



February 20, 2018
NCST Advisory
Committee Meeting

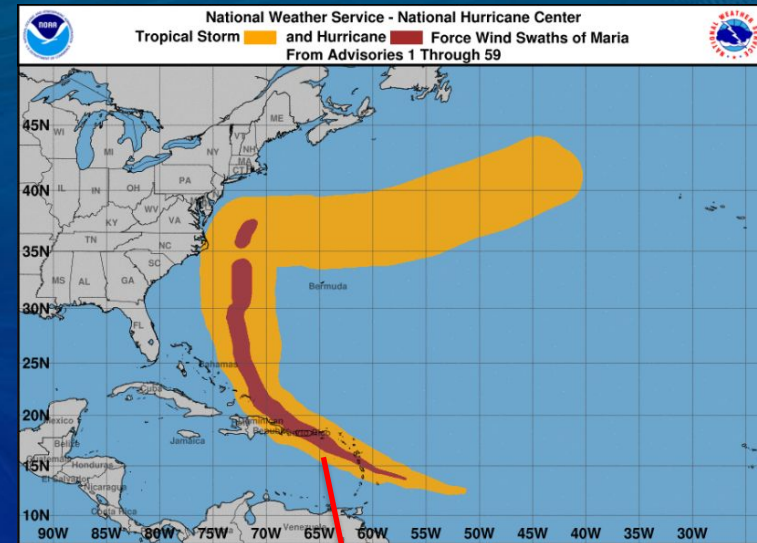
Update on Preliminary Reconnaissance of Hurricane Maria (Puerto Rico)

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Storm Summary

- TS Maria formed west of the Lesser Antilles on Sept 16*.
- Maria intensified to Category 5 status in two days, with sustained winds of 175 mph*.
- Hurricane Maria made landfall in Puerto Rico on Sept. 20 as a strong Category 4 storm*.
- Most intense hurricane to strike Puerto Rico since the Category 5 Okeechobee Hurricane of 1928**.
- Maria impacted Puerto Rico just 13 days after Hurricane Irma, which brought tropical storm-force winds to the entire



Source: NOAA/NWS

C. Hazard and/or Failure Intensity			
Earthquake	≤ MMI IV	MMI V to VII	≥MMI VIII
Hurricane at Landfall	≤Cat 3	Cat 4	Cat 5

*Source: <https://www.nhc.noaa.gov/archive/2017/MARIA.shtml>;
<http://www.weather.gov/sju/maria2017>

**Source: <https://www.nhc.noaa.gov/outreach/history/#okee>

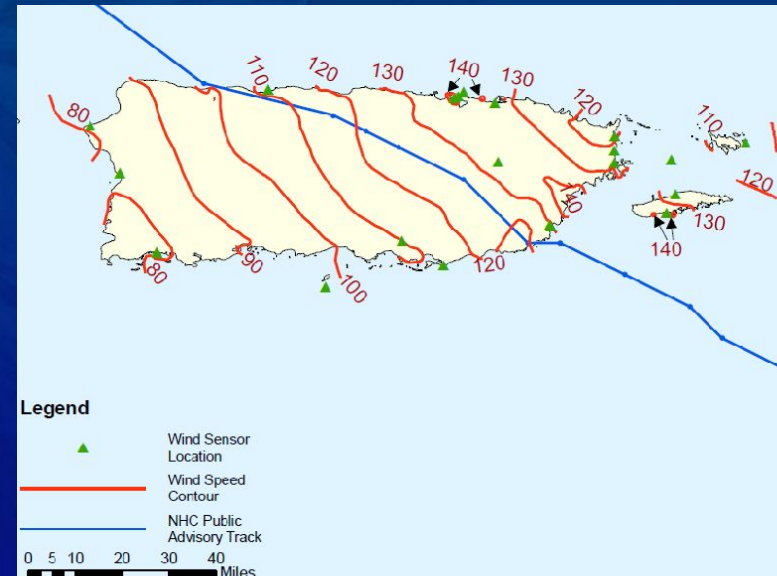
***Source: <https://www.nhc.noaa.gov/archive/2017/IRMA.shtml>



Storm Hazards (1/2)

- **Winds:** The storm tracked diagonally across Puerto Rico, with hurricane-force winds extending over the entire Commonwealth
 - The greatest wind speeds occurred in the eastern third of Puerto Rico and on Vieques.
 - Maximum estimated peak wind gusts were 140+ mph.
 - Topographic effects (not included in the isotach map shown) would have significantly increased wind speeds in mountainous areas.
- **Storm Surge*:** Occurred around the entire perimeter of Puerto Rico and the smaller Commonwealth islands
 - Surge elevations in most coastal areas ranged from 2 to 6 feet above mean sea level.
 - Resultant coastal flooding typically did not extend very far inland due to the islands' narrow coastal plains.

Hurricane Maria Maximum Winds
(3-second peak gust speeds at 10 m height over open terrain, in mph)



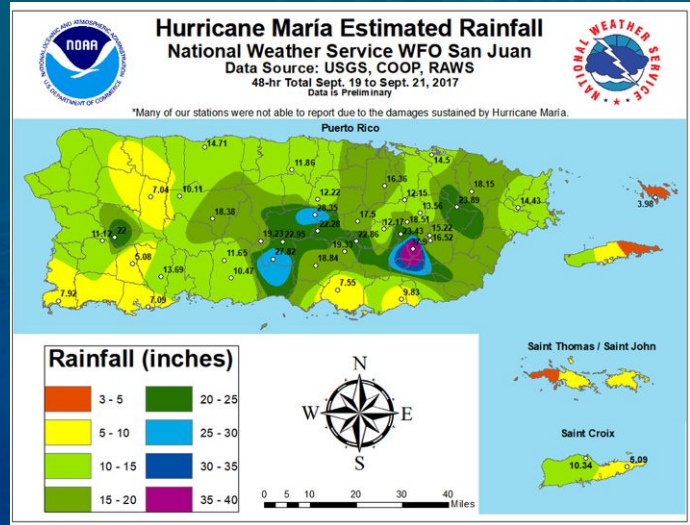
*Source: USGS (Flood Event Viewer:
<https://stn.wim.usgs.gov/fev/#MariaSeptember2017>).



Storm Hazards (2/2)

Source: NOAA

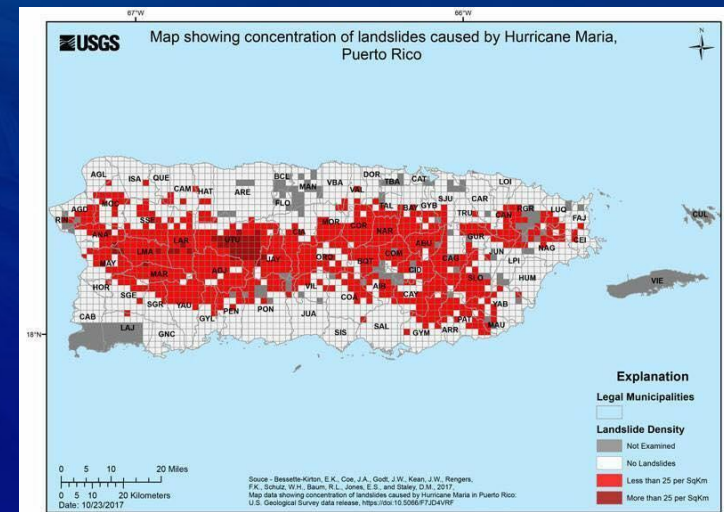
- **Rain***: Extensive rainfall across Puerto Rico
 - 15 – 40 inches of rain across the eastern 2/3 of the island
 - 5 – 15 inches of rain across the western third of Puerto Rico
 - Hurricane Irma deposited 5-15 inches of rain across most of Puerto Rico, less than two weeks prior to Maria
 - Rain-induced flooding occurred across much of the Commonwealth



- **Landslides****: Many hundreds of landslides occurred
 - Concentrated in the mountainous central areas of Puerto Rico
 - Soils still saturated from Hurricane Irma rainfall contributed to slope instability



Source: FEMA



Source: USGS

*Source: NOAA Hurricane Maria Estimated Rainfall maps (<http://www.weather.gov/sju/maria2017>)

**Source: USGS map showing concentration of landslides caused by the hurricane (<https://landslides.usgs.gov/research/featured/2017-maria-pr/>)



Mortality and Exposed Population

- **Mortality:** As of December 9, 64 deaths in Puerto Rico were attributed to Hurricane Maria.
 - The New York Times* and other news organizations estimate that the actual death toll could be over 1,000, based on analysis of daily mortality data from Puerto Rico's Vital Statistics Record Office
 - The Governor of Puerto Rico ordered a recount and review of certified deaths in mid-December

- **Exposed Population:** The entire Commonwealth of Puerto Rico was exposed to Maria (total population is approximately 3.4 million).

A. Mortality			
Facility context	0	1 to 2	>2
Community context ¹	0 to 3	4 to 9	>10
Regional context ²	0 to 5	6 to 19	>20
B. Exposed Population			
Facility context	<100	100 to 499	≥500
Community context	<1 000	1 000 to 9 999	≥10 000
Regional context	<100 000	100 000 to 999 999	≥1 000 000

*Source: <https://www.nytimes.com/interactive/2017/12/08/us/puerto-rico-hurricane-maria-death-toll.html>



Hurricane Maria Preliminary Reconnaissance Team

Team 1 (NIST Deployed Team Member, embedded with FEMA)

- Marc Levitan (Structural Engineering)

Team 2 (NIST Deployed Team, shadowing FEMA)

- Erica Kuligowski (Sociology, Emergency Communication)
- Judy Mitrani-Reiser (Engineering, Resilience)
- Carmen Martinez (IT, Logistics)



Meetings with Hospital staff/officials

Meetings with FEMA; Emergency management officials; Depts. of Housing and Education officials; Directors/staff at Puerto Rico Manufacturing Extension; Researchers from University of PR; and National Weather Service

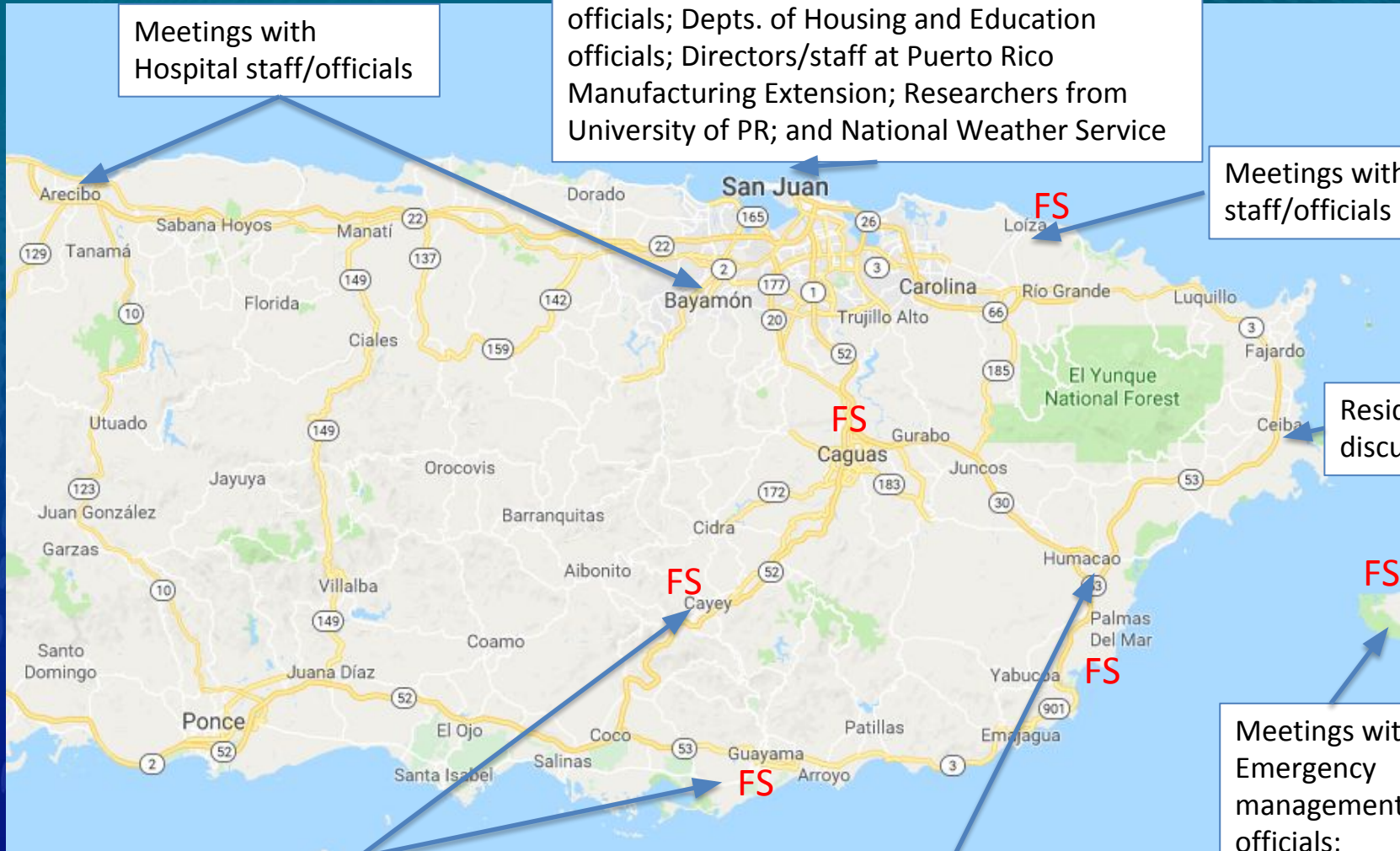
Meetings with school staff/officials

Resident discussions

Meetings with Emergency management officials; Hospital staff

Meetings with officials in Emergency management and Planning

Meetings with officials in Emergency management, Department of Education



Physical Damage – Engineered Building Systems (1/2)

- Preliminary observations identified minimal *structural* damage caused by wind hazards to reinforced-concrete and concrete- block buildings with concrete roofs, however the team observed the following:
 - Some roof failures on reinforced-concrete and concrete-block buildings having *other-than-concrete* roofs (wood frame and steel frame)
 - Wind damage to metal building systems
 - Wind-induced failures of metal buildings and rooftop equipment, potentially due to corrosion
 - Varied performance of rooftop solar areas exposed to high winds



D. Physical Damage ³			
Failure during Construction or In Service ⁴	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Engineered Building Systems ⁵	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function



Physical Damage – Engineered Building Systems (2/2)

- Preliminary observations also identified engineered buildings with good structural performance that suffered extensive *nonstructural damage and loss of function*
- Damage potentially due to rainwater penetration of the building envelope, via:
 - Roof covering and rooftop equipment damage
 - Window and door damage
 - Rainfall ponding on the roof
 - Wind-driven rain penetration through undamaged cladding, such as windows and doors.



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Engineered Building Systems ⁵	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function



Physical Damage – Non-Engineered Building Systems

- Preliminary observations identified severe physical damage and loss of function to non-engineered buildings
- The following observations were made:
 - Wind damage to light framed wood construction
 - Buildings with concrete block walls and wood frame roofs that had experienced complete roof loss, or extensive roof damage
 - Poor performance of unpermitted (informal) construction
 - People still living in houses with no roofs, as of mid-December



Source: FEMA

Non-Engineered Building Systems

Minimal physical damage
and/or loss of function

Moderate physical damage
and/or loss of function

Severe physical
damage and/or loss of
function



Physical Damage – Transportation & Utility Systems

- Preliminary observations and discussions identified the following regarding electric power:

- Complete electrical outage across Puerto Rico
- Severe physical damage to **electric power generation, transmission and distribution systems**, including utility-scale solar and wind power generation
- Cascading effects: water, wastewater, communications

- Preliminary observations and discussions identified the following regarding the communications system:

- Near complete loss of digital communications across PR
- Severe physical damage to tower- and building-mounted cellular communications equipment
- Damage to “hundreds of miles” of fiber optic cable, impacting wireless and wireline communications (source: AT&T)*
- Some cell tower collapses

Source: FEMA



Source: FEMA



Transportation & Utility Systems®	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
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*Source:

http://about.att.com/inside_connections_blog/hurricane_maria



Evacuation and Response (1/2)

- Preliminary observations and discussions identified the following regarding evacuation and response:
 - Governor urged people in flood zones to evacuate; specifically identified people in certain types of structures (e.g., wooden) to move to shelters
 - Emergency information was provided via multiple channels, by multiple sources (NWS, Commonwealth and local governments, media); however, perceived credibility of channel and source is key to response
 - Many people/families had to be rescued from flooding in multiple towns on the island

2.0 Evacuation and Response ⁷			
A. Evacuation	Normal evacuation	Moderate evacuation challenges	Severe evacuation challenges
B. Emergency Response	Normal operations	Moderate operational challenges	Severe operational challenges
Count x Weight:	0 x 1 = 0	0 x 3 = 0	2 x 5 = 10
Evacuation and Response Score:	10/2 = 5.0		



Evacuation and Response (2/2)

- Based on preliminary observations and discussions, emergency response challenges existed during/after the hurricane:
 - Lack of communication between emergency and building officials, and with the public for extended periods of time
 - Implementation of NWS back-up Weather Forecast Office in Miami, FL (since San Juan was offline)
 - Reliance on less efficient communication techniques to deliver and retrieve information
 - Recognized gaps in redundancy



2.0 Evacuation and Response⁷

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Recovery of Critical Social Functions

- Preliminary observations of the hurricane identified negative impacts on critical social functions:
 - Education/schools:
 - Shelter populations inhabiting schools months after the event, potentially delaying access to education
 - Power losses/generator failures also delayed/disrupted education
 - Healthcare:
 - Non-structural building damage/generator failures impacted delivery of healthcare services
 - Patients in multiple facilities had to be evacuated
 - Communities throughout Puerto Rico
 - Ongoing outmigration since the hurricane hit
 - Puerto Rico (pre-storm) had been facing years of economic decline/recession





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Questions?

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