Summary of NIST's Efforts to Investigate and Study Hurricane Maria's Impacts on Puerto Rico:

NCST Technical Investigation and NWIRP Research Study

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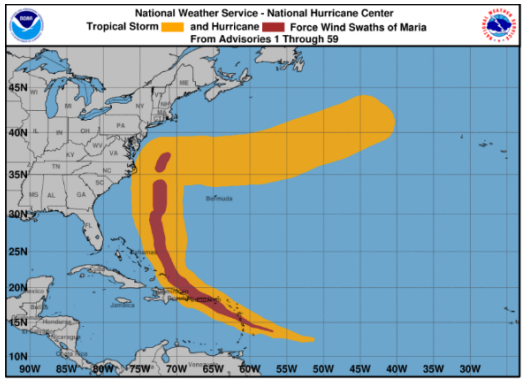
Hurricane Maria's Impacts on Puerto Rico (Initial Reconnaissance)

- Hurricane Maria made landfall in Puerto Rico on Sept. 20 as a strong Category 4 storm.
- Entire Commonwealth exposed to the hurricane (~3.3 M people)
- **Engineered buildings** suffered extensive nonstructural damage and loss of function (and minimal structural damage)
- **Mortality estimates** range from 64 (direct) to ~3,000 excess deaths*
- **Emergency response** challenges with rescues in flooded areas, further complicated by loss of communications for extended periods
- **Infrastructure failures** presented emergency response and recovery challenges – complete or near complete loss of electrical, communications
- Negative impacts on **recovery** of education, healthcare and businesses due to power loss, non-structural building damage, generator failures, and road closures



* The George Washington University Project Report: *Ascertainment of the Estimated Excess Mortality from Hurricane Maria in Puerto Rico* (https://publichealth.gwu.edu/sites/default/files/downloads/projects/PRstudy/Acertainment%20of%20the%20Estimated%20Excess%20Mortality%20from%20Hurricane%20Maria%20in%20Puerto%20Rico.pdf)

NCST Technical Investigation of Hurricane Maria

NIST is studying the effects of Hurricane Maria on Puerto Rico's buildings, communities, and supporting infrastructure

The NIST Director established a Team under the National Construction Safety Team (NCST) Act Public Law 107-231 on February 21, 2018 to conduct a technical investigation of the effects of Hurricane Maria on the U.S. territory of Puerto Rico, with the goals of characterizing:

(1) *the wind environment and technical conditions associated with deaths and injuries;*

(2) *the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on lifelines; and*

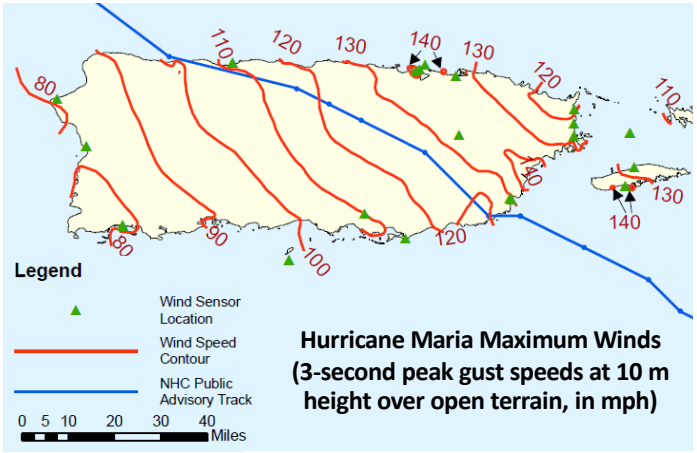
(3) *the performance of emergency communications systems and the public's response to such communications.*

NCST Technical Investigation Projects

1. Hazard Characterization (Yeo and Weaver)
2. Performance of Critical Buildings (Main)
3. Evacuation and Emergency Communications (Kuligowski)
4. Characterization of Morbidity and Mortality (Mitrani-Reiser)
5. Contract, Project Management and Communication Support (Davis)

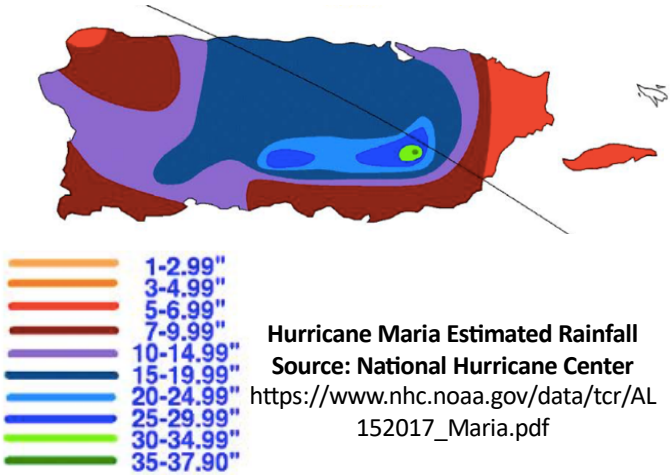
NCST Investigation Project 1: Characterization of Hazards

Background: Hurricane Maria subjected Puerto Rico to multiple hazards: peak gusts exceeded 140 mph, peak coastal inundation exceeded 6 ft, rainfall totaling up to 40 inches causing inland flooding. The storm damaged instrumentation, resulting in challenges to the metrology of the hazards related to the windstorm.



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

Objective: To characterize the wind environment associated with Hurricane Maria's impact on Puerto Rico, including topographic effects, and to document other hazards associated with the hurricane, including storm surge, rainfall, flooding, and landslides.



Hurricane Maria Estimated Rainfall
Source: National Hurricane Center
https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf

NCST Investigation Project 2: Performance of Critical Buildings

Background: Preliminary reconnaissance observations of engineered structures showed: extensive ***nonstructural*** damage and loss of function; limited ***structural*** damage to reinforced concrete and concrete-block buildings with concrete roofs; some failures of non-concrete roofs on reinforced concrete and concrete-block buildings; and wind-induced damage to and failure of metal building systems

Objective: To characterize the performance of critical buildings in Hurricane Maria by evaluating damage and loss of function for representative samples of hospitals, schools, and storm shelters with respect to the hazards they experienced, including an evaluation of selection criteria and design requirements for storm shelters.

NCST Investigation Project 3: Evacuation and Emergency Communications

Background: Preliminary reconnaissance observations showed challenges in evacuation and emergency communications:

- An island's heterogenous terrain that posed different risks (flooding, heavy winds, storm surge, landslides), requiring different protective actions;
- Societal preference for sheltering in place;
- Lack of communication for extended periods of time;
- Many people/families requiring rescues

Objective: Identify the factors that influenced the public's decision to take protection (evacuate) prior to the hurricane, and to understand the role of emergency communications in that decision; and characterize the use of emergency communication (technology and information) before, during and after the hurricane

NCST Investigation Project 4: Characterization of Morbidity and Mortality

Background: The official death toll by Puerto Rico's Dept. of Public Safety was initially 64*, but later the Government of Puerto Rico updated the official count based on George Washington University's study**. There is a lack of standards, consistent data collection and reporting. Death certificates generally greatly underestimate deaths (both direct and indirect) caused by a disaster event.

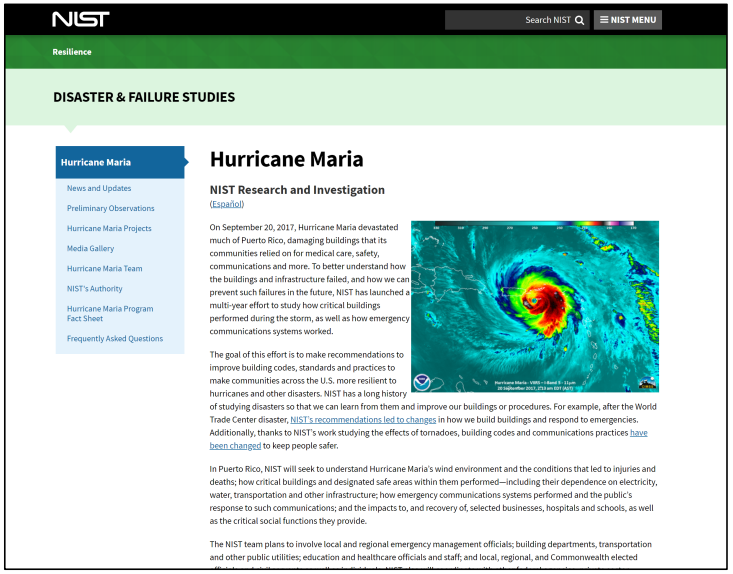
Objective: To complete a quantitative morbidity and mortality assessment in Puerto Rico, to better understand how damaged buildings and supporting infrastructure played a role in the injuries and deaths associated with Hurricane Maria.

**Robles, F., Davis, K., Fink, S, Almukhtar, S., 2017. "Official Toll in Puerto Rico: 64. Actual Deaths May Be 1,052." The New York Times. December 9, 2017.*
***George Washington University , in collaboration with the University of Puerto Rico Graduate School of Puerto Rico, 2018. "Ascertainment of the Estimated Excess Mortality from Hurricane Maria in Puerto Rico," a Project Report for the Governor of Puerto Rico, August 28, 2018.*

NCST Investigation Project 5: Contract, Project Management and Communication Support

Background: Previous NCST Investigations have required contract support, including technical writing and editing, graphic design, and outreach and engagement support. Unique to this investigation, most of the data collection via survey/interviews or technical engagements will require Spanish language skills, requiring contractors with translation/interpretation support. Therefore, a dedicated project that focuses on contract, project management and communication support was vital.

Objective: To ensure that the Hurricane Maria NCST Investigation Projects and the NWIRP Study Projects are properly supported, monitored, and communicated via contract support, project management, and communication support (including a website dedicated to this effort).



https://www.nist.gov/topics/disaster-failure-studies/hurricane-maria

NWIRP Research Study of Hurricane Maria

NIST is studying the effects of Hurricane Maria on Puerto Rico's recovery of buildings, communities, and supporting infrastructure

Under the National Windstorm Impact Reduction Act Reauthorization of 2015 (Public Law 114-52)*, NIST is conducting a scientific study of Hurricane Maria's impacts on Puerto Rico and subsequent recovery processes, with the goals of characterizing:

(1) *The impacts to and recovery of small and medium-sized manufacturers (SMMs), as well as businesses in retail and service industries;*

(2) *The impacts to and recovery of education and healthcare services;*

(3) *The impacts to and recovery of infrastructure systems in Puerto Rico, with a focus on infrastructure that supports the functioning of critical buildings (i.e., hospitals and schools) and emergency communications.*

* https://www.congress.gov/114/plaws/publ52/PLAW-114publ52.pdf

NWIRP Research Study Projects

1. Recovery of Business and Supply Chains (Helgeson)
2. Recovery of Social Functions (Dillard)
3. Recovery of Infrastructure Systems (Harrison)

Source: NOAA

NWIRP Study Project 1:
Recovery of Business and Supply Chains

Background: Manufacturing and retail business services are an important part of understanding the impacts of Hurricane Maria, as well as the long term recovery of Puerto Rico and its supply chains. Manufacturing activity in the Commonwealth accounts for about 45% of Puerto Rico's Gross Domestic Product (GDP) and over 20% of its employment*. According to FEMA**, 40% of small businesses never reopen after a disaster and another 25%, that do reopen, fail within a year.

Objective: To characterize the recovery of small- and medium-sized businesses, including manufacturing, retail, and service sectors in Puerto Rico to provide greater understanding of business continuity resilience planning and supply chain continuity and how these may differ between industries/affected regions.

** Puerto Rico Department of Labor and Human Resources Bureau of Labor Statistics. (2017). "Puerto Rico Economic Analysis Report 2015-2016."*
https://www.doleta.gov/performance/results/AnnualReports/docs/2017_State_Plans/Economic_Reports/Puerto%20Rico/PR%20Economic%20Analysis.pdf (April 15, 2018)
*** "Protecting Your Businesses," Federal Emergency Management Agency, last updated June 24, 2016, https://www.fema.gov/protecting-your-businesses.*

NWIRP Study Project 2: Recovery of Social Functions

Background: Both education and healthcare services are an important part of understanding the impacts of Hurricane Maria, as well as the long term recovery of Puerto Rico. Approximately one-quarter of the schools have closed in Puerto Rico, disproportionately affecting rural communities where the majority of school closures have taken place*.

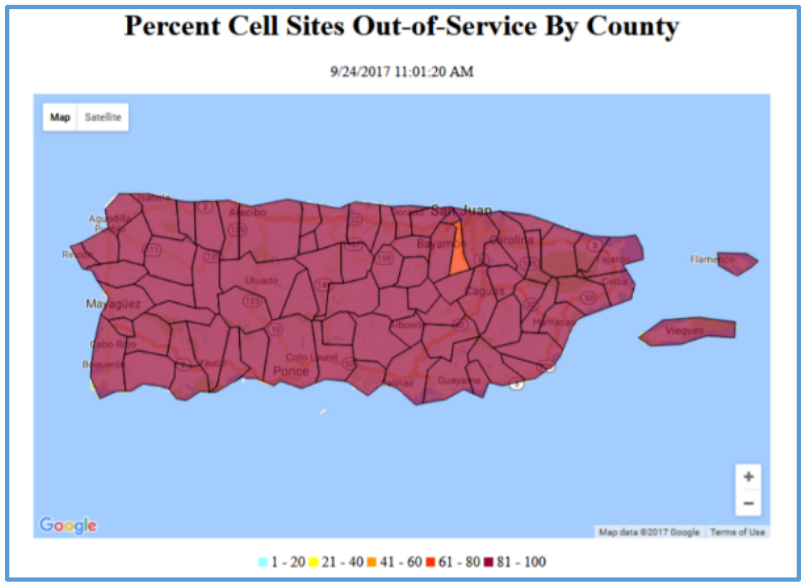
Objective: To examine the recovery trajectories of sampled schools and hospitals in Puerto Rico to identify the underlying characteristics and conditions associated with recovery of critical social functions from Hurricane Maria

** Hinojosa, Melendez and Severino Pietri, "Population Decline and School Closure in Puerto Rico"* https://centropr.hunter.cuny.edu/sites/default/files/PDF_Publications/centro_rb2019-01_cor.pdf.

NWIRP Study Project 3: Recovery of Infrastructure Systems

Background: Infrastructure failures presented emergency response and recovery challenges. There was a complete electrical outage across the island and cascading effects to other lifelines, with extensive damage to generation, transmission, and distribution systems. There was also near complete loss of digital communications across Puerto Rico.

Objective: To investigate dependencies of building function on infrastructure (power, water, and transportation), including cascading loss of function and sequencing of recovery activities, and to investigate causes of the loss of functionality and extended-duration outage of the wireless communication system in Puerto Rico following Hurricane Maria.



Source: NOAA

NCST Technical Investigation Projects' and NWIRP Research Study Projects' Regions Selected for Study

Source: PR.gov
http://prfaa.pr.gov/wp-content/uploads/2017/09/Oficinas-Regionales.pdf

Thank you!

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