

Hurricane Maria Program Update

NCST Advisory Committee Meeting

October 19, 2022

Joe Main

Team Lead

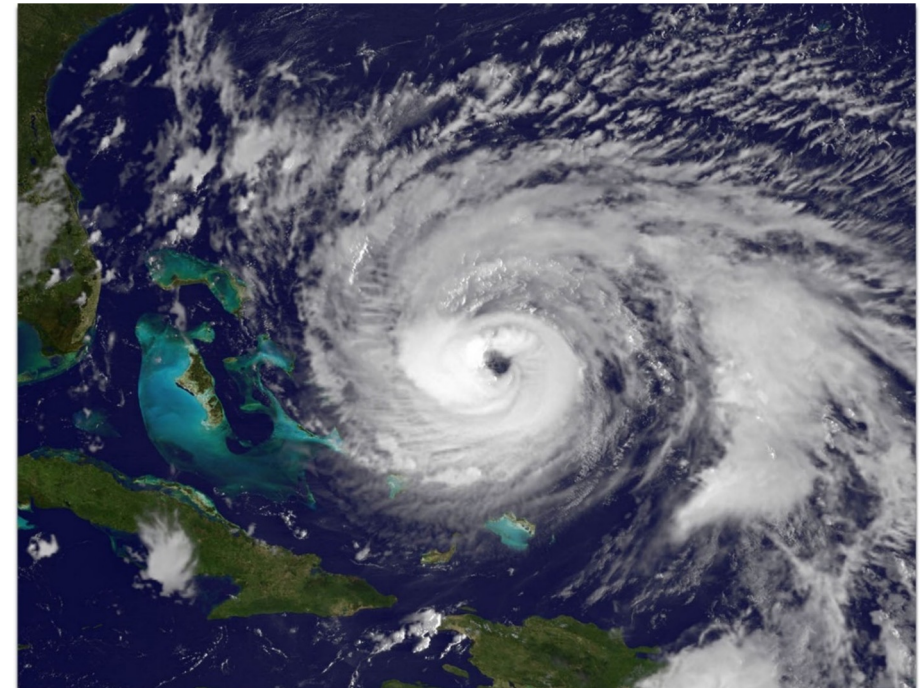
Maria Dillard

Associate Team Lead

NIST Hurricane Maria Program



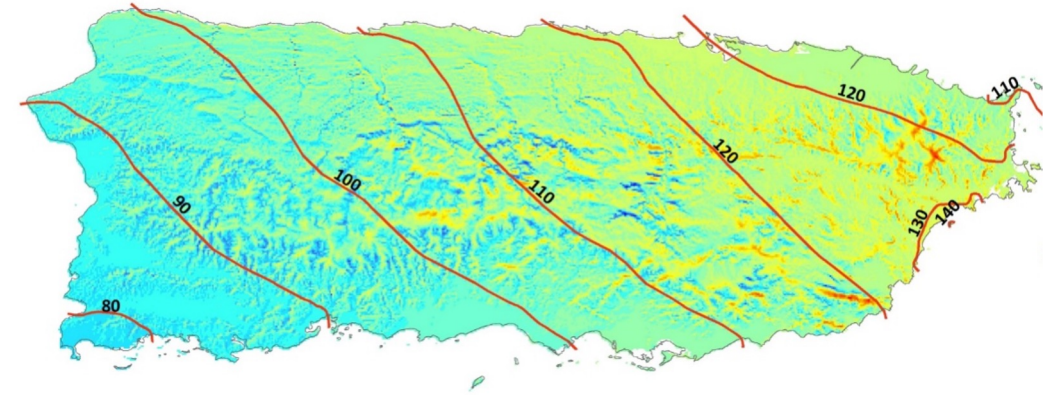
- **NIST is studying** Hurricane Maria's effects on Puerto Rico and subsequent recovery
- **Goal:** Recommend improved building codes, standards, and practices to help communities in Puerto Rico and across U.S. to be more resilient
- Launched February 2018; authorized by:
 - National Construction Safety Team Act
 - National Windstorm Impact Reduction Act



Credit: NOAA

Hurricane Maria's Impacts on Puerto Rico

- **Hazard Exposure:** Strong Category 4 hurricane, peak gusts near 140 mph (greater with topographic speedup), up to 40" rain, extensive flooding, landslides
- **Exposed Population:** Entire Commonwealth (~3.3M people)
- **Mortality:** Challenges attributing hurricane-related deaths; excess mortality estimate: 2,975
- **Engineered Buildings:** Extensive nonstructural damage, rainwater intrusion, loss of function



Hurricane Maria's Impacts on Puerto Rico

- **Emergency Response:** Challenges with rescues in flooded areas, complicated by loss of communications for extended periods
- **Infrastructure Systems:** Severe physical damage and complete/near complete loss of function for electrical and communications systems presented emergency response and recovery challenges
- **Education, Healthcare and Businesses:** Impacts on recovery due to power loss, non-structural building damage, generator failures, road closures



September 20, 2017

Hurricane Maria struck Puerto Rico – just 13 days after Hurricane Irma affected the island

December 2017

NIST preliminary reconnaissance of damage

February 2018

NIST Director established team to conduct a technical investigation under National Construction Safety Team Act

Hurricane Maria Program Overview



2 Program Components

NCST Investigation

NWIRP* Research Study

7 Technical Projects

Hazard
Characterization

Performance of
Critical Buildings

Public Response
to Emergency
Communications

Morbidity &
Mortality

Impacts to and Recovery
of Infrastructure
Systems

Recovery of Business
and Supply Chain

Recovery of Social
Functions

5 Major Contracts

Applied Research Associates

University of Florida

Stantec Consulting

George Washington
University

Horsley Witten Group

Multiple Collaborating and Coordinating Agencies

FEMA

NOAA

HHS

USGS

NCDMHP

PRDOH

PRDOE

PRDTOP

PRASA

PRFAA

Many others...

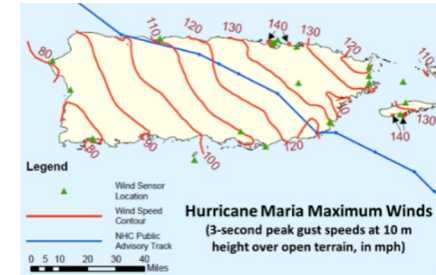
1 Coordinated Program

*National Windstorm Impact Reduction Program

NCST Investigation Projects

Hazard Characterization

Document and understand wind environment and other hazards, including storm surge, rainfall, flooding, and landslides



Performance of Critical Buildings

Evaluate how critical buildings performed (hospitals and shelters) – including dependence on electricity, water, and other infrastructure



Public Response to Emergency Communications

Document role of emergency communications and public's response – focusing on communications during response and recovery



Morbidity and Mortality

Better understand how damaged buildings and failures in supporting infrastructure played a role in injuries and deaths



NWIRP Research Projects

Impacts to and Recovery of Infrastructure Systems

Evaluate dependencies of building function on infrastructure (power, water, and transportation) and causes of the loss of functionality and extended-duration outage of the wireless communication system



Recovery of Business and Supply Chains

Study recovery of small- and medium-sized businesses (in manufacturing, retail, and service sectors) and supply chain disruption



Recovery of Social Functions

Examine recovery of schools and hospitals, including physical repairs, services, and staffing



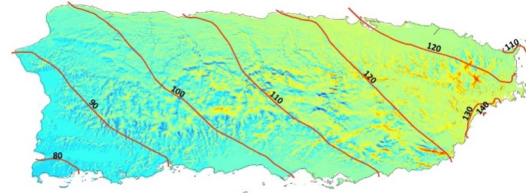
Supporting Contracts

Contract	Contractor(s)	Project(s) Supported
Wind Field Modeling	Applied Research Associates	<ul style="list-style-type: none">• Hazard Characterization• Critical Buildings
Wind Tunnel Testing and Field Measurement of Winds	University of Florida <ul style="list-style-type: none">• WeatherFlow, Inc.	<ul style="list-style-type: none">• Hazard Characterization• Critical Buildings
Engineering Services to Evaluate Critical Building Performance	Stantec Consulting Services, Inc. <ul style="list-style-type: none">• Virella Crespo & Associates (Mayagüez)• University of Puerto Rico at Mayagüez	<ul style="list-style-type: none">• Critical Buildings
Social Science Data Collection	Horsley Witten Group, Inc. <ul style="list-style-type: none">• Eastern Research Group• Issues and Answers• Albizu University (San Juan)	<ul style="list-style-type: none">• Emergency Communications• Recovery of Business• Recovery of Social Functions• Infrastructure Systems
Morbidity and Mortality Assessment	Milken Institute School of Public Health at George Washington University <ul style="list-style-type: none">• University of Puerto Rico Graduate School of Public Health• University of Washington	<ul style="list-style-type: none">• Morbidity and Mortality

Supporting Contracts

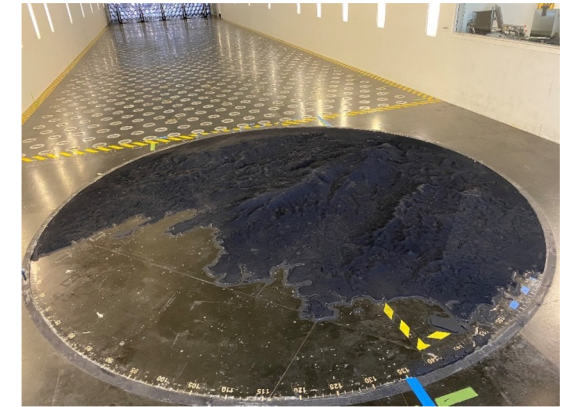
Contract

Wind Field Modeling



Applied Research Associates

Wind Tunnel Testing and Field Measurement of Winds



University of Florida

Engineering Services to Evaluate Critical Building Performance



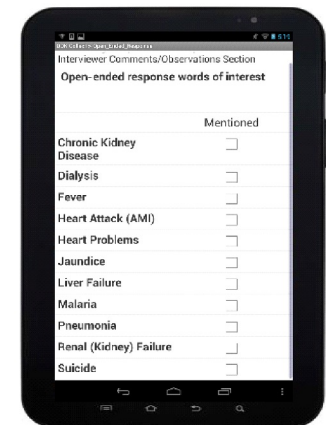
Stantec Consulting

Social Science Data Collection



Horsley Witten Group

Morbidity and Mortality Assessment



Source: Bernardo Hernández Prado

GW/UPR

Stakeholder Outreach & Coordination

**Federal Departments
& Agencies**

**Puerto Rico Government
Agencies, Associations,
Universities, Companies
& Individuals**

**Collaborate
Coordinate
Cooperate**

NIST Engineering Laboratory

**Other NIST Laboratories
& Offices**

Stakeholder Outreach & Coordination



Federal

Federal Emergency Management Agency
NOAA's National Weather Service
U.S. Army Corps of Engineers
Nat'l Ctr for Disaster Medicine and Public Health
U.S. Geological Survey
Small Business Administration
Dept of Health & Human Services

Puerto Rico

Depts of Education, Health, Housing, Transportation & Public Works, Economic Development & Commerce
PR Ports Authority, PR Energy and Power Authority
PR Aqueduct & Sewer Authority, Emergency Management
Central Office for Recovery, Reconstruction & Resiliency
Municipalities, universities, businesses, nonprofits
Governor's Federal Affairs Administration
Resident Commissioner's Office

**Collaborate
Coordinate
Cooperate**

NIST Engineering Laboratory

Disaster & Failure Studies Program
Community Resilience Group
Structures Group
Earthquake Engineering Group
Applied Economics Office
Data, Security, Technology Group

Other NIST Units

Public Affairs
Office of Chief Counsel
Congressional & Legislative Affairs
Program Coordination
Management & Organization
Acquisition & Agreements Mgt
Statistical Engineering Division of ITL
Research Protections

Stakeholder and Public Communications



Recent meetings with PR government agencies and organizations:

- Resources for Communities and People (RCAP) Solutions: June-Sept 2022
- PRASA: June-Aug 2022

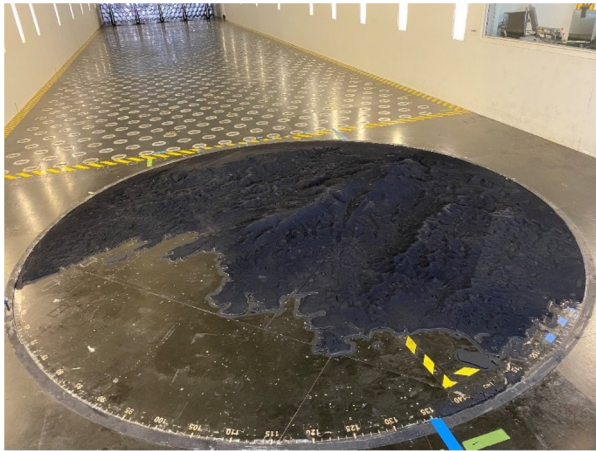
Additional outreach for information and data requests:

- FEMA
- PR Department of Education

News update and social media posts for Hurricane Maria's 5th anniversary



NCST Investigation Project Updates



Hazard Characterization

Completed wind tunnel testing of topographic models

Critical Buildings

Completed administrator interviews and first phase of evaluation work for selected shelters

Emergency Communications

Completed household surveys

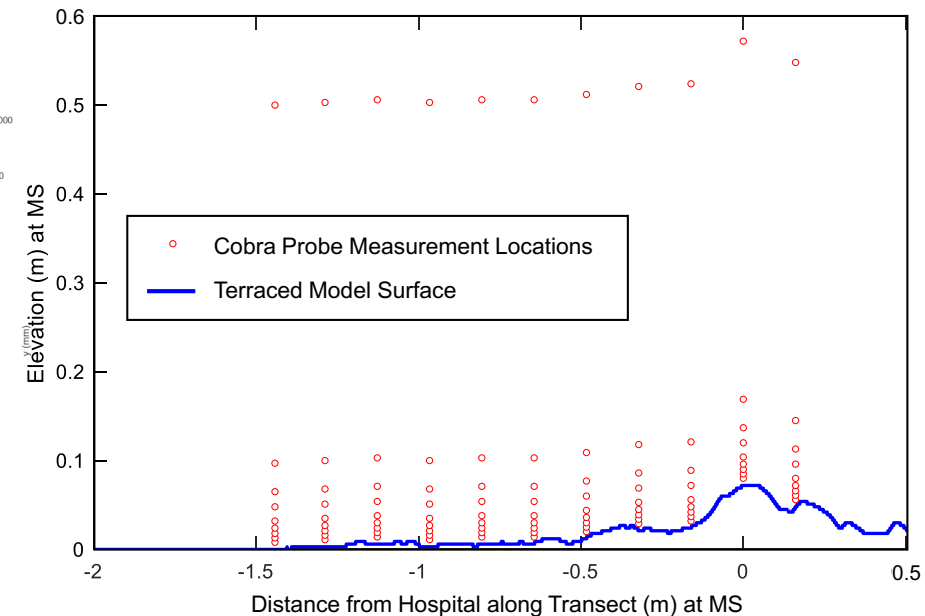
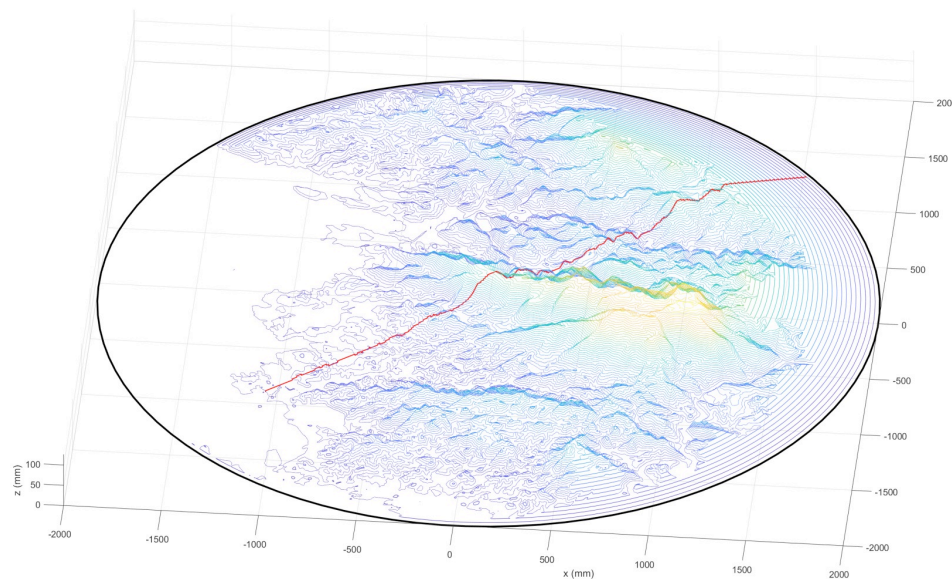
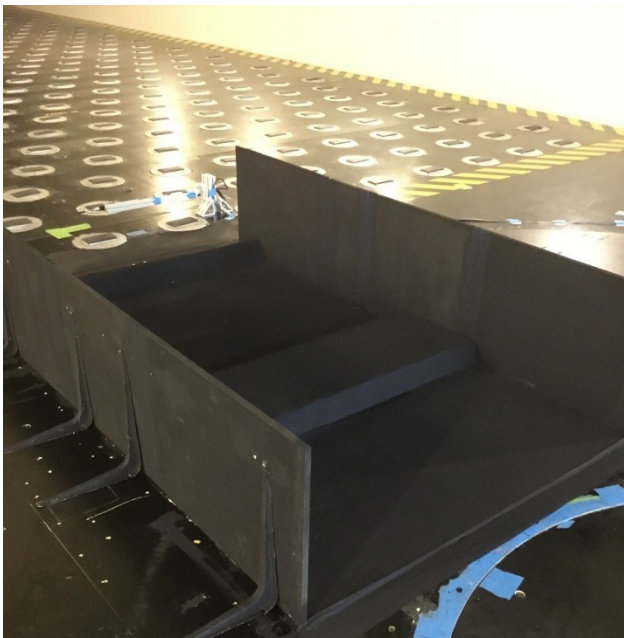
Morbidity & Mortality

Completed hospital interviews and medical records extraction

Hazard Characterization Project

Wind Tunnel Testing

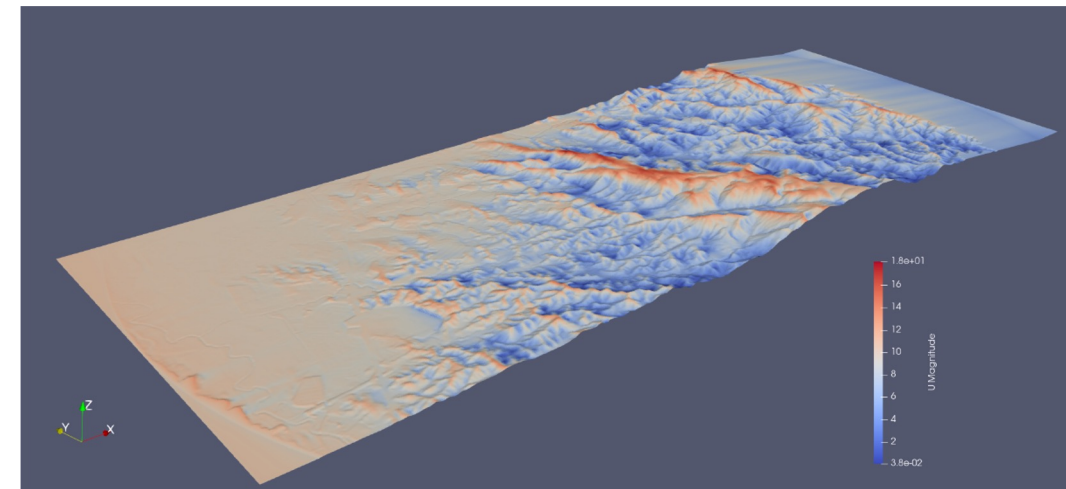
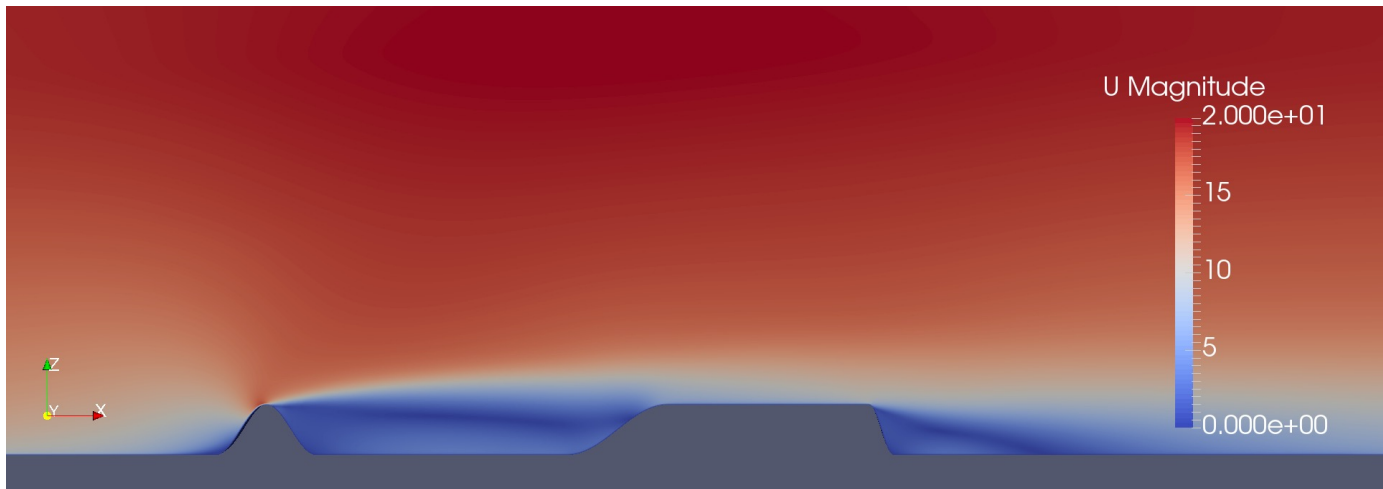
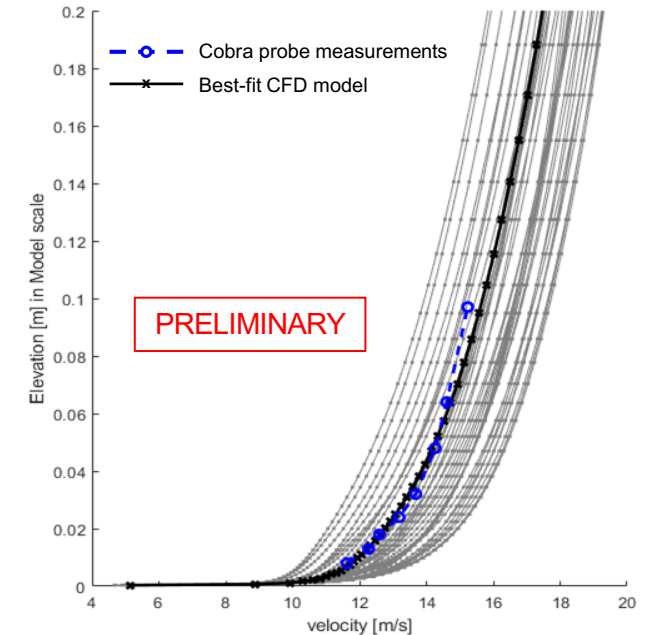
- Completed testing of final topographic model: generic ridge and plateau model with rough surface (smooth and terraced models tested previously)
- Received processed velocity probe data from wind flow over Yabucoa and Mayagüez topographic models; completed quality control review of data



Hazard Characterization Project

Computational Fluid Dynamics

- Completed an optimization procedure to select model parameters to best match the measured approach flow profile in the wind tunnel tests
- Performed comparisons of CFD results with Cobra probe measurements from wind tunnel testing



Hazard Characterization Project

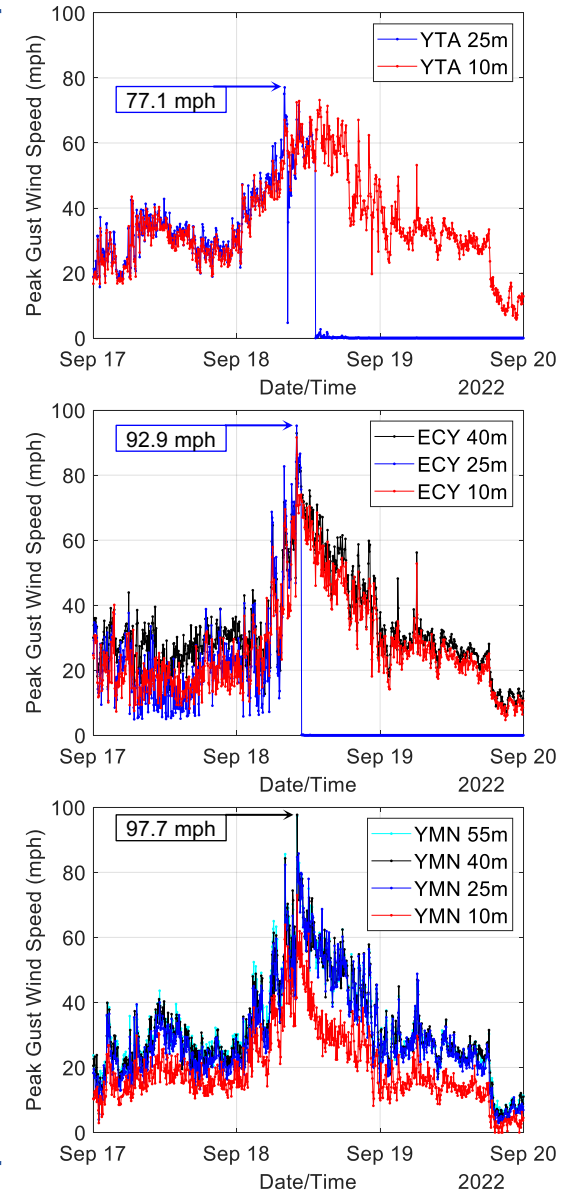


Field Measurements

- Analyzed 18 months of data (March 2021 – Sept 2022), including comparisons with wind tunnel and CFD results
- Measured high winds during **Hurricane Fiona** (2 of 12 sensors sustained damage)



Credit for aerial imagery: Google, Maxar Technologies, CNES / Airbus, Landsat / Copernicus



Evaluation of Shelter Facilities

- Completed Phase 1 evaluations for 5 selected shelter facilities (4 schools, 1 non-school):
collection and review of documentation on facility characteristics (e.g., building plans) and damage assessments
- Completed interviews with administrators at each of the 5 selected shelters using previously developed interview guide (4 interviews completed since June)

Interview Guide Categories

1. Participant Background
2. Facility Description Prior to Hurricane Maria
3. Hazard Exposure and Impacts to the Facility
4. Damage to Buildings
5. Function and Operation of the Facility
6. Wrap-Up

Phase 1: Initial document collection and review

Phase 2: Interviews, additional document collection and review, field investigation

Emergency Communications Project

NIST



Household Survey

Data collection is now complete

1522 households surveyed

Survey data collection took place from August 2021-September 2022

Content

Topics included: prior disaster experience, emergency communications, evacuation decisions, hurricane impacts and healthcare needs, social and demographics characteristics

Modes

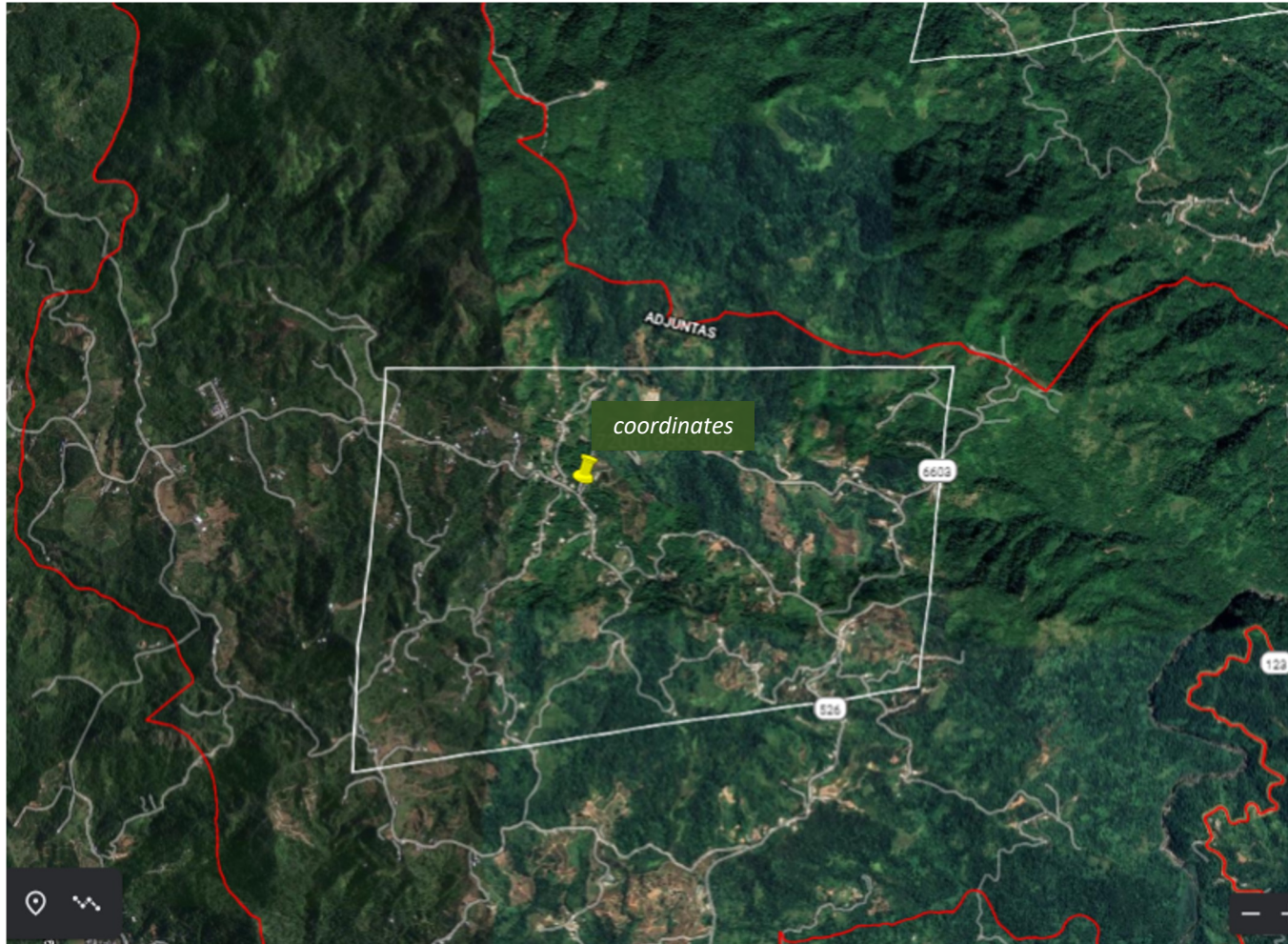
Face to face and online surveying were conducted

In-person surveying far more effective; 95% responded in person; Puerto Rican data collectors were critical to success

Emergency Communication Project



Sample Size & Area Probability Sampling



Credit for aerial imagery: Google, Maxar Technologies, CNES / Airbus

Initial sample size per region ($n=380$) was determined using a 95% Confidence Interval and a Margin of Error of 5%.

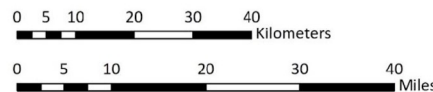
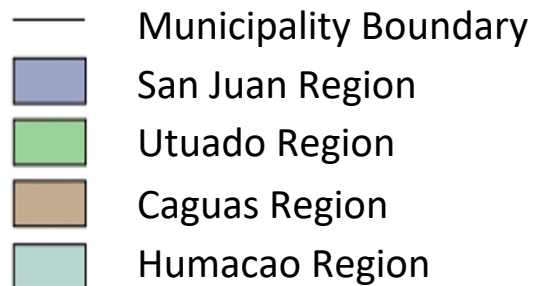
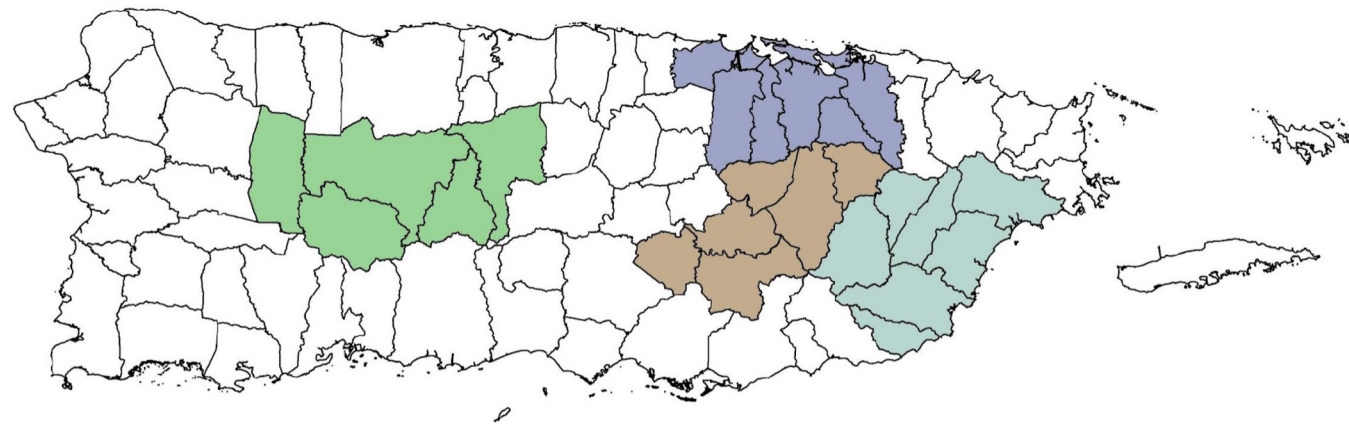
Surveyed households were in geographic clusters. The sampling design had a target of 10 complete interviews for each of 152 Census Block Groups.

Selected Blocks Groups included typical residential and rural areas as well as areas prone to landslide and flooding risks.

Enumerators distributed invitations to households following specific Walking Rules.

Emergency Communications Project

- Target Sample: 1,500 households across the four study regions; stratified for *flood risk* and *landslide risk*
- The selection of Block Groups within municipalities was checked to ensure appropriate representation of socioeconomic status across Puerto Rico



Study Region	Disposition		
	In person	Online	Total
San Juan Region	347	33	380
Utuado Region	365	15	380
Caguas Region	360	22	382
Humacao Region	374	6	380
Total by disposition	1446	76	1522

Preliminary Results

Morbidity and Mortality Project

Verbal Autopsy and Socio-Environmental Survey

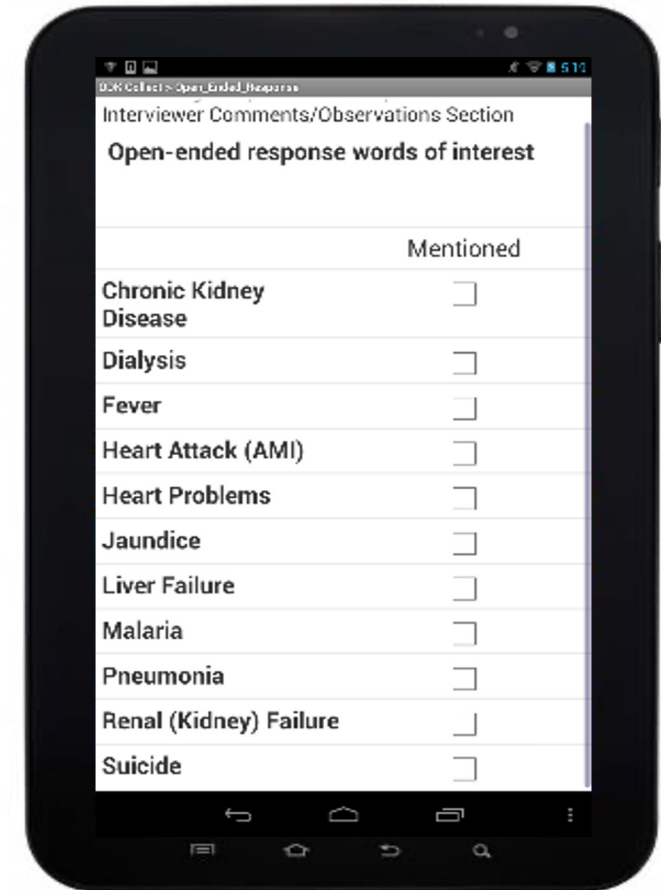
- Additional outreach conducted using a people finder service to contact next of kin and key informants of those who died
- 54 additional interviews completed since June for a total of 412 (*as of 9/27/22*); this represents approximately 23% of the deaths recorded in the first 2 weeks (1,772)

Medical Records and Hospital Functions Review

- Paperwork Reduction Act approval for interviews granted by OMB (6/14/22)
- Contractor completed pilot study and delivered report to NIST
- Interviews completed for 6 hospitals and data extraction completed for 5 hospitals

Spatial and Temporal Analysis

- Geospatial data on hazards and infrastructure shared by other projects to inform cause-specific mortality assessments



Source: Bernardo Hernández Prado
(with permission)

NWIRP Research Project Updates



Infrastructure

Interviews with Infrastructure Managers and Operators for power, transportation, and water to begin Fall 2022



Business & Supply Chain

Interviews of Shipping and Transportation Sector Representatives in progress, expected to conclude Winter 2022

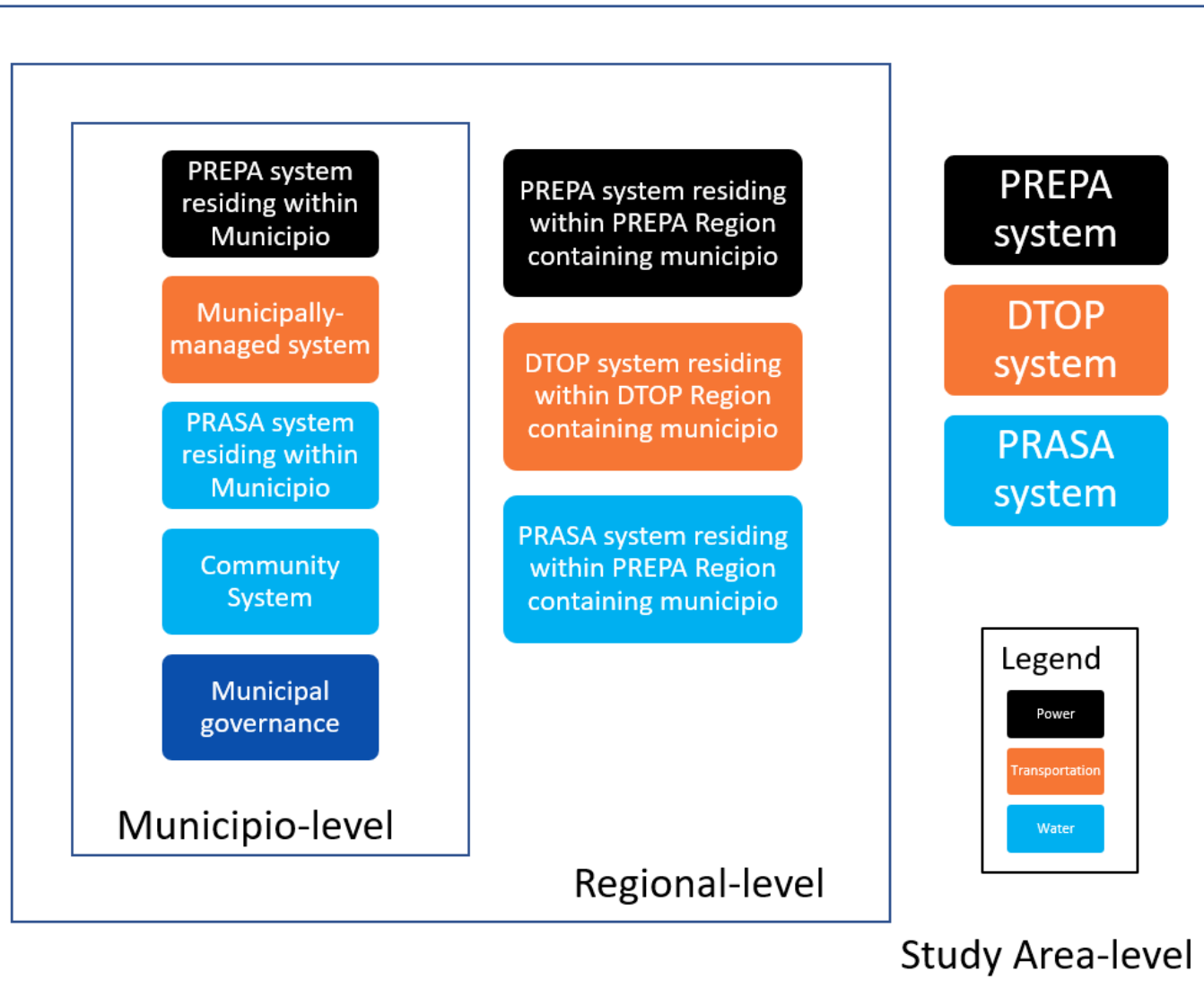


Schools & Hospitals

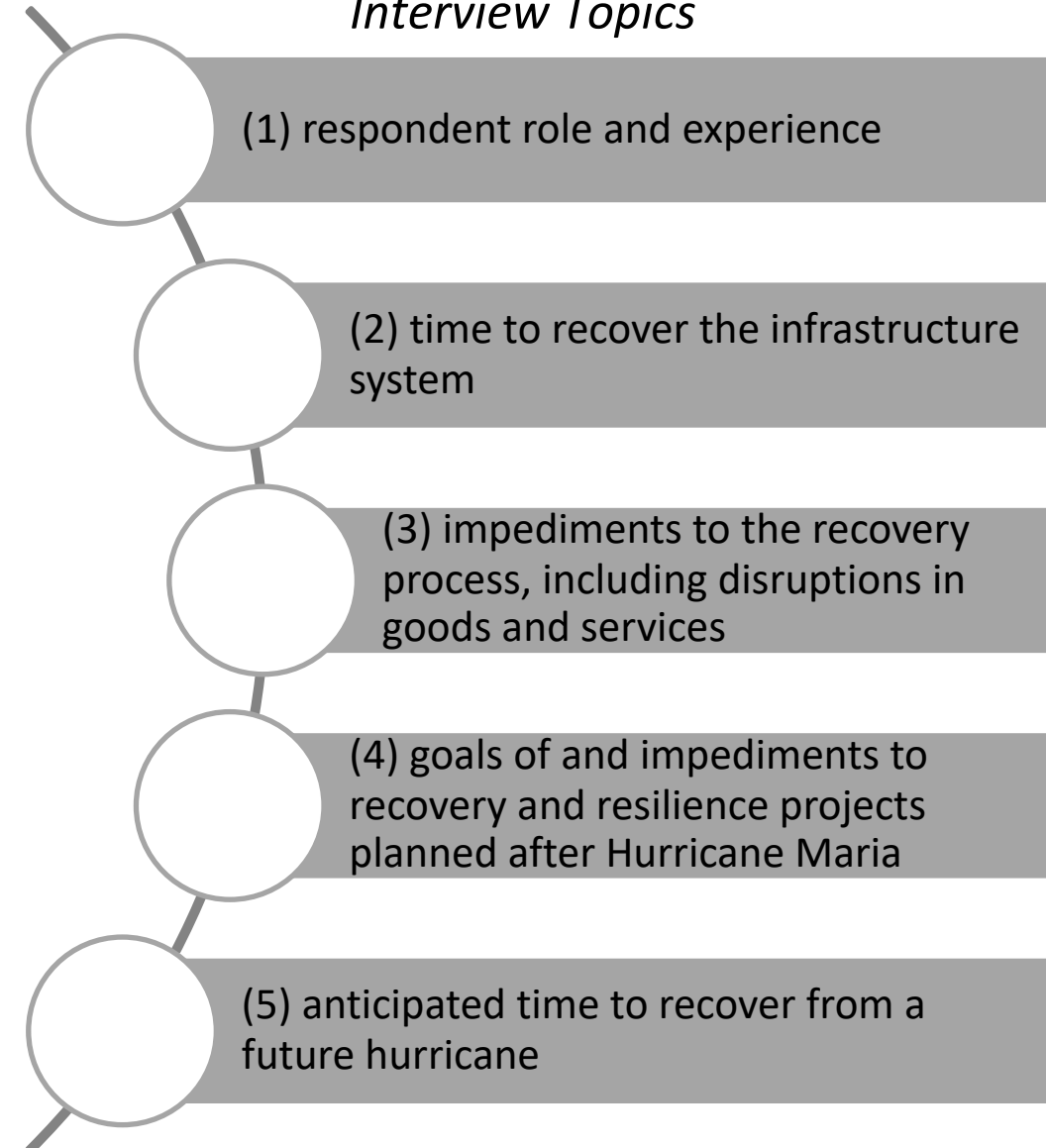
Wave 1 Surveys and Interviews of School and Hospital Representatives in progress, expected to conclude in Winter 2022

Infrastructure Interviews

Interview Respondents



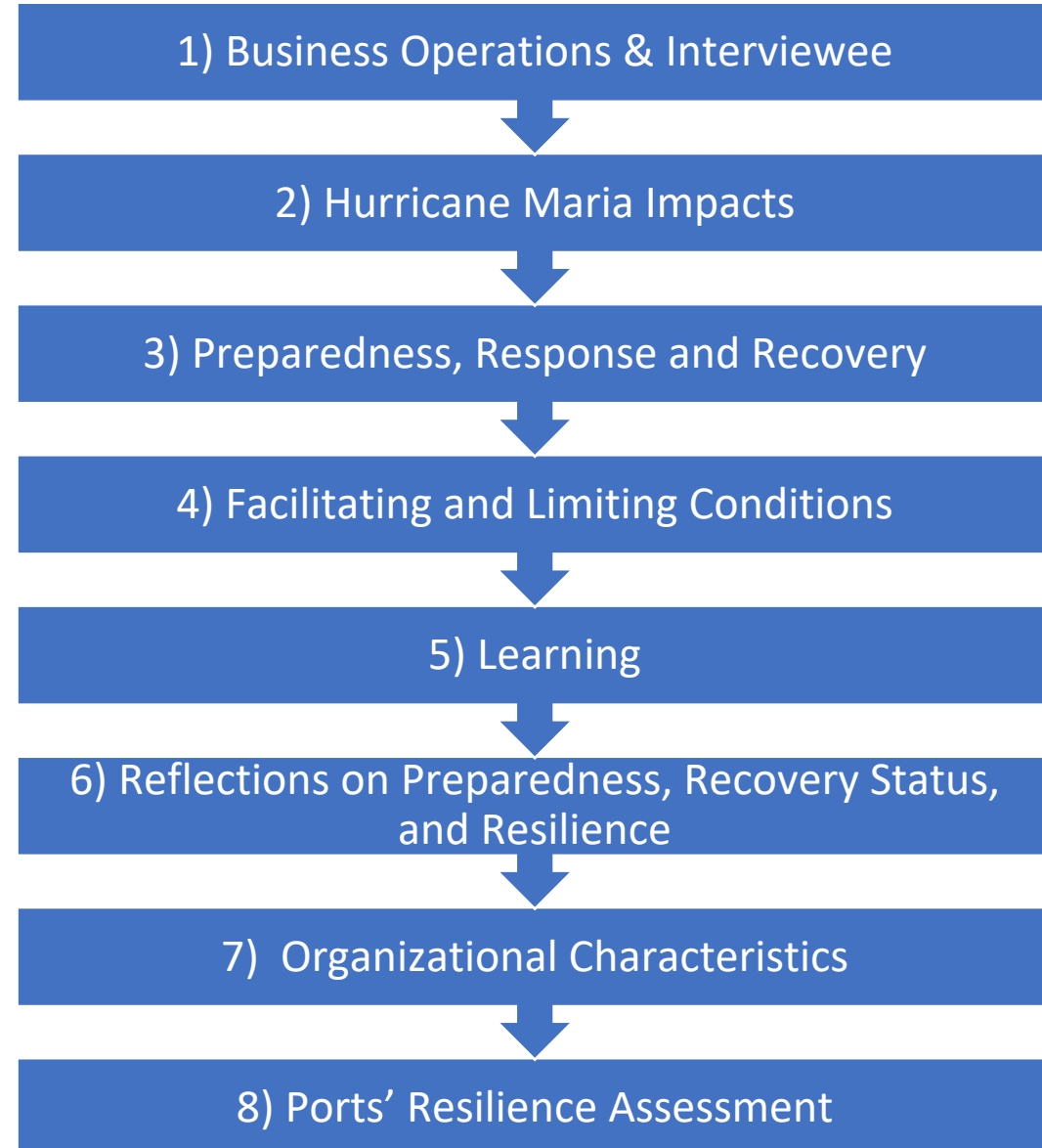
Interview Topics



Shipping and Transportation Interviews



Interview Topics →



Interview Status (9/23/2022)

Status	Total Counts	Air and Water Transport.	Truck Transport.	Support Activities for Transport.	Couriers and Messengers; Warehousing and Storage
Scheduled	1	0	0	1	0
Completed	11	1	3	6	1
Sample Frame Total	76	9	11	46	10
Target Completes	30	4 - 7	5 - 10	7 - 16	4 - 8

School and Hospital Surveys

Survey Status (9/23/2022)

Disposition	Institution type			Total x disposition
	Public Schools	Private Schools	Hospitals	
Complete	140	74	12	226
In Progress	52	37	8	97
Sample Frame Total	1038		45	323
Target Completes	365		45	410

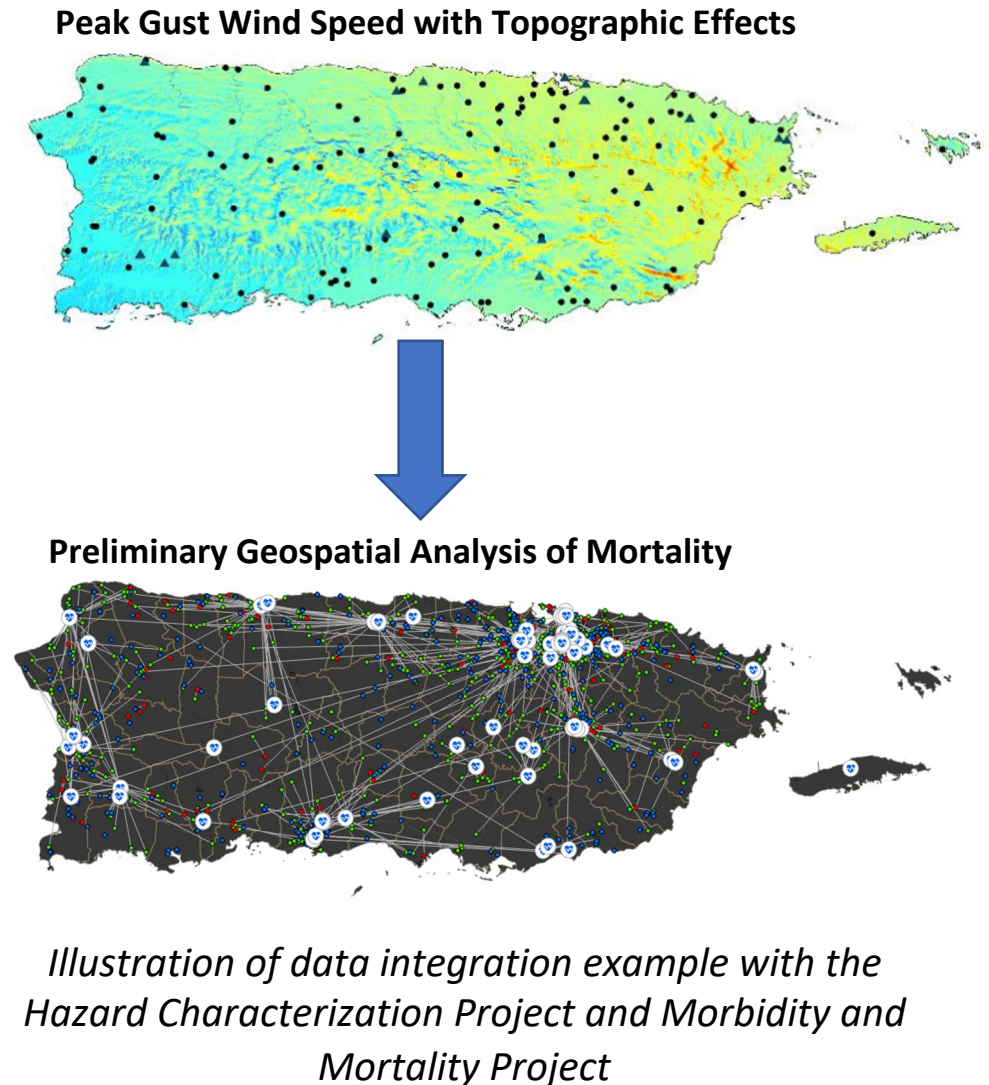
Target (sample size) for schools determined by a 95% Confidence Interval with a 5% Margin of Error; Target for hospitals is a census for the study area

Survey Topics



Project Integration

- Project leaders held two working sessions to identify and prioritize opportunities for sharing of datasets across projects, with consideration of:
 - spatial and temporal scales required for integration
 - timeline for data availability and use
 - questions that the integrated analysis could address in support of findings and recommendations
- Priority examples of cross-project integration include:
 - Sharing of geospatial information on hazards and infrastructure with the GW contractor team to inform cause-specific mortality assessments
 - Information on impacts to schools and hospitals from the Recovery of Social Functions NWIRP Project surveys that could inform the Critical Buildings NCST Project



Hurricane Fiona Themes

- Landfall in southwestern Puerto Rico on September 18 as a Category 1 Hurricane¹
 - Maximum sustained wind speeds estimated at 85 mph
 - Major rainfall event (> 25in)²
- Infrastructure failures
 - Complete power outage across PR followed by widespread and ongoing disruptions³
 - At the height, more than 800,000 without water service⁴
 - Wireless communications remained mostly functional⁵
- PR Dept. of Health reports 18 confirmed deaths as attributed to Hurricane Fiona, 13 more under investigation by the PR Dept. of Health⁶

¹<https://www.nhc.noaa.gov/archive/2022/al07/al072022.update.09181935.shtml?>

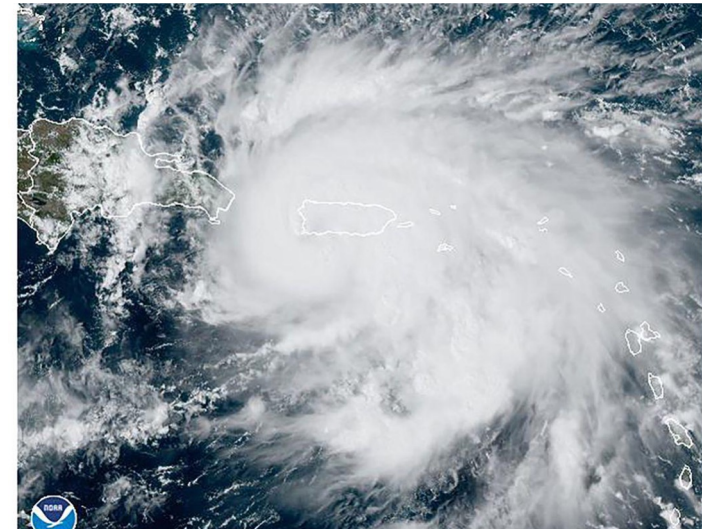
²https://www.cnn.com/weather/live-news/hurricane-fiona-news-09-19-22/h_000d9fc187a59665ee1d0fd1c15af8a9

³https://www.cnn.com/weather/live-news/hurricane-fiona-news-09-19-22/h_029110cba468c4af3ca8b87f00f47cfc

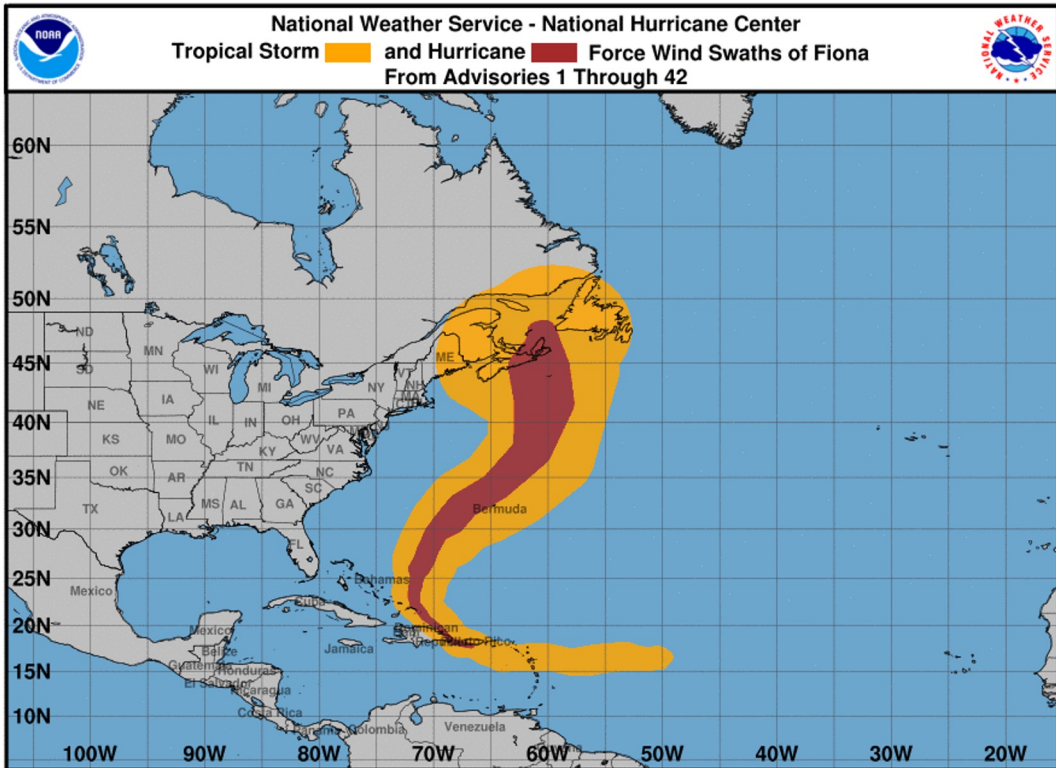
⁴<https://www.elnuevodia.com/noticias/locales/notas/acueductos-dice-que-redujeron-a-48-la-cantidad-de-clientes-sin-servicio-de-agua-potable/>

⁵<https://www.whitehouse.gov/briefing-room/presidential-actions/2022/09/18/president-joseph-r-biden-jr-approves-puerto-rico-emergency-declaration/>

⁶https://www.salud.gov.pr/vigilancia_Fiona



Impacts of Hurricane Fiona on Current Work



Credit: NOAA

Hurricane Fiona made landfall in Puerto Rico at 3:20pm on Sunday, September 18, 2022.

Hurricane Fiona's impacts on Puerto Rico have posed challenges for our projects and Team:

- contract team members without power and water
- hospitals on generators
- few schools in normal operating mode
- infrastructure agencies under great strain

The Team is evaluating opportunities where consideration of Hurricane Fiona in future surveys and interviews could strengthen our findings and recommendations:

- Effectiveness of post-Maria adaptations and mitigations
- Impact of Hurricane Fiona on long-term recovery of infrastructure systems and social functions

Questions?

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