service.govdelivery.com/accounts/USDHSFEMA/subscriber/new?topic_id=USDHSFEMA_193.

Visit the Building Science Branch of the Risk Management Directorate at FEMA's Federal Insurance and Mitigation Administration at https://www.fema.gov/building-science.

To order publications, contact the FEMA Distribution Center:

Call: 1-800-480-2520
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Fax: 240-699-0525

Email: FEMA-Publications-Warehouse@fema.dhs.gov

Additional FEMA documents can be found in the FEMA Library at https://www.fema.gov/media-library/resources.

Please scan this QR code to visit the FEMA Building Science web page.

Soffit Installation in Florida

HURRICANE IRMA IN FLORIDA

Recovery Advisory 2, May 2018

Purpose and Intended Audience

This Recovery Advisory provides soffit installation guidance and resources to meet or exceed minimum provisions of the 6th Edition (2017) Florida Building Code, Residential (FBCR). The primary audience for this advisory includes contractors and homeowners, but may also be helpful for building officials and design professionals.

Key Issues

- Wind-damaged soffits allowed wind-driven rain to enter building envelopes, resulting in costly damage to building interiors.
- While some water was blown into attics through soffit vents, the amount of water intrusion increased dramatically when the soffit material was missing (Figure 1).
- Need for clarification of how to meet the 6th Edition (2017) FBCR soffit installation criteria.

This Recovery Advisory Addresses

- Soffit design wind loads and installation in the Florida Building Code
- Installing the soffit

Soffit Design Wind Loads and Installation in the Florida Building Code

Compliance with the 6th Edition (2017) of the Florida Building Code (FBC) is required throughout the state for building permits issued after December 31, 2017, including projects to repair and rebuild Hurricane Irma damage. One- and two-family dwellings are covered under the scope of the FBCR. Soffit provisions in the 6th Edition (2017) of FBCR were updated from the previous (5th) edition as follows:

1. In the 6th Edition (2017) FBCR Component and Cladding Load Table R301.2(2), design wind pressures are tabulated as Allowable Stress Design (ASD)-level values. The 5th Edition (2014) FBCR tabulated strength design-level

Florida Building Code and International Code Council Codes

The 2015 International Residential Code (IRC) serves as the base code for the 6th Edition (2017) FBCR. Florida-specific amendments are added through the state's established code development process. The Florida Building Codes can be viewed for free through the "Public Access" option on the ICC website: https://codes.iccsafe.org/public/collections/FL.

Figure 1: Vinyl soffit damage on a home in Sugarloaf Key

Soffit Vents

Refer to the 6th Edition (2017) of FBCR Section R806 for roof venting provisions. To avoid water entry at soffit vents, options include eliminating soffit vents and providing an alternate method for air to enter the attic, or designing for an unvented attic. Another approach is to place filter fabric (like that used for heating, ventilation, or air conditioning system filters) above the vent openings; however, such an approach needs to be custom designed. For additional guidance on mitigating water intrusion through attic vents and strengthening undamaged soffits, refer to Technical Fact Sheet No. 7.5, "Minimizing Water Intrusion Through Roof Vents in High-Wind Regions" in FEMA P-499, *Homebuilder's Guide to Coastal Construction* (FEMA 2010).

wind pressures and included a note that permitted the values to be multiplied by 0.6 for ASD. Since component and cladding products are rated using ASD wind pressures, the 6th Edition table values should be easier to use than the previous edition's.

2. The effective wind area for soffit design pressures is specified as 10 square feet. The clarification simplifies soffit load determination. Unlike Table R301.2(2) in the FBCR, Table 1 on page 3 of this advisory is further simplified for soffit applications and only includes design pressures for effective wind areas of 10 square feet.

Installing the Soffit

Meeting the 6th Edition (2017) FBCR soffit installation criteria requires determining (1) the site- and location-specific wind loads that soffits must resist, and (2) which soffit assemblies are rated and approved to meet the wind load demand, and how the chosen soffit assembly must be installed to perform as designed.

FBCR Soffit Installation Provision

The following Chapter 7 (Wall Covering) provisions specifically address soffit installation:

R703.1.2.1 Wind resistance of soffits: Soffits and their attachments shall be capable of resisting wind loads specified in Tables R301.2(2) and R301.2(3) for walls using an effective wind area of 10 square feet.

R703.11.1.4 Vinyl soffit panels: Soffit panels shall be individually fastened to a supporting component such as a nailing strip, fascia or subfascia component or as specified by the manufacturer's instructions.

Source: 6th Edition (2017) FBCR

Step 1: Determine the Wind Loads

Follow the steps below to find minimum soffit wind loads (pressures) in accordance with the 2017 FBCR.

1. Determine location- and site-specific factors that affect the soffit wind pressures.

   a. **Design wind speed:** Find location-specific design wind speeds in Figure R301.2(4) of the 6th Edition (2017) FBCR. Wind speeds for specific addresses and latitude/longitude can be found at http://windspeed.atcouncil.org or https://asce7hazardtool.online/. For one- and two-family dwellings, select wind speeds given for ASCE 7-10, Risk Category II.

   b. **Exposure category:** Check with your local building official to determine site-specific exposure category (B, C, or D) in accordance with the 6th Edition (2017) FBCR Section 301.2.1.4.3. Keep in mind that exposure category can vary within individual neighborhoods because it is related to the terrain that surrounds the building.

   c. **Mean roof height:** Determine the mean roof height (MRH) in accordance with the 6th Edition (2017) FBCR Section R202 definition: "The average of the roof eave height and the height to the highest point on the roof surface, except that eave height shall be used for a roof angle of less than or equal to 10 degrees." Refer to Figure 2 for clarification.

2. Using the site-specific wind speed determined in Step 1a, find the Zone 4 and Zone 5 pressures using Table 1.

   Zone 5 wind pressures apply to soffit surfaces within 4 feet of wall corners, and Zone 4 wind pressures apply to all other areas. The selected soffit system must resist the building's highest (Zone 5) wind pressures, so calculating Zone 4 pressures will not be necessary for many assemblies (refer to Figure R301.2(7)).

3. Modify the wind pressure(s) for the specific wind zone, as determined in Step 2, for factors determined in Steps 1b and 1c.

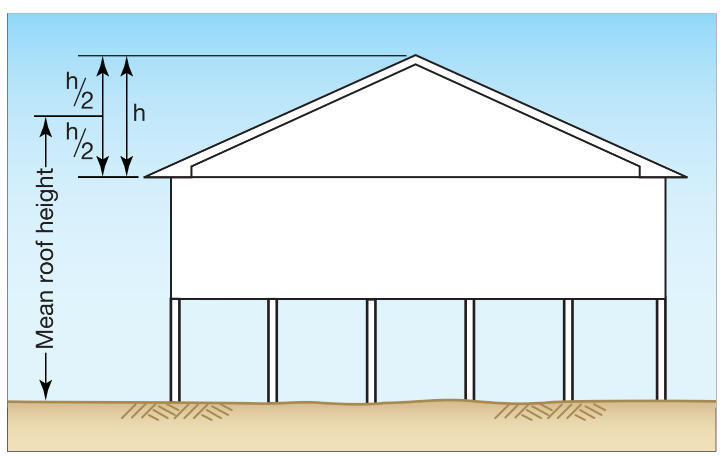

Figure 2: Illustration showing how to determine the MRH

To do this, multiply wind pressure values by the coefficients in Table 2 as needed to adjust for exposure categories other than B and MRHs other than 30 feet. For MRHs between those given in Table 2, use the value assigned to the higher MRH or interpolate between the higher and lower values.

4. Select a soffit system rated to resist Zone 5 pressures determined in Step 3.

   In some cases, such as the prescriptive wood structural panel soffit, the soffit attachment schedule may be reduced for (lesser) Zone 4 pressures where soffit sections are 4 feet or more from building corners. Follow material-specific guidance in Step 2 of this advisory to ensure compliant application.

Table 1: Soffit Positive and Negative Pressures (Pounds per Square Foot) for Zones 4 and 5 with MRH=30 feet, Exposure B

	115 mph	120 mph	130 mph	140 mph	150 mph	160 mph	170 mph	180 mph
Zone 4	-15.0	-16.0	-19.0	-22.0	-26.0	-30.0	-33.0	-37.9
	14.3	15.5	18.2	21.2	24.3	27.7	31.2	35.0
Zone 5	14.3	-20.0	-24.0	-28.0	-32.0	-37.0	-41.0	-46.8
	-19.0	15.5	18.2	21.2	24.3	27.7	31.2	35.0

Source: Table R301.2(2) in the FBCR, abbreviated to address Florida-specific wind speeds and wall zones only; available at https://codes.iccsafe.org/public/collections/FL.

Table 2: Height and Exposure Adjustment Coefficients for Soffit Pressure

Mean Roof Height (feet)	Exposure B	Exposure C	Exposure D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

Source: Table R301.2(3) in the FBCR available at https://codes.iccsafe.org/public/collections/FL.

Step 2: Material-Specific Soffit Installation

Whether or not a soffit installation is code-compliant depends on both the material and product. In Florida, manufactured soffit products must be approved as described in the text box titled “Florida Product Approval” because they are part of the building envelope and included under the “panel walls” product category. As such, selecting manufactured soffit products with up-to-date Florida product approval is the first required step for most soffit installations. Alternately, wood structural panel soffits may be assembled and installed on site to resist the wind pressures determined in Step 1 using the prescriptive approach described at the end of this section.

Soffit system support and corrosion resistance. Regardless of whether the chosen soffit system is manufactured or assembled prescriptively using wood structural panels, soffit system support and the corrosion resistance of the soffit fasteners must be addressed. Section 802 of the 6th Edition (2017) FBCR and Section 3.5 of the 2015 Edition Wood Frame Construction Manual provides requirements for ceiling joists, rafter overhangs, rake overhangs, and outlookers that support soffit systems. Section R703.3.2 of the 6th Edition (2017) FBCR requires corrosion-resistant wall covering fasteners in accordance with manufacturer’s installation instructions. Refer to Note 1 of Table 3 for guidance on corrosion protection specific to wood structural panel soffits.

Florida Product Approval

Rule 61G20-3 of the Florida Administrative Code applies to products and systems that comprise the building envelope and structural frame. The rule requires the following products to have product approval for compliance with the structural requirements of the Florida Building Code:

- Panel walls
- Exterior doors
- Roofing products
- Skylights
- Windows
- Shutters
- Structural components
- Impact protective systems

Products may be approved using either the optional statewide product approval system or local product approval. Regardless of the method used, products have to be evaluated for compliance (evaluation report, certification, test report, etc.), be validated for compliance with the evaluation, and approved by the Florida Building Commission. For additional information on product approval in the State of Florida, see Rule 61G20-3 of the Florida Administrative Code or the Building Code Information System at http://www.floridabuilding.org administered by the Florida Department of Business and Professional Regulation. A database of products approved using the statewide product approval system can be found under the "Product Approval" tab at http://www.floridabuilding.org.

Navigating the Florida Approval Website to Find Approved Products for Your Location

1. Link to the main page: http://www.floridabuilding.org
2. Select the "Product Approval" option from the left margin
3. From the Product Approval menu, select "Find a Product or Application"
4. From the "Category" pull-down options, select "Panel Walls"
5. From the "Subcategory" pull-down options, select "Soffits"
6. For "Application Status," select "Approved"
7. If in Broward or Miami-Dade Counties, select "Yes" from "Approved for use in HVHZ"
8. Click on "Search"
9. Select any given listing to determine allowable "Design Pressure" and installation instructions

In some cases, allowable design pressures are shown in "Summary of Products" at the bottom of the page. In other cases, it is necessary to open the Evaluation Report(s) or Installation Instructions linked in the right column of "Summary" for design pressures.

Since fastener vulnerability to corrosion varies with location, check with your local building official for any specific requirements or guidelines. For further recommendations on corrosion-resistant connectors, see Table 1 in the National Flood Insurance Program Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas* (FEMA 1996).

Manufactured soffit systems. Since February 2018, the Florida Product Approval website has listed approved soffit assemblies for vinyl, metal (aluminum and steel), fiber cement, and engineered wood assemblies.

To find the rated design pressures approved for each product, refer to the evaluation report and/or the installation instructions linked at the bottom of each product page. Only soffit panels that have been rated to meet or exceed the wind pressures determined for the specific location and site should be installed. See the text box for Florida Product Approval website navigation tips.

When selecting soffit systems from the Florida Product Approval website that meet the wind pressure loading for your building, note that individual product installation instructions vary with respect to the information and level of detail provided. Review the installation instructions on the Florida Product Approval website for any prospective product prior to purchasing while considering the following:

- When determining soffit pressure resistance from the evaluation report or installation instructions, select “Allowable Design Load,” not “Ultimate Load.” If needed, Ultimate Loads can be converted to Allowable Design Loads by multiplying values by 0.6.
- Check whether the installation instructions have sufficient detail needed to install and inspect the soffits. In cases where blocking or substrate size and/or attachment to framing indicates “by others” or “per project requirements,” the details will need to be specified and sealed by a professional engineer licensed in Florida for site-specific loads.
- Ensure that the installation instructions include all referenced details needed for the chosen design pressure application.

Wood structural panel, closed soffit. As an alternative to manufactured soffit systems, wood structural panel soffits may be prescriptively installed to resist the location- and site-specific wind pressures determined in Step 1.

Where the design pressure is 30 pounds per square foot (psf) or less, wood structural panel soffits should be a minimum of 3/8 inch in thickness and fastened to framing or nailing strips with a minimum of 6d box nails (2-inch x 0.099-inch x 0.266-inch head diameter [flat head]) spaced not more than 6 inches on center at panel edges and 12 inches on center at intermediate supports.

For design pressures greater than 30 psf, refer to Table 3 for modified panel thickness, fastener type, size, and spacing. See Figure 3 for a detail of a wood structural panel, closed soffit.

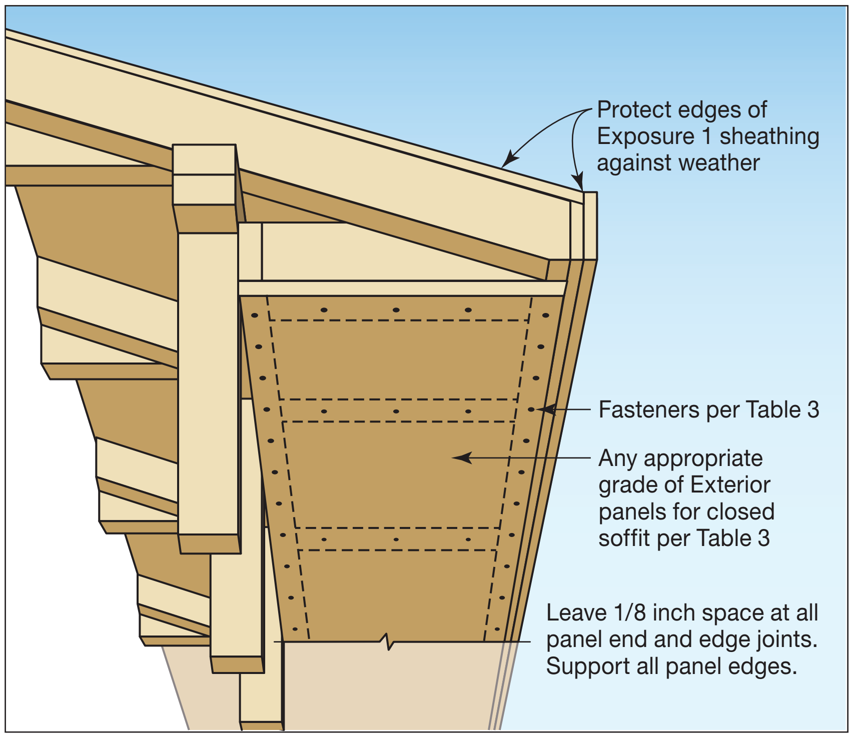

Figure 3: Detail of wood structural panel, closed soffit

Wood Structural Panel Sheathing

Wood structural panel sheathing is manufactured with span ratings of 12/0, 16/0, 20/0, 24/0, 24/16, 32/16, 40/20, and 48/24, in performance categories ranging from 5/16 to 3/4, and in two bond classifications: Exterior and Exposure 1.

Span ratings appear as two numbers separated by a slash, such as 32/16, 48/24, etc. The left-hand number denotes the maximum recommended spacing of supports when the panel is used for roof sheathing with the strength axis of the panel across three or more supports (two or more spans). The right-hand number denotes the maximum recommended spacing of supports when the panel is used for subflooring with the strength axis of the panel across three or more supports (two or more spans). A panel marked 32/16, for example, may be used for roof decking over supports up to 32 inches on center or for subflooring over supports up to 16 inches on center.

Source: APA, http://www.wooduniversity.org/glossary

Table 3: Installation Information for Wood Structural Panel, Closed Soffit

Maximum Design Pressure (- or + psf)	Minimum Nominal Panel Thickness (inch)	Nail Type and Size (inch)	Fastener Spacing along Supports (inch)	
			Galvanized Steel	Stainless Steel
40	3/8	6d box (2 x 0.099 x 0.266 head diameter)	6	4
50	3/8	6d box (2 x 0.099 x 0.266 head diameter)	4	4
		8d common (2½ x 0.131 x 0.281 head diameter)	6	6
60	3/8	6d box (2 x 0.099 x 0.266 head diameter)	4	3
		8d common (2½ x 0.131 x 0.281 head diameter)	6	4
70	7/16	8d common (2½ x 0.131 x 0.281 head diameter)	4	4
		10d box (3 x 0.128 x 0.312 head diameter)	6	4
80	7/16	8d common (2½ x 0.131 x 0.281 head diameter)	4	4
		10d box (3 x 0.128 x 0.312 head diameter)	6	4
90	15/32	8d common (2½ x 0.131 x 0.281 head diameter)	4	3
		10d common (3 x 0.148 x 0.312 head diameter)	6	4

Notes:

1: Fastener spacing for galvanized steel nails can be larger than for stainless steel nails of the same diameter and length because galvanized steel nails have better withdrawal resistance from wood. Hot-dip galvanized steel nails or stainless steel nails are recommended in coastal areas.

2: Maximum spacing of soffit framing members = 24 inches; tabulated values assume minimum two-span continuous condition.

3: Only exterior panels should be used for closed soffits. To achieve pressure values shown in Table 3, panels must be installed with strong axis across supports. A 3/8-inch, 7/16-inch, and 15/32-inch minimum nominal panel thickness is associated with minimum panel span ratings (e.g., panel grade) of 24/0, 24/16, and 32/16, respectively.

4: Tabulated nail spacing assumes sheathing is attached to soffit framing members with a specific gravity of at least 0.42, which includes the following species combinations: spruce-pine-fir, hem-fir, Douglas-fir-larch, and southern pine.

Source: Table adapted from data available in *National Design Specifications for Wood Construction* (AWC 2015) and *Special Design Provisions for Wind & Seismic* (AWC 2015).

References and Useful Links

References

ASCE (American Society of Civil Engineers). 2010. ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*.

AWC (American Wood Council). 2015. *National Design Specifications for Wood Construction*. http://www.awc.org/pdf/codes-standards/publications/nds/AWC-NDS2015-ViewOnly-1603.pdf?_sm_au_=iVV06qrjPvPZPnZj.

AWC. 2015. *Special Design Provisions for Wind & Seismic*. http://www.awc.org/pdf/codes-standards/publications/sdpws/AWC-SDPWS2015-ViewOnly-1508.pdf.

AWC. 2015. *Wood Frame Construction Manual for One- and Two-Family Dwellings*. http://www.awc.org/pdf/codes-standards/publications/wfcm/AWC-WFCM2015-ViewOnly-1510.pdf.

FEMA (Federal Emergency Management Agency). 1996. Technical Bulletin 8, *Corrosion Protection of Metal Connectors in Coastal Areas.* https://www.fema.gov/media-library/assets/documents/3509.

FEMA. 2010. *Home Builder's Guide to Coastal Construction.* FEMA P-499. https://www.fema.gov/media-library/assets/documents/6131.

Useful Links

"Florida Building Codes." Florida Department of Business & Professional Regulation (DBPR). Link: https://www.floridabuilding.org/bc/bc_default.aspx.

"APA Glossary." WoodUniversity.Org. Link: https://www.wooduniversity.org/glossary.

"APA Help Desk." WoodUniversity.Org. Link: https://www.apawood.org/help.

"Hazards by Location." Applied Technology Council. Link: https://hazards.atcouncil.org/.

"ASCE 7 Hazard Tool." American Society of Civil Engineers (ASCE). Link: https://asce7hazardtool.online/.

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions-building-science.

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Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code

FEMA

HURRICANE IRMA IN FLORIDA *Recovery Advisory 3, May 2018*

Purpose and Intended Audience

This Recovery Advisory provides guidance on wind mitigation triggers for roof repairs and replacement in the 6th Edition (2017) Florida Building Code (FBC). The information in this advisory is particularly pertinent to repairs and rebuilding in areas of Florida recovering from Hurricane Irma. However, this information applies generally throughout Florida. The primary audience for this advisory includes building owners, operators, and managers; design professionals; building officials; contractors; and municipal building and planning officials.

The guidance in this advisory should be incorporated or referenced to help in the development of repair scopes of work and/or hazard mitigation proposals for FEMA Section 406 Public Assistance grants or used by designers and various stakeholders for other projects. Relevant guidelines and codes are listed in the text boxes to the right.

Key Issues

- Damage requiring reroofing or roof repairs to withstand future events
- Need for clarification of the applicability of the 25% Rule in the FBC for reconstruction
- Need for clarification of mitigation actions required when a roof covering is replaced or repaired in Florida

This Recovery Advisory Addresses

- Roof repairs
- Residential wind mitigation
- Commercial wind mitigation

Roof Repairs

Building codes have historically required reroofing to meet the same requirements as new construction but permitted repairs to be made using like materials, provided no dangerous or unsafe condition was created by using such materials. However, as a result of the damage caused by the hurricanes of 2004, the FBC adopted several wind mitigation measures that apply when roofs are replaced or repaired. These provisions recognize that with the roof covering removed, upgrades and improvements to the resistance of the roof assembly (underlayment, roof decking, roof-to-wall connections) to wind loads and water penetration are more easily performed.

FEMA Public Assistance Program and Policy Guide

See Section VII, "Permanent Work Eligibility" in FEMA's Public Assistance Program and Policy Guide (FEMA 2018).

Florida Building Code

- Florida Building Code, Building (FBCB)
- Florida Building Code, Residential (FBCR)
- Florida Building Code, Existing Building (FBCEB)

Florida Building Code Definitions

High-Velocity Hurricane Zones (HVHZ): The HVHZ consists of Broward and Dade Counties.

Reroofing: The process of recovering or replacing an existing roof covering.

Roof Repair: Reconstruction or renewal of any part of an existing roof for the purposes of its maintenance.

Roof Replacement: The process of removing the existing roof covering, repairing any damaged substrate, and installing a new roof covering.

Source: 6th Edition (2017) FBC

FBC 25% Rule. The FBC limits how much of an existing roof can be repaired within a specific period of time before triggering the requirement to comply with the latest code, often referred to as the "25% Rule." The 25% Rule has applied to construction in South Florida as far back as the 1957 South Florida Building Code. In the 2001 and 2004 FBC, the 25% Rule only applied to buildings within a High-Velocity Hurricane Zone (HVHZ). In the 2007 FBC, the rule was modified slightly and adopted to be applicable to the rest of Florida. The applicability of the 25% Rule has differed somewhat for buildings within and outside the HVHZ, with changes made between the 5th Edition (2014) and 6th Edition (2017), as described below.

5th Edition (2014) FBC. The 5th Edition (2014) versions of the rule are as follows:

- Areas outside the HVHZ: "Not more than 25 percent of the total roof area or roof section of any existing building or structure shall be repaired, replaced or recovered in any 12-month period unless the entire roofing system or roof section **conforms** to requirements of this code" (Section 708.1.1, FBCEB 2014).
- Areas within the HVHZ: "Not more than 25 percent of the total roof area or roof section of any existing building or structure shall be repaired, replaced or recovered in any 12-month period unless the entire existing roofing system or roof section **is replaced to conform** to requirements of this code" (Section 1521.4, FBCB 2014).

The distinction is that for areas outside the HVHZ, if more than 25 percent of the total roof area or roof section had to be repaired, replaced, or recovered in any 12-month period, the remainder of the roof only had to be replaced if it did not conform to the requirement of the current code. For areas in the HVHZ, if more than 25 percent of the total roof area or roof section had to be repaired, replaced, or recovered in any 12-month period, the remainder of the roof or roof section had to be replaced to conform to the requirements of the code, regardless of whether it complied with the current code.

6th Edition (2017) FBC. In the 6th Edition (2017) FBC, the 25% Rule was revised for areas outside the HVHZ to make it consistent with how it is applied in the HVHZ. Therefore, if more than 25 percent of the total roof area or roof section has to be replaced or recovered in any 12-month period, the 6th Edition (2017) FBC requires the remainder of the roof or roof section to be replaced to conform to the requirements of the code, regardless of whether it complies with the current code (see FBCR Section R908.1.1, FBCB Sections 1511.1 and 1521.4, and FBCEB Section 706.1.1).

Roof Sections: If a building roof contains multiple levels or is divided by, for example, parapet walls or expansion joints, each area is considered an individual roof section when applying the 25% Rule. Therefore, in accordance with the 6th Edition (2017) of the FBC, if more than 25 percent of the total roof area or roof section of a building has to be repaired or replaced, the entire roof or roof section has to be replaced to conform to the requirements of the code. Figures 1 and 2 show examples of roof sections on two different buildings.

Florida Building Code Definitions

Roof Section: A separation or division of a roof area by existing joints, parapet walls, flashing (excluding valleys), difference of elevation (excluding hips and ridges), roof type, or legal description, not including the roof area required for a proper tie-off with an existing system.

Source: 6th Edition (2017) FBC

Figure 1: Example of residential building with two roof sections

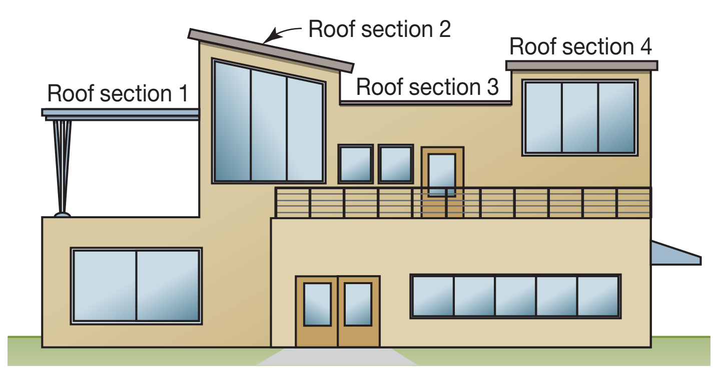

Figure 2: Example of non-residential building with four roof sections

Residential Wind Mitigation

When a roof covering system on a single-family dwelling is removed and replaced, the 6th Edition (2017) FBCR requires the following components to be investigated and subsequent measures to be taken if deficiencies are found:

- **Roof deck attachment** – Several options are provided for improving the roof deck attachment.
- **Enhanced underlayment (secondary water barriers)** – Since the underlayment requirements for new construction have been improved, the secondary water barrier requirements now simply reference the applicable underlayment table for new construction.
- **Roof-to-wall connections** – Improvements to roof-to-wall connections are covered in Section R908.8.

As indicated in the text box titled "FBCR Wind Mitigation Requirements," single-family residential structures permitted subject to the Florida Building Code are exempt from the residential wind mitigation requirements. The phrase "permitted subject to the Florida Building Code" means a building permitted to any version of the Florida Building Code (2001, 2004, 2007, 2010, 5th Edition [2014], or 6th Edition [2017]).

Additionally, the FBCR and FBCEB permit the investigation of the roof decking and any mitigation measures taken to be performed by a roofing contractor.

FBCR Wind Mitigation Requirements

R908.7: When a roof covering on an existing site-built single-family residential structure is removed and replaced, the following procedures shall be permitted to be performed by the roofing contractor:

- Roof-decking attachment shall be as required by Section R908.7.1.
- A secondary water barrier shall be provided as required by Section R908.7.2.

Exception: Single-family residential structures permitted subject to the Florida Building Code are not required to comply with this section.

Source: 6th Edition (2017) FBCR

Roof Deck Attachment

An evaluation of the existing roof deck fastening is required to determine if mitigation is required. If the existing connections are found to be insufficient, specific supplemental fasteners are required at specific spacings. Supplemental fasteners must be ASTM F1667 RSRS-01 ring shank nails with the minimum dimensions specified in the FBCEB and FBCR. The number and minimum spacing of supplemental fasteners depend on the spacing of the existing fasteners as specified in Table R908.7.1.2 of the FBCR and shown in Table 1. Figure 3 is an illustration of a roof decking showing where supplemental fasteners are required and the required spacing.

Table 1: Supplemental Fasteners at Panel Edges and Intermediate Framing (FBCR)

Existing Fasteners	Existing Spacing	V_{asd} 110 mph or Less Supplemental Fastener Spacing Shall Be No Greater Than	V_{asd} Greater Than 110 mph Supplemental Fastener Spacing Shall Be No Greater Than
Staples or 6d	Any	6 inches on center [b]	6 inches on center [b]
8d clipped head, round head, smooth or ring shank	6 inches on center or less	None necessary	None necessary
8d clipped head, round head, smooth or ring shank	Greater than 6 inches on center	6 inches on center [a]	6 inches on center [a]

a. Maximum spacing determined based on existing fasteners and supplemental fasteners.

b. Maximum spacing determined based on supplemental fasteners only.

Note: V_{asd} (nominal wind speed per FBC) shall be determined in accordance with Section 1609.3.1 of the Florida Building Code, Building or Section R301.2.1.3 of the Florida Building Code, Residential.

Source: Table R908.7.1.2 in the FBCR, modified slightly to define terms, available at https://www.floridabuilding.org

Florida Building Code Wind Speeds

Wind Speed, V_{ult}: Ultimate design wind speeds. V_{ult} is determined from the wind speed maps.

Wind Speed, V_{asd}: Nominal design wind speeds. V_{asd} is determined by multiplying V_{ult} by $\sqrt{0.6}$.

Source: 6th Edition (2017) FBC

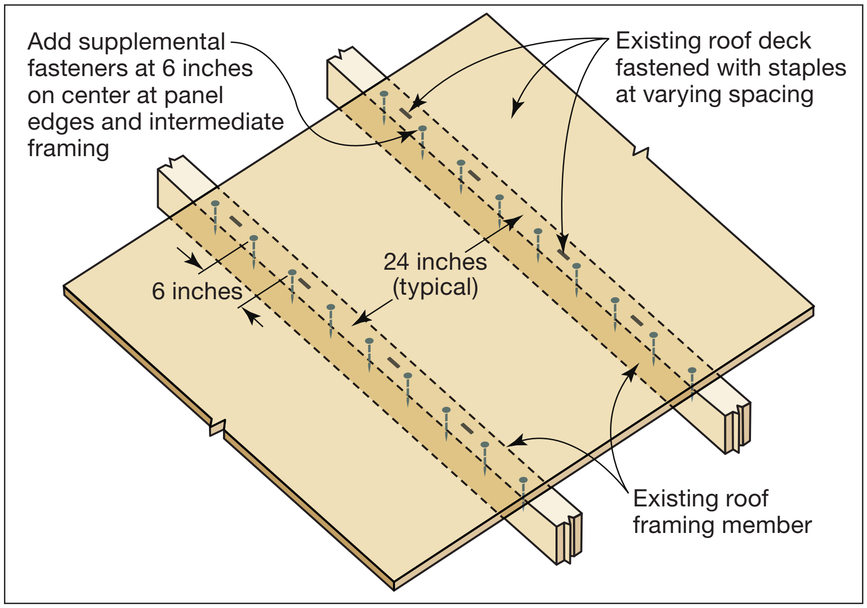

Figure 3: Example of roof decking showing placement and spacing of supplemental roof deck fasteners

Secondary Water Barriers

Criteria for the required secondary water barrier are addressed in Section R908.7.2 of the FBCR. Provisions for areas within and outside the HVHZ are provided separately; while the requirements for within and outside the HVHZ are generally similar, there are subtle differences. Additionally, the requirements also differ slightly depending on the type of roof covering being installed. Table 2 summarizes what qualifies as a secondary water barrier for asphalt shingle roofs that are removed and replaced in the HVHZ and outside the HVHZ.

Table 2: Summary of Secondary Water Barrier Options for Asphalt Shingle Roofs

Roof Slope	Material	Details
Within High-Velocity Hurricane Zones		
2:12 and greater	Approved asphalt impregnated 30# felt underlayment or approved synthetic underlayment (ASTM D226 Type II or ASTM D4869 Type IV)	• Single layer with 4-inch side lap • 6-inch end laps • Metal cap nails with a cap diameter of not less than 1-5/8 inches but no more than 2 inches and thickness of 32-gage sheet metal • Nails are required to be minimum 12 gauge, annular ring shank nails having not less than 20 rings per inch, heads not less than 3/8 inch (9.5 mm) in diameter, and lengths sufficient to penetrate the thickness of plywood panel or wood plank decking not less than 3/16 inch (4.8 mm), or to penetrate into a 1-inch (25 mm) or greater thickness of lumber not less than 1 inch • Fasteners to be in a grid pattern of 12 inches between laps • Fasteners at side and end laps at 6 inches on center
	ASTM D1970	• Apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified in the FBC for the HVHZ over the entire roof deck Note: In the HVHZ, if the self-adhering membrane is to be applied over the entire roof, it must be applied over a mechanically fastened anchor sheet (using one of the underlayment materials and attachment methods described in the row above).

Table 2: Summary of Secondary Water Barrier Options for Asphalt Shingle Roofs (concluded)

<table>
<tr><th>Roof Slope</th><th>Material</th><th>Details</th></tr>
<tr><td colspan="3">Outside High-Velocity Hurricane Zones</td></tr>
<tr><td rowspan="2">2:12 to less than 4:12</td><td>ASTM D226 Types I or II
ASTM D4869 Types II, III, or IV
ASTM D6757</td><td>• Double layer with 19-inch side lap for all types
• 6-inch end laps offset 6 feet
• Metal or plastic cap nails with a cap diameter of not less than 1 inch and thickness of 32-gage sheet metal
• One row of fasteners in the field of the sheet at 12 inches on center
• Fasteners at side and end laps at 6 inches on center</td></tr>
<tr><td>ASTM D1970</td><td>• Apply self-adhering membrane over the entire roof
• Alternatively, apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified above over the entire roof deck</td></tr>
<tr><td rowspan="2">4:12 and greater</td><td>ASTM D226 Type II
ASTM D4869 Type IV
ASTM D6757</td><td>• Single layer with 4-inch side lap for all types
• 6-inch end laps offset 6 feet
• Metal or plastic cap nails with a cap diameter of not less than 1 inch and thickness of 32-gage sheet metal
• Two staggered rows of fasteners in the field of the sheet with a maximum fastener spacing of 12 inches on center
• Fasteners at side and end laps at 6 inches on center</td></tr>
<tr><td>ASTM D1970</td><td>• Apply self-adhering membrane over the entire roof
• Alternatively, apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified above over the entire roof deck</td></tr>
</table>

Source: Compiled from Sections R908.7 and 2 and Table R905.1.1 of the 6th Edition (2017) FBCR and Sections 1517.5.1, 1517.5.2, 1518.2, 1518.3, and 1518.4 of the 6th Edition (2017) FBCB.

For areas outside the HVHZ, Section R905.1.1 of the FBCR permits the use of a reinforced synthetic underlayment that is approved as an alternative to underlayment complying with ASTM D226 Type II. In addition, a minimum tear strength of 20 pounds in accordance with ASTM D1970 or ASTM D4533 is permitted as an alternative outside the HVHZ. This underlayment is required to be installed and attached in accordance with the requirements for the applicable roof covering and slope, except metal cap nails are required where the ultimate design wind speed, V_{ult}, equals or exceeds 150 mph. In the HVHZ, a synthetic underlayment installed with tin tabs is permitted in accordance with Sections 1518.2, 1518.3, and 1518.4 of the FBCB.

Figures 4 through 8 illustrate some of the secondary water barrier methods that are summarized in Table 2.

Roof-to-Wall Connections

Improvements to roof-to-wall connections are covered in Section R908.8 of the FBCR and only apply to buildings located in the wind-borne debris region with an insured value of $300,000 or more, or if uninsured, have a just valuation for purposes of ad valorem taxation of $300,000 or more. The code requires roof-to-wall connections to be retrofitted only up to a 15 percent increase in the cost of reroofing. As with roof deck attachments and secondary water barriers, single-family residential structures permitted subject to the Florida Building Code are exempted from these requirements.

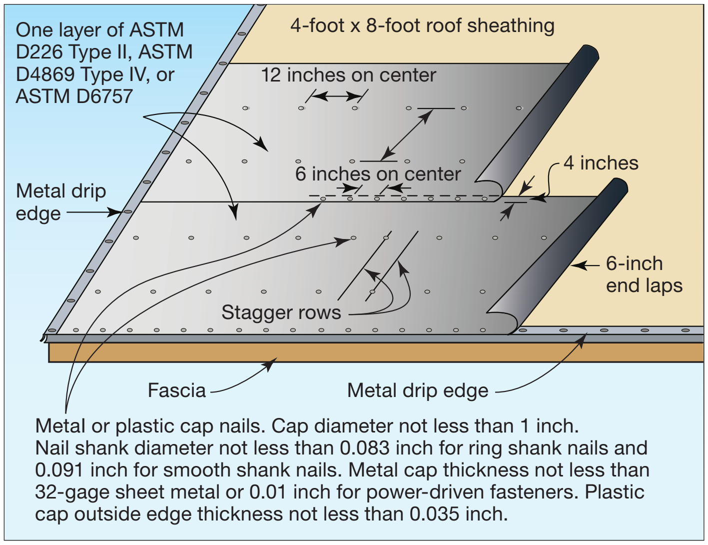

Figure 4: Example 1 – Outside the HVHZ

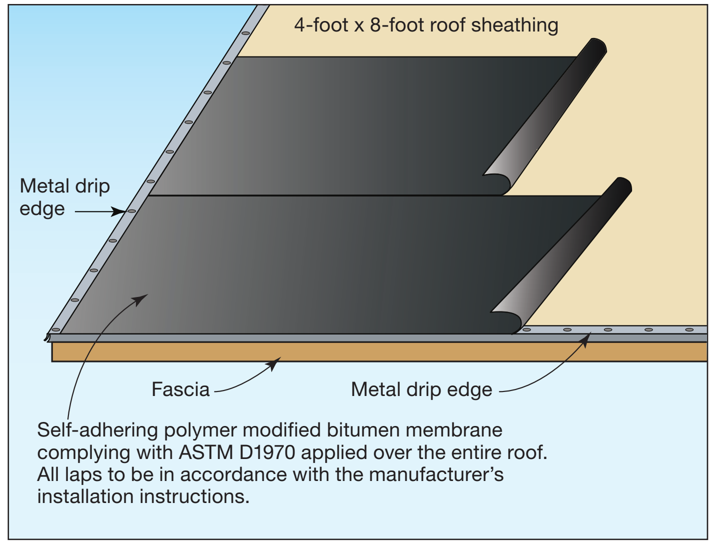

Figure 5: Example 2 – Outside the HVHZ

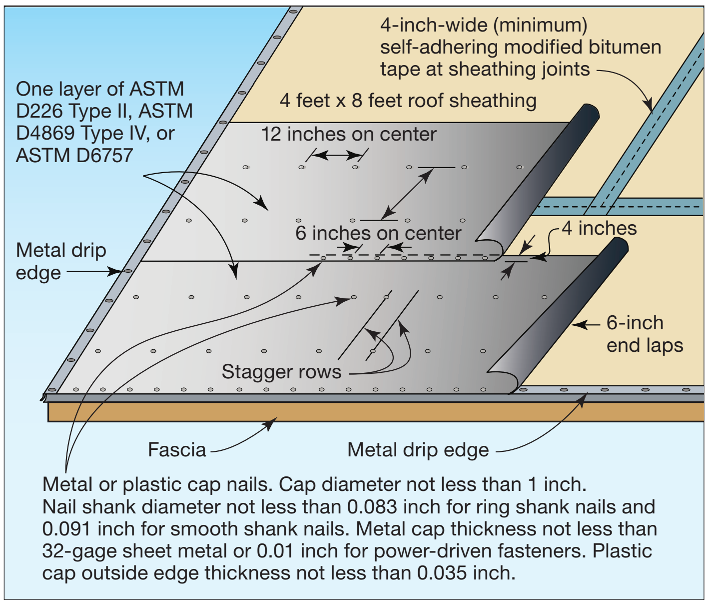

Figure 6: Example 3 – Outside the HVHZ

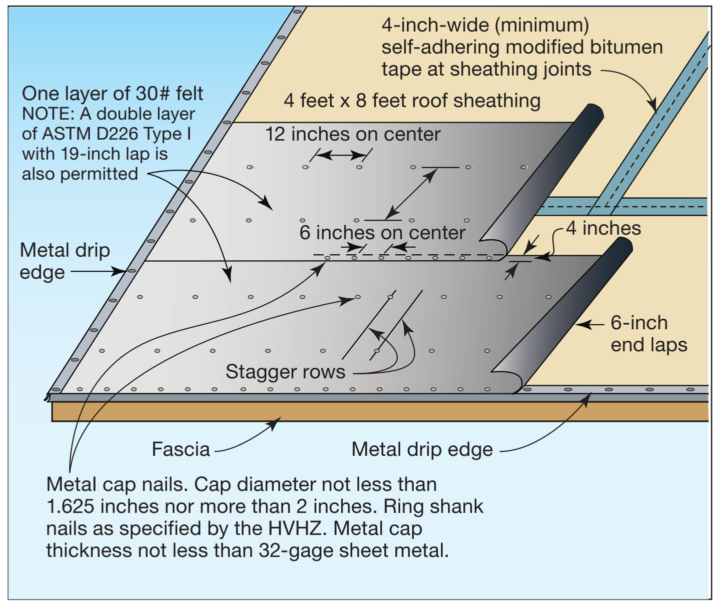

Figure 7: Example 1 – Within the HVHZ

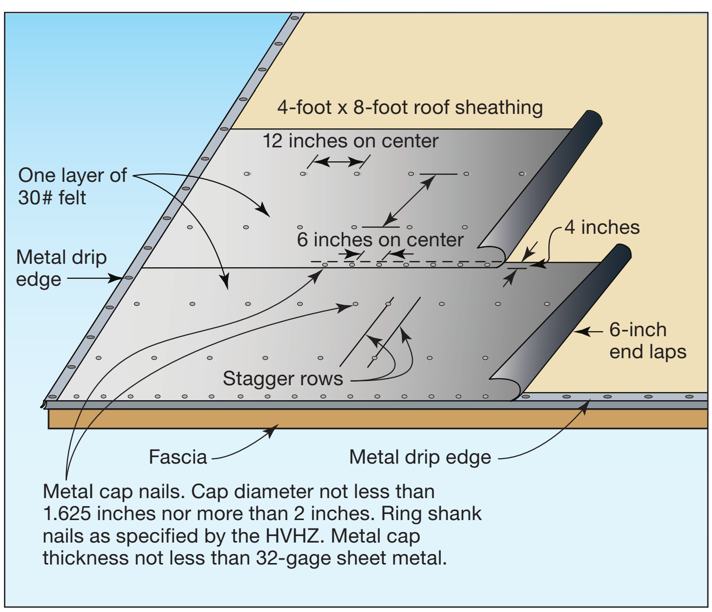

Figure 8: Example 2 – Within the HVHZ

The FBCR and FBCEB codes provide prescriptive solutions for various roof configurations and wall types. They also address the most vulnerable locations by prioritizing mandated roof-to-wall retrofit expenditures.

Commercial Wind Mitigation

While the wind mitigation provisions for commercial buildings are not as encompassing as those for single-family dwellings, the FBCEB requires certain roof components to be evaluated and potentially improved when the roof covering is replaced.

Section 707.3.2 of the FBCEB requires an evaluation of the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections when roofing materials are removed from more than 50 percent of the roof diaphragm or section. If the diaphragm and the connections specified are not capable of resisting 75 percent of the wind loads specified in the FBCB, they are required to be replaced or strengthened to meet those loads (refer to the text box titled "Roof Diaphragms Resisting Wind Loads").

The 6th Edition (2017) FBCEB includes new exceptions to Section 707.3.2 shown in the text box. They are intended to apply to buildings that have been designed for wind loads that are comparable to modern wind load standards. The American Society of Civil Engineers (ASCE) *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-88) and the 1991 Standard Building Code (SBCCI 1991) specified component and cladding loads comparable to the loads in modern codes and standards. When an evaluation is performed by a registered design professional confirming that the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections are in compliance with ASCE 7-88 or the 1991 Standard Building Code, the strengthening or replacing of these components is not required.

Florida Building Code, Existing Building – Roof Diaphragms Resisting Wind Loads

707.3.2 Roof diaphragms resisting wind loads in high-wind regions. Where roofing materials are removed from more than 50 percent of the roof diaphragm or section of a building located where the ultimate design wind speed, V_{ult}, determined in accordance with Figure 1609.3(1) of the Florida Building Code, Building, is greater than 115 mph (51 m/s), as defined in Section 1609 (the High-Velocity Hurricane Zone shall comply with Section 1620) of the Florida Building Code, Building, roof diaphragms, connections of the roof diaphragm to roof framing members, and roof-to-wall connections shall be evaluated for the wind loads specified in the Florida Building Code, Building, including wind uplift. If the diaphragms and connections in their current condition are not capable of resisting at least 75 percent of those wind loads, they shall be replaced or strengthened in accordance with the loads specified in the Florida Building Code, Building.

Exceptions:

1. This section does not apply to buildings permitted subject to the Florida Building Code.
2. This section does not apply to buildings permitted subject to the 1991 Standard Building Code or later edition, or designed to the wind loading requirements of ASCE 7-88 or later editions, where an evaluation is performed by a registered design professional to confirm the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections are in compliance with the wind loading requirements of either of these standards or later editions.
3. Buildings with steel or concrete moment resisting frames shall only be required to have the roof diaphragm panels and diaphragm connections to framing members evaluated for wind uplift.
4. This section does not apply to site built single family dwellings. Site-built single-family dwellings shall comply with Sections 706.7 and 706.8.
5. This section does not apply to buildings permitted within the HVHZ after January 1, 1994, subject to the 1994 South Florida Building Code, or later editions, or where the building's wind design is based on the wind loading requirements of ASCE 7-88 or later editions.

Source: 6th Edition (2017) FBCEB

Similar to the mitigation provisions for residential construction, Section 707.3.2 does not apply to buildings permitted subject to the Florida Building Code. In addition, the provisions do not apply to site-built single-family dwellings, as those structures are addressed in Section R908.7 of the FBCR (also covered in Section 706.7 of the FBCEB).

Buildings with moment-resisting frames do not have roof-to-wall connections and are therefore only required to have roof diaphragm panels and diaphragm connections to framing members evaluated for wind uplift.

References and Resources

References

ASCE (American Society of Civil Engineers). 1988. *Minimum Design Loads for Buildings and Other Structures.* ASCE Standard ASCE 7-88.

ASTM (American Society for Testing and Materials). 2009. *Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing.* D226 / D226M-09.

ASTM. 2015. *Specification for Self-Adhering Polymer Modified Bitumen Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.* D1970 / D1970M-15.

ASTM. 2015. *Specification for Driven Fasteners, Nails, Spikes, and Staples.* F1667-15.

ASTM. 2015. *Standard Test Method for Trapezoid Tearing Strength of Geotextiles.* D4533 / D4533M-15.

ASTM. 2016. *Specification for Asphalt-Saturated Organic Felt Underlayment Used in Steep Slope Roofing.* D4869 / D4869M-16a.

ASTM. 2016. *Standard Specification for Inorganic Underlayment for Use with Steep Slope Roofing Products.* D6757-2016.

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SBCCI (Southern Building Code Congress International). 1991. *Standard Building Code.*

Resources

FEMA (Federal Emergency Management Agency). 2009. *Local Officials Guide for Coastal Construction.* FEMA P-762. https://www.fema.gov/media-library/assets/documents/16036.

FEMA. 2010. *Home Builder's Guide to Coastal Construction.* FEMA P-499. https://www.fema.gov/media-library/assets/documents/6131.

FEMA. 2010. *Wind Retrofit Guide for Residential Buildings.* FEMA P-804. https://www.fema.gov/media-library/assets/documents/21082.

FEMA. 2011. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th Edition.* FEMA P-55. https://www.fema.gov/media-library/assets/documents/3293.

Useful Links

FBC (Florida Building Code), multiple years and editions, can be obtained from ICC at https://codes.iccsafe.org/public/collections/Florida.

Insurance Institute for Business & Home Safety (IBHS) Fortified Home Standards and Technical Bulletins. https://disastersafety.org/fortified/resources/.

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Hurricane Irma Housing Recovery and Mitigation Programs

Monroe County – The Florida Keys

Repair, Reconstruct, Elevate Damaged Homes

- **$50 million in CDBG-DR "Rebuild Florida Program"** allocated to fund the repair, replacement, and elevation of damaged, non-code compliant, primary homes of vulnerable persons and affordable rental properties
- **$3.6 million HMGP** funds to mitigate/reconstruct/elevate non-code compliant homes. Goal is to rebuild 26 homes
- **$848,000 and $349,000 in PDM and FMA** funds requested to mitigate/reconstruct/elevate at risk homes

Mobile Home Park & Parcel Acquisition

- **$10 million in CDBG-DR** for land acquisition of scattered lots and mobile home parks with damaged homes
- **$25 million in CDBG-DR** funds for construction of new, code compliant, affordable workforce rental housing to replace damaged substandard homes
- **County Land Authority** will seek these funds to purchase high-risk, destroyed mobile home parks and scattered lots
- Land is owned by Monroe County, and affordable workforce rental housing is managed by the **Monroe County Housing Authority**

Weatherization

- **$5,000** to low-income homeowners or renters to improve energy efficiency
- Grant funds for contractors to:
  - replace **non-compliant windows or add shutters**,
  - add **insulation** and weather-stripping around doors and windows,
  - replace **non-efficient old appliances**
  - replace incandescent light bulbs with **fluorescent bulbs,**
  - replace low flow toilets and shower heads
- Combine with SHIP rehabilitation funds to maximize weatherization services to the home.

	Cost	Units
Howard's Haven	$ 850,000	10
Conch Key	$ 1,165,000	10
Key Largo	$ 450,000	5
Scattered Sites on BPK	$ 1,360,000	12

Build 4 Tiny Resilient Prototype Homes

- Monroe County contracted 4 different contractors
- Each will build a **model, resilient, code compliant prototype Tiny Home** on County owned land
- Models will serve as affordable and resilient replacement dwellings for homes destroyed by Hurricane Irma
- The goal is to identify unique approaches to **minimize wind and flood risk**, while providing safe, functional, and economical housing solutions

Acquisition / Demolition /Green Space

- **$10 million CDBG-DR – "Voluntary Home Buyout Program" allocated** to purchase damaged or destroyed homes in high risk areas for conservation
- **$16.9 million in HMGP** funding has been requested to purchase high-risk areas and return to open space
- **$953,000 in PDM program** funds to has been requested to purchase high-risk areas and return to open space

Housing Repair

- **$2 million SHIP-DR** funding of up to $35,000, per housing unit for repair of eligible homeowners, with the goal of reducing future risk to Federal, State, and local resources

Housing Mitigation and Recovery Program Abbreviations

CDBG-DR: Community Development Block Grant–Disaster Recovery Program
FMA: Flood Mitigation Assistance Program
HMGP: Hazard Mitigation Grant Program
PDM: Pre-Disaster Mitigation Program
SHIP-DR: Florida State Housing Initiatives Partnership – Disaster Recovery

The Florida Keys – Rising Above Recovery

MONROE COUNTY/CITIES POST-IRMA HOUSING STRATEGY

GOAL: Rebuilding a stronger Florida Keys

- ✓ Promote public health, safety and general welfare;
- ✓ Advance adaptation to coastal flooding, storm surge and other hazards;
- ✓ Protect property, residences and businesses, from storm impacts and minimize damages;
- ✓ Minimize public and private losses due to storms;
- ✓ Preservation of economy during and after disaster, including business viability and workforce housing;
- ✓ Preserve and protect the environment, including natural and historic resources; and enhance resiliency.

STRATEGY: To address the unique challenges and diverse needs in our long term housing recovery

Develop programs to:

- ✓ Wind retrofitting of residential structures – provide funding options to harden existing housing units
  - Installation of hurricane shutters or impact-windows; metal roofs, reinforced trusses and reinforced garage doors
- ✓ Provide funding to elevate existing private residences above BFE (base flood elevation)
- ✓ Provide funding to demolish and replace private residences to meet or exceed Building Code and Floodplain requirements (Demolish and Rebuild of Mitigated Building Envelope)
- ✓ Develop and increase the supply of workforce housing & choice of rental housing opportunities – identify areas of damaged properties or areas of less damaged properties to more easily and more quickly rebuild safe, energy-efficient and cost effective housing units (Community Workforce Housing Programs)
  - Purchase scattered sites for single family homes; purchase parks and redevelop multi-family housing, purchase less vulnerable sites for workforce housing
- ✓ Provide funding to rebuild and repair resilient existing housing units as safe, energy-efficient and coste effective housing units (New construction or rehabilitating residences damaged by the storm)
- ✓ Identify areas to purchase and not rebuild that area (provide financial incentives to purchase areas in dangerous or high-risk zones)
  - Provide funding to purchase developed properties in V-zone with existing residences to create additional open space and natural buffers and rebuild housing outside of V-zone
- ✓ Relocate and rebuild other less vulnerable location – safe, durable, physically accessible, energy-efficient and cost effective housing units (Purchase & Rehab assistance)
- ✓ Provide funding to purchase abandoned/damaged structures and demolish unsafe structures
- ✓ Provide funding to improve infrastructure for drainage at housing units – lessen flooding vulnerability
- ✓ Develop infrastructure for improved mass transit – improve mobility & access to services/ jobs
- ✓ Provide funding to repair and flood-proof commercial structures and add housing units over the commercial structure to improve local economic conditions, particularly the continued availability of workforce housing & jobs (Flood-proofing of Non-residential Structures)
- ✓ Identify/explore cost effectiveness of different types of factory-built housing to replace manufactured housing units.

Damage Assessment Results

PRELIMINARY DAMAGE ASSESSMENT (SUMMARY W PARK INFO) - THRU 11/26/17					
KEY NAME	UNAFFECTED	AFFECTED	MINOR	MAJOR	DESTROYED
KEY LARGO	2581	3992	326	75	46
VILLAGE OF ISLAMORADA	0	468	427	47	34
FIESTA KEY	0	0	0	257	0
CRAIG KEY	0	1	0	0	0
CITY OF LAYTON	4	0	160	15	0
LONG KEY	304	86	14	0	1
CONCH KEY	0	78	13	4	10
DUCK KEY	292	361	83	7	0
CITY OF KEY COLONY BEACH	0	462	888	206	1
CITY OF MARATHON	0	4018	829	1402	394
OHIO KEY	0	0	0	397	0
BAHIA HONDA KEY	6	9	6	0	0
BIG PINE KEY	264	1538	663	299	473
LITTLE TORCH KEY	389	300	80	25	37
MIDDLE TORCH KEY	3	0	12	0	0
BIG TORCH KEY	11	4	37	1	0
RAMROD KEY	31	20	493	12	19
SUMMERLAND KEY	1	706	20	10	1
CUDJOE KEY	134	914	624	52	81
SUGARLOAF KEY	125	995	207	103	19
UPPER SUGARLOAF KEY	175	0	0	0	0
LOWER SUGARLOAF KEY	6	161	110	0	0
SADDLEBUNCH KEYS	82	0	0	0	0
SHARK KEY	0	39	0	0	0
BIG COPPITT KEY	122	538	63	4	6
GEIGER KEY	41	252	0	7	12
ROCKLAND KEY	1	60	31	0	5
KEY HAVEN	0	457	1	0	0
STOCK ISLAND	895	565	22	15	17
CITY OF KEY WEST	0	11625	282	39	23
Grand Total	5467	27649	5391	2977	1179

Lessons Learned:

- ✓ Lack of resources for Recovery, including staff, funding, knowledge of programs
  - ▪ Demolition not allowed
- ✓ Locations for temporary housing – pre-determined/code flexibility
- ✓ Procurement under Federal regulations
- ✓ Long Term Recovery Group formations to link survivors with case management and assistance
- ✓ Substantial Damage and floodplain regulations
- ✓ Insurance (wind & flood)
  - ▪ Promotion to homeowners before a storm
  - ▪ Knowledge of Increased Cost of Compliance (ICC)
  - ▪ Liaison between County and insurance companies

Hurricane Irma Business Recovery Unmet Needs Survey

Summary of Key Findings

May 30, 2019

MONROE COUNTY
FLORIDA

Islamorada Chamber of Commerce

Lower Keys Chamber of Commerce

Legendary Key Largo Chamber of Commerce

Greater Marathon Chamber of Commerce

Hurricane Irma Business Recovery Survey Summary

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Executive Summary

On September 10, 2017, Hurricane Irma made landfall in the Florida Keys as a category four storm. Nearly 18 months later, the island chain's business community continues to struggle to regain full operations. Hotels, attractions, shops, and restaurants are not operating at full capacity due to loss of qualified personnel, destroyed equipment and damaged facilities. Reconstruction of workforce housing and businesses is delayed due to a shortage of construction workers needed to make the repairs. The Florida Keys Commercial Fisherman's Association estimates that the lobster fishing industry alone lost over $42 million in revenue as a result of Hurricane Irma.

Monroe County and its partners, the Chambers of Commerce in Key Largo, Islamorada, Marathon and the Lower Keys are committed to continuing to advocate for the long-term recovery of their community. This survey was conducted to understand unmet needs within the business sector and to inform specific long-term recovery actions in a countywide Post-Disaster Redevelopment Strategy. This document will guide future major long-term recovery projects and priorities for the county and its municipalities. In addition, it will be provided to the Florida Department of Economic Opportunity, as requested, to inform the development of new statewide programs that address long-term economic recovery of the communities that were significantly impacted by Hurricane Irma.

Overwhelmingly, business owners stated that a major recovery issue today is a lack of skilled workers and workforce housing options for employees. While there are housing recovery programs ramping up to address this challenge through funding from the Community Development Block Grant – Disaster Recovery administered through the Florida Department of Economic Opportunity's "Rebuild Florida" program, the Florida Housing Finance Corporation, and many other private sector partners, it will take years for the impacts of these programs to be seen in the Keys. As business owners wait for these resources, they continue to struggle with ongoing issues.

Ongoing Business Recovery Issues in the Keys Following Hurricane Irma

- Over 60 percent of survey respondents represented very small businesses with less than 4 full or part-time employees and most have been in operation for over 10 years.
- Eighty percent of respondents noted a decline in sales and customers for more than 30 days following Hurricane Irma.
- Nearly 60 percent of businesses stated that the assistance they received was not enough to support the long-term recovery of their business.
- Close to 50 percent of business owners report still having physical damage today.
- Fifty-four percent of businesses reported to be uninsured or under-insured. Some business owners who had insurance reported ongoing litigation battles with insurance companies to receive necessary recovery compensation.
- Only 20 percent of respondents received support through a bridge loan with majority of those respondents receiving under $50,000 of support.
- Even with the support provided through insurance, loans and other sources only 47 percent of businesses reported that they were currently stable. This means that almost half of the businesses are experiencing decline, are struggling to stay open or may have already closed in the wake of Hurricane Irma.

- Sixty-five percent of respondents point to financial assistance as the most helpful form of assistance to fully recover their business.

Introduction

Hurricane Irma, a category four storm, struck the Florida Keys on September 10, 2017 devastating communities and exacerbating challenges that have existed for decades. Nearly seventy-five (75) percent of the population was evacuated prior to the storm. Over 4,000 homes were majorly damaged or destroyed. Residents struggle to find places to live as they rebuild their homes and lives. In addition, marine and fisheries related industries were hit hard with more than 1,300 boats damaged, destroyed, or displaced. This displacement of residents and blow to the marine fisheries and tourism industry deeply affected the small businesses that make this community unique.

Hotels, attractions, shops, and restaurants are not operating at full capacity due to loss of qualified personnel, destroyed equipment and damaged facilities. Reconstruction of the housing and businesses that is needed to attract workers back to the community is slow due to a shortage of construction workers needed to make the repairs. This is evident through the blue tarped roofs on homes and closed signs on the doors of businesses that have yet to reopen. **The Florida Keys Commercial Fisherman's Association estimates that the lobster fishing industry alone lost over $42 million in revenue as a result of Hurricane Irma**. About six months after the storm, the International Economic Development Council conducted a door-to-door survey of businesses to better understand their needs. Below is a summary of their key findings:

> *Tourism is a $2.7 billion sector of the economy in Monroe County and employs about half of the county's workforce. Approximately 3 million tourists visit the Keys every year. Last September alone, Monroe County saw a 40 percent decline in hotel room demand.*
>
> *Commercial fishing is the largest single industry by value ($900 million direct impact) and employment (4,500 workers). The Florida Keys Commercial Fishermen's Association estimates lobster fishers lost 94,000 of the 350,000 traps for a loss of $3.7 million in equipment. Lobster output fell by 60 percent last year for an estimated loss of $38.88 million. Total impact to the lobster fishing industry is $42.64 million. (More on the commercial fishing impact was discussed in a separate document provided to IEDC by the association.)*
>
> *Some 56% of the businesses of the Keys are located in Key West. It was not the most physically damaged island during the hurricane, but it did have significant economic impacts that need to be taken into consideration for both the short and long-term. The most serious issue is shortage of worker housing and the need for employees of businesses, both large and small. Workers of Key West cannot commute from mainland Florida, due to the great distance.*

Nearly 18 months later, the workers that are desperately needed to rebuild this economy, have not all returned. To understand the ongoing needs of the business community, Monroe County conducted a follow-up survey in May of 2019. This report details the findings of that survey and will be provided to the Florida Department of Economic Opportunity to inform CDBG-DR economic development programs and to guide long-term economic recovery strategies in the Keys.

Survey Respondent Profile

Monroe County, in partnership with the Chambers of Commerce in Key Largo, Islamorada, Marathon and the Lower Keys to conduct this survey. Eighty-five (85) total responses were received that broadly represent businesses from across the County as detailed in the adjacent graphic.

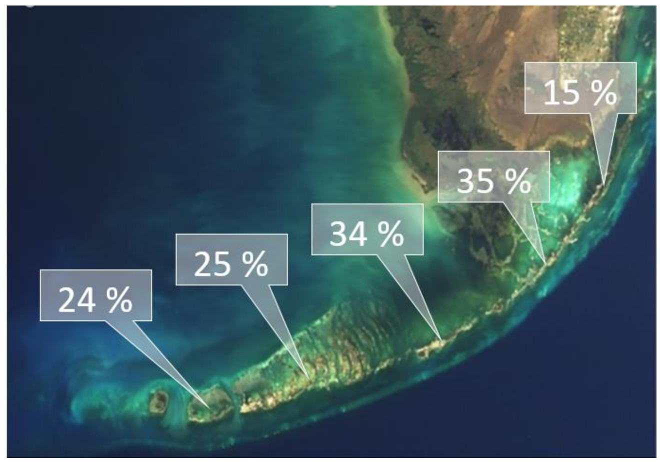


Figure 1: Business Recovery Survey Participation Rates

Reflective of the prevalent tourism-based economy, many respondents were from the Lodging and Hospitality (14 percent), Recreational Water Activities (11 percent), and Restaurants and Nightlife sectors (11 percent). In addition, Marketing and Advertising (8 percent), Commercial Marine Fisheries (8 percent), Shopping and Retail (8 percent), Construction and Home Improvement (6 percent) and Transportation (6 percent) made up the balance of most respondents. Three or less responses were received from the following business sectors:

- Accounting, Banking, Finance
- Business Services
- Education
- Health and Medical
- Real Estate

Other survey respondents who did not feel they fit into the categories established identified as:

- Non-water based recreational providers
- News and Media
- Housekeeping and janitorial services
- Car rental companies
- Automotive repair

Most respondents were very small businesses with less than four full or part-time employees, which points to the strong local business presence in the community. Only 11 percent of responses were from businesses with more than 20 full or part-time employees. The majority of respondents had been in operation within the County for over six years. However, the survey did include representation from some newer businesses that had been in operation for five years or less 18 percent).

Impacts to Businesses Immediately After the Storm

Hurricane Irma brought heavy winds and strong storm surge, leaving almost half of businesses out of operation for more than 30 days. This was primarily due to the need for structural damage (46 percent), loss of supplies and equipment (41 percent) or loss of workers. In fact, **46 percent of respondents reported that their business facility still has physical damage today, 19 months after Hurricane Irma.**

Loss of supplies and equipment also crippled businesses in the wake of Hurricane Irma. Over 40 percent of respondents stated they went over a month lacking supplies or equipment with other businesses (28 percent) reporting a similar condition for less than a month. In addition, communication failures were widespread with nearly 30 percent of respondents stating they experienced challenges with communication beyond the first month of the storm.

The inability of workers to return to their homes also impacted businesses with 35 percent of respondents stating they experienced this challenge beyond the first month of recovery. However, workers seem to be returning to the area as most survey respondents reported they had either more or at least the same number of employees now as they did prior to Hurricane Irma.

Perhaps the biggest impact to the Keys immediately after the storm was the loss of sales and customers, which can likely be attributed to the lack of tourism. **Eighty percent of respondents noted a decline in sales and customers for more than 30 days following Hurricane Irma**.

Summary of Other Immediate Impacts

- Computer system failure was not a long-term issue with only 15 percent of businesses reporting systems to be down for more than 30 days.
- Most businesses (68 percent) reported that lost documents and records either did not affect them at all or at least beyond the first month of recovery.
- While power failure was an issue in the immediate aftermath of the storm, most businesses (81.1 percent) reported that this did not extend beyond 30 days.
- Water failure was an issue with 49 percent of respondents reporting this as an issue for 10 days or less. However, very few (7 percent) reported this issue beyond the first month of recovery.
- As with water failure, wastewater failure was also a short-term issue with over 40 percent of businesses reporting that this affected them for less than 10 days. However, most were operational within the first month of the recovery.
- Many respondents reported a challenge with accessing their business in the immediate aftermath of Hurricane Irma; however, this issue seemed to have been mostly resolved within the first month following the storm with only 10 percent reporting lack of access or transportation to be an issue beyond 30 days.

Resources and Support Provided

After a storm, businesses must rely on reserves, insurance, loans and other support to make repairs, replace damaged equipment and address loss of revenue. Without this type of assistance, many small businesses must close which can have ripple effects on the economy and affect the quality of life of those who live in a community. **Nearly 60 percent of businesses stated that the assistance they received was not enough to support the long-term recovery of their business**.

Insurance

Insurance is the first resource that a business turns to for support. However, 54 percent of businesses reported to be uninsured or under-insured. The following table shows the type of insurance that most respondents reported to have to help them face these challenges.

Table 1. Business Insurance Policies in Effect Post-Storm

Type of Insurance Policy	Percentage of Respondents with Coverage
Business Income Insurance	9%
Business Interruption Insurance	15%
Commercial Automobile Insurance	20%
Flood Insurance	31%
Property Insurance	52%
Workers Compensation Insurance	35%

Other types of insurance coverage reported by businesses include boater's insurance, wind insurance, liability insurance and homeowner's insurance, for business owners who work out of their homes.

Most businesses (67 percent) stated that they either did not receive a payment from their insurance company or that they did not seek this as a resource. However, 12 percent reported receiving under $50,000, 6 percent received between $50,000 - $150,000 and 13 percent received in excess of $150,000 through insurance payouts.

Loans

Businesses can also seek support through loans after a disaster to help bridge the gap between the disaster and insurance payments or help those who were not insured or under-insured. Bridge loans are short-term loans that are intended to bridge the gap to an insurance payment or other forms of assistance, including longer term loans provided through the Small Business Administration (SBA). However, sometimes businesses do not qualify for these loans or may be hesitant to take out a loan in fear of not being able to pay it back in the future. Only 20 percent of respondents received support through a bridge loan with majority of those respondents receiving under $50,000 of support. **Similarly, most respondents (71 percent) reported that they did not receive a SBA loan**. Of those that did receive a loan through SBA, most (13 percent) reported that the loan was under $50,000.

Donations and Philanthropic Support

In some cases, businesses may receive support through a non-profit or charitable organization to support their recovery efforts following a storm. While most respondents (79 percent) reported that they did not receive donations, a small number (12 percent) reported receiving under $50,000 in support through this source. In addition, three respondents reported receiving more than $50,000 in support through donations and philanthropic sources.

Current State of Businesses in the Keys

Even with the support provided through insurance, loans and other sources only 47 percent of businesses reported that they were currently stable. This means that almost half of the businesses are experiencing decline, are struggling to stay open or may have already closed in the wake of Hurricane Irma. Table 4 shows the current condition of businesses, as reported by respondents.

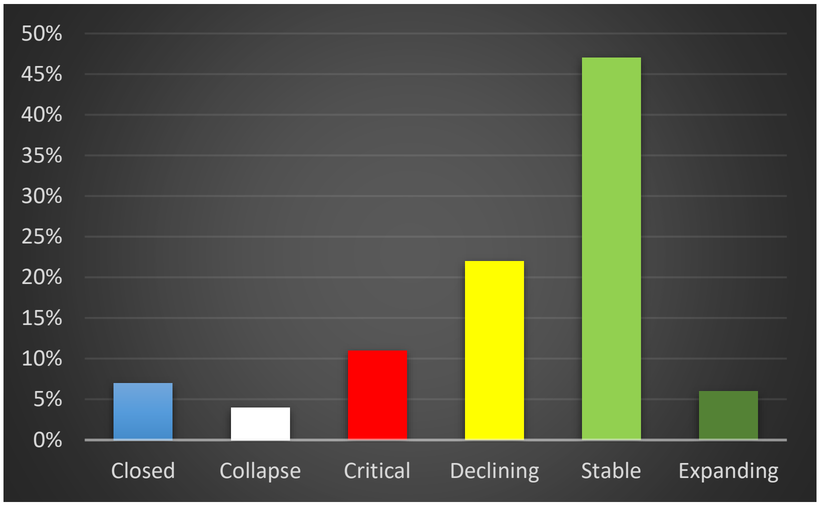


Figure 2 Current Condition of Business

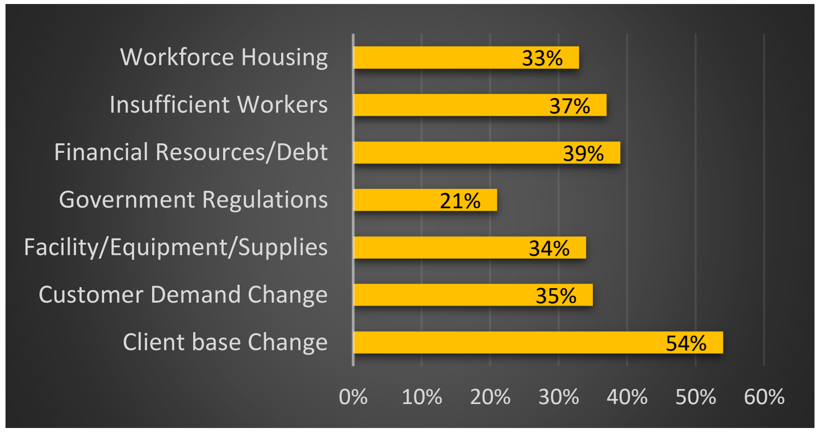
Ongoing Challenges and Unmet Needs

Client Base Change: As the community draws closer to the two-year anniversary of Hurricane Irma, many are still facing significant challenges with recovery. Business owners stated that a primary recovery challenge today is the change in the client base post Hurricane Irma. This could be due to numerous changing demographics of both residents and visitors who are affected by rising cost of travel and accommodations in the Keys and changing needs for good and services post disaster. It is also presently unclear how many residents have permanently relocated outside of the Keys, thereby, decreasing the client base. Business owners also noted that the increase in lodging costs have impacted the expendable income of their customers who can no longer afford some of the activities that they used to enjoy while vacationing in the Keys. Business owners stated that the decline in tourism has impacted their customer base and activities such as destination weddings in the Keys are down significantly and have not yet returned.

Financial Resources: The business community lacks the financial resources to repair structures, replace equipment, and pay off debt. Some business owners noted ongoing battles with insurance companies who are undervaluing the damage to their structures, leading to costly litigation in hopes of getting the resources they need to make them whole. Over a year after the storm, business owners continue to find damage to their structures and systems that were not evident immediately after the storm, compounding their fight with insurance companies and escalating costs to rebuild.

While Bridge Loans and SBA Loans were available after the storm, few businesses took advantage of this opportunity. Several business owners noted that the decline in revenue and increase in operating costs created the concern for long-term ability to repay those loans.

Figure 3: Most Significant Challenge Businesses Continue to Face Today



Workforce: Hurricane Irma exacerbated the workforce crises that the Florida Keys has faced for decades. The lack of skilled tradesmen has drastically affected the reconstruction effort. Businesses repeatedly expressed a lack of qualified, licensed contractors to complete necessary repairs. Businesses also complained of a poor work ethic in the Florida Keys, which is fueled by the strong competition for skilled workers among business owners. Likely, in part due to the lack of housing, many workers have not returned to the Keys and businesses continue to struggle to find the skilled and quality workforce they need to run their businesses at full capacity.

Affordable Workforce Housing: The lack of affordable workforce housing for employees is stifling to businesses across all areas. As an island chain with one main road in and out of the community, limited land available for development, high construction costs, and high rental prices, the need for affordable workforce housing, especially in the Lower Keys, continues to be a challenge. Irma's strong wind and storm surge targeted older, non-code compliant homes built at grade and mobile homes. These less costly residential structures served as de facto affordable workforce housing stock. The business community has begun to construct some housing for their workers (21 percent), but it is far from adequate. This demonstrates a willingness to be part of the solution to the communities overarching problem that affects many different facets. However, with over 60 percent of respondents stating that they are very small businesses with less than four full-time employees, it is likely not financially feasible for many business owners to provide housing.

Numerous post disaster housing recovery programs are designed to address this challenge through the Community Development Block Grant – Disaster Recovery program administered through the Florida Department of Economic Opportunity's "Rebuild Florida" program, the Florida Housing and Finance Corporation funds, and many public and private sector partners. It will take years, however, for the impacts of these programs to be seen in the Keys.

Government Regulations: Other businesses noted a continued struggle with permitting and regulations that affect their ability to recover in a timely manner as an issue that is still prevalent today. As an Area of Critical State Concern with fragile environmental resources, regulations aimed at protecting these resources can be difficult to navigate and lengthen the review time that businesses may have experienced in other parts of the state or nation.

Nearly 80 percent of all businesses reported a decrease in total revenues and almost 75 percent reported a decrease in gross profit. To exacerbate this issue, 55 percent of respondents reported that operating expenses have increased. In addition, almost 65 percent of respondents have taken on new debt since the storm with almost 40 percent reporting that they felt the value of their assets or property has decreased. Table 4 shows the percentage of respondents who felt they were still struggling with common continuing challenges that follow major storm events.

Support Needed to Overcome Challenges

With half of the businesses in the Keys still struggling to get by eighteen months after the storm, respondents feel strongly that more resources are still needed to ensure the long-term recovery of the economy. **Sixty-five percent of respondents point to financial assistance as the most helpful form of assistance to fully recover their business.** Table 6 describe the amount of assistance business owners feel they would need in order to bring their business back to full capacity.

Table 5. Financial Assistance Needed to Fully Recover from Hurricane Irma

Amount of Assistance	Percent of Respondents Who Need this Assistance
No Disaster Assistance Needed	29%
$50,000 or less	26%
$50,000 - $100,000	17%
$100,000 - $150,000	4%
$150,000 - $200,000	7%
More than $200,000	15%

Additional Assistance Needed

In addition to financial assistance, respondents felt that the following types of assistance would also be helpful. The percentage of respondents who indicated that the assistance would be helpful is noted by each of the potential categories.

- Skilled workers (35 percent)
- Equipment and supplies (19 percent)
- Legal/tax services (17 percent)
- Training for workers (13 percent)

Conclusion and Next Steps

The results from this survey demonstrate that there are many businesses in the Florida Keys that continue to struggle nearly 18 months after Hurricane Irma. Monroe County and its partners will use this report to inform specific long-term recovery actions in a countywide Post-Disaster Recovery Strategy. This strategy will guide future major long-term recovery projects and priorities for the county and its municipalities. In addition, it will be provided to the Florida Department of Economic Opportunity as requested to help inform the development of new statewide programs to address long-term economic recovery of the communities that were significantly impacted by Hurricane Irma. The Florida Keys understands that long-term recovery from a major storm can take many years and in some cases over a decade. The Post-Disaster Recovery Strategy is intended to demonstrate the commitment of Monroe County and its partners to the redevelopment of a resilient community that will continue to thrive in the future.

Appendix A: Post Hurricane Irma Business Recovery Survey

Post-Hurricane Irma
Business Recovery Survey

Monroe County, in partnership with the Chambers of Commerce in Key Largo, Islamorada, Marathon, and the Lower Keys, welcomes all business owners/operators or former business owners/operators to complete this Post Hurricane Irma business recovery survey. The purpose of this survey is to determine how the business community is recovering from the impacts of Hurricane Irma. We are interested in determining what actions can be taken to continue to support economic redevelopment. This survey will also help to determine the need for any financial programs to help businesses in their long-term recovery from Irma. The survey has 23 questions and should take approximately 15 minutes to complete. This survey may be completed online at: **http://www.monroecounty-fl.gov/2019businesssurvey** or you may email it to **Wetherington-Helene@monroecounty-fl.gov.**

1. **Business Location/s:** (Mark all responses that apply to your business location/s)

- ☐ Upper Keys (Key Largo area)
- ☐ Upper Keys (Islamorada area)
- ☐ Middle Keys (Marathon area)
- ☐ Lower Keys (south/west of the 7-mile bridge)
- ☐ Key West

2. **Please indicate the type of business you own or operate**: (Mark one response)

- ☐ Accounting, Banking,
- ☐ Finance
- ☐ Business Services
- ☐ Construction & Home Improvement
- ☐ Commercial Marine Fisheries
- ☐ Education
- ☐ Health and Medical
- ☐ Insurance
- ☐ Legal Services
- ☐ Lodging & Hospitality
- ☐ Marketing & Advertising
- ☐ Real Estate
- ☐ Recreational Water Activities
- ☐ Restaurants & Nightlife
- ☐ Shopping & Retail
- ☐ Transportation
- ☐ Utilities
- ☐ Other:____________________

3. **Please indicate the total number of FULL-TIME employees (30+ hours) working in your business TODAY: (Mark one response)**

   ☐ Business Closed
   ☐ 1 to 4 full time employees
   ☐ 5 to 9 full time employees
   ☐ 10 to 19 full time employees
   ☐ 20 to 99 full time employees
   ☐ More than 100 full time employees

4. **Please indicate the total number of PART-TIME employees (less than 30+ hours) working in your business TODAY: (Mark one response)**

   ☐ Business Closed
   ☐ 1 to 4 part time employees
   ☐ 5 to 9 part time employees
   ☐ 10 to 19 part time employees
   ☐ 20 to 99 part time employees
   ☐ More than 100 part time employees

5. **Before Hurricane Irma (September 10, 2017) impacted your business did you have more or less total employees?**

   ☐ More employees before Hurricane Irma
   ☐ Less employees before Hurricane Irma
   ☐ About the same amount of employees before and after Hurricane Irma
   ☐ Not applicable

6. **How long has your business been in operation within Monroe County? (Mark one response)**

   ☐ Less than two years. Business opened after Hurricane Irma (September 10, 2017)
   ☐ 2-5 years
   ☐ 6-10 years
   ☐ More than 10 years
   ☐ Not operational today

7. **How long was your business OUT OF OPERATION due to Hurricane Irma? (Mark one response)**

   ☐ No loss of operation
   ☐ Less than 10 days
   ☐ Between 10 Days and 30 Days

☐ More than 30 Days

☐ Not sure

8. **How long did it take your business to repair/restore the following after Hurricane Irma?** (Mark one response for each of the items).

a. Structure Repair:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

b. Loss of Supplies and Equipment:

☐ less than 10 days ☐ 10 to 30 days ☒ more than 30 days☐ Not applicable

c. Loss of sales/customers:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

d. Loss of Workers:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

e. Failed Computer System:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

f. Lost Documents & Records:

☒ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

9. **Does your business facility still have physical damage due to Hurricane Irma?**

☐ Yes

☐ No

10. **How long did the following situations significantly impact your business operation?** (Mark one response for each of the items).

a. Communication Failure:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

b. Power Failure:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

c. Water Failure:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

d. Wastewater Failure:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

e. Access to my Business:

☐ less than 10 days ☐ 10 to 30 days ☐ more than 30 days ☐ Not applicable

11. **What type of insurance did your business have prior to Hurricane Irma (September 10, 2017)**

    ☐ No Insurance Coverage
    ☐ Flood Insurance
    ☐ Property Insurance
    ☐ Business Interruption Insurance
    ☐ Business Income Insurance
    ☐ Commercial Automobile Insurance
    ☐ Workers' Compensation Insurance
    ☐ Not applicable
    ☐ Other: ________________________________

12. **In hindsight, were you adequately insured, under-insured, or not insured for the impacts caused by Hurricane Irma?** (Mark one response)

    ☐ Adequately insured
    ☐ Under-insured
    ☐ Not insured

13. **Please indicate the amount of assistance you have received to help your business recover: (Mark all items that apply).**

    a. Insurance Payments:

    ☐ under $50,000 ☐ between $50,000 - $150,000 ☐ more than $150,000 ☐ not applicable

    b. Federal Emergency Management Agency (FEMA) Assistance

    ☐ under $50,000 ☐ between $50,000 - $150,000 ☐ more than $150,000 ☐ not applicable

    c. Bridge Loans

    ☐ under $50,000 ☐ between $50,000 - $150,000 ☐ more than $150,000 ☐ not applicable

    d. Small Business Administration (SBA) Loans

    ☐ under $50,000 ☐ between $50,000 - $150,000 ☐ more than $150,000 ☐ not applicable

    e. Donations/philanthropic sources

    ☐ under $50,000 ☐ between $50,000 - $150,000 ☐ more than $150,000 ☐ not applicable

14. Was the assistance you received sufficient to support the long-term recovery of your business?

- ☐ Yes
- ☐ No
- ☐ Don't know

15. Did you relocate your business due to the impacts of Hurricane Irma?

- ☐ Yes
- ☐ No
- ☐ Other

16. **What is the current condition of your business as compared to the same timeframe before Hurricane Irma?** (Mark only one response)

- ☐ Expanding: Business is **exceeding** expected gross profit margins
- ☐ Stable: Business is **meeting** expected gross profit margins
- ☐ Declining: Business is up to **25% below** expected gross profit margin
- ☐ Critical: Business is operating between **25-50 % below** expected gross profit margins
- ☐ Collapse: Business is operating at **more than 50% below** expected gross profit margins
- ☐ Business is Closed
- ☐ Not applicable

17. **How did Hurricane Irma impact the following**

a.	Total revenues	☐ Increased	☐ Decreased	☐ About the Same
b.	Operating expenses	☐ Increased	☐ Decreased	☐ About the Same
c.	Value of assets/property	☐ Increased	☐ Decreased	☐ About the Same
d.	Debt	☐ Increased	☐ Decreased	☐About the Same
e.	Gross Profit	☐ Increased	☐ Decreased	☐ About the Same

18. What are the most significant challenges your business continues to face as a result of Hurricane Irma? (Mark all responses that apply)

- ☐ Facility, equipment and supplies
- ☐ Client base change
- ☐ Customer demand change
- ☐ Not enough workers
- ☐ Lack of financial resources / debt
- ☐ Government regulations
- ☐ Workforce Housing

19. **Indicate what type of assistance is needed to fully recover your business?** (Mark all responses that apply)

- ☐ Financial support
- ☐ Training for workers
- ☐ Equipment and Supplies
- ☐ Skilled Workers
- ☐ Legal / Tax Services

20. **Estimate how much funding you would need to bring your business operations to full capacity**? (Mark one response)

- ☐ No disaster assistance funds needed
- ☐ $50,000 or less would be required to support business recovery
- ☐ $50,001-$100,000 would be required to support business recovery
- ☐ $100,001-$150,000 would be required to support business recovery
- ☐ $150,001-$200,000 would be required to support business recovery
- ☐ $200,001 or more would be required to support business recovery

21. How many housing units do you provide for your work force? (Mark one response)

- ☐ Provide no employee housing
- ☐ Provide housing for 20 percent of my employees
- ☐ Provide housing for 50 percent of my employees
- ☐ Provide housing for more than 50 percent of my employees

22. Would you be interested in learning more about how to build a more resilient business? (Mark one response)

- ☐ Yes
- ☐ No
- ☐ Maybe

23. Comments: What is the major challenge you are facing 18 months after the storm?

Appendix B: Survey Data

Showing submissions from 4/28/2019 - 5/28/2019

1. Mark all Business Location(s).

84 of 85 Answered (98.8%)
Checkbox
Key West (20 responses, 23.5%)
Lower Keys (south/west of the 7 mile bridge) (21 responses, 24.7%)
Middle Keys (Marathon area) (29 responses, 34.1%)
Upper Keys (Islamorada area) (30 responses, 35.3%)
Upper Keys (Key Largo area) (13 responses, 15.3%)

2. Indicate the type of business you own or operate.

72 of 85 Answered (84.7%)
Radio Buttons
Accounting, Banking, Finance (2 responses, 2.4%)
Business Services (1 response, 1.2%)
Commercial Marine Fisheries (7 responses, 8.2%)
Construction & Home Improvement (5 responses, 5.9%)
Education (2 responses, 2.4%)
Health and Medical (3 responses, 3.5%)
Insurance (0 responses, 0.0%)
Legal Services (1 response, 1.2%)
Lodging & Hospitality (12 responses, 14.1%)
Marketing & Advertising (7 responses, 8.2%)
Real Estate (2 responses, 2.4%)
Recreational Water Activities (9 responses, 10.6%)
Restaurants & Nightlife (9 responses, 10.6%)
Shopping & Retail (7 responses, 8.2%)
Transportation (5 responses, 5.9%)
Utilities (0 responses, 0.0%)

2a: Other: List your business type if not included above. Otherwise proceed to the next question.

Long Answer
38 of 85 Answered (44.7%)

3. Please indicate the total number of FULL-TIME employees (30+ hours) working in your business TODAY.

82 of 85 Answered (96.5%)
Drop-Down
More than 100 full time employees (1 response, 1.2%)
1 to 4 full time employees (53 responses, 62.4%)
10 to 19 full time employees (7 responses, 8.2%)
20 to 99 full time employees (6 responses, 7.1%)
5 to 9 full time employees (8 responses, 9.4%)
Business Closed (7 responses, 8.2%)

4. Please indicate the total number of PART-TIME employees (less than 30+ hours) working in your business TODAY.

62 of 85 Answered (72.9%)
Drop-Down

1 to 4 part time employees (42 responses, 49.4%)
10 to 19 part time employees (3 responses, 3.5%)
20 to 99 part time employees (1 response, 1.2%)
5 to 9 part time employees (9 responses, 10.6%)
Business Closed (6 responses, 7.1%)
More than 100 part time employees (1 response, 1.2%)

5. Before Hurricane Irma impacted your business did you have more or less total employees?

80 of 85 Answered (94.1%)
Drop-Down
About the same amount of employees before and after Hurricane Irma (34 responses, 40.0%)
Less employees before Hurricane Irma (7 responses, 8.2%)
More employees before Hurricane Irma (26 responses, 30.6%)
Not applicable (13 responses, 15.3%)

6. How long has your business been in operation within Monroe County?

81 of 85 Answered (95.3%)
Drop-Down
Less than 2 years. Business opened after Hurricane Irma (September 10, 2017) (2 responses, 2.4%)
More than 10 years (47 responses, 55.3%)
2-5 years (13 responses, 15.3%)
6-10 years (19 responses, 22.4%)
Not operational today (0 responses, 0.0%)

7. How long was your business OUT OF OPERATION due to Hurricane Irma?

83 of 85 Answered (97.6%)
Drop-Down
Between 10 Days and 30 Days (26 responses, 30.6%)
Less than 10 days (13 responses, 15.3%)
More than 30 Days (41 responses, 48.2%)
No loss of operation (3 responses, 3.5%)
Not sure (0 responses, 0.0%)

8 (a): Structure Repair

85 of 85 Answered (100.0%)
Drop-Down
10-30 days (8 responses, 9.4%)
Less than 10 days (12 responses, 14.1%)
More than 30 days (39 responses, 45.9%)
Not applicable (26 responses, 30.6%)

8 (b): Loss of Supplies and Equipment

82 of 85 Answered (96.5%)
Drop-Down
10-30 days (12 responses, 14.1%)
Less than 10 days (12 responses, 14.1%)
More than 30 days (35 responses, 41.2%)
Not applicable (23 responses, 27.1%)

8 (c): Loss of sales/customers

83 of 85 Answered (97.6%)
Drop-Down
10-30 days (10 responses, 11.8%)
Less than 10 days (3 responses, 3.5%)
More than 30 days (68 responses, 80.0%)
Not applicable (2 responses, 2.4%)

8 (d): Loss of workers

79 of 85 Answered (92.9%)
Drop-Down
10-30 days (12 responses, 14.1%)
Less than 10 days (7 responses, 8.2%)
More than 30 days (30 responses, 35.3%)
Not applicable (30 responses, 35.3%)

8 (e): Failed Computer System

82 of 85 Answered (96.5%)
Drop-Down
10 to 30 days (23 responses, 27.1%)
less than 10 days (19 responses, 22.4%)
more than 30 days (13 responses, 15.3%)
Not applicable (27 responses, 31.8%)

8 (f): Lost Documents & Records:

79 of 85 Answered (92.9%)
Drop-Down
10 to 30 days (4 responses, 4.7%)
less than 10 days (11 responses, 12.9%)
more than 30 days (21 responses, 24.7%)
Not applicable (43 responses, 50.6%)

9. Does your business facility still have physical damage due to Hurricane Irma?

85 of 85 Answered (100.0%)
Drop-Down
No (46 responses, 54.1%)
Yes (39 responses, 45.9%)

10 (a): Communication Failure

83 of 85 Answered (97.6%)
Drop-Down
10-30 days (26 responses, 30.6%)
Less than 10 days (26 responses, 30.6%)
More than 30 days (27 responses, 31.8%)
Not applicable (4 responses, 4.7%)

10 (b): Power failure:

85 of 85 Answered (100.0%)
Drop-Down
10-30 days (28 responses, 32.9%)
Less than 10 days (41 responses, 48.2%)
More than 30 days (10 responses, 11.8%)
Not applicable (6 responses, 7.1%)

10 (c): Water failure:

84 of 85 Answered (98.8%)
Drop-Down
10-30 days (18 responses, 21.2%)
Less than 10 days (42 responses, 49.4%)
More than 30 days (6 responses, 7.1%)
Not applicable (18 responses, 21.2%)

10 (d): Wastewater failure:

82 of 85 Answered (96.5%)
Drop-Down
10-30 days (10 responses, 11.8%)
Less than 10 days (38 responses, 44.7%)
More than 30 days (4 responses, 4.7%)
Not applicable (30 responses, 35.3%)

10 (e): Access to my business/Transportation:

84 of 85 Answered (98.8%)
Drop-Down
10-30 days (27 responses, 31.8%)
Less than 10 days (30 responses, 35.3%)
More than 30 days (8 responses, 9.4%)
Not applicable (19 responses, 22.4%)

11. What type of insurance did your business have prior to Hurricane Irma (September 10, 2017).

81 of 85 Answered (95.3%)
Checkbox
Business Income Insurance (8 responses, 9.4%)
Business Interruption Insurance (13 responses, 15.3%)
Commercial Automobile Insurance (17 responses, 20.0%)
Flood Insurance (26 responses, 30.6%)
No Insurance Coverage (19 responses, 22.4%)
Not applicable (9 responses, 10.6%)
Property Insurance (44 responses, 51.8%)
Workers' Compensation Insurance (30 responses, 35.3%)

11 a: Other: List other types of business insurance not listed above.

Short Answer
37 of 85 Answered (43.5%)

12. In hindsight, were you adequately insured, under-insured, or not insured for the impacts caused by Hurricane Irma?

84 of 85 Answered (98.8%)
Drop-Down
Adequately insured (38 responses, 44.7%)
Not insured (17 responses, 20.0%)
Under-insured (29 responses, 34.1%)

14 (a): Insurance Payments

83 of 85 Answered (97.6%)
Drop-Down
between $50,000 - $150,000 (5 responses, 5.9%)
more than $150,000 (11 responses, 12.9%)

Not applicable (57 responses, 67.1%)
under $50,000 (10 responses, 11.8%)

14 (b): Federal Emergency Management Agency (FEMA) Assistance

82 of 85 Answered (96.5%)
Drop-Down
between $50,000 - $150,000 (1 response, 1.2%)
more than $150,000 (0 responses, 0.0%)
not applicable (67 responses, 78.8%)
under $50,000 (14 responses, 16.5%)

14 (c): Bridge Loans

78 of 85 Answered (91.8%)
Drop-Down
between $50,000 - $150,000 (4 responses, 4.7%)
more than $150,000 (2 responses, 2.4%)
not applicable (61 responses, 71.8%)
under $50,000 (11 responses, 12.9%)

13 (d): Small Business Administration (SBA) Loans

81 of 85 Answered (95.3%)
Drop-Down
between $50,000 - $150,000 (5 responses, 5.9%)
more than $150,000 (4 responses, 4.7%)
not applicable (60 responses, 70.6%)
under $50,000 (12 responses, 14.1%)

13 (e): Donations/philanthropic sources

81 of 85 Answered (95.3%)
Drop-Down
between $50,000 - $150,000 (3 responses, 3.5%)
more than $150,000 (1 response, 1.2%)
not applicable (67 responses, 78.8%)
under $50,000 (10 responses, 11.8%)

14. Was the assistance you received sufficient to support the long-term recovery of your business?

82 of 85 Answered (96.5%)
Drop-Down
Don't know (18 responses, 21.2%)
No (50 responses, 58.8%)
Yes (14 responses, 16.5%)

15: Did you relocate your business due to the impacts of Hurricane Irma?

82 of 85 Answered (96.5%)
Drop-Down
No (69 responses, 81.2%)
Other (4 responses, 4.7%)
Yes (9 responses, 10.6%)

16. What is the current condition of your business?

83 of 85 Answered (97.6%)
Drop-Down

Closed: Business is closed (6 responses, 7.1%)
Collapse: Business is operating at more than 50% below expected gross profit margins (3 responses, 3.5%)
Critical: Business is operating between 25-50 % below expected gross profit margins (9 responses, 10.6%)
Declining: Business is up to 25% below expected gross profit margin (19 responses, 22.4%)
Expanding: Business is exceeding expected gross profit margins (5 responses, 5.9%)
Not applicable (1 response, 1.2%)
Stable: Business is meeting expected gross profit margins (40 responses, 47.1%)

17 (a): Total revenues

85 of 85 Answered (100.0%)
Drop-Down
About the same (12 responses, 14.1%)
Decreased (66 responses, 77.6%)
Increased (7 responses, 8.2%)

17 (b): Operating Expenses

85 of 85 Answered (100.0%)
Drop-Down
About the Same (28 responses, 32.9%)
Decreased (10 responses, 11.8%)
Increased (47 responses, 55.3%)

17 (c): Value of assets/property

83 of 85 Answered (97.6%)
Drop-Down
About the Same (46 responses, 54.1%)
Decreased (33 responses, 38.8%)
Increased (4 responses, 4.7%)

17 (d): Debt

84 of 85 Answered (98.8%)
Drop-Down
About the Same (29 responses, 34.1%)
Decreased (0 responses, 0.0%)
Increased (55 responses, 64.7%)

17 (e): Gross Profit

85 of 85 Answered (100.0%)
Drop-Down
About the Same (15 responses, 17.6%)
Decreased (63 responses, 74.1%)
Increased (7 responses, 8.2%)

18. What are the most significant challenges your business continues to face as a result of Hurricane Irma?

83 of 85 Answered (97.6%)
Checkbox
Client base change (46 responses, 54.1%)
Customer demand change (30 responses, 35.3%)
Facility, equipment, supplies damaged (29 responses, 34.1%)
Government regulations (18 responses, 21.2%)

Lack of financial resource / Debt (33 responses, 38.8%)
Not enough workers (31 responses, 36.5%)
Workforce Housing (28 responses, 32.9%)

19. Indicate what type of assistance is needed to fully recover your business:

75 of 85 Answered (88.2%)
Checkbox
Equipment and supplies (16 responses, 18.8%)
Financial support (55 responses, 64.7%)
Legal/Tax services (14 responses, 16.5%)
Skilled workers (30 responses, 35.3%)
Training for Workers (11 responses, 12.9%)

20. Estimate how much funding you would need to bring your business to full capacity:

83 of 85 Answered (97.6%)
Drop-Down
$100,001-$150,000 would be required to support business recovery (3 responses, 3.5%)
$150,001-$200,000 would be required to support business recovery (6 responses, 7.1%)
$200,001 or more would be required to support business recovery (13 responses, 15.3%)
$50,000 or less would be required to support business recovery (22 responses, 25.9%)
$50,001-$100,000 would be required to support business recovery (14 responses, 16.5%)
No disaster assistance funds needed (25 responses, 29.4%)

21. How many housing units do you provide for your workforce?

83 of 85 Answered (97.6%)
Drop-Down
Provide housing for 20% of my employees (15 responses, 17.6%)
Provide housing for 50% of my employees (1 response, 1.2%)
Provide housing for more than 50% of my employees (2 responses, 2.4%)
Provide no employee housing (65 responses, 76.5%)

22. Would you be interested in learning more about how to build a more resilient business?

83 of 85 Answered (97.6%)
Drop-Down
Maybe (28 responses, 32.9%)
No (17 responses, 20.0%)
Yes (38 responses, 44.7%)

23. Comments: What is the major challenge you are facing 18 months after the storm

Long Answer
69 of 85 Answered (81.2%)

First Name

Short Answer
55 of 85 Answered (64.7%)

Last Name

Short Answer
54 of 85 Answered (63.5%)

Email:

Short Answer
58 of 85 Answered (68.2%)

Business Name:

Short Answer
55 of 85 Answered (64.7%)

Appendix C: Survey Long-form Answers

Question 2a: List your business type, if not included above. Note: This information has not been edited and is captured as provided.

1. Chamber of Commerce
2. News....we report the news!
3. Recreational_ non water activities
4. Charter Boat
5. Fishing, snorkeling, lobstering charters. Offshore/backcountry
6. On location Wedding planning, Photography, Officiants.
7. Custom Frame shop
8. Flats Fishing Charters
9. Janitorial , vacation rental cleaning.
10. DESIGN SERVICES
11. Housekeeping business
12. Radio Station
13. Sale of signs, banners, t-shirts, promotional products
14. Window Cleaning
15. Guided Bicycle Tour
16. Swimming pool.
17. 30 years in same location-dinner only restaurant-Mangia Mangia
18. Web based retail
19. We are a marketing and advertising company that focuses on lodging and hospitality
20. Religious and non-profit
21. Thrifty Car rental
22. commercial charter boat - six pack off shore
23. Offshore Charter Fishing
24. Charter fishing guide
25. Automotive: Tire repair & replace. Front end service, brakes, etc. Oil change, fluid flushes.
26. Professional Musician and sound technician.
27. Non profit
28. Sightseeing Tours
29. Music Entertainment...performing as the "Coconut Cowboy" with the following services provided: Solo, Dou or Full Band (4 people)
30. Marina
31. Charter Boat
32. Music & Arts
33. Fishing Guide
34. Alternative health & wellness i.e. massage & homeopathic care.
35. Franchise Creation/Development
36. Marina and Restaurant plus employee housing
37. Mobile Home/RV park

Question 11a: Other: List other types of business insurance not listed above.

1. Marine Boat Insurance
2. FYI: There is NO SUCH THING as "BUSINESS INCOME INSURANCE" Believe me.
3. Boat insurance
4. Wind
5. Wind
6. Wind Insurance
7. wind
8. liability umbrella
9. wind
10. Liability
11. liability and fire
12. hull & machinery-medical- pollution-collision-liability1 million,protection & Indemnity
13. Liability
14. Boat Insurance, which is the only thing available
15. Commercial marine liability
16. liquor liabilty insurance
17. Liability
18. wind
19. Liability
20. Wind
21. Wind
22. General Compensation Insurance
23. Homeowners
24. Liability
25. E & O
26. Liability insurance
27. renters insurance
28. Fuel storage tank liability
29. Professional & General Liability Insurance

Question 23: Comments: What is the major challenge you are facing 18 months after the storm

1. Work force housing -
2. Less tourists came to Key West after the storm. However, my business is located in Key West and had no physical damage.
3. shortage of workforce housing....this is critical
4. New arriving competition busnesses
5. Customer
6. Lease breached by thd landlord, Postcard Inn. Business has all funds/workers/equipment to reopen but has been denied by Postcard Inn mangement/owners since Irma.
7. Clients stopped advertising... my income dropped 50% in the first 3 months...and then the landlord upped my rent by 45%!

8. The FEMA question is a joke. There was zero help. As well as Emergency assistance. After many hours and long drives being promised help with getting ourselves back up and running, we were denied because we weren't actually open or us, the business owner, going out and getting a job while we tried to rebuild and open. The housing question is also weird - we have units for housing but not anywhere near the numbers listed.
9. People that want to work. We can find people, but they don't want to really work. Working full time would kill them. Helping do the things that need to be done to re-open, too much work for the people we were finding.
10. No employees.
11. Easier Permitting by the City, location of debris fields needs to change.
12. Equipment such as ice machines, freezers, bait, tackle, bait pens all destroyed.

    No gas stations for fuel. No hotels for clients, no marinas for pick ups. No tourists for business.
13. Cancer
14. The wedding business in the Florida Keys has been DOWN a minimum of 50 to 60 %....for 3 years now. It began with the ZIKA VIRUS scare, then it came back a little when that bad news all disappeared from the news.....and they we got crushed with IRMA. In a nut shell.....the Wedding business in the Keys and especially Key West has been down by 60% for too long now.....and DOESN'T APPEAR to be coming back.
15. decideing if it is worth it to keep the business open
16. Trying to recover financially
17. Work from home. Roof leaking, electrical issues, hot water heater broken, plumbing issues.
18. Government overreach/intrusion; insurance not paying/litigation; slow response time from County Growth Management
19. Citizens was awful War to get paid It took more than 14 months and losses were more than they paid. Bank was no help
20. Not finding enough trained or willing to be trained people in town to work.
21. Getting approval to rebuild, housing for employees
22. We were not located in the Keys prior to Irma, so we have to experience to draw from; however, we have certainly seen the lingering impact on Monroe County, specifically Marathon/Big Pine. We are eager to be of any assistance to Monroe County, in this, or other, endeavors.
23. Lack of workers
24. Our Radio tower equipment was heavily damaged, we did not realize the extent of the damage to the tower until just last week. This was just in April 2019. We are facing a six figure repair bill to repair damage to our tower.
25. Still dealing with rebuilding client base as many customers left the Keys or closed their doors. Other curtailed spending in my product categories to put funds toward recovery.
26. Employees
27. Work force and work force housing
28. The only challenge has been qualified workers, but that was the problem before too. It just seems like there's less housing in Key West since the storm that's available to workers.

29. Stop pretending that the builders will build "affordabile or workforce housing" .they havent and won't. The county needs to force the military to either fix the base housing and have their peiople live there or fix the base housing and allow workers to live there. We dont need "more" the county has poroven that they can not manage what they have - 800+ units by their own reporting 80% of current AH is owned by people who neither live or work here.
30. Keeping stable skilled employees.
31. Rising out of Debt; paying off the SBA emergency loan; employee stability/housing
32. Increase customers
33. Employees had to leave as the work wasn't available to sustain themselves, and they never returned.
34. Customer base is reluctant to spend money to promote their business
35. Lack of skilled workers and affordable places for them to live.
36. Insurance (wind and flood) will not pay. We are in a lawsuit. Total amount paid was less than $100,000 with damages of over $3,000,000. Our attorneys have structural engineers and contractors who support our damage claims. Dealing with insurance companies after the storm was almost as bad as the storm itself.
37. We need a new roof and at present have not been able to find the funding.
38. Trying to make up for the loss income when slow season comes in the summer just extremely tight on funds to continue flow.
39. Rebuilding lost storage areas, skilled labor
40. Although hotels have finally reopened returning tourist traffic to our store, customers no longer have expendable income because the cost of those hotel rooms have increased significantly. The tourists that used to visit annually are unhappy with the increased hotel prices and are seeking new destinations to visit.
41. The hotel we operated our business at closed. It took 18 months for the resort to rebuild. We lost most of our equipment do to damage as well as the facility we operated at on the beach. Because we had a legal binding contract to operate out of the resort we were asked to wait and rebuild. We were encouraged to take out an SBA loan as we waited for the resort to rebuild. After 18 months We were then informed that our contract was going to be breached by the resort. Because of the amount of money they received from their insurance they were able to operate from in-house rather than honor our contract. We suffered a total loss because of the impact hurricane Irma had on the resort. We also had loss of income for those 18 months and as a result of not being able to apply the SBA business loan to reopen we had to relocate for employment and put our Keys home up for sale.
42. trying to pay back loans taken out to keep business afloat.
43. Employees having a place to live
44. Loss of revenue from delays in corporate owned resorts not opening in a timely mannor... loss of tourism due to not having facilities open in timely fashion
45. paying off debt
46. My biggest challenge has been customers not being able to find reasonable lodging in Islamorada. I have not increased my prices to try to attract customers but I continue to hear complaints about room rates. Im afraid that we are out pricing ourselves

47. Financial

    Unable to pay bills

48. My business plan is based on tourism and the challenge is the enough tourist traffic for resorts and restaurants to warrant daily opportunity to work. I will have to leave the area again this year to fill in the open calendar
49. Lack of affordable housing. Delays in construction projects due to contractors not showing up.
50. our sign is still not fixed, job is to small for most contractors, local customers do not have the consistent income to spend, gaining new customers, tourists.
51. The above is given from the perspective of a Artist/Entertainer that has had the blessed opportunity to "perform my service" of entertaining in several business environments that have been altered and/or no longer exist...therefore creating a "major negative opportunity impact" on individuals like me that provide similar services. Business that have "not recovered" due to the incredible impact that Hurricane Irma created include EVERY ENVIRONMENT I perform in. NO EMPLOYEE HOUSEING affects the NUMBER of AVAILABLE within the WORKFORCE as THE NUMBER OF JOBS continue to IMPROVE as each BUSINESS ENVIRONMENT attempts to MAKE POSITIVE STRIDES over the course of the LAST 18 MONTHS...in their ATTEMPT to "GET BACK" to where their "BUSINESS BECOMES PROFITABLE". The lack of within the AVAILABLE WORKFORCE "LOCALLY" (not from HOMESTEAD or the MAINLAND) has made businesses RE-ADJUST their "BUSINESS MODELS" for making a profit and, as NEW & OLD BUSINESS slowly RE-OPEN, they are PULLING THE WORKFORCE AWAY from these EXISTING, OPERATIONAL BUSINESSES therefore creating a "COMPETITION" amongst themselves regarding EMPLOYEE PAY/SALARY...while still HAVING THE SAME AMOUNT OF WORKERS to pick from WITHIN THIS ENVIRONMENT. More WORKERS that HAVE to COME DOWN from the MAINLAND, traveling BACK & FORTH everyday CREATES MANY ISSUES...ON MANY LEVELS...not to mention TRAFFIC.
52. Fishing recovery is slow. Probably years for things to get back to pre Irma fushing.
53. Bringing customers back
54. Lack of clients. Restaraunt and bar at the marina I am based out of was torn down due to Hurricane Irma. Which affected my business greatly.
55. holding onto damaged records, hoping to destroy soon.
56. Buyer confidence
57. Getting out of debt
58. Survival
59. As an Eco Tour guide, the amount of hurricane debris still in our mangroves and coastal areas is appalling. We need major help with this.
60. We had to sue Citizens Insurance to which took a year and three months. Coverage was inadequate to repair all damages from storm/salt driven wind. Many repairs had to be done out of pocket which we have been unable to recover from. Many repairs are still needed. Length of time waiting for roof to be repaired created damage in rooms. We were unable to get SBA assistance.
61. I have financially not caught up from the loss of income due to Hurricane Irma.
62. Getting the customers back into the keys to go fishing

63. Lack of revenue and Major increase in housing costs. I can't maintain a business here if I can't afford to live here! There are ZERO housing options for single people, and single people with businesses pay two rents [business lease/residential lease].

64. 1) Location Repairs (due to contractors not being able to hire workforce) 2) Communication (internet, etc) took a very long time to be restored to consistent and reliable service (we were informed this is/was due to the main lines not being "up to par" prior to the storm. Since my business is based on communication accessibility, this has been a major issue. 3) Even though the workforce I directly need to operate my business is not as dependent on local talent as some businesses, the services that I utilize are very dependent upon the local workforce. The lack of affordable housing for those individuals has been a major issue that is still present 18 months later. 4) I feel that the financail support to our local businesses was laughable., myself included. 5) while this survey is a step in the right direction, there are many subjects not covered or options for answers that are not even close. Our community is made of an extremely diverse cross-section of businesses. From the local face to face businesses to national/ international businesses that are based here but provide services and/or sales anywhere in the world. 5) In addition, none of the questions seemed relevant to independent contractors, single person business owners/operators, nor did it appear that post storm support was available to them. Is this due to a non-traditional business structure without multiple employees? If so, what is being done to prevent the loss of this workforce in the future? I am aware of many people that moved out of our area, taking their small business with them. Typically they are part of the support that binds our larger business community together with their affordable services. This is a great loss.