

# Infrastructure - Bridges

*Alvin Rodríguez, PE  
CMA Architects and Engineers LLC  
February 20, 2018*



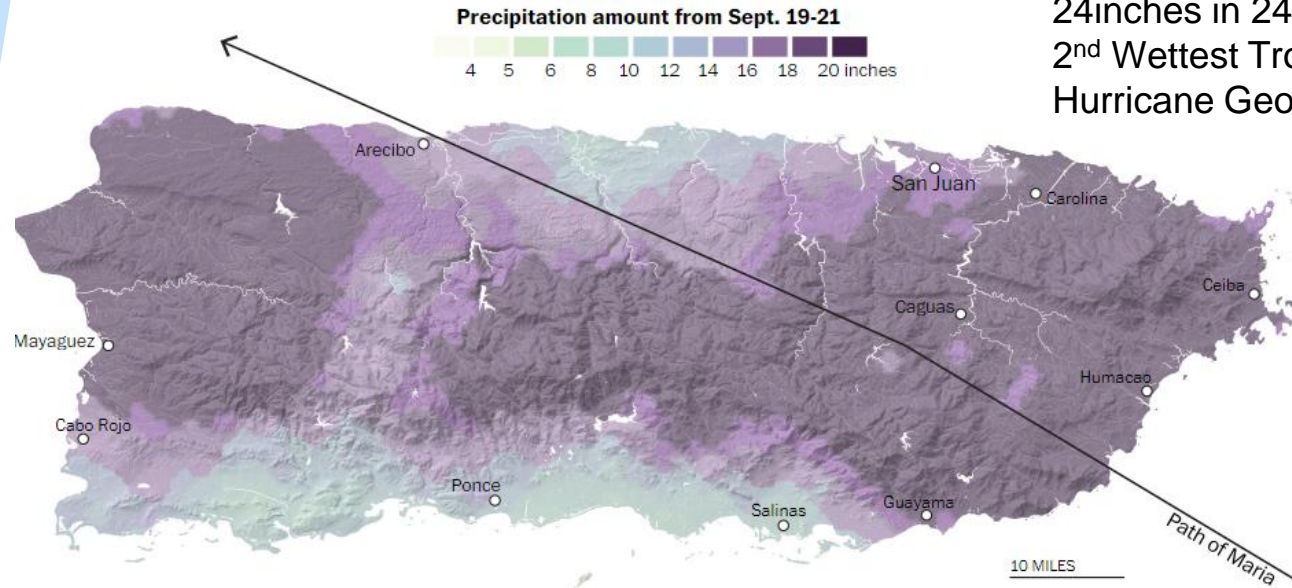
# Precipitation Sept 19-21

## Hurricane Maria:

24 inches in 24 hours

2<sup>nd</sup> Wettest Tropical Storm - 38in

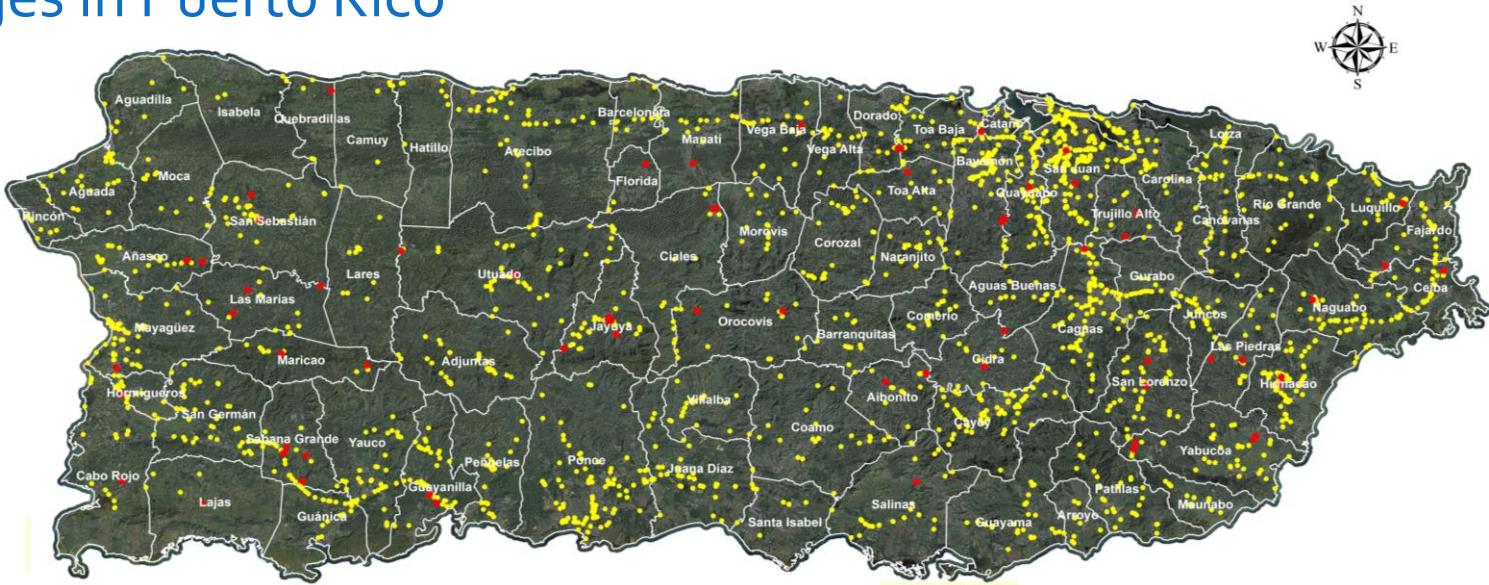
Hurricane Georges ranked 5<sup>th</sup> - 30in



Source: Flood Gauge data from National Weather Service



# Bridges in Puerto Rico



● Initial Screening - All 2,324 bridges

● Required Additional Site Visit – 200 bridges

27% Severely Damage - 63% Moderately Damage



# Sabana Grande Guanajibo River PR-121 Km 1.2



# Sabana Grande Guanajibo River PR-121 Km 1.2

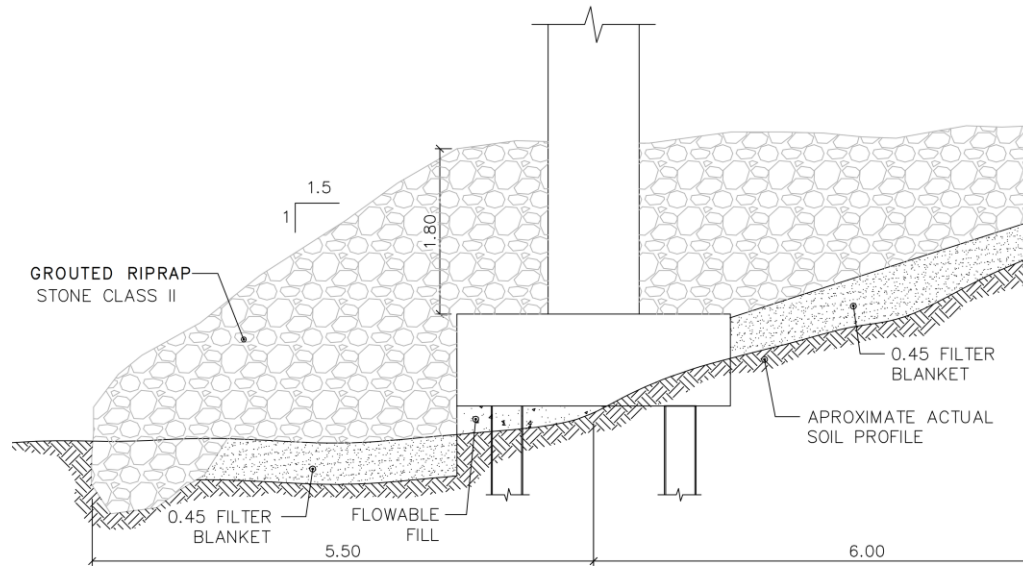




# Sabana Grande Guanajibo River PR-121 Km 1.2



# Sabana Grande Guanajibo River PR-121 Km 1.2



**SECTION 1-1**  
SCALE: 1:50



# San Sebastian PR-446 Km 1.7



**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*



*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*



# San Sebastian PR-446 Km 1.7



**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*

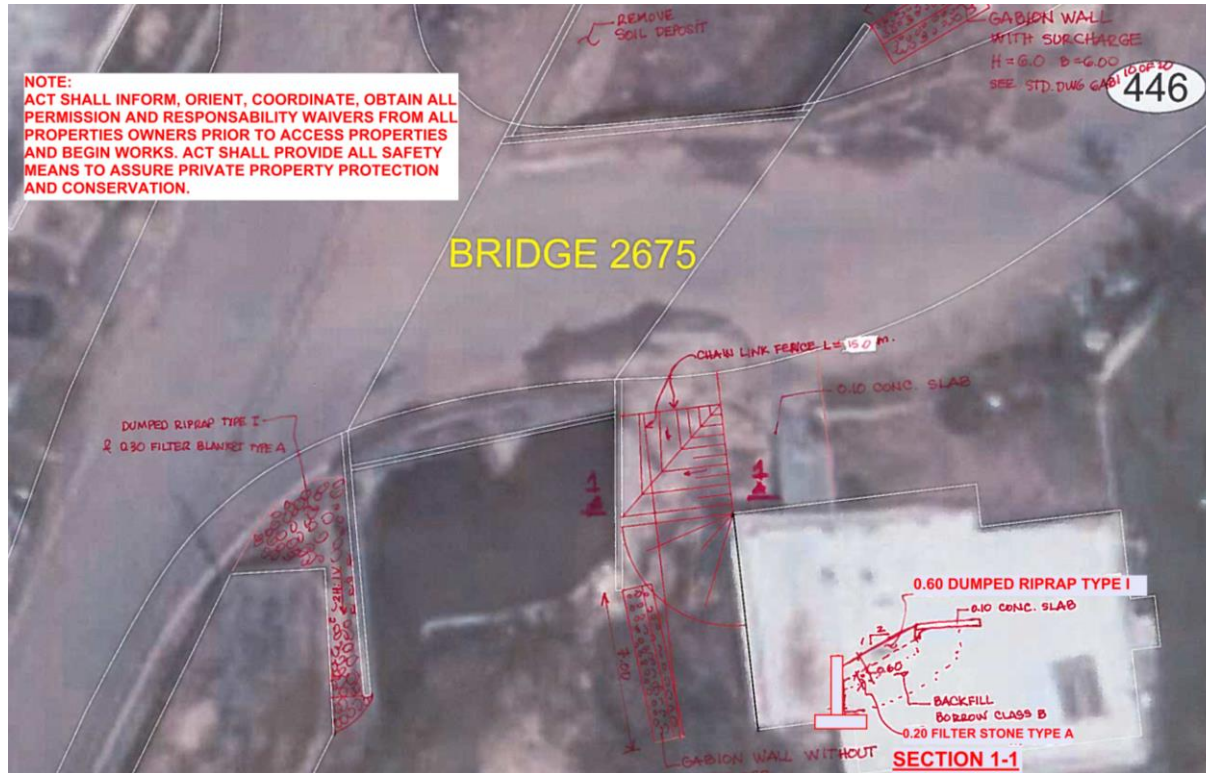


# San Sebastian PR-446 Km 1.7





# San Sebastian PR-446 Km 1.7





# Moca PR-404 Km 4.1



# Moca PR-404 Km 4.1



**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*





## Moca PR-404 Km 4.1



**COASTAL RESILIENCE CENTER**

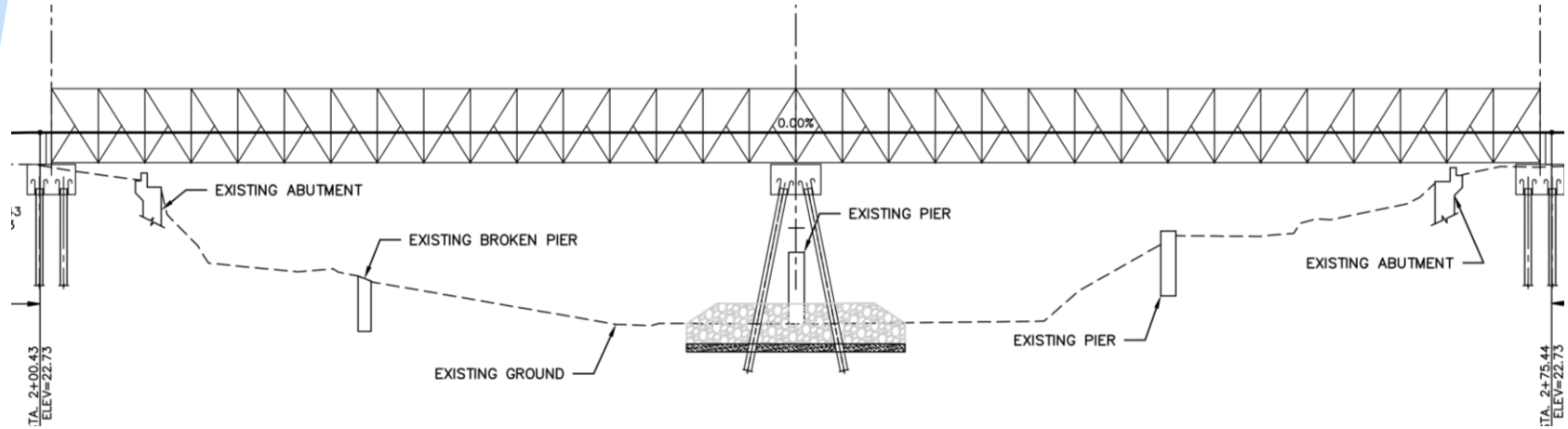
*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*





# Moca PR-404 Km 4.1



# Moca PR-404 Km 4.1





## Moca PR-404 Km 4.1





# Utuado PR-111 Km 47





## Utuado PR-111 Km 47



**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*

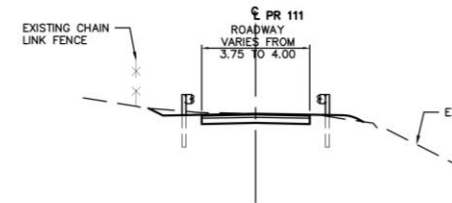
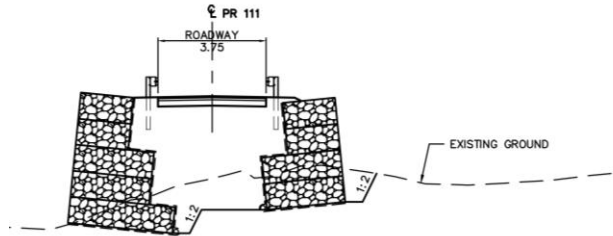
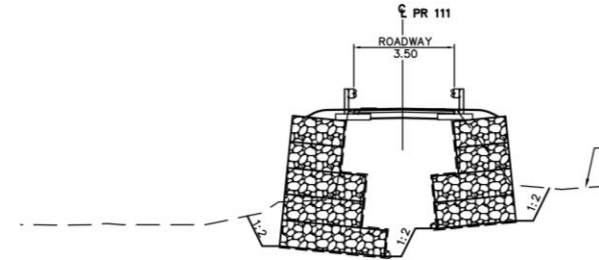
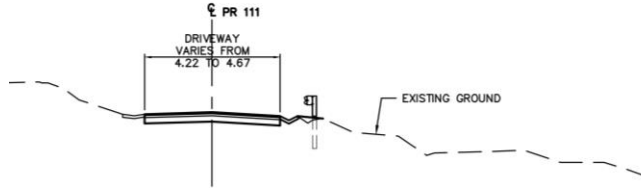




# Utua PR-111 Km 4.1



# Utuado PR-111 Km 4.1





## Lessons Learned

---

- **Debris** an important factor (Needs to be incorporated in Design as a Critical Factor in Stream Loads)
- **Hydraulics & Hydrology** of the area for final bridge elevation determination
- **Scour** considerations for bridge stability
- Upstream **embankment protection** required

# Things to think about....





# Hotel El San Juan



## COASTAL RESILIENCE CENTER

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*



# Dorado



## COASTAL RESILIENCE CENTER

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*





# City View Plaza



**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*



What do these structures have in COMMON?

Design as per  
**PR Building Code 2011**



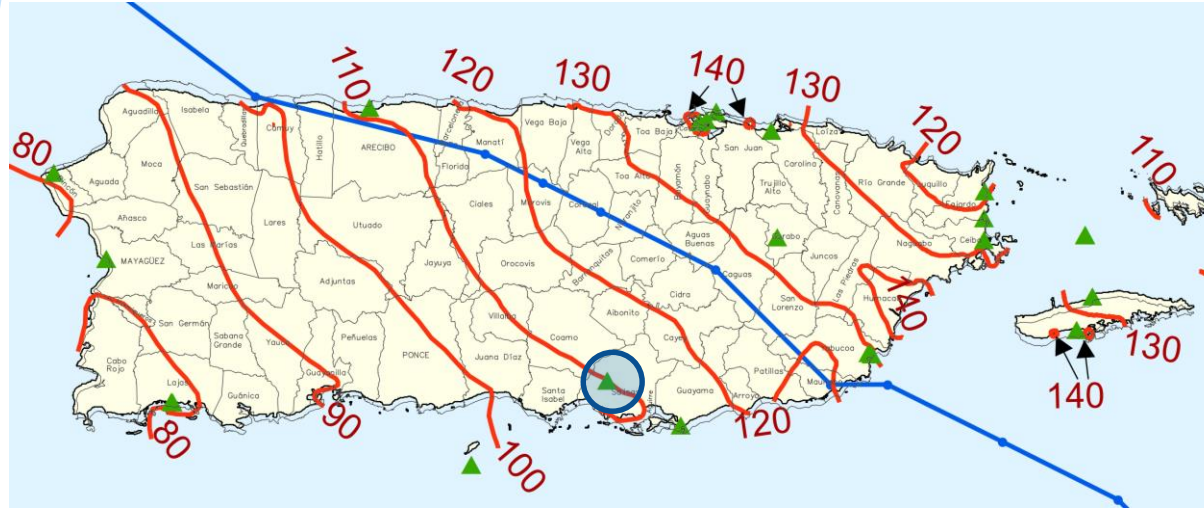
**COASTAL RESILIENCE CENTER**

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*



# Hurricane Maria Wind Maps v17.1

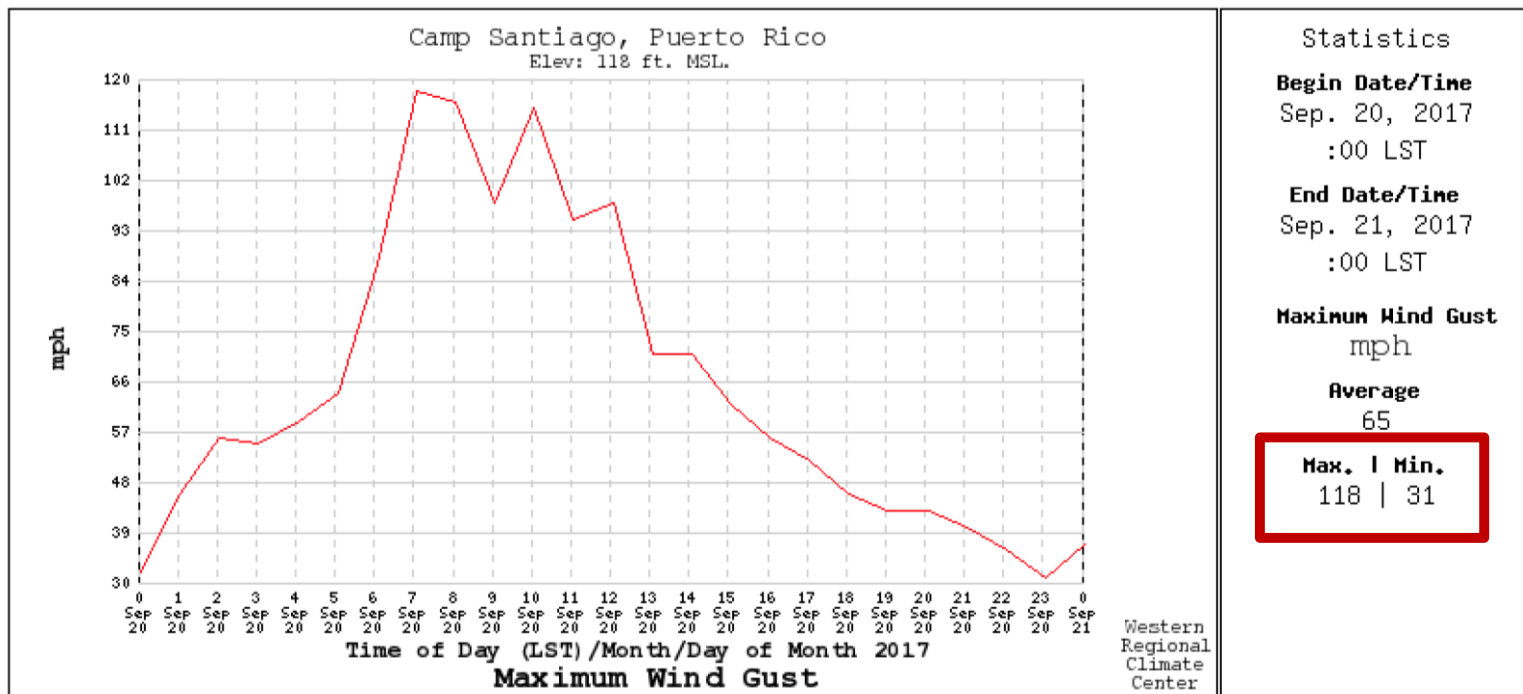


Isla Culebrita	137 mph
Gurabo	120 mph
Yabucoa	116 mph
Fajardo	100 mph
Salinas	118 mph

Preliminary Peak Wind Gust (mph) 3-sec gust at 10m  
Source: Applied Research Associates (ARA)



# Hurricane Maria Wind Maps v17.1



# Things to think about....

---

## Typical Building

- Enclosed Building
- Exposure C
- Roof Height 15ft

PR Building Code 1999 (ASCE 7-95)

PR Building Code 2011 (ASCE 7-05)

Proposed PR Building Code 2018 (ASCE 7-16)

Factory Mutual (Industrial Facility Design Recommendations)

## Things to think about....

PR Building Code 1999 (ASCE 7-95) - Service

$V = 125$  mph

Building Classification II

Importance Factor 1

**Basic Wind Pressure = 34 psf**

Design Load Combination

**1.3 Wind**

Building Area	Pressure
Windward Wall	7
Windward Roof	-30
Leeward Roof	-19
Leeward Wall	-16

**39 PSF**





## Things to think about....

PR Building Code 2011 (ASCE 7-05) - Service

$V = 145$  mph

Building Classification II

Importance Factor 1.0

**Basic Wind Pressure = 39 psf**

Design Load Combination

**1.6Wind**

Building Area	Pressure
Windward Wall	9
Windward Roof	-34
Leeward Roof	-21
Leeward Wall	-18

**54 PSF**



# Things to think about....

Proposed PR Building Code 2018 (ASCE 7-16) - Ultimate

$V = 160 \text{ mph}$

Risk Category II (Wind Maps)

Velocity varies 150-170 mph

~~Importance Factor 1 (Not Used)~~

**Basic Wind Pressure = 47 psf**

Design Load Combination

**1.0 Wind**

Building Area	Pressure
Windward Wall	10
Windward Roof	-41
Leeward Roof	-26
Leeward Wall	-22

**41 PSF**



## Things to think about....

Factory Mutual (Insurance Company) (ASCE 7-05) - Service

$V = 175\text{mph}$

Importance Factor 1.15

**Basic Wind Pressure = 65 psf**

Design Load Combination

**1.6Wind**

Building Area	Pressure
Windward Wall	14
Windward Roof	-57
Leeward Roof	-36
Leeward Wall	-31

**91 PSF**







# COASTAL RESILIENCE CENTER

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*





## COASTAL RESILIENCE CENTER

*A U.S. Department of Homeland Security Center of Excellence*

*Department of Civil Engineering and Surveying - University of Puerto Rico at Mayagüez*



# Things to think about....

---

- Wind Velocity with consideration on Wind Pressure (Service Loads vs Factored Loads)
- Failure of non-structural elements (i.e. Windows, Doors, Metal Siding Anchorage)
- How do we tackle “Informal Construction” and Compliance with Planning Board Site Allocations (Plan Territorial)
- Detailed study on collapse mechanism of communication and power infrastructure.





## Things to think about....

---

<https://storms.ngs.noaa.gov/storms/maria/index.html#16/18.1360/-65.8166>

