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**EVERY COMMUNITY AN ISLAND:
PREPARING FOR CATASTROPHIC DISASTERS**

by

Sean Card

March 2021

Co-Advisors:

Glen L. Woodbury
Nadav Morag (contractor)

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**EVERY COMMUNITY AN ISLAND:
PREPARING FOR CATASTROPHIC DISASTERS**

Sean Card
Preparedness and Analysis Branch Chief - FEMA Region II,
Department of Homeland Security
BA, American Military University, 2016

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March 2021**

Approved by: Glen L. Woodbury
Co-Advisor

Nadav Morag
Co-Advisor

Erik J. Dahl
Associate Professor, Department of National Security Affairs

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ABSTRACT

This thesis is a single-case study of Puerto Rico's experience with Hurricane Maria and its catastrophic impacts. As the nation faces more complex and frequent catastrophic disasters, practitioners must consider how to build resilience in a meaningful way by beginning with the community. America's approach to disaster preparedness and response outlined in the National Preparedness Goal (NPG) and the National Response Framework (NRF) has respectively produced "whole community" concepts and a tiered response approach to disasters. However, the NPG has yet to realize the concept of "whole community" fully by effectively integrating community-based actors and other non-governmental entities into disaster preparedness, response, and recovery cycles. The NRF also does not outline contingencies for the collapse of the framework in catastrophic disasters when mutual aid, state, and federal resources become unavailable or insufficient for lengthy periods of time, leaving communities isolated. To examine these issues, Puerto Rico's disaster impacts are examined via the Federal Emergency Management Agency's community lifelines as a categorical method of organization. By synthesizing a large body of literature, this study provides disaster preparedness and response conclusions for all lifelines and identifies overarching themes centered upon a need for holistic disaster preparedness, integration of non-governmental actors, decentralization, and redundant critical infrastructure systems.

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TABLE OF CONTENTS

I.	INTRODUCTION.....	1
	A. PROBLEM STATEMENT	1
	B. RESEARCH QUESTIONS	5
	C. RESEARCH DESIGN	6
	D. THESIS OVERVIEW	8
II.	HURRICANE MARIA AND PUERTO RICO	9
	A. LITERATURE REVIEW	9
	1. National Frameworks, Strategies, and Plans	10
	2. Emerging Trends	15
	3. After-Action Reports, Academic Studies, Oversight Reports, Media Accounts, Media Accounts, and Published Non-fiction	18
	4. Literature Review Summary	21
	B. BACKGROUND	22
	1. Historical Context	22
	2. Hurricane Maria	23
	3. Background Summary	25
III.	CATASTROPHIC PREPAREDNESS GAPS AND COMMUNITY ADAPTATIONS	27
	A. SAFETY AND SECURITY LIFELINE	29
	1. Law Enforcement.....	29
	2. Fire Service.....	33
	3. Search and Rescue	36
	4. Government Service.....	40
	5. Community Safety	43
	6. Conclusion	45
	B. FOOD, WATER, AND SHELTER LIFELINE	46
	1. Food.....	46
	2. Water.....	54
	3. Shelter	58
	4. Agriculture.....	61
	C. HEALTH AND MEDICAL LIFELINE	66
	1. Medical Care	67
	2. Public Health	76
	3. Patient Movement	79

	4.	Medical Supply Chain	81
	5.	Fatality Management.....	84
	6.	Conclusion	87
D.		ENERGY LIFELINE	88
	1.	Power Grid	89
	2.	Fuel.....	99
	3.	Conclusion	101
E.		COMMUNICATIONS LIFELINE	102
	1.	Infrastructure.....	103
	2.	Responder Communications.....	106
	3.	Alerts, Warnings, and Messages.....	111
	4.	Finance.....	114
	5.	911 Communications	115
	6.	Conclusion	118
F.		TRANSPORTATION LIFELINE.....	119
	1.	Highway/Roadway/Motor Vehicle	119
	2.	Mass Transit.....	123
	3.	Railway.....	126
	4.	Aviation.....	126
	5.	Maritime	127
	6.	Conclusion	129
G.		HAZARDOUS MATERIALS LIFELINE.....	130
	1.	Facilities	130
	2.	HAZMAT, Pollutants, Contaminants.....	133
	3.	Conclusion	136
H.		SUMMARY	137
IV.		THEMES AND CONCLUSIONS	139
A.		THEMES	139
	1.	Holistic Disaster Preparedness	139
	2.	Integration of Non-governmental Actors.....	141
	3.	Decentralization	144
	4.	Redundant Systems.....	148
B.		CONCLUSIONS	149
	1.	Safety and Security Lifeline	149
	2.	Food, Water, and Shelter Lifeline	151
	3.	Health and Medical Lifeline.....	153
	4.	Energy Lifeline	155
	5.	Communication Lifeline.....	158
	6.	Transportation Lifeline	160

7. Hazardous Materials Lifeline162
C. RECOMMENDATIONS FOR FUTURE RESEARCH.....164
D. SUMMARY165

LIST OF REFERENCES167

INITIAL DISTRIBUTION LIST195

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LIST OF FIGURES

Figure 1.	Pulley System to Span the Río Viví.....	51
Figure 2.	The Primary Hospital on the Island of Vieques, Shuttered and in Disrepair as of April 2019.....	75

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LIST OF TABLES

Table 1. Lifeline Components and Subcomponents.28

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	After-Action Report
ALI	Automatic Location Identifier
AM	Amplitude Modulation
APJ	Asociación Pro Juventud y Comunidad de Barrio Palmas
ARC	American Red Cross
ARES	Amateur Radio Emergency Service
ARRA	American Recovery and Reinvestment Act
ARRL	American Radio Relay League
ASCE	American Society of Civil Engineers
ASPR	Assistant Secretary for Preparedness and Response
ATF	Alcohol, Tobacco, and Firearms
ATI	Integrated Transit Authority (Spanish acronym)
BFS	Bureau of Forensic Sciences
BGAN	Broadband Global Area Networks
CAD	Caribbean Area Division
CAISE	Civil Affairs Information Support Element
CBO	Community-Based Organization
CBP	Customs and Border Protection
CDC	Centers for Disease Control
CHDS	Center for Homeland Defense and Security
CONUS	Continental United States
COSSAO	Corporación de Servicios de Salud Primaria y Desarrollo Socioeconómico El Otoo
CT	Computerized Tomography
DHS	Department of Homeland Security
DIRS	Disaster Information Reporting System
DLA	Defense Logistics Agency
DMAT	Disaster Medical Assistance Team
DMORT	Disaster Mortuary Operations Response Team
DOD	Department of Defense

DOJ	Department of Justice
DTOP	Puerto Rico Department of Transportation
DWTP	Drinking Water Treatment Plant
EHS	Extremely Hazardous Substances
EMAC	Emergency Management Assistance Compact
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EPCRA	Emergency Planning And Community Right-To-Know Act
FBI	Federal Bureau Of Investigation
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FM	Frequency Modulation
FMS	Federal Medical Station
GAO	Government Accountability Office
GDP	Gross Domestic Product
GIS	Geographic Information System
HAM	Term Used To Describe an Amateur Radio Operator
HAZMAT	Hazardous Materials
HHS	Health and Human Services
HRSA	Health Resources and Services Administration
HSI	Homeland Security Investigations
HSPD	Homeland Security Presidential Directive
ICE	Immigration and Customs Enforcement
IPAWS	Integrated Public Alert and Warning System
IRP	Integrated Resource Plan
ISB	Incident Support Base
IV	Intravenous
JFO	Joint Field Office
JPATS	Joint Patient Assessment and Tracking System
Kwh	Kilowatt Hour
LE	Law Enforcement
LEPC	Local Emergency Planning Committee

LMR	Land-Mobile Radio
LSCMS	Logistics Supply Chain Management System
MASTT	Multi-Agency Shelter Transition Taskforce
Mb	Millibars
MERS	Mobile Emergency Response Support
MEU	Marine Expeditionary Unit
MRC	Medical Reserve Corps
MRE	Meals Ready to Eat
MSDS	Material Safety Data Sheet
NDMS	National Disaster Medical System
NEMA	National Emergency Management Association
NGO	Non-Governmental Organization
NHS	National Highway System
NPG	National Preparedness Goal
NRF	National Response Framework
NWS	National Weather Service
NYPA	NY Power Authority
ODNI	Office of the Director of National Intelligence
OIG	Office of Inspector General
PA	Public Assistance
PEP	Primary Entry Point
POD	Point Of Distribution
PPD	Presidential Policy Directive
PRASA	Puerto Rico Aqueduct and Sewer Authority
PREMA	Puerto Rico Emergency Management Agency
PREMB	Puerto Rico Emergency Management Bureau
PREPA	Puerto Rican Electric Power Authority
PRFD	Puerto Rico Fire Department
PRHTA	Puerto Rico Highway and Transit Authority
PRIDCO	Puerto Rico Industrial Development Company
PROMESA	Financial Oversight and Management Board (Spanish Acronym)
PRPA	Puerto Rico Ports Authority

PSAP	Public Safety Answering Point
QRT	Quick Reaction Team
RSA	regional staging area
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SERC	State Emergency Response Commission
SNS	Strategic National Stockpile
STIP	Statewide Transit Improvement Program
SW-RAMC	Southwestern Regional Academic Medical Center
THIRA	Threat and Hazard Identification and Risk Assessment
TSA	Temporary Sheltering Assistance
US&R	Urban Search and Rescue
USACE	United States Army Corps of Engineers
USAID	U.S. Agency Of International Development
USDN	Urban Sustainability Directors Network
VHF	Very High Frequency
VOIP	Voice Over Internet Protocol
VSAT	Very Small Aperture Terminal
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

In 2017, the Federal Emergency Management Agency (FEMA) administrator testified on Capitol Hill that America is a nation unprepared for disasters.¹ The current American emergency management structure exhibits an overreliance on federal disaster aid and too little focus on American communities. This dynamic is problematic amid catastrophic disasters that threaten the integrity of the tiered National Response Framework, which stipulates that higher levels of government and outside disaster response resources fill resource voids. When truly catastrophic disasters strike, American communities will be “on their own” for significant periods and must consider how to prepare for such contingencies. Preparing for and surviving such catastrophes requires what FEMA commonly refers to as a “whole community approach” to disaster management.²

This thesis employs a single case study methodology of Puerto Rico’s 2017 experience of a catastrophic disaster, Hurricane Maria, a Category 4 hurricane at landfall on September 20. This thesis seeks to answer one primary research question via two supporting questions:

How can the whole community prepare to manage the consequences of catastrophic disasters without the aid of organizations beyond their borders?

- a. What were the preparedness gaps in the Commonwealth of Puerto Rico in 2017 following Hurricane Maria?
- b. How did communities and the Commonwealth of Puerto Rico overcome disaster preparedness gaps amid catastrophe through formal and informal networks?

¹ The former FEMA Administrator, Brock Long’s, exact words were, “We don’t have a true culture of preparedness in this country. Our citizens are not prepared.” “2017 Hurricane Disaster Lessons,” C-SPAN, video, March 15, 2018, 3:17:03, <https://www.c-span.org/video/?442612-1/federal-state-officials-testify-lessons-learned-2017-disasters>.

² Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action*, FDOC 104-008-1 (Washington, DC: Department of Homeland Security, 2011), 3, https://www.fema.gov/media-library-data/20130726-1813-25045-3330/whole_community_dec2011__2_.pdf.

The two elements supporting the primary research question—response shortcomings and improvisations—are cataloged in the context of FEMA’s seven community lifelines. This structure allows communities and emergency management practitioners to view Hurricane Maria’s impacts as component parts whereby the whole community response actions can be retrospectively examined to understand better and inform more effective approaches to build community preparedness and disaster resilience against future catastrophic disasters. Puerto Rico’s shortfalls and adaptations, considered collectively, will contribute to informing how communities cope when the National Response Framework enters partial or total collapse when outside response resources become unavailable or otherwise inadequate to meet the needs of those impacted by disaster.

The results of this study highlight that Hurricane Maria occurred in the context of many systemic issues plaguing the island, primarily rooted in extractive industries, and associated divestment in the island’s business sector when favorable tax structures “sunsetted” in legislation. The resulting fragile roadways, power grid, communications systems, water networks, and other infrastructure served as amplifiers of disaster impacts. Additionally, Puerto Rico faces significant public health challenges that presented increased population vulnerability to disaster impacts and response challenges.

However, the study also indicated highly cooperative and determined communities that came together to survive collectively in the days, weeks, and months following Hurricane Maria. Community cooperation was facilitated by long-standing community-based organizations (CBOs). Since Maria, many other CBOs have surfaced to address population needs, such as food, housing, medical care, solar energy, farming, etc.

The conclusions of this study center upon four distinct themes and the seven community lifelines. Each of the four themes was derived from findings common across all lifelines and included holistic disaster preparedness, integration of non-governmental

actors, decentralization, and redundant systems. These themes appeared to reside at the root of all critical response and recovery shortcomings throughout the study.

In brief, the following represents a brief summation and crosscut of conclusions reached for each community lifeline:

- **Safety and Security Lifeline**—The near-total collapse of disaster response capabilities in Puerto Rico suggests the island should reimagine community safety and security by reaching deeply into communities and involving them in disaster preparedness so they can operate as assets at times when government resources are overwhelmed.
- **Food, Water, and Shelter Lifeline**—In a catastrophic disaster, community needs will outpace available resources, which calls for more resilient communities and that “slack” be built into available supply chains to boost resiliency. Puerto Rico also maintains a heavy and risky reliance on imported food goods due to the long-term degradation of its agricultural sector.
- **Health and Medical Lifeline**—Puerto Rico faces a stark public health situation that will continue to exacerbate an effective disaster response in the future if not viewed as a priority. It is also necessary to bolster dispersed medical capacity to ensure it is in close proximity to those in need, which can be accomplished by local medical networks and non-government organizations (NGOs) or paramedicine providers.
- **Energy Lifeline**—Puerto Rico’s power sector filed for bankruptcy just months before Hurricane Maria struck the island. Amid the storm, both distribution and transmissions lines were devastated, which resulted in the largest power outage in U.S. history and second-largest outage in recorded

history.³ The widespread power outage, lasting nearly a year in many areas, affected and complicated all other community lifelines. The power grid remains financially plagued as the island seeks to repair the system, and solar has become a favorable alternative in many communities.

- **Communications Lifeline**—A near-total loss of communications capability left communities uninformed, unable to communicate resource needs, and hindered first responders’ operational coordination. Non-governmental actors, such as the American Radio Relay League (ARRL), and Google’s X-Lab, proved able to bridge critical gaps in communications capabilities. The ARRL provided HAM, or amateur radio operator assistance, and Google was able to field experimental technology in an attempt to re-establish communications rapidly across the island.⁴
- **Transportation Lifeline**—Puerto Rico’s transportation infrastructure was in a state of decline and disrepair for years preceding Hurricane Maria.⁵ Maria caused a record 40,000 landslides across the island that isolated many communities and prevented commodity distribution.⁶ Many pre-disaster debris management contracts also failed to deliver required services to re-establish access quickly to hard-hit communities. This

³ New York Power Authority et al., *Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico* (Albany, NY: State of New York, Office of the Governor, 2017), 11, https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf; American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure* (San Juan, PR: American Society of Civil Engineers, 2019), 28, <https://www.infrastructurereportcard.org/state-item/puerto-rico/>.

⁴ American Radio Relay League, *2017 Hurricane Season After-Action Report* (Washington, DC: American Radio Relay League, 2018), 2, <http://www.arrl.org/files/file/Public%20Service/ARES/2017%20Hurricane%20Season%20AAR.pdf>; Jessica Guynn, “Google Parent’s Project Loon Delivers Internet to 100,000 in Puerto Rico,” *USA Today*, November 9, 2017, <https://www.usatoday.com/story/tech/2017/11/09/google-parents-project-loon-delivers-internet-100-000-puerto-rico/849627001/>.

⁵ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 38.

⁶ Erin K. Bessette-Kirton et al., “Landslides Triggered by Hurricane Maria: Assessment of an Extreme Event in Puerto Rico,” *GSA Today* 29, no. 6 (June 2019): 4–10.

capability gap prompted many communities to search for basic supplies and band together to clear debris in their own communities.⁷

- **Hazardous Materials Lifeline**—Puerto Rico faces various hazardous materials (HAZMAT) risks primarily from long-term infrastructure degradation due to fiscal constraints and divestment from the island.⁸ The poor safety track records of drinking and wastewater facilities and high rates of exposure to HAZMAT from several industries, such as farming, pharmaceutical production, petroleum facilities, coal plants, and others, serve as major public risk factors requiring consideration in planning for future catastrophic disasters.

In total, the experience of Puerto Rico illustrates what occurs when the national response framework is under extreme stress. Local and state response apparatuses collapsed, and mutual-aid and federal resources were slow to respond within that unexpected context. The response delay compelled informal actors, the private sectors, and communities to fulfill often unconventional roles and to provide critical resources and services to bridge resource shortfalls until a sense of normalcy could be returned to the island.

The study indicated that despite informal and community actors rising to the occasion, their inclusion in disaster response and recovery was mostly unplanned, which likely resulted in under-leveraged resources. Since Hurricane Maria, many groups have renewed energies on disaster preparedness and resilience to foster greater synergy in future disasters. Still, the island faces systemic preparedness obstacles on many fronts.

⁷ Associated Press, “Puerto Ricans Hunt for Precious Wi-Fi and Cell Signals,” *Boston Globe*, September 25, 2017, <https://www.bostonglobe.com/news/world/2017/09/25/puerto-ricans-hunt-for-precious-and-cell-signals/umetMJbhJ46QgMmO9D10tM/story.html>; Patrick J. Holladay et al., “Utuaado, Puerto Rico and Community Resilience Post-Hurricane Maria: The Case of Tetuan Reborn,” *Recreation, Parks, and Tourism in Public Health* 3 (2019): 5–16, <https://doi.org/10.2979/rptph.3.1.02>.

⁸ Jordan R. Fischbach et al., “After Hurricane Maria: Predisaster Conditions, Hurricane Damage, and Recovery Needs in Puerto Rico,” RAND, 275, September 30, 2020, https://www.rand.org/pubs/research_reports/RR2595.html.

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I would like to acknowledge the men and women of local, state, and federal government agencies from all around the nation who responded to Puerto Rico in a time of great need. Your dedication and perseverance brought vital resources and services to the island and helped relieve human suffering while setting the stage for long-term recovery.

While many government agencies responded to Puerto Rico, response and recovery operations were also heavily dependent upon non-governmental organizations (NGOs) that proved to be well-connected to the communities they serve, and diligent in their efforts to reach hard-hit areas to provide vital relief supplies. A disaster of such scope and scale truly requires a whole of community approach to succeed. Moreover, NGOs were true partners in response to Hurricane Maria.

I would also like to acknowledge the grit, tenacity, and indomitable spirits of the millions of Puerto Ricans who weathered the storm and all the struggles that followed. In areas where both government and NGO resources fell short, communities stepped in to fill the void through ingenuity and determination to provide for themselves, their families, their neighbors, and their communities. The response and recovery to Hurricane Maria would not have been possible without the critical actions of actors at all levels from small communities to federal agencies. Together, we must chart a path forward that is inclusive and aimed toward catastrophic disaster preparedness and built upon fundamental resiliency.

Last, but certainly not least, I would like to thank all Center for Homeland Defense and Security (CHDS) faculty and staff for their tireless mentorship and support throughout the program. I would especially like to thank my advisors, Mr. Glen Woodbury and Dr. Nadav Morag, for their expert guidance and insight throughout the design and writing of this thesis. Without such support and passion for education shown by the staff of CHDS, this thesis would not have been possible.

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I. INTRODUCTION

This thesis is a single-case study evaluating the impacts of Hurricane Maria on Puerto Rico to extract lessons learned in catastrophic disaster preparedness and resilience when standard response structures collapse or struggle to meet the humanitarian needs of impacted populations. As the nation peers into the future, various disasters capable of collapsing traditional response and recovery models exist. By examining cases in which partial collapse occurred, valuable lessons may be gleaned that communities can utilize in crafting preparedness strategies that elevate catastrophic disaster resilience.

A. PROBLEM STATEMENT

In 2017, the Federal Emergency Management Agency (FEMA) administrator testified on Capitol Hill that America is a nation unprepared for disasters.¹ These comments came shortly after the record-setting 2017 disaster season. Six years prior, in 2011, FEMA had attempted something novel by calling on every American to join in a “whole of community” approach to prepare for disasters. The same year, FEMA issued a doctrine titled, *Whole Community Approach to Emergency Management* that envisioned an integrated, all of nation approach, to disaster preparedness and response, and identified pathways for realizing the vision.² However, years of preparedness data indicate FEMA has been unable to increase individual and community preparedness. In a 2014 report,

¹ The former FEMA Administrator, Brock Long’s, exact words were, “We don’t have a true culture of preparedness in this country. Our citizens are not prepared.” “2017 Hurricane Disaster Lessons,” C-SPAN, video, March 15, 2018, 3:17:03, <https://www.c-span.org/video/?442612-1/federal-state-officials-testify-lessons-learned-2017-disasters>.

² Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action*, FDOC 104-008-1 (Washington, DC: Department of Homeland Security, 2011), 19, https://www.fema.gov/media-library-data/20130726-1813-25045-3330/whole_community_dec2011__2_.pdf.

Preparedness in America, FEMA indicated that the proportion of Americans taking tangible preparedness actions had remained virtually static since 2007.³

In 2018, FEMA again envisioned a more fundamentally prepared nation and set forth to achieve it with two of its three strategic goals, (1) build a culture of preparedness, and (2) ready the nation for catastrophic disasters.⁴ However, the agency largely set forth to accomplish these goals by utilizing the same methods as it always has in the past. In a 2019 report, the FEMA Higher Education Program stated, “Ready.gov, America’s PrepareAthon, and National Preparedness Month, all aimed at individual households and communities, have not produced the desired results.”⁵ In recent household surveys, most Americans believe first responders will arrive to provide rescue, supplies, and aid within 72 hours following any disaster despite being more skeptical of local, state, and federal government competency.⁶ Over half of Americans believe help will arrive within one hour of a “major emergency.”⁷ These survey results are interesting since the public is almost always the real first responders.

Approximately 87% of those in the twin towers on 9/11 survived. A majority were evacuated to safety by their officemates. Ferry services and private boat owners self-organized the largest maritime evacuation in recorded history by evacuating lower Manhattan immediately after the towers fell. The Cajun Navy made the critical difference

³ Federal Emergency Management Agency, *Preparedness in America: Research Insights to Increase Individual, Organizational, and Community Action* (Washington, DC: Federal Emergency Management Agency, 2014), 1, <https://www.hsdl.org/?abstract&did=764015>; Katherine E. Browne and Laura Olson, *Building Cultures of Preparedness: Report for the Emergency Management Higher Education Community* (Washington, DC: Federal Emergency Management Agency, 2019), 6, <https://www.hsdl.org/?abstract&did=820838>.

⁴ Federal Emergency Management Agency, *Strategic Plan: 2018–2022* (Washington, DC: Federal Emergency Management Agency, 2018), 4, <https://www.hsdl.org/?abstract&did=808818>.

⁵ Katherine E. Browne and Laura Olson, *Building Cultures of Preparedness: Report for the Emergency Management Higher Education Community* (Washington, DC: Federal Emergency Management Agency, 2019), 6, <https://www.hsdl.org/?abstract&did=820838>.

⁶ Lori Uscher-Pines et al., “Citizen Preparedness for Disasters: Are Current Assumptions Valid?,” *Disaster Medicine and Public Health Preparedness* 6, no. 2 (June 2012): 170–73, <https://doi.org/10.1001/dmp.2012.23>; Earth Institute, “Ready for Natural Disasters? Not So Much,” *State of the Planet* (blog), February 9, 2016, <https://blogs.ei.columbia.edu/2016/02/09/ready-for-natural-disasters-not-so-much/>.

⁷ Elisaveta P. Petkova et al., *The American Preparedness Project: Where the U.S. Public Stands in 2015*, Briefing Report no. 2 (New York: Columbia University, 2016), 22, <https://doi.org/10.7916/D84Q7TZN>.

in waterborne search and rescue efforts amid catastrophic flooding in Louisiana in 2016 and Houston, Texas, following Hurricane Harvey in 2017. Nearly all rescues from structural collapse following the 2010 major earthquake in Haiti were executed by the general public, and not by highly specialized urban search and rescue teams.⁸ Latent capability continues to remain absent in governmental planning frameworks and is rarely if ever, anticipated, or well integrated into response operations. In light of the threats of the 21st century and their catastrophic potential, America must discover new pathways to cultivating citizen preparedness meaningfully for catastrophic disasters.⁹ In the words of former FEMA Administrator Craig Fugate, “Government can and will continue to serve disaster survivors. However, we fully recognize that a government-centric approach to disaster management will not be enough to meet the challenges posed by a catastrophic incident. That is why we must fully engage our entire societal capacity.”¹⁰

Catastrophic threats and hazards jeopardize the integrity of current national preparedness and response models developed and led by FEMA, and by extension,

⁸ Russell R. Dynes, “Social Capital: Dealing with Community Emergencies,” *Homeland Security Affairs* 2, no. 2 (July 2006): 5; “Boatlift—Tom Hanks Narrates ‘An Untold Tale of 9/11 Resilience’,” American Waterways Operators, September 2014, <https://www.americanwaterways.com/media/videos/boatlift-tom-hanks-narrates-untold-tale-911-resilience>; Tricia Wachtendorf and James Kendra, “‘Cajun Navy’ Rescuers in Hurricane Harvey Show Vital Role of Volunteer Boats,” Salon, September 3, 2017, https://www.salon.com/2017/09/03/cajun-navy-rescuers-in-hurricane-harvey-show-vital-role-of-volunteer-boats_partner/; Charles Perrow, *The Next Catastrophe: Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters*, paperback ed. (Princeton, NJ: Princeton University Press, 2011), 4, <https://doi.org/10.1515/9781400838516>.

⁹ The Department of Homeland Security has previously defined a catastrophic disaster as “any natural or manmade incident, including terrorism, that results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, and/or government functions . . . [that] could result in sustained national impacts over a prolonged period of time; almost immediately exceeds resources normally available to State, local, tribal, and private-sector authorities in the impacted area; and significantly interrupts governmental operations and emergency services to such an extent that national security could be threatened.” Department of Homeland Security, *National Response Plan* (Washington, DC: Department of Homeland Security, 2004), 43, <https://www.hsdl.org/?view&did=450766>.

¹⁰ Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management*, 2.

every American community.¹¹ FEMA’s 2019 National Threat and Hazard Identification and Risk Assessment (THIRA) has outlined various catastrophic threats and hazards facing the nation, including a cumulative effect of plausible concurrent operations, Cascadia and San Andreas earthquakes, a New Madrid earthquake, Texas, Florida, and Hawaii hurricane scenarios, a pandemic, and even a space weather event threatening the power grid.¹²

FEMA’s National Response Framework (NRF) outlines the foundation for the national approach to disaster response. The framework indicates that federal, state-to-state, private-sector, and non-governmental organization (NGO) disaster response and recovery resources can respond to a disaster to render aid to a location when local response and recovery resources are overwhelmed.¹³ However, when outside resources become unavailable, such as during a major power outage, after a major hurricane or earthquake, or other climate change-fueled catastrophe, American communities must manage disaster consequences with the resources they have locally available. To date, a lack of decentralized and widespread citizen involvement in disaster preparedness and response has placed an overwhelming burden on top-down, government-centric disaster aid. If communities have not adequately recognized the limitations of government resources and prepared for this situation, they will be vulnerable in a catastrophic disaster.

Traditionally, when a disaster affects a community, local responders are the first on the scene. When local resources reach their limits, many communities look to neighboring communities for support and state-level emergency management agencies

¹¹ The National Response Framework defines catastrophic disasters as “one of such extreme and remarkable severity or magnitude that the Nation’s collective capability to manage all response requirements would be overwhelmed” and “potential threats to national security, national economic security, and/or the public health and safety of the Nation.” Department of Homeland Security, *National Response Framework*, 4th ed. (Washington, DC: Department of Homeland Security, 2019), 4, https://www.fema.gov/media-library-data/1572366339630-0e9278a0ede9ee129025182b4d0f818e/National_Response_Framework_4th_20191028.pdf.

¹² Federal Emergency Management Agency, *2019 National Threat and Hazard Identification and Risk Assessment (THIRA): Overview and Methodology* (Washington, DC: Federal Emergency Management Agency, 2019), 19, https://www.fema.gov/sites/default/files/2020-06/fema_national-thira-overview-methodology_2019_0.pdf.

¹³ Department of Homeland Security, *National Response Framework*, 6.

for additional resources. In rarer instances, when a state's response apparatus is overwhelmed, FEMA intervenes by providing support and coordinating resources from around the nation. Under typical emergency and disaster demands, most American communities can self-sufficiently manage common emergencies, and FEMA can adequately coordinate national resources in response to disasters. The NRF outlines this approach to disaster response by illustrating a multi-tiered system reliant upon bringing resources into an affected area after a disaster.¹⁴ However, in a nationally catastrophic disaster, this approach may not be feasible. A fundamental NRF assumption—that outside resources have the capacity and capability to respond to support communities across the nation—drives national preparedness for disasters and constitutes a preparedness gap worthy of consideration.¹⁵

As the nation peers into the future, it faces various potential disasters that could swiftly sap the existing government response capability, which is something FEMA's whole-community policy has recognized.¹⁶ Americans are remarkably unprepared for *catastrophic* disasters that may result in the collapse of the NRF.¹⁷ In each case, the disaster would affect a vast region of or the entire United States, and thus affect both the states' ability to aid each other and the federal government's ability to mount an adequate response to meet all critical needs.

B. RESEARCH QUESTIONS

This thesis seeks to answer one primary research question via two supporting questions:

¹⁴ Department of Homeland Security, 6.

¹⁵ Department of Homeland Security, 6; For an overview of the National Preparedness Goal, see Federal Emergency Management Agency, *National Preparedness Goal*, 2nd ed. (Washington, DC: Department of Homeland Security, 2015), 3, https://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf.

¹⁶ Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management*, 2.

¹⁷ Department of Homeland Security, *National Response Plan*, 43.

How can the whole community prepare to manage the consequences of catastrophic disasters without the aid of organizations beyond their borders?

- a. What were the preparedness gaps in the Commonwealth of Puerto Rico in 2017 following Hurricane Maria?
- b. How did communities and the Commonwealth of Puerto Rico overcome disaster preparedness gaps amid catastrophe through both formal and informal networks?

C. RESEARCH DESIGN

FEMA's 2018–2022 Strategic Plan holds three strategic goals. This study addresses two of them, (1) build a culture of preparedness, and (2) ready the nation for catastrophic disasters. The most outstanding question is *how* to achieve these goals, and this study seeks answers to this question, in small part, in the context of Puerto Rico following the devastating impacts of Hurricane Maria. This thesis employs a single case study methodology focused on Hurricane Maria's lessons, uncovered by examining the shortcomings in disaster response resources and improvisations employed to compensate for resource shortages so that Puerto Rico and other communities can learn from the Hurricane Maria experience to reduce future disaster risk.

The two elements supporting the primary research question—response shortcomings and improvisations—are discussed in the context of FEMA's seven community lifelines. This format allows communities and emergency management practitioners to view Hurricane Maria's impacts in their component parts. The whole community response actions can be retrospectively examined to understand better and inform more effective approaches to build community preparedness and disaster resilience against future catastrophic disasters.

Taken collectively, Puerto Rico's shortfalls and adaptations will contribute to informing how communities cope when the NRF enters partial or total collapse when outside response resources become unavailable or otherwise inadequate to meet the needs of those impacted by disaster. The study's ultimate intent is to determine the challenges communities will face in catastrophic disasters when external response and recovery

resources are unavailable to respond. By examining how communities in Puerto Rico adapted in the absence of external support, other communities and disaster practitioners can craft new strategies aimed at catastrophic disaster preparedness, primarily at the community level. This study compiles and utilizes secondary data sources. Secondary data includes government reports and academic studies specifically related to Hurricane Maria's impacts from September 2017 to September 2018.

The Commonwealth of Puerto Rico was selected as the single case to evaluate based on several criteria. Following Hurricane Maria, the island experienced two catastrophic hurricanes in close sequence and endured the most extended power outage in the U.S. recorded history, the disaster occurred recently in 2017, the Commonwealth of Puerto Rico presents a geographically isolated and resource-constrained environment, literature is widely available documenting the impacts of Hurricane Maria and the subsequent catastrophic effects, and the author has spent a considerable amount of time operating in Puerto Rico as an emergency management professional.¹⁸

The author is conscious of the unique aspects of Puerto Rico's pre-existing fiscal and infrastructure status before Hurricane Maria and its limitations on the generalization of the study findings. However, Puerto Rico was selected as a *literal* island to explore the reliance on outside resources to offer lessons to Puerto Rico and other jurisdictions that may one day become *figurative* islands in a catastrophic disaster. This case study is conducted in a structured educational environment respective to existing resource constraints. The study is designed to offer relatively generalizable knowledge and case-specific insight into the reliance on outside resources likely to be unavailable in a major national disaster and how Puerto Rico overcame adversity.

¹⁸ This source indicates the durations of several major power outages linked to disasters. President's National Infrastructure Advisory Council, *Surviving a Catastrophic Power Outage: How to Strengthen the Capabilities of the Nation* (Washington, DC: President's National Infrastructure Advisory Council, 2018), 28, https://www.cisa.gov/sites/default/files/publications/NIAC%20Catastrophic%20Power%20Outage%20Study_FINAL.pdf.

D. THESIS OVERVIEW

The following is a brief thesis overview that affords a roadmap for this chapter and the following chapters.

Chapter I reviews catastrophic disaster preparedness, and presents the research questions and the research design as a single case study.

By defining the problem, positing research questions, and building a research design to answer the research questions, readers are led to Chapter II. This chapter addresses the literature review and presents the background of Puerto Rico and Hurricane Maria. Chapter II also provides insight into literature influential to the topic of catastrophic disaster preparedness spanning national frameworks, strategies, plans, emerging trends, and various other literature, such as after-action reports (AARs), books, research articles, and media accounts.

Chapter III serves as the core of this study and details Hurricane Maria's impacts, the various preparedness, response, and recovery gaps, and where possible, illustrates community adaptations to resource shortfalls. The chapter reviews FEMA's seven community lifelines and their respective sub-components to organize large volumes of information into a useable format.

Chapter IV offers themes and conclusions derived from the case study. Themes presented emerged through grounded theory and were consistently observed across all community lifelines. The study's conclusions are more tactile and are also organized according to the lifeline format.

While this study focuses on Puerto Rico, the themes and conclusions are likely useful to other jurisdictions around the nation when considering how to prepare for, respond to, and recover from catastrophic disasters. In total, this study aims to transition the governmental concept of "whole community" into more tactile findings and to contextualize emerging trends in society and disaster preparedness by grounding them in the real-world example of Puerto Rico.

II. HURRICANE MARIA AND PUERTO RICO

This chapter provides the case study context in the form of a literature review, the historical background of Puerto Rico, and a brief overview of Hurricane Maria. The literature review evaluates preparedness concerning governing doctrine before turning to emerging trends in disasters, preparedness, and modern society. The review then evaluates available literature that offers a historical record of Hurricane Maria's nature and impacts.

The following sections relating to historical context, and Hurricane Maria, are intended to stress that disasters do not occur in a vacuum. Instead, factors, such as geography, economy, politics, and public health, play influential roles in disaster preparedness, response, and recovery outcomes. The case of Hurricane Maria and Puerto Rico illustrates a convergence of underlying risk factors coupled with a catastrophic disaster that informs the research questions in this specific case and may also provide useful application in other contexts in communities considering how to become more prepared for, and resilient to, disasters.

A. LITERATURE REVIEW

This literature review focuses on several key areas concerning community preparedness for catastrophic disasters. The first section addresses current government doctrine, such as strategies, frameworks, and plans outlining the national approach to disaster preparedness and response. The second section focuses on provides context and insight by evaluating literature addressing emerging trends that affect the way society will manage disasters in the 21st century. The third and final section considers available AARs, academic studies, media accounts, and published non-fiction accounts of Hurricane Maria. A review of this literature reveals a well-developed multi-tiered emergency management framework, primarily driven by government-centric solutions that may be ill equipped to face 21st-century realities without adapting to an evolving world.

1. National Frameworks, Strategies, and Plans

After 9/11, the federal government actively pursued an organized, systematic approach to national preparedness and response, beginning with the 2003 Homeland Security Presidential Directive (HSPD) 5, *Management of Domestic Incidents*, which established the National Incident Management System, and HSPD 8, *National Preparedness*, which called for the formation of a national preparedness system.¹⁹ The former is how the nation “work [s] together to share resources, integrate tactics, and act collaboratively,” and recognizes the need to develop an “interoperable approach to sharing resources, coordinating and managing incidents, and communicating information” when responding to disasters.²⁰ The latter serves the same purpose of providing a national organizing framework for the preparedness mission.

Following the devastating impacts of Hurricane Katrina in August 2005, which claimed more than 1,800 human lives, Congress issued an essential piece of legislation, the Post-Katrina Emergency Management Reform Act of 2006. As a central theme, this act refocused FEMA on “all-hazards” preparation and response and mandated that FEMA adopt a risk-based approach to assessing national preparedness.²¹ President Obama reinforced his predecessor’s mandates in 2011 by issuing Presidential Policy Directive (PPD) 8, *National Preparedness*.²² PPD-8 called explicitly for not only a national preparedness system but also a national preparedness goal; importantly, it also recognized the shared mission of disaster preparedness and response, “All levels of government, the private sector and nonprofit sectors, and individual citizens” should endeavor to create “an integrated, all-of nation, capabilities-based approach to preparedness.”²³ PPD-8 was

¹⁹ George W. Bush, *Management of Domestic Incidents, Homeland Security Presidential Directive 5* (Washington, DC: White House, 2003), 3, <https://www.dhs.gov/publication/homeland-security-presidential-directive-5>; George W. Bush, *National Preparedness, Homeland Security Presidential Directive 8* (Washington, DC: White House, 2003), 1747, <https://fas.org/irp/offdocs/nspd/hspd-8.html>.

²⁰ Federal Emergency Management Agency, *National Incident Management System*, 3rd ed. (Washington, DC: Department of Homeland Security, 2017), 1, <https://www.fema.gov/media-library/assets/documents/148019>.

²¹ Post-Katrina Emergency Management Reform Act, S. 3721, 109th Cong., 2nd sess. (2006).

²² PPD-8 rescinded HSPD-8 except for paragraph 44 of Annex I.

²³ Barack Obama, *National Preparedness, Presidential Policy Directive 8* (Washington, DC: White House, 2011), 1, <https://www.dhs.gov/presidential-policy-directive-8-national-preparedness>.

the first time “individual citizens” were mentioned in federal disaster directives in the context of limited federal government response capacity. All prior frameworks had implied that the federal government was the last resort, whereas PPD-8 recognized that an effective response to a catastrophic disaster requires a whole-of-community approach due to inherent limitations of the federal government response capacity.

While each piece of legislation aspired to the common goal of readying America for disasters, each also maintained a federalist worldview that supported the 10th Amendment and recognized state sovereignty. For instance, the National Preparedness Goal (NPG) provided direction toward a more prepared nation while issuing no state or local mandate to perform any specific action other than via federal grant requirements.²⁴ To influence community preparedness action without directing it, the Obama administration followed PPD-8 with *A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action*, which offered a philosophical approach and definition of “whole community.” The whole-community approach recognizes that “government at all levels cannot manage disasters alone” and that “the issue of social capital becomes an important part of encouraging communities to own and lead their own resilience activities.”²⁵ The guidance maintained six “strategic themes,” all centered on a bottom-up approach to build up capability in recognition of resource constraints at all levels of government. While the *Whole Community* document successfully changed the mindset of the nation’s emergency management community to be more inclusive in disaster preparedness and response, the practical implementation of the approach has not been systematically evaluated.²⁶ The “whole community approach”

²⁴ The first iteration of the National Preparedness Goal (NPG) was issued in 2012 following the 2011 issuance of PPD-8. A subsequent update to the NPG, which added a core capability and modified several other core capability names and definitions, was issued in 2015. Regarding the federal prescription of action, state and local requirements typically derive from the federal government as a condition of receiving a variety of preparedness, mitigation, and disaster recovery grants made available to state and local entities, which are administered by FEMA.

²⁵ Federal Emergency Management Agency, *A ‘Whole Community’ Approach to Emergency Management* (Washington, DC: Federal Emergency Management Agency, 2011), 14, <https://www.hsdl.org/?view&did=776745>.

²⁶ The *mindset shift* is noted in emergency management courses and FEMA doctrine and is commonly used in the emergency management lexicon.

to emergency management was an open and honest admission of the limitations of government in the face of catastrophic disasters and represented a genuine interest in involving all Americans in preparing for disasters. The policy clearly stated that to survive and thrive amid catastrophe, the entire nation would need to work together to achieve common goals. Both the document and the administration that created it made efforts to bring the policy to life; however, clearly defined roles for non-governmental actors, particularly every American community, remain absent from subsequent policy and doctrine.

Instead, the *Whole Community Approach* operates as a “philosophical” document, and avoids over-prescribing specific action in recognition that each American community possesses unique characteristics, a reality that makes blanket approaches impracticable. Other agencies have adopted a similar ethos. For instance, the U.S. Agency of International Development (USAID) has developed the “Journey to Self-Reliance,” which the agency describes as “a framework for the future” aimed at making international aid unnecessary.²⁷ In addition, in partnership with the Office of Foreign Disaster Assistance, the USAID has co-championed the “neighborhood approach,” whose aim is increasing service effectiveness in urban environments.²⁸ Nearly a decade since its inception, FEMA’s adoption and implementation of the *Whole Community Approach* has not been formally evaluated. However, the USAID *has* formally researched the implementation of its urban policy and issued findings in a June 2019 report.²⁹ This report is offered as a contrast between FEMA’s philosophical approach and the USAID’s more concrete approach to common problems of resilience.

²⁷ “The Journey to Self-Reliance,” U.S. Agency of International Development, August 6, 2020, <https://www.usaid.gov/selfreliance>.

²⁸ U.S. Agency of International Development and Office of Foreign Disaster Assistance, *The ‘Neighborhood Approach’: A Means of Improving the Delivery of Humanitarian Assistance in Urban Areas* (Washington, DC: U.S. Agency of International Development, 2011), 1, <https://www.humanitarianlibrary.org/sites/default/files/2014/01/USAID-OFDA%20Neighborhood%20Approach%20One-Pager%20’11%20Sept%202023.pdf>.

²⁹ U.S. Agency of International Development, *Assessment of the Implementation of USAID’s Urban Policy* (Washington, DC: U.S. Agency of International Development, 2019), 7, <https://urban-links.org/assessment-of-the-implementation-of-usaids-urban-policy/>.

National frameworks are another key requirement outlined in PPD-8.³⁰ The NRF, for example, “provides foundational emergency management doctrine for how the Nation responds to all types of incidents.”³¹ In the latest edition of the response framework, published in October 2019, FEMA recognized that due to both the unparalleled impact of recent natural disasters and potential threat actors developing weapons and tactics that threaten national infrastructure, an urgent need emerges to “build resilient capabilities to respond to disasters of increasing frequency and magnitude.”³² The framework also notes that disaster responses should be “federally supported, state managed, and locally executed.”³³ It is the first time the NRF placed this much emphasis on local response capacity and its ability to drive rapid, effective solutions in disaster response and recovery and noted, “local partners know their community’s needs, capabilities, and resources best and are positioned to have the most effective impact in the aftermath of an incident.”³⁴ This approach is noteworthy for its ideological departure from the former FEMA administration under Craig Fugate who strived to mold FEMA into an “expeditionary organization” in the agency’s *2014–2018 Strategic Plan*.³⁵ While FEMA in 2014 was intent on responding faster and more comprehensively, the FEMA of 2020 is placing greater focus on levels of capability and building capacity leading up to the federal level. The fourth edition of the NRF was a timely reflection on the increasing scope, scale, frequency, and complexity of disasters and the limitations of government at all levels. The framework also presents a continuation of PPD-8’s recognition of the limitations of the federal government through an emphasis on foundational resilience of American communities.

³⁰ Frameworks included national prevention, protection, mitigation, response, and disaster recovery. “National Planning Frameworks,” Federal Emergency Management Agency, October 30, 2019, <https://www.fema.gov/national-planning-frameworks>.

³¹ Department of Homeland Security, *National Response Framework*, ii.

³² Department of Homeland Security, ii.

³³ Department of Homeland Security, 7.

³⁴ Department of Homeland Security, 16.

³⁵ Federal Emergency Management Agency, *FEMA Strategic Plan 2014–2018* (Washington, DC: Federal Emergency Management Agency, 2014), 13, <https://www.fema.gov/media-library-data/1405716454795-3abe60aec989ecce518c4cdba67722b8/July18FEMAStratPlanDigital508HiResFINALh.pdf>.

A contingency for the collapse of support structures is absent in all the governing legislation, directives, and frameworks. For example, the NRF references the ability to scale disaster responses from local capabilities to state and federal resources. The key assumption in the NRF and all policies is that the federal government exists as a bulwark against system overload, yet policies remain silent on threats that may well collapse even a multi-layered support structure. In a major disaster with widespread impacts, the federal government's resources may be overburdened, and vital support mechanisms, such as the Emergency Management Assistance Compact (EMAC) network, may not be viable options to communities across America.

Beyond all-hazards frameworks, the federal government has also developed incident-specific plans aimed at catastrophic power outages. FEMA's *Power Outage Incident Annex* provides the agency a concept of operations when managing a catastrophic power outage.³⁶ Written in 2017, the plan is a step in the right direction toward acknowledging the threat to the national grids. However, the plan is designed only to provide "guidance for federal level responders to provide response and recovery support to local, state, tribal, territorial, and insular area efforts."³⁷ The plan provides a roadmap for the coordination of federal resources but does not serve as a local preparedness guide nor prescribes catastrophic preparedness actions. Similarly, the *National Cyber Incident Response Plan*, developed by the DHS, is "the strategic framework for operational coordination among federal and SLTT governments, the private sector, and international partners."³⁸ While limited in their scope, each of these plans is the bedrock that allows subsequent planning to occur at the regional, state, and local levels; however, little evidence indicates it has been a widespread or coordinated effort to date. Thus, communities are left vulnerable to catastrophic power outages, such

³⁶ Federal Emergency Management Agency, *Power Outage Incident Annex to the Response and Recovery Federal Interagency Operational Plans* (Washington, DC: Federal Emergency Management Agency, 2017), 15, <https://www.hsd.org/?abstract&did=806536>.

³⁷ Federal Emergency Management Agency, 3.

³⁸ Department of Homeland Security, *The National Cyber Incident Response Plan* (Washington, DC: Department of Homeland Security, 2016), 6, https://us-cert.cisa.gov/sites/default/files/ncirp/National_Cyber_Incident_Response_Plan.pdf.

as the one suffered amid Hurricane Maria, which will cripple vital power-reliant critical infrastructure components that drive and sustain modern life.

Disaster preparedness and response doctrine have evolved significantly over the years and represent a far more holistic approach to disaster management as the field continues to professionalize. Presidential directives and post-disaster legislation appear to be the most influential catalysts in effecting systemic change. The tiered disaster preparedness and response system built and honed since 9/11 has offered a great deal of resiliency to the nation's ability to manage the consequences of a wide range of disasters of varying severity. However, national disasters, particularly widespread and long-term power outages, represent a key vulnerability to the overreliance on the perennial viability of outside resource availability. Literature available on the nature of evolving and emerging threats provides the impetus to look beyond the NRF and the progress made within the field of disaster management to scenarios in which local communities cannot rely on disaster aid beyond their borders, thus necessitating that they manage the consequences of the outages only with local resources for an extended period.

2. Emerging Trends

The world is changing, and the nation faces a variety of catastrophic threats, some of which are long-standing while others are new and emerging. A growing body of evidence suggests that decentralized, distributed networks offer the resilience needed to face 21st-century challenges. The Office of the Director of National Intelligence (ODNI)'s report titled *Global Trends: Paradox of Progress* outlines how societies will need to evolve to meet future threats. The report states, "Tomorrow's successful states will probably be those that invest in infrastructure, knowledge, and relationships resilient to shock—whether economic, environmental, societal, or cyber," noting that "openness to mobilizing a wide range of commercial, religious, civil, and advocacy organizations at all levels of government will be key to sustaining positive outcomes."³⁹ Although the report assumes a global view, its adaptation concepts apply to the United States as well.

³⁹ National Intelligence Council, *Global Trends: Paradox of Progress*, NIC 2017-001 (Washington, DC: National Intelligence Council, 2017), 66, <https://www.dni.gov/files/images/globalTrends/documents/GT-Main-Report.pdf>.

The document's underlying philosophy centers upon the decentralization of human networks and the inherent resilience of such an approach. Decentralization does not necessarily equate to a loss of coordination or chaos; instead, it supports the idea of building capability at the lowest levels possible in communities to bolster flexibility and resilience.

Societal evolutions have also been captured via the lens of emergency and disaster management and arrived at similar conclusions. In 2012, FEMA published a forward-looking document titled *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty*. Much like the ODNI's report, FEMA's report offers foresight into future challenges. The report forecasts that "future operating environments may well be characterized by significant decline in governmental resources for emergency management," and considers existing and future vulnerabilities to national and global supply lines.⁴⁰ FEMA's report also offers insight into how the emergency management field should engage its constituents. For instance, the report suggests that "community institutions [be] further empowered and routinely contribute to emergency management" and proposes, "emergency management programs connect to communities through the social, economic, and political structures that are part of daily life."⁴¹ The report's philosophical center of gravity is the devolution of top-down approaches to more community-led, self-reliant endeavors that may be vital to communities withstanding catastrophic disasters.

In keeping with the spirit of decentralized networks, community engagement and resilience, various authors offer their views on the topic. Author and founding Director of the Global Resilience Institute at Northeastern University, Stephen Flynn, opines that America made a misstep in investing in the DHS instead of focusing on national resilience, and offers that just as important as America's ability to deliver a "punch" is its

⁴⁰ Federal Emergency Management Agency, *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty* (Washington, DC: Federal Emergency Management Agency, 2012), 14, <https://www.hsdl.org/?abstract&did=697458>.

⁴¹ Federal Emergency Management Agency, 22.

ability to take one.⁴² Likewise, author Joshua Cooper Ramo advocates for a renewed focus on societal resilience.⁴³ Ramo's main argument is that shocks to human systems occurred because "complexity accumulated" and arrived at seemingly unpredictable breaking points. He used theoretical physicist Per Bak's work and "sandpile" experiments to illustrate his point. Bak's studies revealed that seemingly stable systems "evolve into a poised 'critical' state" where insignificant occurrences can lead to severe consequences.⁴⁴ Ramo's recipe for avoiding unpredictable system shock is to build resilient distributed systems throughout society. It is a "Department of Resilience" as a partner to the Department of Defense that Ramo feels would "bind Americans into a compact of responsibility and a network of personal relationships sealed by working hand in hand."⁴⁵ However, challenges surround Ramo's Department of Resilience, particularly as it relates to the nation-state's role of offering its citizens security and protection.⁴⁶ In the post-World War II world, Fjäder offers that the nation-state offers positive political goods, such as "security, health care, education, law and order, economic opportunity and critical infrastructure, i.e., the protection of the overall well-being of its citizens," and assumes a role in citizens' lives that is both "pervasive and persistent." Fjäder further argues that the globalized world beginning in the 1990s has resulted in greater "deterritorialisation" and increased the interconnectedness of states. This change has made providing security a more complex matter resulting in "cultural, security, social and political impacts," which therefore presents a need for national resilience, for which Ramo and Flynn also advocate that aligns with national security objectives.⁴⁷ In one way or another, all these works point to a need for more agile, adaptable, and resilient human networks. Furthermore, they point to a growing dialogue surrounding resilience as a

⁴² Stephen E. Flynn, *The Edge of Disaster: Rebuilding a Resilient Nation* (New York: Random House, 2007), Loc. 183, Kindle.

⁴³ Joshua Ramo, *The Age of the Unthinkable: Why the New World Order Constantly Surprises Us* (New York: Little, Brown and Company, 2009), 190.

⁴⁴ Ramo, 49.

⁴⁵ Ramo, 191.

⁴⁶ Christian Fjäder, "The Nation-State, National Security and Resilience in the Age of Globalisation," *Resilience* 2, no. 2 (2014): 114–29, <https://doi.org/10.1080/21693293.2014.914771>.

⁴⁷ Fjäder, 115–6.

national concept supporting national security and not merely a characteristic of people or communities. While the precise nature of resilience is still debated, broad consensus feels it facilitates rapid community recovery to normal or near-normal conditions from catastrophic disasters.

3. After-Action Reports, Academic Studies, Oversight Reports, Media Accounts, Media Accounts, and Published Non-fiction

The events surrounding Hurricane Maria’s impact on Puerto Rico have been covered extensively in agency AARs, academic studies, government oversight reports, media accounts, and published non-fiction books. While each source provides valuable information, nearly all references provide agency-specific viewpoints, examine a single subset of issues, or offer a snapshot in time.

AARs contain a wide range of topic-specific information offering critical insight into the challenges and successes of responding to and recovering from Hurricane Maria. These documents also often tangentially shed light or imply upon the state of pre-disaster preparedness. FEMA, as the lead agency for large-scale disaster responses, drafted the *2017 Hurricane Season After-action Report*. While not solely focused on Hurricane Maria and Puerto Rico, it does offer a wealth of information on topics, such as observations on responding to concurrent, complex operations, whole community logistics, long-term infrastructure outages, mass care operations, and disaster staffing.⁴⁸ This report turned a corner in the agency’s willingness for self-reflection and recognition of the role of complexity in disaster responses. Moreover, it stands as one of the most thorough AARs the agency has produced to date.

FEMA was joined by a wide range of agencies and organizations—both governmental and non-governmental—that produced their own AARs. Some of these entities include the Puerto Rico Department of Health, Americares, the American Red Cross (ARC), the ARRL, TRACIE Healthcare Emergency Preparedness Information Gateway, the Medical Reserve Corps, the Puerto Rico National Guard, the National Emergency Management Association (NEMA), the Heritage Foundation, the World

⁴⁸ Federal Emergency Management Agency, *2017 Hurricane Season*, iv.

Meteorological Organization, Oxfam America, the Army Corps of Engineers (USACE), and many others.

Similar to AARs, a wide range of academic institutions have conducted studies on the state of Puerto Rico and the aftermath of Hurricane Maria. Some organizations that have conducted studies include the Milken Institute School of Public Health, the *Journal of Recreation, Parks, and Tourism in Public Health*, the *Journal of Agriculture, Food Systems, and Community Development*, the Geological Society of America, the Institute for Food and Development Policy, the *Journal of Environmental Science and Technology*, the Emergency Medicine Clinics of North America, the *International Journal of Disaster Risk Reduction*, the *Homeland Security Affairs Journal*, the U.S. Geological Survey, the *New England Journal of Medicine*, the Urban Institute, the *International Journal of Climatology*, and many other publications. Each study provides valuable insight into specific issues over isolated periods that, when taken together, offer a more holistic account of the impacts of Hurricane Maria.

Governmental oversight reports also provide helpful insight into what worked well and what proved challenging in response to Hurricane Maria. Several reports from the Government Accountability Office (GAO) and the RAND Corporation (or RAND) contain the most valuable information as each monitor and report specific issues pertaining to the preparedness for, response to, and recovery from Hurricane Maria. Helpful topics include RAND's review of U.S. Army North's response in the Caribbean and general observations of how FEMA can improve for future disasters. Likewise, the GAO published initial 2017 seasonal findings regarding disaster response, addressed issues pertaining to disaster contracting, integration of non-governmental actors into disaster response, reports specific to the role of Health and Human Services (HHS), challenges unique to major emergencies, federal support of electrical grid restoration, and other older reports that offered important context for the events of 2017. Each of these reports operates as a harbinger of issues to be cognizant of as other sources of information are reviewed throughout the course of this study; they also offer an authoritative source on the issues.

Complimentary to official reports and academic studies, a wide range of media outlets also prove valuable in examining the topic of Hurricane Maria because stories in the press often provide experiential insight directly from citizens and tell stories not otherwise depicted in more official reports. Given the focus of this thesis on community catastrophic disaster preparedness, media reports fill an important void whereby communities' stories can be told while being understood in a broader context of the disaster itself. However, each report typically focuses on specific issues, in certain areas, over varying lengths of time. By combining media reports and pairing them with official reports, the goal is to place them in the appropriate context and allow each source to fact-check the others.

Lastly, works of published non-fiction provided much-needed depth on specific issues impacting Puerto Rican communities and community disaster resilience more broadly. Primary texts include *Building Resilience: Social Capital in post-Disaster Recovery*, *We Fed an Island: The True Story of Rebuilding Puerto Rico*, *One Meal at a Time, When the Sky Fell: Hurricane Maria and the United States in Puerto Rico*, and *Out of the Whirlwind: Supply and Demand after Hurricane Maria*. Each story offers largely topic-specific insight, first-person accounts, and in many cases, was founded upon the authors' research. Each text's veracity can be cross-referenced with other available sources in the interest of accuracy and factual accounting for the impacts and events of Hurricane Maria.

Each source type discussed provides valuable insight into the preparedness, response, and recovery associated with Hurricane Maria; however, all were written from a single issue or single agency perspective, which does not detail the entirety of Hurricane Maria's impact on Puerto Rico. This thesis aims to leverage all these sources to provide a more holistic understanding of Hurricane Maria's impact on Puerto Rico, major gaps, ways in which communities overcame adversity, and promising leads to improve disaster resilience not only on the island but for other interested communities as well. Furthermore, a majority of available texts focus on the performance and shortfalls of agencies and entities, while this thesis focuses on the resulting outcome for communities in an effort to paint a community-centric picture of disaster circumstances

in hopes Puerto Rico’s experience instructs other communities on catastrophic disaster preparedness.

4. Literature Review Summary

A comprehensive review of the literature indicates a recognition of the challenges that catastrophic disasters pose to preparedness, response, and recovery, but has yet to transform a vision of disaster resilience from concept to application. For instance, while the federal government has explicitly recognized its own limitations in providing services amid catastrophic disaster—and consequently has expressed the desire to include the “whole community” in the national preparedness endeavor—the NRF and the NPG offer no concrete vision for including the public, comprised of communities across the nation. These frameworks are developed for state and local governments as primary audiences and do little to spur public action. Furthermore, the NRF offers no contingency for communities in the event they become isolated from outside disaster aid resources in a partial or total collapse of the framework. Ergo, Puerto Rico stands as an instructive case in terms of how communities prepare and cope with isolation amid resource deficits following catastrophic disasters.

Literature concerning emerging trends in disasters and society indicates a growing intensity, frequency, and complexity of future disasters that will pose resource challenges on governing bodies to serve as disaster aid providers, and therefore, coalesces around concepts of decentralization and inclusion. Notwithstanding, these concepts lack the context of real-world examples that demonstrate these emerging realities that the various reports outlined provide.

Lastly, scant literature is available that affords a complete picture of the events and consequences of Hurricane Maria in Puerto Rico. Dozens of agency reports, academic studies, humanitarian organization updates, published books, and an array of media stories typically afford only one aspect of the island’s experience either through one discipline or over a limited period of time. This study serves as a compilation of a vast range of available literature and attempts to present relative information as completely as possible.

B. BACKGROUND

The island of Puerto Rico is roughly the geographic size of the State of Connecticut and spans roughly 100 miles east-to-west and approximately 40 miles north-to-south, an area smaller than the Miami, Ft. Lauderdale, and West Palm Beach metro statistical area.⁴⁹ Roughly, 2.3–2.45 million of the island’s 3.2 million residents reside in the northern portion of the island surrounding the present-day capital city of San Juan.⁵⁰ Overall, 93.6% of the population resides in urban areas, and the 2020 population estimate is 3,189,068, which represents a -1.59% growth rate since the 2018 estimation.⁵¹ A vast majority of the population lives in coastal areas, predominantly in the eastern portion of the island. A sizeable population also lives south of the capital city of San Juan. The interior and western portion of the island is dominated by the Cordillera Central mountains and is sparsely populated.⁵²

1. Historical Context

The island has a long Spanish colonial history spanning over 400 years before coming under the control of the United States in 1898 during the Spanish-American War. The first European encounter with the island was in November 1493 under Christopher Columbus; he named the island San Juan Bautista after St. John the Baptist.⁵³ Over time, the name applied to the present-day Bay of San Juan, “Puerto Rico,” meaning “rich port,” began to be applied to the entire island.⁵⁴ Prior to European arrival, the local population knew Puerto Rico as “Bonrinquen.”⁵⁵

⁴⁹ Philip J. Palin, “Learning from H.I.M. (Harvey, Irma, Maria): Preliminary Impressions for Supply Chain Resilience,” *Homeland Security Affairs Journal* 14, no. 7 (September 2018), <https://www.hsdl.org/?abstract&did=816668>.

⁵⁰ Palin.

⁵¹ “The World Factbook, Central America: Puerto Rico,” Central Intelligence Agency, 2020, <https://www.cia.gov/library/publications/the-world-factbook/geos/rq.html>.

⁵² Central Intelligence Agency.

⁵³ Michael Deibert, *When the Sky Fell: Hurricane Maria and the United States in Puerto Rico* (New York: Apollo Publishers, 2019), 13.

⁵⁴ Deibert, 12.

⁵⁵ Deibert, 12.

Today, Puerto Ricans are born American citizens but still have limited political representation.⁵⁶ The Jones-Shafroth Act granted Puerto Ricans citizenship in 1916, some 18 years after coming under United States control, and was heavily influenced by Luis Munoz Rivera, who was a renowned political figure who held office in the House of Representatives from 1911–1916.⁵⁷ Rivera’s son, Luis Munoz Marin, was Puerto Rico’s Governor from 1949–1965. He is credited with bringing the island and its people into an “Estado Asociado Libre” (Free Associated State) that brought the island to its Commonwealth status allowing free travel to and from the mainland, voting in presidential primaries (but not general elections), and permitting Puerto Ricans to serve in the U.S. armed forces.⁵⁸ While many Puerto Ricans have, and do, celebrate the island’s status in relation to the United States mainland, others feel that they are second-class citizens still under quasi-colonial rule largely because of their continued lack of voting power in Congress and inability to vote in Presidential elections.⁵⁹ Many Puerto Ricans are also disenfranchised due to the island’s Financial Oversight and Management Board (PROMESA by its Spanish acronym), established in 2016 to oversee Puerto Rican financials in light of its massive debt crisis. The board consists of seven members, all appointed by the President of the United States, and a majority of the members do not reside in Puerto Rico.⁶⁰

2. Hurricane Maria

Hurricane Maria was the most devastating storm to strike Puerto Rico, in terms of intensity, since the landfall of a Category 5 hurricane known as “Segundo San Felipe” in 1928 and is the third costliest storm in U.S. history, and trails Hurricanes Katrina (2005) and Harvey (2017). Its minimum central pressure of 908 millibars (Mb) is the lowest on

⁵⁶ Deibert, 9.

⁵⁷ Deibert, 10.

⁵⁸ Deibert, 10.

⁵⁹ Deibert, 93.

⁶⁰ Naomi Klein and Lauren Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’ Are Locked in a Pitched Struggle over How to Remake the Island,” *The Intercept*, March 20, 2018, <https://theintercept.com/2018/03/20/puerto-rico-hurricane-maria-recovery/>.

record in the Atlantic basin east of 70°W; Hurricane Irma had set the record just two weeks prior at 914 Mb.⁶¹ In the context of Puerto Rico, Hurricane Maria was by far the costliest storm on record with damages estimated to top 90 billion dollars; the next costliest storm is Hurricane Georges of 1998 with a mere five billion dollar price tag.⁶² At landfall on the morning of September 20, 2017, Maria made landfall near Yabucoa, Puerto Rico with 135-knot winds (155 mph) as confirmed by the National Hurricane Center.⁶³ Maria delivered localized rainfall amounts up to 38 inches across portions of the island and caused record riverine flooding—mainly along the La Plata River—and widespread landslides that severely impacted roadways, bridges, businesses, and homes. Early on the morning of September 20, Maria was undergoing a natural eye-wall replacement cycle when it struck Puerto Rico, which decreased its intensity to Category 4 before landfall but also caused a doubling in size of the eye-wall, which exposed a greater portion of the island to the hurricane’s highest sustained winds found along the edge of the eye-wall.⁶⁴ In addition to rainfall and storm-force winds, Hurricane Maria delivered a storm surge that, when combined with tides, amounted to 6–9 feet in the municipalities of Humacao, Naguabo, and Ceiba along Puerto Rico’s southeastern coast, and storm surge amounts of 3–5 feet along the northeastern coast.⁶⁵ Throughout the day, Hurricane Maria tracked to the northwest for over eight hours and left a wake of destruction.

The response to Hurricane Maria was record setting for FEMA, an agency also simultaneously managing the impacts of one major hurricane in Texas, two major hurricanes in the Caribbean, and the worst wildfire season in California’s modern history, as well as multiple other small-scale disasters around the nation.⁶⁶ Puerto Rico also called on the aid of a majority of U.S. states to perform various disaster response and

⁶¹ National Hurricane Center, *National Hurricane Center Tropical Cyclone Report: Hurricane Maria* (Washington, DC: National Oceanic and Atmospheric Administration, 2019), 4, https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf.

⁶² National Hurricane Center, 7.

⁶³ National Hurricane Center, 2.

⁶⁴ National Hurricane Center, 4.

⁶⁵ National Hurricane Center, 5.

⁶⁶ Federal Emergency Management Agency, *2017 Hurricane Season*, v.

recovery functions. In total, over the course of the next year, 5,659 personnel from 35 states had responded to support residents of Puerto Rico in some form via the EMAC network overseen by NEMA.⁶⁷ Gaps in Puerto Rico's preparedness for this catastrophic disaster are quite evident; however, it is unlikely that even states with greater resources and more mature capabilities would have been able to mount a more effective response amid such devastation. An additional key factor is Puerto Rico's inaccessibility as opposed to mainland states that benefit from overland response and recovery resources that make the application of resources logistically much easier.

3. Background Summary

Puerto Rico's historical context and lived experience of Hurricane Maria helps to ground this study's research questions in a specific place and time that provide context to the lifeline sections within Chapter III. The island's historical economic and political position to the mainland United States, and its current economic realities, informs likely preparedness gaps while also framing likely citizen responses and ideological position vis-à-vis the role of the government. Hurricane Maria struck within a complex societal context that, in many cases, amplified disaster impacts, and in others, showed ingenuity, grit, and community resilience, and revealed untapped potential toward ensuring a more disaster-resilient future.

The context provided for Hurricane Maria as a disaster also serves to highlight the gaps in existing federal preparedness and response doctrine that has thus far proven unable to incorporate citizens and afford them a substantial disaster preparedness, response, and recovery role. Hurricane Maria also illustrated the limitations of the NRF when mutual-aid or federal response resources experience response delays or resource shortages resulting in service provision gaps for the public. Overall, the background indicates where national planning frameworks end and community resilience begins.

⁶⁷ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response to the 2017 Hurricane Season* (Washington, DC: National Emergency Management Association, 2018), 27.

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III. CATASTROPHIC PREPAREDNESS GAPS AND COMMUNITY ADAPTATIONS

The following section examines Puerto Rico’s preparedness gaps and innovative solutions to cope with them in the wake of Hurricane Maria, which are apportioned according to FEMA’s community lifelines as one means of examining a wide range of disaster response functions.






The FEMA community lifelines consist of:

- safety and security
- food, water, and sheltering
- health and medical
- energy
- communications
- transportation
- hazardous materials



Community lifelines “ensure the delivery of critical services that alleviate immediate threats to life and property when communities are impacted by disasters.”⁶⁸ The critical services are outlined and organized into the following seven community lifelines. Each lifeline also consists of components and subcomponents found in Table 1.

⁶⁸ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide (Operational Draft)* (Washington, DC: Federal Emergency Management Agency, 2019), 1, <https://www.hSDL.org/?abstract&did=833977>.

Table 1. Lifeline Components and Subcomponents.⁶⁹

Lifeline	Components	Description
	<ol style="list-style-type: none"> 1. Law Enforcement and Security 2. Fire Service 3. Search and Rescue 4. Government Service 5. Community Safety 	<p>Law enforcement and government services, as well as the associated assets that maintain communal security, provide search and rescue and firefighting capabilities, and support public safety. Includes impending risks to impacted communities, public infrastructure, and national security concerns.</p>
	<ol style="list-style-type: none"> 1. Food 2. Water 3. Shelter 4. Agriculture 	<p>Support systems that enable the sustainment of human life, such as food retail and distribution networks, water treatment, transmission and distribution systems, housing, and agriculture resources.</p>
	<ol style="list-style-type: none"> 1. Medical Care 2. Public Health 3. Patient Movement 4. Medical Supply Chain 5. Fatality Management 	<p>Infrastructure and service providers for medical care, public health, patient movement, fatality management, behavioral health, veterinary support, and the medical industry.</p>
	<ol style="list-style-type: none"> 1. Power Grid 2. Fuel 	<p>Electricity service providers and generation, transmission, and distribution infrastructure, as well as gas and liquid fuel processing, and delivery systems.</p>
	<ol style="list-style-type: none"> 1. Infrastructure 2. Responder Communications 3. Alerts, Warnings, and Messages 4. Finance 5. 911 and Dispatch 	<p>Infrastructure owners and operators of broadband internet, cellular and landline telephone networks, cable services, satellite communications services, and broadcast networks (radio/television). These systems encompass diverse modes of delivery, often intertwined but largely operating independently. Services include alerts, warnings, and messages, 911 and dispatch, and access to financial services.</p>

⁶⁹ Source: Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6–7.

Lifeline	Components	Description
	<ol style="list-style-type: none"> 1. Highway/Roadway/Motor Vehicle 2. Mass Transit 3. Railway 4. Aviation 5. Maritime 	<p>Multiple modes of transportation that often serve complementary functions and create redundancy, adding to the resilience in overall transportation networks. These modes include roadway, mass transit, railway, aviation, maritime, and intermodal systems.</p>
	<ol style="list-style-type: none"> 1. Facilities 2. HAZMAT, Pollutants, Contaminants 	<p>Systems that mitigate threats to public health or the environment. These threats include facilities that generate or store hazardous substances, as well as all specialized conveyance assets and capabilities to identify, contain, and remove pollution, contaminants, oil, or other HAZMAT and substances.</p>

A. SAFETY AND SECURITY LIFELINE

FEMA defines the safety and security lifeline as “law enforcement and government services, as well as the associated assets that maintain communal security, provide search and rescue and firefighting capabilities, and support public safety. Includes impending risks to impacted communities, public infrastructure, and national security concerns.”⁷⁰ The components of this lifeline include law enforcement (LE) and security, fire service, search and rescue, government service, and community safety.⁷¹

1. Law Enforcement

The Policía Estatal de Puerto Rico, or State Police of Puerto Rico, falls under the Puerto Rico Department of Public Safety and maintains 13 districts throughout the island.⁷² Puerto Rico also has 13 local police departments in larger municipalities throughout the island. According to the Federal Bureau of Investigation (FBI), Puerto

⁷⁰ Federal Emergency Management Agency, 6.

⁷¹ Federal Emergency Management Agency, 6.

⁷² The Puerto Rico Department of Public Safety oversees the Puerto Rico Police Bureau, the Firefighters Bureau, the Forensic Science Bureau, the Medical Emergency Bureau, the Emergency Management Bureau, the Special Investigations Bureau, and the 9-1-1 Bureau. “Bienvenidos,” Departamento de Seguridad Pública, 2020, <http://www.dsp.pr.gov/Pages/default.aspx>.

Rico had a total of 13,461 officers in 2017, down from a 2012 high of 17,000.⁷³ While many police stations sustained damages amid Hurricane Maria, by November 2017, the USACE reported that 75% (148 stations) of police stations were “usable,” 23% of stations (43 stations) were “restricted use,” and just 2% (three stations) were deemed “unsafe.”⁷⁴

For many years prior to Hurricane Maria, the Puerto Rican police have been plagued by corruption and poor working conditions. A 2011 Department of Justice (DOJ) investigation reported, “far too many PRPD officers have broken their oath to uphold the rule of law, as they have been responsible for acts of crime and corruption and have routinely violated the constitutional rights of the residents of Puerto Rico.”⁷⁵ Speaking in regard to issues facing police officers, retired FBI Agent and current Secretary of the Department of Public Safety, Hector Pesquera, stated, “We’re fighting different fronts here, salaries, benefits, they have no social security, medical plan is a pittance, and they passed a law several years ago that really eviscerated their pensions.”⁷⁶ Issues with compensation and long delays in overtime payments have led to low morale and absenteeism among the force.⁷⁷

In December 2017, amid a brief spike in crime rates three months post-Hurricane Maria, police chief, Michelle Hernandez, suggested the Puerto Rico National Guard

⁷³ “Puerto Rico and Other Outlying Areas: Full-Time Law Enforcement Employees (Table 81),” 2017 Crime in the United States, Federal Bureau of Investigation, 2017, <https://ucr.fbi.gov/crime-in-the-u.s/2017/crime-in-the-u.s.-2017/tables/table-81/table-81-state-cuts/puerto-rico-outlying-areas.xls>; Stella Levantesi, “Rising Crime and a Shrinking Police Force Stunt Puerto Rico’s Recovery,” *Centro de Periodismo Investigativo*, April 30, 2018, <https://periodismoinvestigativo.com/2018/04/rising-crime-and-a-shrinking-police-force-stunt-puerto-ricos-recovery/>.

⁷⁴ Jordan R. Fischbach et al., “After Hurricane Maria: Predisaster Conditions, Hurricane Damage, and Recovery Needs in Puerto Rico,” 275, September 30, 2020, https://www.rand.org/pubs/research_reports/RR2595.html.

⁷⁵ U.S. Department of Justice, Civil Rights Division, *Investigation of the Puerto Rico Police Department* (Washington, DC: Department of Justice, 2011), 110, https://www.justice.gov/sites/default/files/crt/legacy/2011/09/08/prpd_letter.pdf.

⁷⁶ Levantesi, “Rising Crime and a Shrinking Police Force.”

⁷⁷ Ray Suarez, “As Puerto Rico Rebuilds, Police Protest Working Conditions,” *NPR All Things Considered*, December 30, 2017, <https://www.npr.org/2017/12/30/574810375/as-puerto-rico-rebuilds-police-protest-working-conditions>; Danica Coto, “Thousands of Puerto Rico Police Owed Overtime Call in Sick,” *Bloomberg*, December 27, 2017, <https://www.bloomberg.com/news/articles/2017-12-27/thousands-of-puerto-rico-police-owed-overtime-call-in-sick>.

could fill the void in police officers amid mass absenteeism, a proposition quickly disregarded by Governor Ricardo Rossello.⁷⁸ In February 2018, Florida Senators Marco Rubio and Bill Nelson wrote a letter to the DOJ urging that Attorney General, Jeff Sessions, offer Puerto Rico additional security support citing high rates of unemployment, a recent doubling in monthly homicide rates, and widespread unemployment.⁷⁹ However, FBI crime statistics do not support the notion of a significant or sustained uptick in crime rates. In 2016, the bureau recorded 7,643 violent crimes; in 2017, the FBI recorded an uptick of 119 violent crimes for a total of 7,762 incidents; in 2018, the bureau recorded 6,417, a decrease of 1,345 incidents.⁸⁰ Similar trends were present regarding property crimes. In 2016, the FBI recorded 35,201 property crimes; in 2017, 31,176 property crimes were recorded; and in 2018, just 24,851 non-violent property crimes were recorded, which indicated a sustained and substantial decline despite the catastrophe of 2017 and resulting economic hardships.⁸¹ These statistics indicate no considerable sustained uptick in either violent or property crime surrounding the events of Hurricane Maria. The rallying cry of Marco Rubio and Bill Nelson seems to be in response to an anomalous uptick in violence, instead of a lasting trend.⁸²

Systemic issues in the Puerto Rican police force, and a governor's reluctance to turn to the National Guard for large-scale LE support, led to a large influx of mutual-aid

⁷⁸ Suarez.

⁷⁹ Marco Rubio and Bill Nelson, "Rubio, Nelson Urge DOJ to Work with Puerto Rico to Ensure Safety on the Island after Hurricane Maria," Marco Rubio, U.S. Senator for Florida, February 1, 2018, <https://www.rubio.senate.gov/public/index.cfm/2018/2/rubio-nelson-urge-doj-to-work-with-puerto-rico-to-ensure-safety-on-the-island-after-hurricane-maria>.

⁸⁰ "2016 Crime in the United States: Table 5, Crime in the United States," FBI Uniform Crime Reports, Federal Bureau of Investigation, 2016, <https://ucr.fbi.gov/crime-in-the-u.s/2016>; "2017 Crime in the United States: Table 5, Crime in the United States," FBI Uniform Crime Reports, Federal Bureau of Investigation, 2017, <https://ucr.fbi.gov/crime-in-the-u.s/2017/crime-in-the-u.s.-2017/tables/table-5/table-5.xls>; "2018 Crime in the United States: Table 5, Crime in the United States," FBI Uniform Crime Reports, Federal Bureau of Investigation, 2018, <https://ucr.fbi.gov/crime-in-the-u.s/2018/crime-in-the-u.s.-2018>.

⁸¹ Federal Bureau of Investigation, "2016 Crime in the United States: Table 5, Crime in the United States"; Federal Bureau of Investigation, "2017 Crime in the United States: Table 5, Crime in the United States"; Federal Bureau of Investigation, "2018 Crime in the United States: Table 5, Crime in the United States."

⁸² Politifact found the claim of increased crime to be only partially accurate as well. Allison Graves, "Fact-Checking Statistics about Puerto Rico's Storm Recovery," Politifact, February 7, 2018, <https://www.politifact.com/factchecks/2018/feb/07/bill-nelson/fact-checking-statistics-about-puerto-ricos-storm-/>.

LE capability following Hurricane Maria. In total, NEMA indicates that 901 mutual-aid officers responded who spanned 22 unique mission requests to bolster Puerto Rico's LE, security, and incident management capability.⁸³ By comparison, only 38 mutual-aid LE officers responded to Texas following Hurricane Harvey, and just six responded to Florida following Hurricane Irma.⁸⁴ Puerto Rico National Guard units also provided communities with security and responders with force protection over the course of the response; in total, approximately 6,200 National Guard members originating from 38 states supported disaster relief operations during Hurricane Maria, and 7,893 federal Title 10 troops deployed from various bases.⁸⁵ While not all National Guard personnel were performing security missions strictly, many elements offered vehicles, access, conducted search and rescue operations, provided medical equipment and services, performed maintenance on facilities, and distributed commodities.⁸⁶ A majority of mutual-aid LE officers filled in at posts to afford Puerto Rican police officers much needed rest. This duty often included working traffic control at busy intersections void of operating traffic lights.⁸⁷

a. Discussion

Hurricane Maria does not appear to have led to a systemic rise in crime rates, but underlying LE dysfunctionalities led to operational challenges. In 2012, Puerto Rico had

⁸³ Note: This number is derived from an October 2018 NEMA AAR. Therefore, "901 officers" does not represent a maximum "on-ground" number but rather represents how many LE officers had deployed from other states to support at some point between September 2017 and the time of publication. National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 29, 99.

⁸⁴ National Emergency Management Association, 29.

⁸⁵ Erich B. Smith, "National Guard Wraps up Busy Hurricane Season," *Guard News*, December 1, 2017, <https://www.nationalguard.mil/News/Article/1384972/national-guard-wraps-up-busy-hurricane-season/>; Eric V. Larson et al., *U.S. Army North in the Hurricane Maria Response* (Santa Monica, CA: RAND, 2020), 93, https://www.rand.org/pubs/research_reports/RR2967.html.

⁸⁶ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 28.

⁸⁷ One example is Daniel Vock, "The Pact Changing How Governments Respond to Disaster," *Governing*, March 2018, <https://www.governing.com/topics/transportation-infrastructure/gov-emergency-management-local-federal-fema-states.html>.

17,328 sworn officers and only 13,461 in 2012.⁸⁸ This 22% reduction in the workforce led to a heavy reliance on mutual-aid LE capabilities to maintain 24-hour operations. This workaround solution appears to have largely met the needs of communities across Puerto Rico. However, the island is likely to sustain further reductions in the LE workforce void of salary increases, pension reform, and aggressive recruiting campaigns. This increase will lead to future reliance on mutual-aid LE amid other major disasters occurring over the near-term.

b. Review

A review of the literature did not reveal established community watch groups or other citizen-led security initiatives in Puerto Rico, nor did the review suggest a particular need for such programs due to increased crime. Most post-disaster literature and media reports indicated a cooperative environment of neighbor-helping-neighbor to assure the safety of others and aid in the procurement of critical resources. LE was thus able to provide support to search and rescue operations, welfare checks, and general services, such as traffic control and critical facility security. Each community will have different dynamics at play in disasters; therefore, post-disaster community security and LE from the individual citizen level to local, state, and federal government resources remains a key consideration within the local context.

2. Fire Service

Puerto Rico's fire service is structured as a state agency, as well, under the umbrella of the Department of Public Safety. The department operates under a framework of six zones and 11 districts and maintains 91 fire stations throughout the island.⁸⁹ The department's Special Operations Division operates as an additional district

⁸⁸ "2012 Crime in the United States: Table 81, Puerto Rico and Other Outlying Areas," FBI Uniform Crime Reports, Federal Bureau of Investigation, 2012, https://ucr.fbi.gov/crime-in-the-u.s/2012/crime-in-the-u.s.-2012/tables/81tabledatadecpdf/table-81-state-cuts/Table_81_Full_time_Law_Enforcement_Employees_Puerto_Rico_and_Outlying_Areas_by_State_Tribal_Other_Agencies_2012.xls; Federal Bureau of Investigation, "Puerto Rico and Other Outlying Areas: Full-Time Law Enforcement Employees (Table 81)."

⁸⁹ "Cuerpo de bomberos de Puerto Rico: Organización," Puerto Rico Fire Department, 2015, <http://www.agencias.pr.gov/agencias/bomberos/SobreNosotros/Pages/Organizaci%c3%b3n.aspx>.

and performs first response functions in cooperation with medical and ambulance personnel.⁹⁰

Many fire stations lost power, water, and or communications, which complicated the ability to coordinate operations; floodwaters damaged or destroyed other stations, although precise accounts of damage are not available.⁹¹ In reviewing FEMA public assistance (PA) applications, it appears that approximately \$3.3 million in total fire station claims with roof damages accounted for roughly 23% of the costs and building contents for approximately 70%.⁹² This number may suggest a greater share of flood versus wind damage, but it is difficult to confirm.

Impacts to the island’s emergency land-mobile radio (LMR) system resulted in only 40 of 99 fire stations being able to maintain communications capabilities.⁹³ In total, approximately 50% of all primary radio systems were damaged.⁹⁴ In addition to the loss of communications, FEMA noted in its 2017 AAR, “many critical facilities struggled to gain temporary power,” and stated that numerous critical facilities had no generators, experienced generator failure, or were otherwise afflicted by non-operational temporary power options.⁹⁵ Facing the coupled inability to power fire stations, and communicate, many fire stations sought assistance from HAM radio operators to support a continuity of operations (COOP). ARRL radio operators established communications at the Fire Department Headquarters in Juncos that allowed direct communications with the Joint Field Office (JFO) in San Juan.⁹⁶ HAM radio operators also installed portable radio stations on all fire stations to include the islands of Vieques and Culebra to allow first

⁹⁰ Puerto Rico Fire Department.

⁹¹ Fischbach et al., “After Hurricane Maria,” 268.

⁹² Fischbach et al., 277.

⁹³ Fischbach et al., 169.

⁹⁴ Fischbach et al., 169.

⁹⁵ Federal Emergency Management Agency, *2017 Hurricane Season*, 36.

⁹⁶ American Radio Relay League, *ARRL 2017 After-Action Report*, 3.

responders to continue communicating resource needs to San Juan and to continue coordinating operations.⁹⁷

To reduce long-term vulnerability, the Puerto Rico Fire Department (PRFD) has opted to work with donors to install solar panels on numerous fire stations.⁹⁸ With solar installations ongoing, the American Society of Civil Engineers (ASCE) reinforced the need for “smart grid technologies, redundant power delivery, and hardened communications” on critical infrastructure, specifically police and fire stations, and hospitals. The ASCE also recommended building power redundancy and resilience via local microgrids.⁹⁹

a. Discussion

Responding to Hurricane Maria did not call for conventional firefighting capability. Instead, a large portion of the mission focused on search and rescue, which is covered in the next section. However, fire facilities proved to be important community assets. Once FEMA established operations, restoring communications and power to both fire stations and hospitals became a high priority in the initial response. Some firehouses proved to be vulnerable to flooding and lacked backup power generation and survivable communications capability, which presented a COOP shortfall.

b. Review

The COOP shortfalls drove the fire service to seek external support for generators and turn to the non-profit sector, such as the ARRL, for communications continuity. The PRFD has also decided to take action for future disasters by installing secondary power

⁹⁷ American Radio Relay League, 3.

⁹⁸ While an exact number is not publicly available, the installation of solar panels has been widely reported in available media. Tucker Higgins, “A Fire Department in Puerto Rico Is Now Powered by Solar: ‘It’s a Matter of Life and Death’,” CNBC, October 13, 2017, <https://www.cnbc.com/2017/10/13/puerto-rico-fire-department-now-on-solar-a-matter-of-life-and-death.html>.

⁹⁹ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure* (San Juan, PR: American Society of Civil Engineers, 2019), 32, <https://www.infrastructurereportcard.org/state-item/puerto-rico/>.

sources and communications capabilities to stations in each of the fire districts.¹⁰⁰ Fire stations across the country operate very closely with the communities they serve, which make continuity of these facilities and fire department services of particular importance to initial disaster response and transition to recovery operations.

3. Search and Rescue

In the days following Hurricane Maria, Puerto Rico received heavy mutual-aid assistance. Twelve urban search & rescue (US&R) teams deployed to the island and are credited with saving 837 lives “save or assisted” in the initial response.¹⁰¹ FEMA points out that US&R team rescue estimations are among additional rescues performed by the Department of Defense (DOD), Coast Guard, state and local rescue teams, and individual citizens aiding their neighbors.¹⁰²

A very wide array of government organizations conducted search and rescue operations. Some included FEMA Type 1 US&R teams, Puerto Rican Type 4 US&R Teams, MH-60 helicopters and MV-22 Osprey from the USS *Kearsarge* (CV 33), and USS *Oak Hill* (LSD 51), a naval P-8 Poseidon maritime surveillance aircraft from Naval Air Station Jacksonville, federal LE officers from San Juan, Bureau of Alcohol, Tobacco, and Firearms (ATF) Quick Reaction Teams (QRTs), U.S. Fish and Wildlife Service, Immigration and Customs Enforcement (ICE), Homeland Security Investigations (HSI),

¹⁰⁰ Higgins, “A Fire Department in Puerto Rico”; Umair Irfan, “Puerto Rico Is Starting to Take Solar Power More Seriously,” *Vox*, November 15, 2017, <https://www.vox.com/energy-and-environment/2017/10/19/16431312/elon-musk-richard-branson-clean-energy-puerto-rico-solar-batteries-microgrid>.

¹⁰¹ Note: It is unclear how these statistics are spread between Puerto Rico and the U.S. Virgin Islands, as Hurricane Maria impacted both, and a jurisdictional breakdown is not provided. Federal Emergency Management Agency, “Whole Community Approach to an Unprecedented Year” (paper presented at Metro Chiefs Conference, San Antonio, 2018), 2, <https://www.nfpa.org/-/media/Files/Membership/member-sections/Metro-Chiefs/2018-conference/MetroWednesdayFEMAResponse.ashx>.

¹⁰² Federal Emergency Management Agency, *2017 Hurricane Season*, vi.

and others.¹⁰³ Each FEMA Type 1 US&R consists of 70 members and is capable of splitting into two independently operating Type 3 US&R teams for greater coverage in either time (such as around-the-clock operations) or space (such as spreading out geographically).¹⁰⁴ In all, FEMA maintains 28 US&R teams to respond nationally, and on occasion, internationally.

The response to Hurricane Maria was unconventional for US&R teams. US&R teams are equipped to perform heavy rescue, such as needed following a major structural collapse, but the mission in Puerto Rico called for different operations. Initially, US&R teams established field operations in the Intercontinental Hotel in San Juan and weathered the storm there.¹⁰⁵ When winds subsided, the US&R teams performed incident management functions and were vital to performing wide-area searches, health and welfare checks, and accessing hard-to-reach locations throughout the island.¹⁰⁶ By September 28, FEMA reported that its teams had reached 90% of the island and was aiding in assessing the condition and needs of medical facilities.¹⁰⁷

None of these unconventional responses was planned and was often chaotic, which resulted in a non-systematic, comprehensive, or rapid means of helping those most

¹⁰³ Federal Emergency Management Agency, “Overview of Federal Efforts to Prepare for and Respond to Hurricane Maria,” *Department of Homeland Security* (blog), September 29, 2017, <https://www.dhs.gov/blog/2017/09/29/overview-federal-efforts-prepare-and-respond-hurricane-maria>; U.S. Army Northern Command, “Northcom Providing Disaster Relief Following Hurricane Maria,” U.S. Department of Defense, September 21, 2017, <https://www.defense.gov/Explore/News/Article/Article/1320480/northcom-providing-disaster-relief-following-hurricane-maria/>; “Hurricane Maria,” Southeast Region of the U.S. Fish and Wildlife Service, November 29, 2017, <https://www.fws.gov/southeast/infographic/hurricane-maria/>; “ICE HSI New York SSA Reflects on Hurricane Maria Efforts,” U.S. Immigration and Customs Enforcement, October 18, 2017, <https://www.ice.gov/news/releases/ice-hsi-new-york-ssa-reflects-hurricane-maria-efforts>.

¹⁰⁴ “Urban Search & Rescue,” Federal Emergency Management Agency, July 22, 2020, <https://www.fema.gov/emergency-managers/national-preparedness/frameworks/urban-search-rescue>.

¹⁰⁵ Jesse Roman, “‘A Whole Lot of Good for a Whole Lot of People in a Whole Lot of Need,’” NFPA, November 1, 2017, <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2017/November-December-2017/Features/Storm-Season/Joe-Jardin>.

¹⁰⁶ U.S. Immigration and Customs Enforcement, “ICE HSI New York SSA Reflects on Hurricane Maria Efforts,” News Releases, October 18, 2017, <https://www.ice.gov/news/releases/ice-hsi-new-york-ssa-reflects-hurricane-maria-efforts>.

¹⁰⁷ FEMA Public Affairs, “Overview of Federal Efforts to Prepare for and Respond to Hurricane Maria,” *Homeland Security* (blog), September 29, 2017, <https://www.dhs.gov/blog/2017/09/29/overview-federal-efforts-prepare-and-respond-hurricane-maria>.

in need. The response amounted to a wide variety of actors attempting to assist but often operating independently with little coordination. Puerto Rico did not have a complete catastrophic disaster plan when Maria struck, and one year after Hurricane Maria, the Centro de Periodismo Investigativo filed a lawsuit against the government claiming it still did not have a plan to deal with another disaster on the same scale as Hurricane Maria.¹⁰⁸ The disaster also grossly exceeded FEMA's planning assumptions based upon a Category 3 hurricane versus two close-succession Category 4 storms (Irma and Maria).¹⁰⁹ Relatedly, Georgetown researchers identified a need for FEMA's work to focus on community resilience and statewide plans post-Hurricane Maria.¹¹⁰

Despite records and claims of vast resources reaching nearly all portions of the island, many residents claimed they had no contact with relief organizations of any kind for over a week.¹¹¹ By September 29, FEMA's daily operations brief indicated that 843 individuals had been saved or assisted, 2,647 structures had been searched, and US&R teams had accessed all 78 Puerto Rican municipalities.¹¹² While this briefing affords insightful statistics, the numbers alone do not indicate whether all rescue needs had been met. Slow access to communities and complications of resource distribution, given the logistics of the response operation, does not directly indicate a lack of US&R coverage but does serve to highlight the challenges inherent in the operating environment. Among communities least likely to receive rapid aid, were those of the island's mountainous

¹⁰⁸ Deibert, *When the Sky Fell*, 145; "Gobierno confirma que no está listo el plan de manejo de emergencias para todas las agencias," Centro de Periodismo Investigativo, October 30, 2018, <https://periodismoinvestigativo.com/2018/10/>.

¹⁰⁹ Rob Moore, "Maria Exposed Problems with U.S. Disaster Policy," *Natural Resources Defense Council Expert Blog* (blog), September 19, 2018, <https://www.nrdc.org/experts/rob-moore/maria-exposed-problems-us-disaster-policy>; See Figure 8. Federal Emergency Management Agency, *FEMA After-Action Report*, 9.

¹¹⁰ Jason Thomas Barnosky, Patrick S. Roberts, and Joie D. Acosta, "What Can FEMA Learn from the Historic 2017 Hurricane and Wildfire Seasons?," *Georgetown Journal of International Affairs*, January 28, 2020, <https://gjia.georgetown.edu/2020/01/28/what-can-fema-learn-from-2017/>.

¹¹¹ Samantha Schmidt and Arelis R. Hernández, "Trapped in the Mountains, Puerto Ricans Don't See Help, or a Way Out," *Washington Post*, October 1, 2017, https://www.washingtonpost.com/national/trapped-in-the-mountains-puerto-ricans-dont-see-help-or-a-way-out/2017/10/01/7621867e-a647-11e7-ade1-76d061d56efa_story.html; Deibert, *When the Sky Fell*, 107.

¹¹² Federal Emergency Management Agency, *FEMA Daily Operations Brief: Friday, September 29, 2017* (Washington, DC: Federal Emergency Management Agency, 2017), 7, <http://www.disastercenter.com/FEMA+Daily+Ops+Briefing+09-29-2017.pdf>.

interior most impacted by collapsed bridges and roadways, heavy vegetative debris, and located far from state highways and critical transportation nodes. The US&R teams played a key role in these areas, given their ability to utilize the scarce air assets they had available and smaller vehicles to penetrate isolated areas.

a. Discussion

Regardless of the influx of outside responders, void of high levels of coordination and pre-planning, individual communities will face unmet needs, sometimes for extended periods of time. While US&R teams rescued many Puerto Ricans more often than not, residents had transportation, logistics, and other resource issues that US&R teams were not mandated to perform or were equipped to support. The primary purpose of the US&R teams was to perform rescues as needed, conduct welfare checks, and to be the eyes and ears for San Juan in hard-hit and hard to reach areas.¹¹³ Notwithstanding, many communities reported not having contact with government officials in any form for over a week, and in some cases, much longer.¹¹⁴

b. Review

These same issues are likely to manifest in future disasters, as conditions in Puerto Rico remain largely unchanged. Many areas of the island's interior remain mountainous, have limited cellular service, and are navigated by narrow, steep roadways perennially susceptible to landslides and flooding. Puerto Rico also still struggles with issues of infrastructure disrepair, which places key bridges at risk of future collapse.

¹¹³ Schmidt and Hernández, "Trapped in the Mountains."

¹¹⁴ Pablo Venes, "Starving Puerto Rican Towns Sharing Food, Eating Plants, and Waiting for FEMA," *The Daily Beast*, October 10, 2017, <https://www.thedailybeast.com/starving-puerto-rican-towns-sharing-food-eating-plants-and-waiting-for-fema>. For greater general context, refer to Fischbach et al., "After Hurricane Maria."

4. Government Service

The Puerto Rico Emergency Management Agency (PREMA) maintained a headquarters in San Juan, and in 2017, maintained 12 emergency management zones linked collectively to each of the 78 local municipalities.¹¹⁵ Since Hurricane Maria, the agency has been consolidated into the Department of Public Safety and is now known as the Puerto Rico Emergency Management Bureau (PREMB in English) and operates 10 emergency management zones.

According to the NRF governing emergency response in the United States, each of the 78 municipal emergency operations centers (EOCs) would communicate needs to each of the 12 PREMA zones, who further communicate resource needs to PREMA Headquarters located in San Juan. The state EOCs in San Juan would then communicate needs to assisting agencies, organizations, and the federal government. However, given the extent of destruction on the island, this ideal construct essentially collapsed due to a lack of power, communications, and viable transportation, which inhibited the local and state government's ability to both ascertain the situation and communicate needs to San Juan.¹¹⁶ The *Washington Post* quoted Department of Public Safety Director, Héctor Pesquera as saying, "Everything collapsed. Everything collapsed simultaneously."¹¹⁷

¹¹⁵ Monique Madan, "Trying to Contact Family in Puerto Rico? Here's Who to Call," *Miami Herald*, September 22, 2017, <https://www.miamiherald.com/news/weather/hurricane/article174907471.html>; Following Hurricane Maria, Puerto Rico consolidated to just ten emergency management zones. Government of Puerto Rico, "PR Earthquakes," Puerto Rico Federal Affairs Administration, January 14, 2020, <https://prfaa.pr.gov/pr-earthquake/>.

¹¹⁶ Arelis Hernández, "A Tale of Two Puerto Ricos: What Trump Saw—and What He Didn't," *Washington Post*, October 4, 2017, https://www.washingtonpost.com/politics/a-tale-of-two-puerto-ricos-what-trump-saw--and-what-he-didnt/2017/10/04/2eeee62e-a8b9-11e7-850e-2bdd1236be5d_story.html.

¹¹⁷ Arelis Hernández, Dan Lamothe, and Joel Achenbach, "When Hurricane Maria Hit Puerto Rico, 'Everything Collapsed Simultaneously'," *Washington Post*, October 2, 2017, https://www.washingtonpost.com/national/when-hurricane-maria-hit-puerto-rico-everything-collapsed-simultaneously/2017/10/02/a945dfa4-a79c-11e7-850e-2bdd1236be5d_story.html.

FEMA was placed in the non-traditional role of performing as the first responder to the entire island.¹¹⁸

The collapse of the local and commonwealth emergency management structure prompted FEMA and the Puerto Rican government to establish joint operations at the Pedro Roselló Convention Center in San Juan. The consolidated footprint was far less efficient than the original design but afforded an otherwise crippled system the ability to continue. By achieving face-to-face interaction between FEMA and the commonwealth, the two parties were able to coordinate the delivery of personnel and resources around the island, albeit at a hobbled pace. The Convention Center quickly became an island hub of information and resources for reporters, NGOs, locals, citizens, and the private sector.

a. Discussion

The state emergency management structure appears to have largely collapsed amid Hurricane Maria, which thrust the federal government into a first responder role. It was not a pre-planned approach to disaster response in Puerto Rico, which led to delays and coordination challenges. The breakdown has largely been attributed to the loss of power supply and an inability to communicate.¹¹⁹ COOP must be taken particularly seriously in isolated environments, such as an island in the Caribbean where resupply and disaster aid are more delayed than in the continental United States. Failure of power and communications, coupled with chaotic initial responses, challenging coordination, and an

¹¹⁸ RAND noted that, “Hurricane Maria destroyed infrastructure important to emergency response, such as power and transportation. As a result, FEMA had to take on more responsibility for the response and recovery than anticipated.” Jason Thomas Barnosky, Patrick Roberts, and Joie D. Acosta, “What Can FEMA Learn from the Historic 2017 Hurricane and Wildfire Seasons?,” *The Rand Blog* (blog), February 3, 2020, <https://www.rand.org/blog/2020/02/what-can-fema-learn-from-the-historic-2017-hurricane.html>; Christopher Currie, *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges*, GAO-18-472 (Washington, DC: Government Accountability Office, 2018), <https://www.gao.gov/assets/700/694231.pdf>. For additional general context, see Brock Long, *Statement of William B. Long Administrator, Federal Emergency Management Agency, U.S. Department of Homeland Security before the Homeland Security Committee United States House of Representatives, Washington, D.C., Preparedness, Response, and Rebuilding: Lessons from the 2017 Disasters* (Washington, DC: Federal Emergency Management Agency, 2018), <https://www.fema.gov/media-library-data/1521125792822-e47099fa3ecf84bc9e7646317ece29ed/FINALFEMALongF19.pdf>.

¹¹⁹ Fischbach et al., “After Hurricane Maria,” 2.

inability to access hard-hit areas, are both predictable and partially preventable if proper preparedness measures are taken pre-disaster.

b. Review

In the absence of robust government response in the initial days and weeks post-landfall, Puerto Ricans across the island resorted to creativity and helping each other to cope with the disaster's impacts. Residents would often check on neighbors, travel long distances to find cell service, charge phones, and procure food, water, and other essential supplies. In some areas, such as Utuado, where roadways and bridges had collapsed, community members erected pulley systems rigged with hardware and a shopping cart to ferry much-needed supplies to populations cut off from the outside world.¹²⁰ The community began referring to itself as “el campamento de olvidados,” the camp of the forgotten, in English.¹²¹ In Toro Negro, a community that was completely isolated, area residents have started a community foundation focusing on solar power generation, establishing a safe mountain aqueduct, and installing footbridges across a river to avoid future disaster vulnerability and isolation.¹²² While representing community ingenuity, this communal support function can also be cultivated under steady-state conditions via community preparedness programs to afford a more reliable, robust system of self-reliance until such a time that local, state, and federal authorities, as well as their private sector and non-profit partners, can erect a functioning incident management structure and free-flow of critical supplies. In the words of one Utuado residents, “The important thing

¹²⁰ Simón Rios, “In Puerto Rico, Community Groups Transform into Relief Brigades,” WBUR News, October 20, 2017, <https://www.wbur.org/news/2017/10/20/puerto-rico-community-groups-relief>; Caitlin Dickerson, “Stranded by Maria, Puerto Ricans Get Creative to Survive,” *New York Times*, October 16, 2017, <https://www.nytimes.com/2017/10/16/us/hurricane-maria-puerto-rico-stranded.html>; Greg Allen, “To Build Resilience, Puerto Rico Communities Embrace Grassroots Partnerships,” NPR All Things Considered, July 6, 2019, <https://www.npr.org/2019/07/06/739227604/to-build-resilience-puerto-rico-communities-embrace-grassroots-partnerships>; Oren Dorell, “With Long Lines for Food, Water and Fuel and No Electricity, Puerto Ricans Help Each Other,” *USA Today*, October 2, 2017, <https://www.usatoday.com/story/news/nation/2017/10/01/puerto-rico-want-and-generosity/720663001/>.

¹²¹ Accuweather, “Hurricane Maria: How Rural Utuado, Puerto Rico, Survived Isolated after the Storm,” ABC 30 Action News, September 20, 2018, <https://abc30.com/4295365/>.

¹²² Louie Porta, “Lessons in Community Resilience,” The Commission for Environmental Cooperation, December 19, 2020, <https://medium.com/@cecweb/lessons-in-community-resilience-7a90e5cfeb32>.

here is personal readiness—that you and your family are ready to survive for three weeks or a month without government help.”¹²³

5. Community Safety

This lifeline component is inclusive of other subcomponents, such as flood control, “other hazards,” and protective actions.¹²⁴ Following Hurricane Maria, the most acute public threat was the potential collapse of the aging Guajataca Dam. Built in 1929, the Lago Guajataca earthen dam is an aging piece of infrastructure that suffered a structural fissure that threatened the safety of approximately 70,000 Puerto Ricans two days post-landfall on September 22. The dam flood area borders the municipalities of San Sebastian, Quebradillas, and Isabela. In an address to residents, Governor Ricardo Rosselló said, “To those citizens ... who are listening: Please evacuate. We want your life to be protected ... Please, if you’re listening, the time to evacuate is now.”¹²⁵ The dam’s release gates had been damaged amid Hurricane Maria, which prevented the off letting of excess water volume that then created a situation the National Weather Service (NWS) identified as an “extremely dangerous situation” that drove fears the dam may structurally collapse.¹²⁶ The NWS later issued an urgent warning stating, “All Areas surrounding the Guajataca River should evacuate NOW. Their lives are in DANGER! Please SHARE!” on its Twitter account.¹²⁷ The threat posed by the Guajataca Dam first appeared in FEMA’s September 23, Daily Operations Brief, which noted the evacuation of roughly

¹²³ Greg Allen, “‘I Don’t Feel Safe’: Puerto Rico Preps for Next Storm without Enough Government Help,” NPR, July 3, 2019, <https://www.npr.org/2019/07/03/737001701/i-don-t-feel-safe-puerto-rico-preps-for-another-maria-without-enough-government>.

¹²⁴ Note: Protective actions, such as evacuation, overlap with the communications lifeline.

¹²⁵ Samantha Schmidt et al., “‘Thousands of People Could Die’: 70,000 in Puerto Rico Urged to Evacuate with Dam in ‘Imminent’ Danger,” *Washington Post*, September 22, 2017, <https://www.washingtonpost.com/news/post-nation/wp/2017/09/22/at-least-6-dead-in-puerto-rico-due-to-hurricane-maria-officials-say/>.

¹²⁶ Guardian Staff and Agencies in San Juan, “Puerto Rico Evacuates 70,000 after Dam Fails in Hurricane Maria’s Wake,” *The Guardian*, September 22, 2017, <https://www.theguardian.com/world/2017/sep/22/puerto-rico-hurricane-maria-dam>.

¹²⁷ Guardian Staff and Agencies in San Juan.

70,000 residents.¹²⁸ The dam failure was later determined not to be imminent, but severe erosion was occurring by floodwaters overtopping the dam. In the days following, the government supplied buses to evacuate residents in high-risk areas.¹²⁹

a. Discussion

At the time of the dam’s possible collapse, FEMA’s reports indicated that the island was experiencing 95% cellular service outages, and Hurricane Maria remained an off-shore Category 3 hurricane anticipated to produce another 1–3 inches of rainfall across large portions of the island.¹³⁰ This rainfall posed significant challenges to alerting and warning the 70,000 residents comprising the at-risk population, not only because of cellular outages but also because many in the flood risk area experience sporadic cellular service under normal conditions.¹³¹

b. Review

These challenges highlight the importance of local and state governments understanding areas of acute risk and limiting factors, as well as having alternative means to alert and notify the public. Following Hurricane Maria, PREMA began to procure alert and warning sirens for the Guajataca Dam flood hazard area. As of August 2019, however, reports indicated only three of seven sirens had been installed due to bureaucratic delays, and it remains to be seen if these sirens adequately cover the entire alert area or not.¹³²

¹²⁸ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017,” The Disaster Center, 2020, <http://www.disastercenter.com/FEMA%20Daily%20Situation%20Report%20Archive%202017.html>.

¹²⁹ Anthony Zurcher, “Evacuation Order over Puerto Rico Dam,” BBC News, September 23, 2017, <https://www.bbc.com/news/world-us-canada-41368478>; Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017”; Schmidt et al., ““Thousands of People Could Die””; Ralph Ellis, “Puerto Rico Dam: Evacuations Begin Along River,” CNN, September 23, 2017, <https://www.cnn.com/2017/09/22/us/puerto-rico-guajataca-river-dam-evacuations/index.html>.

¹³⁰ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017.”

¹³¹ Frances Robles, “New Emergency Sirens Sat in Storage as Hurricane Dorian Skimmed Puerto Rico,” *New York Times*, August 29, 2019, <https://www.nytimes.com/2019/08/29/us/hurricane-dorian-puerto-rico.html>.

¹³² Robles.

6. Conclusion

Providing services in the safety and security lifeline proved impossible for an extended period of time and was very challenging thereafter. While Puerto Rico did not experience widespread or sustained crime increases, LE was strained most by long-term systemic problems related to finances, failing pensions, and understaffing. Likewise, challenges to the fire service did not directly conflict with its core mission of firefighting but more generally concerned the department's ability to continue operations and a state of readiness amid failed communications platforms and structural damage to stations. The disaster also called for the department to execute unconventional responses. For instance, search and rescue teams were consumed not by dramatic rescues or building extractions, but instead by a need to perform reconnaissance that provided San Juan with situational awareness in remote areas of the island, wide area searches, and welfare checks. Both the fire service and its search and rescue elements suffered from unconventional requirements and a lack of redundancy in key areas concerning COOP. In much the same way, communities were at elevated risk due to a lack of redundancy in alerts and warnings concerning the potential collapse of the Guajataca Dam. Amid major challenges, certain non-governmental actors, such as ARRL operators, proved adept at filling critical capability gaps despite no direct prior planning for their participation in disasters.¹³³ Had non-governmental actors been included in disaster planning, it is reasonable to assume they could have contributed far more to bridging critical gaps in governmental response capabilities.¹³⁴

Taken collectively, these impacts illustrate a system overwhelmed. The initial lack of situational awareness across the island due to destroyed communications, coupled with staffing issues and shortages, as well as a disaster requiring rapid restructuring of mission sets, had a ripple effect in communities in need of food, water, and shelter. As

¹³³ ARRL's Amateur Radio Emergency Service (ARES) does maintain a disaster focus; however, no evidence has been presented of their planned employment in Puerto Rico prior to Hurricane Maria.

¹³⁴ This claim is similar in nature to that of the GAO when examining the role of the Red Cross in providing mass care services. Kathryn A. Larin, *Disaster Response: FEMA and the American Red Cross Need to Ensure Key Mass Care Organizations Are Included in Coordination and Planning*, GAO-19-526 (Washington, DC: Government Accountability Office, 2019), 19–21, <https://www.gao.gov/products/GAO-19-526>.

the safety and security lifeline experienced overload, so too did the food, water, and shelter lifeline, which resulted in many unmet needs of disaster survivors for extended periods. Resource shortages spurred communities to develop crude and often creative solutions cooperatively to provide life-sustaining services for themselves, their neighbors, and their communities.

B. FOOD, WATER, AND SHELTER LIFELINE

FEMA defines the food, water, and shelter lifeline as “support systems that enable the sustainment of human life, such as food retail and distribution networks, water treatment, transmission and distribution systems, housing, and agriculture resources.”¹³⁵ The components of this lifeline include food, water, shelter, and agriculture.¹³⁶

1. Food

Puerto Rico’s food shortage following Hurricane Maria appears to have been caused by a collapsed distribution system rather than a lack of supplies. The island has a higher density of supermarkets compared to the mainland United States. At the time of Hurricane Maria’s impact, Puerto Rico had an estimated 471 supermarkets, which represented a 1:7,500 supermarket to resident ratio; the mainland U.S. average ratio is 1:8,800.¹³⁷ With an estimated decline of 400,000 people leaving Puerto Rico between 2000 and 2016, and an additional 200,000 estimated to have relocated to the mainland after Hurricane Maria, market consolidation is likely to occur.¹³⁸ Despite Puerto Rico’s high-density supermarkets, shelves quickly went empty when the power failed, resupply shipments did not arrive, and employees failed to report to work. For stores able to re-open on generator power, resupply shipments continued to lag as the island’s ports (primarily via San Juan) struggled to re-establish a functioning distribution network.¹³⁹ Once distribution began to operate at comparably normal levels, supermarkets began re-

¹³⁵ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6.

¹³⁶ Federal Emergency Management Agency, 6.

¹³⁷ Palin, “Learning from H.I.M. (Harvey, Irma, Maria).”

¹³⁸ Palin.

¹³⁹ Palin.

opening. One month post-impact, 417 of the 471 (89%) store locations had re-opened for business.¹⁴⁰

In the interim, the feeding and water mission requirements in Puerto Rico following Hurricane Maria were grossly underestimated. The agency anticipated a need to distribute food and water to 500,000 residents following a major hurricane impact, not the entire island population of over three million people, which prompted the agency to lean on an earthquake and tsunami plan instead of one that contained higher planning assumptions for food and water distribution.¹⁴¹ Plans also did not account for the total loss of communications capabilities.¹⁴² Consequently, Puerto Rico's needs quickly outpaced FEMA's 15 pre-established contracts for "tarps, water, blankets, meals, etc."¹⁴³ What resulted was the longest sustained airborne food and water distribution mission in the agency's history.¹⁴⁴ By February 2018, all federal agencies had obligated roughly \$2 billion in for food, water, and shelter supplies, across all 2017 disasters.¹⁴⁵ By April 2019, FEMA had obligated \$115.4 million for food and water supplies for Hurricane Maria alone.¹⁴⁶ Between September 23 and December 23, FEMA distributed 48 million

¹⁴⁰ Palin.

¹⁴¹ Federal Emergency Management Agency, *2017 Hurricane Season*, 8; Frances Robles, "FEMA Was Sorely Unprepared for Puerto Rico Hurricane, Report Says," *New York Times*, July 12, 2018, <https://www.nytimes.com/2018/07/12/us/fema-puerto-rico-maria.html>; Joshua Hoyos, "Underprepared, Understaffed, and Uninformed—FEMA Audit Faults Agency Response to 2017 Hurricanes," ABC News, July 14, 2018, <https://abcnews.go.com/Politics/underprepared-understaffed-uninformed-fema-audit-faults-agency-response/story?id=56558164>.

¹⁴² Christopher Currie, *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges*, GAO-18-472 (Washington, DC: Government Accountability Office, 2018), <https://www.gao.gov/assets/700/694231.pdf>.

¹⁴³ Federal Emergency Management Agency, *2017 Hurricane Season*, 30.

¹⁴⁴ Federal Emergency Management Agency, 41.

¹⁴⁵ Marie A. Mak, *2017 Disaster Contracting: Observations on Federal Contracting for Response and Recovery Efforts*, GAO-18-335 (Washington, DC: Government Accountability Office, 2018), <https://www.gao.gov/assets/700/690425.pdf>.

¹⁴⁶ Marie A. Mak, *2017 Disaster Contracting: Actions Needed to Improve the Use of Post-Disaster Contracts to Support Response and Recovery*, GAO-19-281 (Washington, DC: Government Accountability Office, 2019), 65, <https://www.gao.gov/assets/700/698676.pdf>.

meals to the public.¹⁴⁷ One month later, FEMA reported it had distributed 57 million meals in total.¹⁴⁸

Before Hurricane Maria's impact, FEMA had distributed 80% of commodity and disaster supply stockpiles housed in Puerto Rico to the U.S. Virgin Islands in response to Hurricane Irma two weeks before Hurricane Maria. Therefore, the shelves of FEMA's Caribbean Area Division (CAD) distribution center were nearly empty with no cots or tarps, fewer than 20 "blue roofs," less than 98,000 meals, and just 70,000 liters of water.¹⁴⁹ Thus, few supplies and commodities were available for immediate distribution in Puerto Rico, or its islands of Culebra and Vieques, which required island residents to await resupply from the mainland. Beyond initial warehouse shortages, as noted under the energy lifeline, Puerto Rico's supply shortages were associated more with issues of distribution, not supply.¹⁵⁰ Puerto Rico's ports were full of commodities with roughly 9,000 shipping containers within one week following Hurricane Maria, but responders struggled to deliver items quickly to those most in need.¹⁵¹ Distribution difficulties primarily stemmed from a lack of communications, road blockages, a lack of truck drivers, confusing restrictions on fuel sales and curfews, and FEMA's inability to track supply shipments via its Logistics Supply Chain Management System (LSCMS).¹⁵²

¹⁴⁷ Philip J. Palin, *Out of the Whirlwind: Supply and Demand after Hurricane Maria* (Lanham, MD: Rowman & Littlefield Publishers, 2019), loc. 310 of 1721, Kindle.

¹⁴⁸ Laura Robles and Reynaldo Jr. Leanos, "Puerto Rico Food Aid Brought Too Much Salt and Sugar, Some Residents Say," *USA Today*, February 1, 2018, <https://www.usatoday.com/story/news/nation/2018/02/01/puerto-rico-food-aid-brought-chocolate-bars-and-cookies-some-residents-say/1085800001/>.

¹⁴⁹ Robles, "FEMA Was Sorely Unprepared"; Hoyos, "Underprepared, Understaffed, and Uninformed." FEMA refers to a deficit in warehouse commodities in Federal Emergency Management Agency, *2017 Hurricane Season*, 26.

¹⁵⁰ Associated Press, "Puerto Rico Residents Outraged after Discovering Unused Aid from Hurricane Maria," NBC News, January 19, 2019, <https://www.nbcnews.com/news/latino/puerto-rico-residents-outraged-after-discovering-warehouse-full-unused-aid-n1118501>.

¹⁵¹ Camila Domonoske, "In Puerto Rico, Containers Full of Goods Sit Undistributed at Ports," NPR Morning Edition, September 28, 2017, <https://www.npr.org/sections/thetwo-way/2017/09/28/554297787/puerto-rico-relief-goods-sit-undistributed-at-ports>; Rachel Frazin, "FEMA Confirms Thousands of Expired Water Bottles Left on Farmland in Puerto Rico," *The Hill*, July 30, 2019, <https://thehill.com/policy/energy-environment/455280-fema-confirms-thousands-of-expired-water-bottles-left-on-farmland>; Palin, *Out of the Whirlwind*.

¹⁵² Palin, *Out of the Whirlwind*; Federal Emergency Management Agency, *2017 Hurricane Season*; Palin, "Learning from H.I.M. (Harvey, Irma, Maria)."

Additionally, many containers arrived at the Port of San Juan generically labeled “disaster relief,” which made distribution of the right materials to the right place nearly impossible.¹⁵³ A recent DHS Office of Inspector General (OIG) report indicated that in total, FEMA lost track of approximately 38% of commodity shipments worth about \$257 million and that it took an average of 69 days for FEMA shipments to travel from point-of-origin to final destinations in Puerto Rico.¹⁵⁴ The specific breakdown of this timeline shows that it took FEMA 13 days to ship from the contractors’ point of origin in the Continental United States (CONUS) to Puerto Rico.¹⁵⁵ Once on the island, commodities remained in FEMA’s custody for approximately 48 days, and onward distribution timelines took an additional average of 7.5 days to reach the final destination where commodities were needed.¹⁵⁶ This issue spurred FEMA to pursue a significant overhaul and upgrades to its logistic tracking technology. The agency has updated staffing, training, and in August 2019, procured 2,000 solar satellite transponders that drastically improve remote monitoring and commodity tracking capability.¹⁵⁷ In June 2020, FEMA also undertook an integration project with UPS and FedEx aimed at increasing real-time product shipment information.¹⁵⁸

Overall, FEMA was adhering to its planned distribution methods but did not anticipate the scale of the need and storm damages or that the agency would be the primary food and water provider. In basic terms, FEMA and federal partners moved disaster supplies, including food items, from ports of entry to several large incident support bases (ISBs) then onward to smaller regional staging areas (RSAs) where the commodities were transferred to the Puerto Rican National and State Guard for further movement to Puerto Rico’s 78 municipalities.¹⁵⁹ FEMA also worked with federal

¹⁵³ Palin, loc. 174.

¹⁵⁴ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process in Response to Hurricanes Irma and Maria*, OIG-20-76 (Washington, DC: Office of Inspector General, 2020), 48.

¹⁵⁵ Office of Inspector General, 8.

¹⁵⁶ Office of Inspector General, 8.

¹⁵⁷ Office of Inspector General, 22, 31.

¹⁵⁸ Office of Inspector General, 30.

¹⁵⁹ Federal Emergency Management Agency, *2017 Hurricane Season*, 29.

partners, contracted box trucks and drivers to make community commodity deliveries, and directly delivered commodities to impacted residents via federal workers and NGO staff.¹⁶⁰ Additionally, local municipalities also shared responsibility for community commodity distribution.

With scant disaster supplies available, particularly early in the response phase, many residents were left to seek their own food, water, and shelter. In some parts of the island, food aid did not arrive for over two weeks, particularly in hard to access areas that were heavily impacted by landslides.¹⁶¹ Amid major supply shortages, some municipal mayors resorted to extreme measures, such as ordering that schools' food storage be broken into and utilized to feed local communities.¹⁶² When food did arrive, many received what was described as “junk food” in boxes containing such items as cookies, pudding, crackers, Skittles, processed meats, and Cheez-It crackers.¹⁶³ FEMA and Defense Logistics Agency (DLA) spokespersons explained that snack packs were delivered in addition to more nutrient shelf-stable meals that can last up to nine months and contain at least 600 calories consisting of the main meal, a starch item, a fruit, and a snack.¹⁶⁴ The exact caloric makeup of meals delivered, exact quantities of meals, and whether meals made it to the areas most in need, remains a difficult topic to reverse-engineer with precision.

In addition to government distributed meals, communities also came together to feed those in need. As seen in Figure 1, in the isolated village of Utuado, residents of the

¹⁶⁰ Federal Emergency Management Agency, 29.

¹⁶¹ Palin, *Out of the Whirlwind*, loc. 157; Deibert, *When the Sky Fell*, 8.

¹⁶² Fischbach et al., “After Hurricane Maria,” 129.

¹⁶³ Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’,”; Caitlin Dewey, “Why FEMA Sent ‘Junk Food’ to Puerto Rican Hurricane Survivors,” *Washington Post*, October 24, 2017, <https://www.washingtonpost.com/news/wonk/wp/2017/10/24/why-fema-sent-junk-food-to-puerto-rican-hurricane-survivors/>.

¹⁶⁴ Robles and Leanos, “Puerto Rico Food Aid.”

remote village of Charco Abajo erected a pulley system to span the Río Viví as a means of shuttling food and other supplies where a lone bridge used to stand.¹⁶⁵



Figure 1. Pulley System to Span the Río Viví.¹⁶⁶

In the village of Mariana, the site of an annual food festival, local women came together to pool the food they could find and cook 400 meals per day, and continued their operation long-term.¹⁶⁷ Other examples of community-led disaster relief involved existing community groups assuming new roles. One organization serves as an example, Proyecto Enlace del Caño Martin Peña, founded in 2002 to promote health and environmental justice alliance in eight communities in the Santurce area of San Juan. Years of pre-established connectivity allowed the group to mobilize amid Hurricane Maria to provide a variety of services from employing water pumps, temporarily

¹⁶⁵ Dickerson, “Stranded by Maria”; Mattathias Schwartz, “Hurricane Maria Was a Natural Catastrophe. The Aftermath Is a Man-Made Disaster,” *Intelligencer*, December 22, 2017, <https://nymag.com/intelligencer/2017/12/hurricane-maria-man-made-disaster.html>.

¹⁶⁶ Source: Dickerson. Resident of Charco Abajo using an improvised pulley system to traverse the Vivi River after the bridge collapsed.

¹⁶⁷ Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’ .”

replacing roofs, clearing debris, and providing 5,000 hot meals to neighbors.¹⁶⁸ On a much larger scale, award-winning chef José Andrés began scaling his operation in San Juan to feed the island with two groups he founded, World Central Kitchen, and Chefs for Puerto Rico.¹⁶⁹ Andrés’ scaled his operation to serve 100,000 meals a day at more than a dozen sites around the island in a time of critical need.¹⁷⁰ Collectively, community members and pre-existing groups took tangible actions and called upon the Puerto Rican diaspora to help relieve suffering on the island.¹⁷¹ Within three months, José Andrés and his team had served over three million meals islandwide.¹⁷²

a. Discussion

The commodity distribution issues faced in Puerto Rico offer concrete evidence that government capabilities alone cannot manage catastrophic disasters.¹⁷³ It also supports former FEMA Administrator Craig Fugate’s assertion that “a government-centric approach to disaster management will not be enough to meet the challenges posed by a catastrophic incident. That is why we must fully engage our entire societal capacity.”¹⁷⁴ To meet the needs of disaster survivors adequately, the disaster response truly needs to be a top-down and bottom-up approach that coalesces around the critical needs of impacted communities. Full reliance on governmental disaster relief in future disasters is likely to be met with similar outcomes. Communities must consider other

¹⁶⁸ Maria Brodine, “Proyecto ENLACE del Caño Martín Peña: Restoring an Ecosystem and Building Resilient Communities in Puerto Rico,” Urban Waters Learning Network, December 22, 2017, <https://www.urbanwaterslearningnetwork.org/resources/proyecto-enlace-del-cano-martin-pena-restoring-ecosystem-building-resilient-communities-puerto-rico/>.

¹⁶⁹ Terry Gross, “After Hurricane Maria, Chef José Andrés Had a ‘Crazy Dream’ to Feed Puerto Rico,” NPR, September 10, 2018, <https://www.npr.org/sections/thesalt/2018/09/10/646242247/after-hurricane-maria-chef-jos-andr-s-had-a-crazy-dream-to-feed-puerto-rico>.

¹⁷⁰ Stuart Anderson, “Immigrant Chef José Andrés Has Served Americans 20 Million Free Meals,” *Forbes*, July 28, 2020, <https://www.forbes.com/sites/stuartanderson/2020/07/28/immigrant-chef-jos-andrs-has-served-americans-20-million-free-meals/>; José Andrés, *We Fed an Island: The True Story of Rebuilding Puerto Rico, One Meal at a Time* (New York: Harper Collins, 2019), 179.

¹⁷¹ Rios, “In Puerto Rico.”

¹⁷² Andrés, *We Fed an Island*, x.

¹⁷³ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*, 11.

¹⁷⁴ Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management*, 2.

means of building food supply resiliency. To provide one tangible example, a group calling itself the “Center of Mutual Support” in the community of Las Carolinas, in the municipality of Caguas, set up community kitchen operations in an abandoned school building and began distributing meals.¹⁷⁵ Since Hurricane Maria, the community has petitioned the government for ownership of the building, which they hope to continue using as a community kitchen in the event of another major disaster, next time with solar panels installed.¹⁷⁶ The group also prepared and delivered warm meals to elderly residents for an extended period of time.¹⁷⁷

b. Review

As FEMA maintains the role of coordination with state and local governments, it is up to communities to assume a role in catastrophic disaster preparedness as well. The lived experience of Puerto Rico aligns with evidence that indicates communities that display higher levels of social capital pre-disaster suffer lower rates of food insecurity and prove better able to leverage physical capital.¹⁷⁸ Furthermore, communities of high social capital can decrease the impacts felt by communities of lower social capital by providing bridging capital inclusive of said communities.¹⁷⁹ The relationship between social capital and food security is important as matters of disaster resilience are considered in Puerto Rico. Despite the record-setting feeding mission of FEMA and federal agency partners, many across the island went without food for extended periods or spent larger portions of their time seeking rations. In addition, much like the health and medical lifeline, close proximity to needed resources proved decisive in the days and weeks following the catastrophic disaster when the government provided aid failed to meet disaster survivor basic needs. Since 2017, FEMA has made efforts to bolster on-

¹⁷⁵ Allen, “‘I Don’t Feel Safe’.”

¹⁷⁶ Allen.

¹⁷⁷ Allen.

¹⁷⁸ Alana Chriest and Meredith Niles, “The Role of Community Social Capital for Food Security Following an Extreme Weather Event,” *Journal of Rural Studies* 64 (November 2018): 80–90, <https://doi.org/10.1016/j.jrurstud.2018.09.019>.

¹⁷⁹ Chriest and Niles, 23–4.

island stockpiles. In 2017, the agency reported having 50,000 meals available; in August 2020, the number of on-hand shelf-stable meals had risen to 6.6 million.¹⁸⁰

2. Water

Much like the island's power grid, the water system was also plagued with issues prior to Hurricane Maria. Puerto Rico is served primarily by the Puerto Rican Aqueduct and Sewer Authority (PRASA), which provides 97% of the island's water supply; the remaining water supply is afforded by approximately 240 very small water systems, collectively referred to as "non-PRASA" systems, that supply the remaining 3% of island residents with water.¹⁸¹ Non-PRASA systems serve roughly 126,000 residents in rural Cordillera Central mountainous areas throughout the island's interior.¹⁸² Per capita, Puerto Rico's water systems have the highest number of safe drinking water violations.¹⁸³ Collectively, 201 out of 406 water stations committed 545 health-related violations in 2015 that primarily related to a lack of testing for water quality, safety standards, and failure to report safety issues.¹⁸⁴ Between 2005 and 2015, the island had a total of 33,842 recorded violations of the Safe Drinking Water Act (SDWA).¹⁸⁵ The most violated rules were "Total Coliform Rule, the Synthetic Organic Contaminants Rule, the Volatile Organic Contaminants Rule, and the Surface Water Treatment

¹⁸⁰ "Hurricane Maria by the Numbers," Federal Emergency Management Agency, August 2020, <https://www.fema.gov/fact-sheet/hurricane-maria-numbers>.

¹⁸¹ Stacey Berahzer, "Who Is Supplying the Water in Puerto Rico?," *Environmental Finance* (blog), November 17, 2015, <http://efc.web.unc.edu/2015/11/17/who-is-supplying-water-in-puerto-rico/>; Elias Rodriguez and Brenda Reyes, "EPA Responds to Puerto Rico Earthquakes; Assessing Sites and Facilities to Help the Puerto Rico Government," Environmental Protection Agency, January 15, 2020, <https://www.epa.gov/newsreleases/epa-responds-puerto-rico-earthquakes-assessing-sites-and-facilities-help-puerto-rico>.

¹⁸² Berahzer, "Who Is Supplying the Water in Puerto Rico?"

¹⁸³ Natural Resources Defense Council, *Threats on Tap: Drinking Water Violations in Puerto Rico* (New York: Natural Resources Defense Council, 2017), 1, <https://www.nrdc.org/resources/threats-tap-drinking-water-violations-puerto-rico>.

¹⁸⁴ Natural Resources Defense Council, 2.

¹⁸⁵ Natural Resources Defense Council, 1.

Rule.”¹⁸⁶ Puerto Rico’s small water systems also ranked second in the nation for having Tier 1 water safety violations in October 2011.¹⁸⁷

When Hurricane Maria struck the island, destroying the power supply, water-pumping facilities without backup generation power also went offline and quickly became a FEMA priority for emergency generator installations.¹⁸⁸ Peak outages resulted in roughly 80% of PRASA customers losing water service.¹⁸⁹ One month following Hurricane Maria, living conditions for many Puerto Ricans remained dire. Roughly 4,300 residents remained in shelters, 80% of residents remained without power, and 30% remained without running water.¹⁹⁰ Temporary water provision suffered the same distribution issues as food products and other commodities because the bottled water was shipped in tandem with food supplies in the same shipping containers that were stuck in ports.¹⁹¹

Until water systems were reconstituted, Puerto Rican residents relied upon distributed water bottles and whatever untreated natural water source were accessible near their homes. Those who were fortunate had rainwater runoff from the hillsides, or spring water, to use for laundry, bathing, house cleaning, and to flush toilets.¹⁹² Others went to local rivers to fetch water for daily needs.¹⁹³ However, not everyone was fortunate enough to have water sources near their residences or the physical ability to seek it out. For example, just outside of San Juan, in Carolina, an elderly community in a

¹⁸⁶ Natural Resources Defense Council, 2.

¹⁸⁷ Natural Resources Defense Council, 2.

¹⁸⁸ Federal Emergency Management Agency, *2017 Hurricane Season*, 37.

¹⁸⁹ Currie, *2017 Hurricanes and Wildfires*, 29.

¹⁹⁰ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017.”

¹⁹¹ Federal Emergency Management Agency, *2017 Hurricane Season*, 27.

¹⁹² Pam Radtke Russell and Scott Blair, “Puerto Rico Recovery Inches On,” *ENR* 280, no. 10 (2018): 6; Dickerson, “Stranded by Maria”; Claritza Jiminez and Whitney Leaming, “‘We Are in Crisis.’ How One City in Puerto Rico Is Surviving without Water,” *Washington Post*, September 29, 2017, https://www.washingtonpost.com/video/national/we-are-in-crisis-this-puerto-rico-city-is-using-a-creek-as-its-water-source/2017/09/29/b1b5871e-a546-11e7-b573-8ec86cdfef1ed_video.html.

¹⁹³ Deibert, *When the Sky Fell*, 107; Ben Fox and Danica Coto, “Scope of Puerto Rico Damage so Wide that U.S. Aide Hard to See,” CBS 21 News, September 27, 2020, <https://local21news.com/news/local/scope-of-puerto-rico-damage-so-wide-that-us-aid-hard-to-see>.

multi-story building called Las Teresas went without water resupply for roughly two weeks until discovered by a group of volunteers organized in coordination with the local San Juan municipality.¹⁹⁴ When the power failed in Carolina, elevators in the high-rise building stopped working, and many residents were too frail to utilize the stairs, which left them trapped in their apartments with no means of resupply.¹⁹⁵ Retirement home administrators had left the area preceding the storm, and elderly residents' families were either not in the area or otherwise unaware of their condition.¹⁹⁶ The San Juan relief brigade consisted of 50 to 100 volunteers per day made up of local residents wanting to provide help to those in need. Once located, volunteers continued to bring food, water, and medical supplies to elderly residents.

When water service was restored, residents continued to struggle with water quality and service reliability.¹⁹⁷ Nearly one-third of wastewater treatment plants went offline following Hurricane Maria, which resulted in widespread contamination of waterways many residents were using as emergency water supplies.¹⁹⁸ Health complications stemming from contaminated water sources, such as skin and soft-tissue infections, as well as gastrointestinal, respiratory, zoonotic, and vector-borne diseases, are known to spike following extreme hydrological weather events.¹⁹⁹ By November

¹⁹⁴ Amanda Holpuch, "Life or Death as Puerto Rico's Older People Go without Essentials," *The Guardian*, October 3, 2017, <https://www.theguardian.com/world/2017/oct/03/puerto-rico-elderly-hurricane-victims>; Deibert, *When the Sky Fell*, 105.

¹⁹⁵ Holpuch, "Life or Death."

¹⁹⁶ Holpuch.

¹⁹⁷ Carmen Heredia Rodriguez, "Water Quality in Puerto Rico Remains Unclear Months after Hurricane Maria," PBS News Hour, June 14, 2018, <https://www.pbs.org/newshour/health/water-quality-in-puerto-rico-remains-unclear-months-after-hurricane-maria>; Oxfam America, *Far from Recovery: Puerto Rico Six Months after Hurricane Maria* (Washington, DC: Oxfam America Inc., 2018), 5, <https://www.oxfamamerica.org/explore/research-publications/far-from-recovery-puerto-rico-six-months-after-hurricane-maria/>.

¹⁹⁸ Heredia Rodriguez.

¹⁹⁹ Stephen Y. Liang and Nicole Messenger, "Infectious Diseases after Hydrologic Disasters," *Emergency Medicine Clinics of North America* 36, no. 4 (November 2018): 835–51, <https://doi.org/10.1016/j.emc.2018.07.002>.

2017, 99 suspected cases of leptospirosis, 18 confirmed cases, and four fatalities were reported; the island typically sees between 63 and 95 cases over a 12-month period.²⁰⁰

In terms of reliability, once restored, the water supply was only as reliable as the power line or generator that provided water pumps with electricity. As the grid remained fragile, basic water provision did so also. Particularly outside of urban areas, reliable water supply remained intermittent and of questionable purity. FEMA addressed the issue by installing some 700 generators supplying power to water pumping stations and installing 161 water storage units in remote areas that the National Guard assumed responsibilities for refilling and maintaining.²⁰¹

a. Discussion

Research since Hurricane Maria has identified a positive correlation between communities' "remoteness" and the length of time spent without power, water, and cell phone service.²⁰² On average, residents throughout the island went without water service for 68 days.²⁰³ Many communities in rural areas went much longer periods without water. For instance, when FEMA shut down its food and water distribution mission in late January 2018, a full third of the island remained without power—and therefore, water—and the USACE estimated it would take until the summer to restore power fully.²⁰⁴

²⁰⁰ David Cordero, "Aumenta la cantidad de casos sospechosos y confirmados de leptospirosis en Puerto Rico," *Metro*, November 7, 2017, <https://www.metro.pr/pr/estilo-vida/2017/11/07/aumenta-la-cantidad-casos-sospechosos-confirmados-leptospirosis-puerto-rico.html>; Michael Nedelman, "Suspected Leptospirosis Cases on Rise in Puerto Rico," CNN, October 24, 2017, <https://www.cnn.com/2017/10/24/health/leptospirosis-puerto-rico/index.html>.

²⁰¹ Heredia Rodriguez, "Water Quality in Puerto Rico."

²⁰² Nishant Kishore et al., "Mortality in Puerto Rico after Hurricane Maria," *New England Journal of Medicine* 379, no. 2 (July 12, 2018): 162–70, <https://doi.org/10.1056/NEJMsa1803972>.

²⁰³ Kishore et al., 165.

²⁰⁴ Adrian Florido, "FEMA to End Food and Water Aid for Puerto Rico," NPR All Things Considered, January 29, 2018, <https://www.npr.org/sections/thetwo-way/2018/01/29/581511023/fema-to-end-food-and-water-aid-for-puerto-rico>; Diana M. Holland, "Responding to the Perfect Storm: The U.S. Army Corps of Engineers and Disaster Response in Puerto Rico, 2017," *Military Review* 99, no. 3 (June 2019): 10–25.

b. Review

FEMA gauged that since markets were back open from which residents could procure resources, the state and non-governmental partners could meet other unmet needs.²⁰⁵ This assumption proved problematic for interior mountainous communities, such as Morovis, where the median household income is just \$18,000 per year, and families were spending \$25–40 per day on fuel to run household generators.²⁰⁶ This dynamic represents a critical break in the reliable water supply chain that impacted remote, hard-to-reach areas of the island that have yet to see a permanent resolution. In 2017, FEMA reported having 800,000 liters of water on-hand in stockpiles; that number has increased to seven million liters of water as of August 2020.²⁰⁷

3. Shelter

Determining the precise number of shelters opened for Puerto Rican residents, and their population numbers is difficult to ascertain, as reported numbers and timeframes vary by source. According to one source, on Tuesday, September 19, the Puerto Rican government opened roughly 500 schools as emergency shelters while the GAO reported just eight shelters open with a population of 306 persons on the same date.²⁰⁸ FEMA first reported shelter statistics beginning on September 20 and reported 172 open shelters with a population of 9,981.²⁰⁹ According to FEMA, Puerto Rico reached a maximum official shelter population of 11,359 on September 25.²¹⁰ However, unofficial conversations with a senior member within the Puerto Rican government place their estimation at closer to 15,000. As late as November 10, FEMA reported 62 open shelters with 2,374 occupants. This report represented a reduction of 86 from the previous two-day report, which signaled that residents were either going home, being

²⁰⁵ Florido.

²⁰⁶ Florido.

²⁰⁷ Federal Emergency Management Agency, “Hurricane Maria by the Numbers.”

²⁰⁸ Palin, *Out of the Whirlwind*, loc. 196; Currie, *2017 Hurricanes and Wildfires*, 79.

²⁰⁹ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017.”

²¹⁰ Federal Emergency Management Agency, *2017 Hurricane Season*, 40.

placed by FEMA into the Temporary Sheltering Assistance (TSA) program, or were moving elsewhere either on or off-island.²¹¹ The number of open shelters and individual shelter population counts steadily declined beyond this point. Regardless of the ultimate shelter statistics, it is clear that less than 1% of the island's more than three million residents *did not* seek refuge in a public shelter.

Public shelters were established in the island's public school network. Many of the schools were not of remarkably resilient design in that they lacked backup generation capability and varied in physical sturdiness. A lack of power poses challenges to the medically dependent and otherwise frail as temperatures rose steeply during daylight hours. Additionally, the water systems servicing schools require electrical power to cycle drinking and sewage water. When the power failed, the water systems did so as well, which created unsanitary conditions in shelters.²¹²

Eventually, residents needed to transition from emergency shelters to more permanent housing solutions. Emergency shelters were primarily located in public schools and were only designed to serve as a temporary congregate sheltering option until residents could go home or be transitioned to other housing programs. From public shelters, many residents transitioned to the TSA program, which is a government-funded program whereby displaced disaster-impacted residents are placed in private hotels. As of 2018, FEMA indicated that approximately 7,000 families had been brought into the program and housed at 1,000 hotels in 41 states, Washington, DC, and within participating hotels in Puerto Rico.²¹³ To facilitate the migration from public shelters to the TSA program, FEMA implemented Multi-Agency Shelter Transition Taskforces (MASTTs).²¹⁴ As the name suggests, MASTTs bring various agencies together as a means of merging disaster solutions for displaced residents.

²¹¹ Federal Emergency Management Agency, "FEMA Daily Situation Report Archive 2017."

²¹² Greg Allen and Marisa Peñaloza, "Desperation in Puerto Rican Town Where 60 Percent Are Now Homeless," NPR All Things Considered, September 25, 2017, <https://www.npr.org/2017/09/25/553532405/in-puerto-rican-town-situation-turns-dire-at-packed-shelter>.

²¹³ Aisha E. Krieger, "Disaster Housing for Urban Environments" (master's thesis, Naval Postgraduate School, 2019), 47, <https://www.hsdl.org/?abstract&did=828245>.

²¹⁴ Federal Emergency Management Agency, *2017 Hurricane Season*, 41.

a. Discussion

Despite the devastating storm forecast, most Puerto Rican residents did not seek public shelter. Instead, most residents sought shelter with those in their own social networks. By the official peak estimate, 11,359 Puerto Ricans sought public shelter in the lead up to and aftermath of Hurricane Maria, which represented just .003% of the island's population.²¹⁵ This percentage indicates that nearly all Puerto Rican residents weathered the storm in private dwellings. Puerto Rico has an estimated 1,237,180 million homes, of which 1,138,843 sustained hurricane damages, according to the American Bar Association, which represents 92% of all homes on the island.²¹⁶ However, by FEMA's damage inspection standards, the agency recorded only 357,492 damaged homes, of which only 1% had greater than \$30,001 in damages.²¹⁷ In February 2018, Puerto Rico's Housing Secretary indicated that by his count, approximately 250,000 homes sustained major damage, 70,000 of which were destroyed, and at that time, he anticipated the number to raise another 50,000-damaged homes as inspections continued.²¹⁸ These numbers display a vast disparity in housing stock damage estimations from 23–92% between FEMA and the American Bar Association. Most severely damaged homes were unsurprisingly in the direct path of the storm or stood in flood-prone areas.²¹⁹ The larger point is that no matter the measure of damaged homes, nearly 100% of island residents did not go to public shelters. This percentage indicates that a vast majority of Puerto Rican residents weathered the storm in their own homes or those of friends, family, or neighbors, which highlights a need for strong community planning, risk mitigation,

²¹⁵ Federal Emergency Management Agency, 40.

²¹⁶ Ivis Garcia, "The Lack of Proof of Ownership in Puerto Rico Is Crippling Repairs in the Aftermath of Hurricane Maria," American Bar Association, February 21, 2020, https://www.americanbar.org/groups/crsj/publications/human_rights_magazine_home/vol--44--no-2--housing/the-lack-of-proof-of-ownership-in-puerto-rico-is-crippling-repai/.

²¹⁷ Jennifer Hinojosa and Edwin Meléndez, *The Housing Crisis in Puerto Rico and the Impact of Hurricane Maria* (New York: Centro de Estudios Puertorriqueños, 2018), 15, <https://centropr.hunter.cuny.edu/research/data-center/research-briefs/housing-crisis-puerto-rico-and-impact-hurricane-maria>.

²¹⁸ Andres Viglucci, "Half of Puerto Rico's Housing Was Built Illegally. Then Came Hurricane Maria," *Miami Herald*, February 14, 2018, <https://www.miamiherald.com/news/nation-world/world/americas/article199948699.html>.

²¹⁹ Hinojosa and Meléndez, *The Housing Crisis in Puerto Rico*, 15.

floodplain management, and up-to-date, well-enforced building codes. Since nearly half of the dwellings in Puerto Rico were built without a government permit or according to any official building code standard, this task will be daunting.²²⁰

b. Review

In the wake of Hurricane Maria, the GAO found that mass care services, such as food, water, and shelter, left the needs of many unmet because local agreements did not always detail what services voluntary agencies could provide. In total, the GAO made six recommendations based upon findings. A majority of the recommendations involved FEMA and mass care partners better understanding the needs of local communities, capabilities of voluntary agencies, and a need for better leveraging existing local community groups that can meet the needs of survivors near to their homes.²²¹ These recommendations appear to respond well to the lived experience in Puerto Rico, where despite massive amounts of resources available, many needs went unmet in the wake of this catastrophic disaster, and the reality that community groups appeared able to fill this void when government resources could not.

4. Agriculture

Like all other community lifelines, Hurricane Maria pummeled Puerto Rico's agricultural industry. More than one-fifth of Puerto Rico's landmass is dedicated to agricultural use; 6.6% is arable land, 5.6% is for permanent crops, and 9.8% is designated as permanent pastureland.²²² Puerto Rican agriculture represents .8% of the island's GDP, and primary crops and livestock include sugar cane, coffee, pineapples, plantains, bananas, and livestock products, such as cattle dairy and chicken farms.²²³

²²⁰ Viglucci, "Half of Puerto Rico's Housing Was Built Illegally"; Nick Brown, "Special Report: In Puerto Rico, a Housing Crisis U.S. Storm Aid Won't Solve," Reuters, February 6, 2018, <https://www.reuters.com/article/us-usa-puertorico-housing-specialreport-idUSKBN1FQ211>.

²²¹ Larin, *Disaster Response*, 36–7.

²²² The current estimate is 22%. Central Intelligence Agency, "The World Factbook, Central America: Puerto Rico."

²²³ Central Intelligence Agency; Frances Robles and Luis Ferré-Sadurní, "Puerto Rico's Agriculture and Farmers Decimated by Maria," *New York Times*, September 24, 2017, <https://www.nytimes.com/2017/09/24/us/puerto-rico-hurricane-maria-agriculture.html>.

For nearly 400 years, Puerto Rico had an agriculturally based economy consisting largely of sugar cane, tobacco, and citrus fruits.²²⁴ The sector began to decline rapidly after WWII as the economy rapidly industrialized under the 1947 Operation Bootstrap led by the U.S. federal government and the Puerto Rico Industrial Development Company (PRIDCO).²²⁵ However, since the island's rather recent economic downturn, many have returned to farming and a growing "farm-to-table" movement increased 3–5% annually from 2011–2017.²²⁶

According to Carlos Flores Ortega, Puerto Rico's Secretary of Agriculture, nearly Hurricane Maria destroyed 80% of Puerto Rico's agriculture that resulted in an approximate \$780 million dollar loss.²²⁷ These losses have created a near-total reliance on imported foods and were coupled with an estimated \$45 million in losses from Hurricane Irma's impact two weeks prior to Hurricane Maria.²²⁸ Relying on importing foodstuffs creates a subsequent reliance on functioning and reliable supply chains for food security. In an island environment, its position is particularly precarious, given ample threats and hazards facing the food pipeline. Under normal conditions, approximately 85% of Puerto Rico's food is imported primarily from the mainland United States; the percentage of imported foods rose to approximately 95% following Hurricane Maria.²²⁹ Puerto Rico also imports produce from the Dominican Republic, Dominica, and St. Martin, which were also heavily impacted by hurricanes in 2017 that further complicated the island's supply chain struggles.²³⁰ For dairy farmers whose farms were not destroyed by Hurricane Maria, the consequent collapse of distribution

²²⁴ Robles and Ferré-Sadurní.

²²⁵ Teresa M. Mares, "Cultivating Comida: What Maria Exposed to Us," *Journal of Agriculture, Food Systems, and Community Development* 9, no. 1 (Summer 2019): 7–11, <https://doi.org/10.5304/jafscd.2019.091.033>. Primary industry sectors and exports now include pharmaceuticals, medical equipment, chemicals, rum, beverage concentrates, electronics apparel, and tourism. Central Intelligence Agency, "Central America: Puerto Rico."

²²⁶ Robles and Ferré-Sadurní, "Puerto Rico's Agriculture and Farmers Decimated by Maria."

²²⁷ Robles and Ferré-Sadurní; Venes, "Starving Puerto Rican Towns Sharing Food."

²²⁸ Venes; Robles and Ferré-Sadurní.

²²⁹ Mares, "Cultivating Comida"; Robles and Ferré-Sadurní.

²³⁰ Robles and Ferré-Sadurní.

networks led to an inability to market their products; some farmers reported disposing of up to 4,000 liters of fresh milk per day that could not be sent to market shelves.²³¹

a. Discussion

Secretary of Agriculture, Mr. Flores, pointed out that agriculture is one of the most disaster vulnerable sectors but is also one of the fastest rebounding.²³² According to a survey of 405 farmers, nearly 43% indicated suffering from total crop losses, and over 45% indicated significant losses.²³³ By late October 2017, 59% of those surveyed indicated they were food insecure; standard farmer food insecurity in Puerto Rico prior to Hurricane Maria was just 1%.²³⁴ According to the same survey, 49% of respondents indicated that the largest hurdle to recovery was a lack of government aid or insurance payouts.²³⁵

Secretary Flores felt that government funds that *are* dispersed provide the opportunity to modernize farming practices on the island by applying federal recovery funds to new farming equipment and techniques.²³⁶ Puerto Rico's agricultural exports currently stand at 15% of what it produces. Senator Eduardo Bhatia Gautier feels that rebuilding Puerto Rico's agricultural sector will provide an opportunity to increase that percentage to a much higher level, and bring revenue to the island while servicing the mainland's fresh food supply demands.²³⁷ This vision aligns with an ethos gaining momentum before Hurricane Maria centered upon food justice and sovereignty.²³⁸ The

²³¹ Robles and Ferré-Sadurní.

²³² Robles and Ferré-Sadurní.

²³³ Luis Alexis Rodríguez-Cruz and Meredith T. Niles, *Hurricane Maria's Impacts on Puerto Rican Farmers: Experience, Challenges, and Perceptions* (Burlington, VT: University of Vermont, 2018), 2, https://www.researchgate.net/publication/333204111_Hurricane_Maria's_Impacts_on_Puerto_Rican_Farmers_Experience_Challenges_and_Perceptions.

²³⁴ Rodríguez-Cruz and Niles, 3.

²³⁵ Teresa M. Mares, "Cultivating Comida: What Maria Exposed to Us," *Journal of Agriculture, Food Systems, and Community Development* 9, no. 1 (Summer 2019): 10, <https://doi.org/10.5304/jafscd.2019.091.033>.

²³⁶ Robles and Ferré-Sadurní, "Puerto Rico's Agriculture and Farmers Decimated by Maria."

²³⁷ Robles and Ferré-Sadurní.

²³⁸ Mares, "Cultivating Comida."

experience of Hurricane Maria is thought to have laid bare the vulnerability of Puerto Rico's food supply chain that is near entirely reliant upon mainland imports.²³⁹ For example, 66% of surveyed farmers indicated they felt the Jones Act negatively impacts Puerto Rico's food security, and 81% felt that food imports prevented Puerto Rican farmers from selling on the local economy.²⁴⁰ Since Maria, many farmers increasingly feel that private sector insurance agencies, big business, such as Monsanto, and the federal government, do not operate in the best interests of Puerto Rican farmers and are not offering needed recovery aid. This upset is leading many to turn to their local communities, particularly those of the younger generation. They are self-organizing more resilient farming models while also campaigning for greater self-determination through food sovereignty.²⁴¹

The end result of the collective trauma of Hurricane Maria's farming sector, coupled with the continued financial struggles, is likely to result in increased interest and political action toward greater food sovereignty for the island. The future of farming in Puerto Rico may be in small, tightly connected farms serving local communities, operated by those of a young generation with fresh memories of the island's precarious position and extreme reliance upon regular food imports, and the impacts when that supply chain collapses.

One such example of this turn toward self-reliance and community-led recovery is in an organization called "Tetuan Reborn" in the remote municipality of Utuado. Tetuan Reborn is a self-organized movement focused upon farm rehabilitation, agritourism, and agrotherapy. The overall mission of the movement is to build resilience to promote "sustainability, public health, and risk reduction through higher levels of community cohesiveness, social capital, and coordination."²⁴² The Tetuan Reborn movement is guided by the Corporación de Servicios de Salud Primaria y Desarrollo Socioeconómico

²³⁹ Mares.

²⁴⁰ Teresa M. Mares, "Cultivating Comida: What Maria Exposed to Us," *Journal of Agriculture, Food Systems, and Community Development* 9, no. 1 (Summer 2019): 10, <https://doi.org/10.5304/jafscd.2019.091.033>.

²⁴¹ Mares, "Cultivating Comida."

²⁴² Holladay et al., "Utuado," 6.

El Otao (COSSAO) and is viewed as a socio-economic endeavor that pairs sustainable agro-ecological farming with agro-tourism and primary health services that exist within a regional context.²⁴³ Divided across three neighborhoods, Tetuan Reborn encompasses roughly 40 farms producing coffee and other crops on land plots that are all approximately 15–20 acres in size.²⁴⁴ The project involves the procurement of abandoned farms and repurposes existing structures to fit the new vision of localized farming and agro-tourism.²⁴⁵ The project will also center on providing health and well-being to local community members via a variety of services to include providing medical services, training, and an education center, building local partnerships, and serving local communities in times of disasters by performing tasks, such as debris and route clearance, and rebuilding of local infrastructure.²⁴⁶

While it is difficult to predict precise outcomes, it is safe to conclude that the underlying perceived deprivation in many Puerto Rican communities is sufficient to drive further self-organization and encourage local co-ops to become less reliant upon traditional economic and governance norms that are predominantly outlined by large corporations, the state, and the federal government. Initiatives, such as Tetuan Reborn and Casa Pueblo, discussed in the energy lifeline, are likely to become more common and scale to meet local needs over the long-term.

b. Conclusion

Food, water, and shelter represent basic human needs. These needs were in short supply in many Puerto Rican communities for an extended period of time following Hurricane Maria. Food and water distribution were limited by a major disruption to the supply chain and rapid influx of additional disaster relief shipments, which inhibited the island’s collective ability to deliver vital commodities efficiently to those most in need. Such shortages drove communities to pool available resources, go in search of food, care

²⁴³ Holladay et al.

²⁴⁴ Holladay et al.

²⁴⁵ Holladay et al.

²⁴⁶ Holladay et al.

for each other, and manually procure water, often from sources of questionable safety. Much of the supply bottleneck appears attributed to San Juan serving as a centralized hub for imported goods. Had Puerto Rico employed a more decentralized import model or invested more in on-island stockpiles, it is logical to assume that more time may have been bought for communities before food and water stocks ran low.²⁴⁷

The impact to, and actions of, the agricultural sector indicate a need to think more holistically about what it means to be prepared for catastrophic disaster. Puerto Rico's current reliance on outside support of critical food needs has driven community-based organizations, such as Tetuan Reborn, and the Center of Mutual Support, to reconsider their position in communities and campaign for greater self-reliance.²⁴⁸ Following Hurricane Maria, hunger, thirst, and shelter needs were coupled with a need for access to definitive medical care in the wake of Hurricane Maria, which also proved to be in a frantic state and short supply.

C. HEALTH AND MEDICAL LIFELINE

FEMA defines the health and medical lifeline as “infrastructure and service providers for medical care, public health, patient movement, fatality management, behavioral health, veterinary support, and the medical industry.”²⁴⁹ The components of this lifeline include medical care, public health, patient movement, medical supply chain, and fatality management.²⁵⁰

The health and medical lifeline suffered the same consequences as other elements of critical infrastructure with the added challenge of maintaining responsibility for the care and treatment of ill residents amid a crisis. Puerto Rico's hospital network includes 67 to 75 hospitals depending upon the source of information. The Centers for Disease Control (CDC) recognizes 67 hospitals, FEMA's AAR, and other analyses, reference 69 hospitals; FEMA's geographic information system (GIS) planning tool indicates 75

²⁴⁷ Fischbach et al., “After Hurricane Maria,” 64–5.

²⁴⁸ Allen, “I Don't Feel Safe”; Holladay et al., “Utuado,” 9.

²⁴⁹ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6.

²⁵⁰ Federal Emergency Management Agency, 6.

hospitals across the island.²⁵¹ Regardless, each hospital dealt with unprecedented disaster impacts, many navigated similar challenges, and several implemented creative solutions to complex problems. It is important to note that hospitals are not nearly the totality of the health and medical system that support communities. Other actors, such as pharmacies, labs, health clinics, behavioral health offices, substance abuse clinics, and a wide range of other institutions, afford community health services.

A variety of actors collaborated in the wake of Hurricane Maria to provide life-saving medical care to many in dire need amid widespread destruction to communities and their critical infrastructure. While a vast number of entities were involved in the provision of care from those operating at point-of-care to those supporting the supply chain, the primary providers discussed as follows include FEMA, the CDC, HHS, federal DOD and National Guard troops, EMAC resources from around the nation, the Medical Reserve Corps, NGOs, community hospitals, and others, such as a faith-based entity that stepped up to serve its community in a time of need.

1. Medical Care

Due to the severity of Hurricane Maria, one week after post-impact, FEMA remained unable to establish communications, and therefore, determine damage and resource status of 37 of the 69 hospitals it was tracking in the network at the time.²⁵² All hospitals experienced a loss of primary power sources, and subsequently, access to clean water. The Mayor of Guayama, Eduardo Cintron, reported that one hospital he was personally aware of remained without power for 53 consecutive days that resulted in unbearable clinical conditions.²⁵³ While federal regulations require hospitals to maintain

²⁵¹ Robert Kadlec, “Testimony from Robert Kadlec, M.D. on Hurricane Response before Committee on Energy and Commerce,” HHS, October 24, 2017, <https://www.hhs.gov/about/agencies/asl/testimony/2017-11/hurricane-response.html>; Federal Emergency Management Agency, *FEMA After-Action Report*, 33; “Resilience and Analysis Planning Tool (RAPT),” Federal Emergency Management Agency, last updated November 3, 2020, <https://www.fema.gov/rapt>; Philip Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season: A Collection of Case Studies About Hurricanes Harvey, Irma, and Maria and Their Impact on Supply Chain Resilience* (Alexandria, VA: CNA Analysis & Solutions, 2018), 16, https://www.cna.org/cna_files/pdf/IRM-2018-U-018098-Final.pdf.

²⁵² Federal Emergency Management Agency, *2017 Hurricane Season*, 33.

²⁵³ Deibert, *When the Sky Fell*, 132.

adequate backup power generation capability, only seven Puerto Rican hospitals had functioning backup generation allowing them to operate fully after Hurricane Maria.²⁵⁴ FEMA noted that many hospitals either lacked backup generators, or the generators were simply inoperable, which left a majority of hospitals in the dark.²⁵⁵

Shortly after landfall, the CDC activated the Strategic National Stockpile (SNS) to begin shuttling critical supplies to Puerto Rico. Initial shipments included six federal medical stations (FMS) spread throughout the island, refrigerators, meals ready to eat (MRE), water, and vaccines.²⁵⁶ FMS are to have a three-day supply of medical equipment and pharmaceuticals capable of sustaining up to 250 “stable primary, or chronic-care patients.”²⁵⁷ In total, the SNS shipped 347 tons of cargo to Puerto Rico, including the FMS units that contained 1,500 beds, 177,000 bottles of water, and 42,000 MREs.²⁵⁸ The SNS also aided in coordinating the purchase and shipment of over \$540,000 in medical supplies and \$2.4 million in needed vaccinations.²⁵⁹ In addition to deploying large quantities of medical equipment and supplies, the HHS deployed a number of Disaster Medical Assistance Teams (DMATs), each comprised of approximately 35 medical professionals.²⁶⁰ DMATs are staffed by medical volunteers from medical organizations around the nation and stand ready to deploy to disasters upon

²⁵⁴ Palin, *Out of the Whirlwind*, loc. 880.

²⁵⁵ Federal Emergency Management Agency, *2017 Hurricane Season*, 36.

²⁵⁶ Centers for Disease Control and Prevention, *Public Health Preparedness and Response: 2018 National Snapshot* (Washington, DC: U.S. Department of Health and Human Services, 2018), 43, <https://www.cdc.gov/cpr/pubs-links/2018/index.htm>.

²⁵⁷ U.S. Department of Health and Human Services, “Medical Assistance,” Public Health Emergency, June 2019, <https://www.phe.gov/Preparedness/support/medicalassistance/Pages/default.aspx>.

²⁵⁸ Centers for Disease Control and Prevention, *Public Health Preparedness and Response*, 45.

²⁵⁹ Centers for Disease Control and Prevention, 45.

²⁶⁰ DMAT expertise includes, “advanced clinicians (nurse practitioners/physician assistants), medical officers, registered nurses, respiratory therapists, paramedics, pharmacists, safety specialists, logistical specialists, information technologists, and communication and administrative specialists.” Mary Denigan-Macauley, *Disaster Response: HHS Should Address Deficiencies Highlighted by Recent Hurricanes in the U.S. Virgin Islands and Puerto Rico*, GAO-19-592 (Washington, DC: Government Accountability Office, 2019), 16, <https://www.gao.gov/products/GAO-19-592>.

request.²⁶¹ Due to severe transportation, communication, and energy impacts throughout the island, the HHS opted to divide the full 35-person DMAT teams into smaller, and more agile, six-person “health medical taskforce teams,” which allows them to disperse across the island to hard-hit areas and provide “acute medical care, stabilize patients, and call for the transport of patients, when needed.”²⁶² In total, the Office of the Assistant Secretary for Preparedness and Response (ASPR), within the HHS, indicated that over 16,000 Puerto Rican residents were provided medical treatment in the month following Hurricane Maria.²⁶³ The ASPR also placed “field medical stations” adjacent to numerous hospitals to provide emergency room decompression.²⁶⁴

The DOD provided a substantial amount of resources in support of Puerto Rico, including a combat support hospital, an expeditionary medical support system, a patient movement detachment, mortuary affairs personnel and equipment, medical support to triage, treat, stabilize, hold, and transport patients, the National Disaster Medical System (NDMS) for aeromedical evacuations, rotary-wing aircraft for patient medevac, and supported DMATs with area support medical companies.²⁶⁵ The DOD also provided a great deal of maritime support. On September 21, the USS *Kearsarge*, USS *Oak Hill*, and USS *Wasp* (CV 18) deployed to the area and provided support to Puerto Rico and the U.S. Virgin Islands under the U.S. Fleet Forces Command, the 24th and 26th Marine Expeditionary Unit (MEU), and a Naval Expeditionary Combat Command Maritime Command Element.²⁶⁶ The USS *Kearsarge* and others provided a wide range of capability from housing USACE personnel, amphibious landing capability, and rotary-wing aviation assets.²⁶⁷ On September 27, the USNS *Comfort* (T-AH 20) deployed as

²⁶¹ Office of the Assistant Secretary for Preparedness and Response, “Disaster Medical Assistance Teams,” Public Health Emergency, September 2017, <https://www.phe.gov/Preparedness/responders/ndms/ndms-teams/Pages/dmat.aspx>.

²⁶² Denigan-Macauley, *Disaster Response*, 16.

²⁶³ Denigan-Macauley, 16.

²⁶⁴ Denigan-Macauley, 17.

²⁶⁵ Larson et al., *U.S. Army North in the Hurricane Maria Response*, 53–4; Denigan-Macauley, *Disaster Response*, 30.

²⁶⁶ Larson et al., 43.

²⁶⁷ Larson et al., 42, 45.

well and would stay on-station until November 17.²⁶⁸ The *Comfort* is a medical vessel capable of providing a wide range of medical care for up to 1,000 patients, houses 12 operating rooms, 80 intensive care wards, a pharmacy, a computerized tomography (CT) scan unit, dental clinic, and x-ray machines.²⁶⁹ While the USNS *Comfort* packs immense capability, the vessel is widely regarded as being underutilized due to coordination issues, including a tedious patient referral process and transfer to the vessel.²⁷⁰ Ultimately, over a 53-day deployment, the USNS *Comfort* admitted 290 patients (six per day), and treated an additional 1,625 as outpatients.²⁷¹ The National Guard of Puerto Rico and other states was also a key asset in medical provision. The Puerto Rico National Guard assigned 47 personnel to assist the Puerto Rican government in supporting vulnerable communities, and ultimately, provided various forms of care to 7,242 patients in 15 communities throughout 11 municipalities.²⁷² Overall, DOD support was pivotal in the ability to continue patient care due to the military's ability to move equipment and operate in austere environments, although proving unable to treat all those in need.

While the DOD did much of the heavy lifting, the Medical Reserve Corps (MRC) served as a valuable national resource comprised of medical professionals from around the nation rostered to serve in disaster situations and was able to provide medical support. The ASPR indicates that approximately 175,000 volunteers are in 850 community-based units around the nation.²⁷³ The MRC, under HHS, provided 14 MRC units consisting of

²⁶⁸ Larson et al., 43.

²⁶⁹ Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the U. S. Fleet*, 18th ed. (Annapolis, MD: Naval Institute Press, 2005), 264–66.

²⁷⁰ Leyla Santiago and Mallory Simon, “Hospital Ship Empty as Ill Puerto Ricans Suffer,” CNN, October 17, 2017, <https://www.cnn.com/2017/10/16/health/puerto-rico-hospital-ship/index.html>; Frances Robles and Sheri Fink, “Amid Puerto Rico Disaster, Hospital Ship Admitted Just 6 Patients a Day,” *New York Times*, December 6, 2017, <https://www.nytimes.com/2017/12/06/us/puerto-rico-hurricane-maria-hospital-ship.html>.

²⁷¹ Robles and Fink.

²⁷² Thirty-five states committed National Guard resources to Puerto Rico, and some performed medical mission assignments. Puerto Rico National Guard, *After Action Report Operation Hurricane Maria* (San Juan, PR: State Guard Command, 2018), 12, https://media.noticel.com/o2com-noti-media-us-east-1/document_dev/2020/01/20/FINAL%202018%20PRSG-HM-AAR%2012MAY18_1579577844647_39800005_ver1.0.pdf.

²⁷³ Office of the Assistant Secretary for Preparedness and Response, “Medical Reserve Corps,” Public Health Emergency, March 2020, <https://www.phe.gov/about/oem/prep/Pages/mrc.aspx>.

212 medical volunteers who served a cumulative total of 2,524 hours in Puerto Rico in a variety of functions, such as behavioral health, medical, supportive care at shelters and clinics, dialysis support, support services to call centers and reception and evacuation centers, patient movement support, commodity distribution support operations, community education and outreach, evacuee support at disaster assistance services centers, and recovery support, such as disaster case management, first responder vaccinations, and donations management.²⁷⁴ In addition to MRC volunteers, many of Puerto Rico's twenty health centers experienced staffing shortages that they sought to fill with volunteer medical professionals.²⁷⁵

NGOs also provided supplemental medical support to Puerto Rico in the early response phase. These organizations were often able to fill gaps in formal, governmental response operations and reach remote portions of the island home to underserved populations. One such organization, AmeriCares, based out of Stamford, Connecticut, has offered over \$40 million in aid since Hurricane Maria, aided in rebuilding 11 health centers, delivered over 290,000 prescriptions, and has trained over 8,400 health workers.²⁷⁶ While NGOs would be challenged to replace the robust capability of military and government assets, they do play a vital and complementary role in disasters that should be recognized and accounted for in governmental disaster responses and recovery planning.

In addition to large metropolitan healthcare networks, Puerto Rico's community hospitals and health centers played a vital role amid Hurricane Maria due to their proximity to the communities they served. At a time when communications and transportation were severely degraded, island residents relied upon close proximity treatment, particularly in rural areas. In 2016, 20 federally funded community health centers were providing service to 86 urban and rural communities administrating full

²⁷⁴ Office of the Assistant Secretary for Preparedness and Response, *2017 Hurricane Season: Medical Reserve Corps Activity Overview* (Washington, DC: Health and Human Services, 2017), 1–2, 7–8, https://mrc.hhs.gov/file/2017%20Hurricane%20Season_MRC%20Overview%20Report.pdf.

²⁷⁵ Shin et al., *Puerto Rico's Community Health Centers*, 10.

²⁷⁶ AmeriCares, *Hurricane Maria Two-Year Report* (Stamford, CT: AmeriCares, 2019), 1, <https://www.americares.org/wp-content/uploads/american-hurricane-maria-2-year-report.pdf>.

primary health care for more than 10% of the population.²⁷⁷ By mid-October, only 13% of 70 medical sites assessed by the Milken Institute School of Public Health had power restored, although 83 out of 93 community health centers reported by Health Resources and Services Administration (HRSA) were open on generator power, or at least, in some limited capacity.²⁷⁸

One such facility was the Southwestern Regional Academic Medical Center (SW-RAMC) comprised of the Ponce Health Science University and affiliates. SW-RAMC spent a great deal of time and energy preparing for hurricanes, and therefore, was able to continue operations throughout Hurricane Maria with a particular focus on intensive care units and emergency room patients.²⁷⁹ As many hospitals lost power and water, SW-RAMC was operating on generator power based upon systems emplaced during steady-state conditions. The network was also able to communicate effectively by word of mouth with their residents according to a plan, several were in possession of functioning satellite phones, and hospital management arranged to purchase fuel for physician residents, allowed close family members of staff to stay at the hospital, paid staff cash stipends in advance, and offered rides to and from the workplace to staff support.²⁸⁰ The SW-RAMC stated that one of the largest lessons learned was that “after a major disaster, there may be a need to operate the ‘old way’—without technology, at least temporarily,” and that while disasters cannot be avoided, having a plan can help mitigate their impacts.²⁸¹ Other lessons learned focused heavily on ensuring the ability to communicate internally and externally, having cash on-hand, and maintaining at least two weeks of

²⁷⁷ Peter Shin et al., *Puerto Rico’s Community Health Centers: Struggling to Recover in the Wake of Hurricane Maria* (Washington, DC: Milken Institute School of Public Health, 2017), 3, <https://publichealth.gwu.edu/sites/default/files/downloads/GGRCHN/GG%3ARCHN%20Policy%20Issue%20Brief%20%2350%20FV.pdf>.

²⁷⁸ Shin et al., 10.

²⁷⁹ Olga Rodríguez de Arzola, “Emergency Preparedness and Hurricane Maria: The Experience of a Regional Academic Medical Center in Southwest Puerto Rico,” *Journal of Graduate Medical Education* 10, no. 4 (August 2018): 477–80, <https://doi.org/10.4300/JGME-D-18-00547.1>.

²⁸⁰ de Arzola, 478–9.

²⁸¹ de Arzola, 480.

supplies of food and water for patients and staff to bridge supply chain collapses.²⁸² SW-RAMC illustrates that grassroots preparedness can lead to resilience and does not require government permission or mandates to be effective. Through forethought and prioritizing preparedness, SW-RAMC was able to continue as a vital community resource in an extraordinary time of need. Void of community hospital networks, such as SW-RAMC, many residents would have gone untreated for a wide variety of injuries and ailments, and others would have added strain to metropolitan medical facilities, networks, and mutual-aid resources.

Lastly, but certainly not least, other community actors bridged gaps in standard medical provision through proactive and innovative means. Despite the exceptional actions of SW-RAMC, and many other actors performing similar roles, many citizens went without life-sustaining treatment and vital medications. This void in medical provision prompted community resources to fill the gap. For example, a Methodist Church in the municipality of Barranquitas, set up a makeshift medical clinic staffed by church employees, volunteers, and medical doctors. Eileen Rivera Diaz, the pastor's spouse, explained that people with chronic conditions, such a kidney disease, diabetes, and heart disease, were especially impacted, and noted little to no federal presence in the area despite critical shortages of life-sustaining supplies, such as prescription medication, food, water, and power.²⁸³

a. Discussion

Catastrophic disasters require significant outside resources to manage medical consequences inflicted on communities void of long-term, highly effective, systemic preparedness. Much of the aid to Puerto Rico that filled early critical gaps was sourced from the DOD, which is particularly concerning due to the possibility that other national security concerns in the future may render the same DOD assets unavailable to provide the same level of support in a natural disaster. Other sources of mutual-aid might also prove unavailable in other circumstances, such as during a national disaster much like

²⁸² de Arzola, 478.

²⁸³ Deibert, *When the Sky Fell*, 9.

that of the SARS CoV-2 pandemic that could render state mutual-aid resource (such as the HHS' DMAT teams being unavailable). Such events may challenge the priorities of sending agencies that have a duty to provide for their own communities first. Heavy reliance on outside support continues to be a Puerto Rican vulnerability.

Functioning medical infrastructure is also highly dependent upon other critical infrastructure sectors, such as power, open roadways, water, and communications. However, the localized and proactive efforts of the SW-RAMC network show what can be accomplished when local leaders value and prioritize disaster preparedness and business continuity practices. Healthcare providers that make the ability to provide temporary power, material stockpiling, water storage, and maintaining survivable communications a priority are far more resilient to disaster impacts. The case of Hurricane Maria also shows that informal actors, such as churches establishing makeshift medical clinics, and dedicated community groups, can act on their own accord and serve as a community asset.

Hurricane Maria also illustrated that patient proximity to point-of-care is a vital factor in successful medical intervention. In the early days following disasters, traveling or communicating long distances is often not feasible. Regardless of record-setting deployment of resources, many residents of Puerto Rico went untreated, or received delayed and inadequate levels of care, which highlights the need for well-prepared and decentralized community healthcare networks that exist in close proximity to residents to afford ease of access. This model also offers healthcare networks opportunities for more personalized care. The distance between communities and point-of-care can be reduced by strong support of community hospitals and clinics, faith-based first-aid capability, and community para-medicine. The SW-RAMC, and the HHS, both highlighted the need for

their respective organizations to re-organize to offer expeditionary medical treatment to impacted communities.²⁸⁴

Lastly, underinvesting in medical infrastructure results in low resiliency and has long-lasting impacts. As shown in Figure 2, Puerto Rico's island of Vieques still lacks a permanent medical facility, as the permanent facility was destroyed in the storm that forced patients with serious ailments to fly to the main island for medical treatment.²⁸⁵ Such disaster vulnerabilities have a layering effect in subsequent disasters. Damages and reductions in community functionality left unresolved from prior disasters are sure to further complicate the next response and recovery operation, and pose risks to human lives.



Figure 2. The Primary Hospital on the Island of Vieques, Shuttered and in Disrepair as of April 2019.²⁸⁶

²⁸⁴ For information on para-medicine: Joseph Cahill, "Community Paramedicine—Bringing the Hospital Home," *Domestic Preparedness Journal*, December 10, 2014, <https://www.domesticpreparedness.com/healthcare/community-paramedicine-bringing-the-hospital-home/>; On the topic of para-medicine: "residents from all programs, their faculty, and medical students of the Ponce Health Sciences University School of Medicine organized to bring food, water, medications, and other supplies and offered health care to people in shelters, remote areas, and damaged homes." de Arzola, "Emergency Preparedness and Hurricane Maria," de Arzola, 479. DMAT's fielded six-person teams to penetrate into hard-to-reach areas of the island. Denigan-Macauley, *Disaster Response*, 16.

²⁸⁵ In February 2020, a 13-year old girl died in air transit to the mainland for a serious medical condition. She could not be treated on her home island of Vieques. Catherine Kim, "A 13-Year-Old's Death Highlights Puerto Rico's Post-Maria Health Care Crisis," *Vox*, February 27, 2020, <https://www.vox.com/identities/2020/2/27/21150176/puerto-rico-health-care-hospital-access-hurricane-maria>.

²⁸⁶ Source: Patricia Mazzei, "Hunger and an 'Abandoned' Hospital: Puerto Rico Waits as Washington Bickers," *New York Times*, sec. U.S., April 7, 2019, <https://www.nytimes.com/2019/04/07/us/puerto-rico-trump-vieques.html>. A hospital on the Puerto Rican Island of Vieques remained closed due to damage and disrepair 18 months after Hurricane Maria. The facility remains unrepaired or replaced other than via a temporary medical clinic not equipped for full-scale treatment.

2. Public Health

Puerto Rico’s healthcare infrastructure was compromised long before Hurricane Maria’s arrival in September 2017. The island had a state-run medical infrastructure consisting of four 280-bed medical facilities, and a smaller hospital in Ponce that served as the foundation of the medical system, and each of the 78 municipalities had a community hospital, clinic, or other medical care facility.²⁸⁷ Through the proceeding decades, the privatization of health plans, and the growth of private sector insurance policies have led to a more fragmented healthcare system, officiated by “La Reforma” in 1993, whereby many state-run hospitals and clinics were sold to private corporations that caused many to seek Medicare and Medicaid treatment options.²⁸⁸ While Puerto Ricans have some of the highest insurance coverage rates in the nation, largely due to public health programs, residents are also among the most vulnerable populations: 43.1% of Puerto Ricans live in poverty, 21.3% are over the age of 65, the average household income is just \$20,166, 15.1% under the age of 65 have a disability, and 7.9% live without health insurance coverage.²⁸⁹ Comparatively, the U.S. national average poverty rate is 11.8%, 16.5% are over the age of 65, median household income is \$60,293, 8.6% live with a disability, and 10% of the population lives without health insurance coverage.²⁹⁰ In Yabucoa, where Hurricane Maria made landfall, poverty rates were estimated to be even higher than the island average, approximately 65%.²⁹¹

Puerto Ricans are also among the most medically vulnerable U.S. population as well with 34% of adults reported to be suffering from poor or fair medical conditions

²⁸⁷ This study was funded by funded by U.S. Department of Health and Human Services, Office of the Assistant Secretary for Planning and Evaluation. Krista Perreira et al., *Puerto Rico Health Care Infrastructure Assessment* (Washington, DC: Urban Institute, 2017), 4.

²⁸⁸ Perreira et al., *Puerto Rico Health Care Infrastructure*, 4; Caroline Behling-Hess, “Healthcare in Puerto Rico: Before and after Hurricane Maria,” Public Health in Latin America, accessed July 19, 2020, <https://sites.google.com/macalester.edu/phla/key-concepts/healthcare-in-puerto-rico-before-and-after-hurricane-maria>.

²⁸⁹ U.S. Census Bureau, “QuickFacts: Puerto Rico,” U.S. Census Bureau QuickFacts, accessed July 19, 2020, <https://www.census.gov/quickfacts/PR>.

²⁹⁰ U.S. Census Bureau, “QuickFacts: United States,” U.S. Census Bureau QuickFacts, accessed July 19, 2020, <https://www.census.gov/quickfacts/fact/table/US/PST045219>.

²⁹¹ Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season*, 49.

compared to 18% across the United States. In addition, 15% live with diabetes compared to 11% in the mainland, and 11% reported a heart attack or living with heart disease as opposed to 7% of the national average.²⁹² Puerto Rico’s public health system underwent reform in 2010 under the “Mi Salud” (my health) program with funding from the American Recovery and Reinvestment Act (ARRA) of 2009.²⁹³ The program exists primarily to serve medically disadvantaged populations and is funded by a combination of federal, commonwealth, and municipal governments.²⁹⁴ Notwithstanding, Puerto Ricans remain medically vulnerable, which leads to an acute susceptibility to disaster impacts. A September 2019 GAO report found that the HHS “lacked plans for the territories that accounted for the chronic and primary care needs in isolated communities,” and drew particular attention to the lack of mobility in elderly populations.²⁹⁵ Island residents also suffer from mental health issues at comparatively high rates. In response, the HHS supported mental health hotlines in concert with HHS’s Substance Abuse and Mental Health Services Administration to assist those struggling mentally and connect them with local behavioral health resources.²⁹⁶ However, following Hurricane Maria, Rosa Miranda Agosto of Movimiento Evitemos el Suicidio (Let’s Avoid Suicide Movement), noted a 21% uptick in suicides on the island following Hurricane Maria.²⁹⁷

Upset to Puerto Rico’s critical infrastructure led Puerto Ricans also to experience upticks in waterborne and respiratory diseases as is common in post-disaster contexts. Waterborne disease, such as leptospirosis, is addressed under the water and HAZMAT lifelines.²⁹⁸ The island also noted increases in respiratory issues due to widespread

²⁹² “Puerto Rico: Fast Facts,” Kaiser Family Foundation, October 2, 2017, <https://www.kff.org/disparities-policy/fact-sheet/puerto-rico-fast-facts/>.

²⁹³ Perreira et al., *Puerto Rico Health Care Infrastructure*, 7.

²⁹⁴ Perreira et al., 7.

²⁹⁵ Denigan-Macauley, *Disaster Response*.

²⁹⁶ Denigan-Macauley, 16.

²⁹⁷ Deibert, *When the Sky Fell*, 132.

²⁹⁸ Daniella Silva, “Puerto Ricans at Risk of Waterborne Disease Outbreaks in Wake of Hurricane Maria,” NBC News, October 26, 2017, <https://www.nbcnews.com/storyline/puerto-rico-crisis/puerto-ricans-risk-waterborne-disease-outbreaks-wake-hurricane-maria-n814461>.

generator use and resulting smog conditions.²⁹⁹ These issues serve as a reminder that not only must practitioners consider the underlying public health contexts of disaster areas, but also understand that common disaster impacts will remain present and overlay upon impacted communities.

a. Discussion

The state of Puerto Rican public health necessitates that preparedness concerning healthcare provision be completely integrated at the local, commonwealth, and federal government levels. Other nations, such as Cuba, have done well to generate comprehensive lists for their medically vulnerable populations, and despite obvious differences in political structures, Puerto Rico may seek to do the same given the marked underlying medical fragility throughout the islands' population.³⁰⁰

b. Review

Puerto Rico also requires community-led long-term health initiatives to increase the overall health of residents via nutrition, lifestyle, and exercise habits to reduce long-term vulnerability. Implementation will require a great deal of political and public will, but serves as the best long-term strategy for decreasing health risks associated with disaster impacts. Many communities have already taken this initiative into their own hands. Small communities and networks around the island have taken up the cause of building community-operated medical clinics centered upon holistic care and community access; many have chosen to convert existing structures, such as old schools and agricultural buildings, to serve community health needs.³⁰¹

Lastly, the GAO found that the HHS did not well understand partner agency capability, which led to rather severe coordination issues amid Hurricane Maria. This

²⁹⁹ Oxfam America, *Far from Recovery*, 5.

³⁰⁰ Emily J. Kirk, "Alternatives—Dealing with the Perfect Storm: Cuban Disaster Management," *Studies in Political Economy* 98, no. 1 (2017): 93–103, <https://doi.org/10.1080/07078552.2017.1297047>.

³⁰¹ Lauren Fisher, Megan Reineccius, and Shannon Evans Engstrom, "Solar Opportunities in Jayuya," *Community Resiliency* (blog), January 11, 2020, <https://www.umnconvergencepuertorico.org/community-resiliency-blog-2020-1/2020/1/11/solar-opportunities-in-jayuya>; Allen, "To Build Resilience"; Holladay et al., "Utuado," 11; Allen, "'I Don't Feel Safe'."

misunderstanding highlights a need for federal agencies to work much more closely together by integrating their preparedness actions. Federal agencies also presented a need to connect better with state resources. In turn, formal state resources are best positioned to establish network connections with local municipalities, community clinics, and informal actors that serve a public health function amid disasters. By better coordinating before disasters strike, Puerto Rico increases its chances for more a coordinated response with less loss of life in future disasters.

3. Patient Movement

A majority of patient movement and evacuations occurred within the NDMS activated by the ASPR and presented a complex challenge to responders from supporting agencies due to the close proximity of Hurricanes Irma and Maria.³⁰² Following Hurricane Irma's strike on the U.S. Virgin Islands, many medically fragile and dialysis patients were transferred to Puerto Rico between September 8 and 16, but these transfers were halted on September 17 due to the approach of Hurricane Maria toward the U.S. Virgin Islands and Puerto Rico.³⁰³ On September 19, the day before Hurricane Maria's impact, some patients were evacuated from both the U.S. Virgin Islands and Puerto Rico to the U.S. mainland; by September 22, just two days after Hurricane Maria made landfall the NDMS continued evacuations to the mainland and would continue to do so until July 1, 2018.³⁰⁴ Evacuated patients required specialty care not practicable to deliver under disaster conditions, such as cancer treatment, dialysis, and other acute care.

The HHS was heavily reliant on the support of other agencies, specifically the DOD, for patient evacuation because the agency lacked its own organic medical airlift

³⁰² The NDMS is comprised of 5,000 intermittent federal employees across 72 teams. "NDMS is capable of providing medical, veterinary, and mortuary response; patient movement support; definitive care; and behavioral health support." Department of Health and Human Services, *Public Health and Social Services Emergency Fund: Justification of Estimates for Appropriations Committee* (Washington, DC: Department of Health and Human Services, 2019), 40, <https://www.hhs.gov/sites/default/files/fy-2019-phssecf-cj.pdf>.

³⁰³ Denigan-Macauley, *Disaster Response*, 12–4.

³⁰⁴ Denigan-Macauley, 13–4.

capability.³⁰⁵ To facilitate the movement of patients, both the DOD and the Department of Veteran Affairs established a mainland and Puerto Rico federal coordinating center that registered patients with receiving NDMS facilities at their final destination.³⁰⁶ Due to delays in deployments of its Joint Patient Assessment and Tracking System (JPATS) personnel, the HHS experienced delays in its ability to track evacuated patients in the NDMS, which led to the HHS not having situational awareness of the location and condition of evacuated patients.³⁰⁷ The HHS indicated to the GAO that patient tracking was not a standard practice at the time, and that the U.S. Virgin Islands and Puerto Rico had not requested pre-deployment of JPATS. Of the approximately 800 persons collectively evacuated from both the U.S. Virgin Islands and Puerto Rico, the HHS could not provide the GAO with the final dispositions of 25% of the patients.³⁰⁸ Since Hurricanes Irma and Maria, the HHS has drafted lessons learned to include re-evaluating how patient tracking is initiated, training clinicians on operating in military aircraft, and building organic airlift capability.³⁰⁹

a. Discussion

Preparedness gaps were evident in regard to patient movement in addition to other areas of the health and medical lifeline. Patient evacuation is a task requiring exceptionally high levels of coordination between multiple entities from sending entities, transportation units, coordination elements, and receiving facilities. The level of coordination required to be successful in moving large numbers of patients rapidly in a disaster environment is difficult without thorough preparedness measures, and is made more difficult in communications-degraded environments, such as Puerto Rico following Hurricane Maria.

³⁰⁵ Denigan-Macauley, 14–5.

³⁰⁶ Denigan-Macauley, 15.

³⁰⁷ Denigan-Macauley, 23.

³⁰⁸ Denigan-Macauley, 25.

³⁰⁹ Denigan-Macauley, 29–31; Ron Miller, “National Disaster Medical System: Bringing More Than Teams of Professional Medical Providers,” *Domestic Preparedness Journal*, February 25, 2019, <https://www.domesticpreparedness.com/updates/national-disaster-medical-system-bringing-more-than-teams-of-professional-medical-providers/>.

b. Review

The GAO noted that the HHS appeared not to have a firm understanding of assisting agency capabilities and limitations, which made coordinating this mission challenging. Thus, a more integrated and cohesive inter-agency approach to preparedness is needed with all entities required to make patient evacuations successful. Moreover, much like the provisions for medical care, it may be prudent to decentralize patient evacuations as well. Washington State has capitalized on private pilots to conduct exercises in preparation for a major Cascadia Fault Zone earthquake in the Pacific Northwest. This example might be a model that could expand both patient inter and intra-island evacuations in future disasters.³¹⁰ A decentralized model affords resiliency and is of particular importance should standard evacuation providers not have the same bandwidth availability amid the next major catastrophe (i.e., the DOD).

To facilitate communications, the same HAM radio operations who aided in the ARC's *Safe and Well Program* may have also been able to operate as a patient tracking stopgap for the eventual deployment of the JPATS had it been planned in advance. These radio operators are trained and proficient in facilitating safe and welfare checks of those impacted by disasters and could be of great assistance in future disasters.

Finally, all the stopgap measures discussed under the medical care section are what remains when patient evacuation is not feasible, as may be the case in future catastrophes, and are a worthwhile investment as a fail-safe mechanism should patient evacuations be delayed or become infeasible for any number of reasons when disaster strikes.

4. Medical Supply Chain

Impacts to Puerto Rico's power supply, physical transportation infrastructure, communications, and general disruption to the routine flow of goods created significant disruptions in the island's medical supply chain that proved difficult to overcome. The

³¹⁰ Sandi Doughton, "Are You Ready for the Big One? Look at What These Folks Have Done—on Their Own—to Prepare," *Seattle Times*, October 17, 2017, <https://www.seattletimes.com/seattle-news/science/are-you-ready-for-the-big-one-look-at-what-these-folks-have-done-on-their-own-to-prepare/>.

impacts were also bi-directional, and impacted goods flowing out of Puerto Rico, and those flowing into San Juan. Puerto Rico produces \$40 billion a year in pharmaceutical and medical supplies that are shipped to the U.S. mainland, to JAXPORT in Jacksonville, Florida.³¹¹ The island manufactures 30 pharmaceutical medications without therapeutic alternatives, and 14 of them are *only* produced in Puerto Rico.³¹² These medications represent 10% of all pharmaceuticals and 43% of all saline consumed in the United States, and the market comprises 30% of Puerto Rico's annual gross domestic product (GDP).³¹³ The island is also recognized as a national hub for intravenous fluid bag manufacturing accounting for 43% of the national supply, which resulted in national shortages following Hurricane Maria.³¹⁴

Meanwhile, on Puerto Rico, Oscar Ruiz of the Sociedad Puertorriqueña de Endocrinología y Diabetología traveled the island in the early aftermath of the storm and established makeshift medical clinics and noted severe shortages of critical medical supplies in communities in need and home to many with chronic health conditions reliant upon regular use of prescription medications.³¹⁵ In another instance, Eunice Vargas trudged through sludge and flooded streets seeking oxygen tanks for her 76-year-old mother when standard deliveries stopped arriving, but was unable to locate additional supplies; she next went to the oxygen manufacturer and found the location to be

³¹¹ Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season*, 127.

³¹² Palin et al., 127.

³¹³ Public-Private Analytic Exchange Program, *Threats to Pharmaceutical Supply Chains* (Washington, DC: Department of Homeland Security, 2018), 4, 6, <https://www.hsdl.org/?abstract&did=817144>; "Statement from FDA Commissioner Scott Gottlieb, M.D. on FDA's Continued Assistance Following the Natural Disaster in Puerto Rico," U.S. Food & Drug Administration, October 6, 2017, <https://www.fda.gov/news-events/press-announcements/statement-fda-commissioner-scott-gottlieb-md-fdas-continued-assistance-following-natural-disaster>.

³¹⁴ Baxter is the largest producer with two plants on Puerto Rico that supplies the United States with over 40% of its supply of intravenous (IV) bags. Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season*, 127; Public-Private Analytic Exchange Program, *Threats to Pharmaceutical Supply Chains*; U.S. Food & Drug Administration, "Statement from FDA Commissioner Scott Gottlieb"; "Hospitals Struggle to Battle Peak Flu Season Amid Widespread IV Bag Shortage," CBS News, January 9, 2018, <https://www.cbsnews.com/news/flu-season-straining-resources-iv-bag-shortage-hurricane-maria-puerto-rico/>.

³¹⁵ Deibert, *When the Sky Fell*, 9.

closed.³¹⁶ Oxygen shortages were prevalent across the island because both oxygen manufacturers on the island were destroyed by the hurricane that thus resulted in Puerto Rico's reliance on imported medical grade oxygen.³¹⁷ Even in clinical settings, hospitals were critically low on oxygen, which forced them to curtail services and ration remaining supplies.³¹⁸

Widespread medical supply shortages prompted the ASPR to establish a "hub and spoke" distribution model in Puerto Rico whereby large metropolitan hospitals served as supply and treatment "hubs" and small rural or community hospitals operated as the "spokes" that relayed their status and resource needs to their assigned "hub."³¹⁹ For example, the ASPR identified San Juan's Centro Medico as a hub managing six spokes and afforded each location, including the hub, with an FMS in front of each hospital.³²⁰ The ASPR used this model for the first time in an attempt to disperse supplies and treatment across a wider range of medical facilities and performed this strategy with the aid of the Department of Veteran Affairs and the DOD.³²¹

a. Discussion

Supply disruptions are largely unavoidable, which compels medical providers to build disruptions into emergency plans in the form of alternative sourcing and sensible stockpiling of supplies. Systemic supply chain resilience requires long-term sustained investments to highways, bridges, ports, airports, communications infrastructure, the power grid, and backup power generation, etc., which may not be in Puerto Rico's and many other community's immediate future. Prudent network-level preparedness

³¹⁶ Daniela Hernandez, "In Puerto Rico, Health Concerns Grow Amid Lack of Clean Water, Medical Care," *Wall Street Journal*, October 4, 2017, <https://www.wsj.com/articles/in-puerto-rico-health-concerns-grow-amid-lack-of-clean-water-medical-care-1507137646>.

³¹⁷ de Arzola, "Emergency Preparedness and Hurricane Maria."

³¹⁸ Natalie Cioffari, "Senators Call on FEMA to Prioritize Medical Oxygen for Puerto Rico," WHSU Public Radio, October 11, 2017, <https://www.wshu.org/post/senators-call-fema-prioritize-medical-oxygen-puerto-rico>.

³¹⁹ Denigan-Macauley, *Disaster Response*, 18.

³²⁰ Denigan-Macauley, 18.

³²¹ Kadlec, "Hurricane Response."

measures thus become the more attainable goal over the short-term, and represent an area over which medical providers can exert control.

b. Review

Hurricane Maria also offered a lesson to small community hospitals and clinics that these entities can expect to be at the end of a long supply line as metropolitan medical facilities are prioritized for resupply. This consideration is critical for smaller providers that serve closer to impacted, and potentially vulnerable, communities. While these same smaller-scale networks may not have the same resources available as larger metropolitan networks, preparedness can be prioritized by leadership, grant funding can offset costs, and other low-cost measures can be taken, such as simply obtaining simple communications equipment, planning how to transport staff to and from clinics, and slowly stockpiling the necessary supplies. The SW-RAMC network offers a strong example of how this lesson can be accomplished.

5. Fatality Management

The death toll in Puerto Rico is a controversial topic under the Trump administration. The initial official death toll was calculated to be 64 by the Puerto Rican government.³²² Harvard and the Milken Institute School of Public Health at George Washington University conducted subsequent studies that resulted in significantly higher estimations. Harvard indicated an adjusted fatality estimation of 14.3 deaths per 1,000, a 62% increase over the same period in 2016, and more than 70 times the official government estimation for a total of 4,645 fatalities.³²³ The Milken Institute School of Public Health, commissioned by the Puerto Rican government, offered a substantially lower estimation after accounting for an 8% migration rate out of Puerto Rico in the recent period following Hurricane Maria that placed their estimation at 2,975 deaths, a number the Puerto Rican government officially recognized as the new official death toll

³²² Kishore et al., “Mortality in Puerto Rico after Hurricane Maria,” 163.

³²³ Kishore et al., 166.

in August 2018.³²⁴ Since Hurricane Maria, the Puerto Rican government has created a plan to revise the death certification protocol that resulted in many deaths not being identified as disaster-related.³²⁵

In addition to DMATs, the HHS maintains Disaster Mortuary Operations Response Teams (DMORTs), which proved pivotal in the response to Hurricane Maria.³²⁶ These teams provided support to the island struggling with several major issues as it pertained to fatality management as identified by the GAO: limited staffing capacity, infrastructure damage, and limited local equipment capacity.³²⁷

Puerto Rican mortuary affairs personnel reported to the GAO that a disaster plan was in place for fatality management, but it was simply overwhelmed by the impact of Hurricane Maria. Part of this plan required unattended deaths to undergo autopsy to determine the cause of death. This requirement prompted a backlog in autopsies and forced staff to request outside resources from the federal government. The Bureau of Forensic Sciences (BFS) in San Juan manages fatalities on the island, and is staffed with just five pathologists.³²⁸ Prior to Hurricane Maria, the office was averaging 73 fatalities per week. Post-Maria, medical examiners advised they were processing upwards of 145 decedents over the same timeframe.³²⁹ This rapid influx exacerbated existing case backlogs, and prompted the BFS to request outside assistance. In addition to other resources, the BFS ultimately needed at least 11 refrigerated trailers to house decedents awaiting final disposition.³³⁰

³²⁴ Sarah Lynch Baldwin and David Begnaud, “Hurricane Maria Caused an Estimated 2,975 Deaths in Puerto Rico, New Study Finds,” CBS News, August 28, 2018, <https://www.cbsnews.com/news/hurricane-maria-death-toll-puerto-rico-2975-killed-by-storm-study-finds/>.

³²⁵ “Puerto Rico Aims to Improve Fatality Reporting Post-Maria,” AP News, November 2, 2018, <https://apnews.com/article/a8ae0e8aeff843c6a53e93d6d6343f11>.

³²⁶ For more on DMORT capability, see Department of Health and Human Services, *Public Health and Social Services Emergency Fund*, 41.

³²⁷ Chris P. Currie, *Disaster Response: Federal Assistance and Selected States and Territory Efforts to Identify Deaths from 2017 Hurricanes*, GAO-19-486 (Washington, DC: Government Accountability Office, 2019), 16–7, <https://www.gao.gov/products/GAO-19-486>.

³²⁸ Currie, 16.

³²⁹ Currie, 16.

³³⁰ Schwartz, “Hurricane Maria Was a Natural Catastrophe.”

Infrastructure damages also led to difficulties processing death certificates and transporting the deceased to the BFS office in San Juan. Damaged roadways made transportation difficult across the island, and impacts to the power supply forced pathologists to process death certificates into Puerto Rico's Central Office of the Demographic Registry only on a weekly versus a daily basis.³³¹ This delay has prompted Puerto Rico to work in conjunction with the CDC on updating to a more resilient system since Hurricane Maria.

The largest equipment shortage throughout Puerto Rico was cold storage for decedents prior to a proper burial. Widespread power outages forced many across the island to rely upon the BFS San Juan office for temporary cold storage, which resulted in a further backlog in San Juan and prompted the BFS to request federal refrigeration resources in the form of trailers with generator capacity.³³² Puerto Rico continues to struggle with equipment shortages and case backlog prompting the BFS to request continued FEMA support via federal fatality management capabilities but is now struggling to have those requests granted outside of a current disaster context.³³³

a. Discussion

Part of Puerto Rico's fatality management problems were related to the process, but the larger problem was underinvestment in medical examiner capability, in terms of staffing, and physical infrastructure, such as morgue space and medical examiner facilities. While Puerto Rico had a plan for disaster fatality management, the process varied little from standard practices that did not allow for the rapid processing of decedents, and contributed to substantial autopsy backlogs that continue to plague the island's fatality management infrastructure.

³³¹ Currie, *Disaster Response*, 17.

³³² Currie, 17.

³³³ Camilo Montoya-Galvez and David Begnaud, "FEMA Denies Puerto Rico Request for Help Processing Backlog of Bodies," CBS News, February 28, 2019, <https://www.cbsnews.com/news/puerto-rico-secures-1-5m-funds-for-backlog-ridden-morgue-after-fema-rejection/>.

b. Review

The island also continues to lack adequate facilities, equipment, and staff to manage disaster caseloads, which likely means that Puerto Rico will be heavily dependent upon outside resources in subsequent disasters. Long-term investment in organic fatality management capability will reduce this reliance, so too will proactive planning and coordination. Puerto Rico is in a position to coordinate cold storage resources with private sector providers owning refrigeration capability, such as reefer trucks, and may establish standing mutual-aid agreements with mainland pathologists, and schools of pathology, to swell the ranks of pathologists rapidly when disaster strikes.

6. Conclusion

The experience of the Puerto Rican medical infrastructure during Hurricane Maria illustrates the fact that amid catastrophe, even a rapid influx of a wide range of medical support is likely to prove inadequate to meet the needs of an entire impacted population.

Major impacts to power, water, transportation, and communications infrastructure made understanding the extent of damages and resource needs of medical providers impossible for a lengthy period.³³⁴ Ergo, despite a large influx of outside medical professionals, delivering treatment to those in most need would take a considerable amount of time to achieve. In the meantime, medical volunteers, community organizations, and NGOs sought to fill the void, particularly in rural hard-to-reach areas of the island.³³⁵

This void in medical provision indicates a need to prioritize preparedness and decentralization of medical capability amid, and despite, restrained budgets and other resource shortfalls. Throughout Hurricane Maria, various informal actors contributed to caring for communities in need. Harvesting of these capabilities in a steady-state

³³⁴ Federal Emergency Management Agency, *2017 Hurricane Season*, 33.

³³⁵ Office of the Assistant Secretary for Preparedness and Response, *2017 Hurricane Season*, 7; Jose Rodriguez, “How a Small Hospital in Rural Puerto Rico Survived Hurricane Maria,” *Stat News*, November 15, 2017, <https://www.statnews.com/2017/11/15/puerto-rico-hurricane-maria-hospital/>; Shin et al., *Puerto Rico’s Community Health Centers*, 10. See Case Study 2 in Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season*, 47–62.

environment, incorporation into disaster planning, and forging of lasting relationships can contribute to higher states of preparedness, and ultimately, disaster resilience. The need to build self-reliance and reduce the need for outside resources is pertinent to all disaster-prone communities as world events, such as COVID-19 and geopolitical tensions, make the availability of outside disaster response resources, such as state mutual aid, and the DOD more uncertain.

Many of Puerto Rico’s underlying conditions served as comorbidities to disaster impacts at levels expectant of an aging and often unhealthy population.³³⁶ The public health status of the island beckons that health and emergency management practitioners join forces in broadening the scope of “disaster preparedness” to have a larger focus on the overall health of communities impacted, or likely to be impacted, by disasters. If health can be brought into the emergency preparedness fold, it is reasonable to assume that stronger, healthier individuals will lead to healthier families, communities, etc. However, the state of public health in Puerto Rico is also linked to other issues of economic hardship and environmental factors that will ensure efforts to improve the health status of residents remain challenging. Underlying the medical lifeline challenges was the total power loss to the island due to a destroyed power grid.

D. ENERGY LIFELINE

FEMA defines the energy lifeline as, “Electricity service providers and generation, transmission, and distribution infrastructure, as well as gas and liquid fuel

³³⁶ For demographic health information in Humacao, see Puerto Rico Department of Health, *Community Assessment for Public Health Emergency Response: Humacao, Puerto Rico* (San Juan: Puerto Rico Department of Health, 2019), 16–37, <http://www.salud.gov.pr/Sobre-tu-Salud/Documents/CASPER%20Reporte%20Final%20Humacao%20Abril%202019.pdf>. For demographic health information in Isabela, see Puerto Rico Department of Health, *Community Assessment for Public Health Emergency Response: Isabela, Puerto Rico* (San Juan: Puerto Rico Department of Health, 2019), 13–34, <http://www.salud.gov.pr/Sobre-tu-Salud/Documents/CASPER%20Reporte%20Final%20Isabela%20Febrero%202019.pdf>; Josh Michaud and Jennifer Kates, “Public Health in Puerto Rico after Hurricane Maria,” *KFF* (blog), November 17, 2017, <https://www.kff.org/other/issue-brief/public-health-in-puerto-rico-after-hurricane-maria/>; Centers for Disease Control and Prevention, *Public Health Preparedness and Response*, 2.

processing, and delivery systems.”³³⁷ The components of this lifeline include power grid and fuel.³³⁸

Hurricane Maria wrought devastation on Puerto Rico resulting in the longest power outage in the United States, and the second longest power outage in recorded history that lasted nearly one year before a majority of customers had power restored.³³⁹ The energy lifeline is of critical importance as a primary facilitator of all other lifelines. For example, whereas it is possible to have total communications outages without impacting the power grid, the inverse is not true. The same logic model applies to all other lifelines as well.

1. Power Grid

The Puerto Rican Electric Power Authority (PREPA) supplies a vast majority of the power and serves nearly 1.5 million customers throughout Puerto Rico and its outlying islands of Culebra and Vieques.³⁴⁰ The island operates on 98% fossil fuels, primarily imported diesel fuel and natural gas delivered to large power generation stations along the island’s northern and southern shores. A majority of the island’s power is generated in the south and is then pushed across expensive, and vulnerable, high-voltage transmission lines to the north that results in energy costs per kilowatt hour (kWh) that are nearly double that of the mainland.³⁴¹ PREPA’s power network consists of six fossil fuel, and seven hydroelectric generation facilities; the island is also home to two cogeneration plants, two windfarms, and five privately owned solar farms.³⁴² In total, the grid consists of “2,478 miles of transmission lines, 31,485 miles of distribution

³³⁷ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6.

³³⁸ Federal Emergency Management Agency, 6.

³³⁹ President’s National Infrastructure Advisory Council, *Surviving a Catastrophic Power Outage*, 69; American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 28; New York Power Authority et al., *Build Back Better*, 11.

³⁴⁰ New York Power Authority et al., 8.

³⁴¹ American Society of Civil Engineers, 29; New York Power Authority et al., 9; U.S. Energy Information Administration, “Puerto Rico Territory Energy Profile,” U.S. Energy Information Administration, July 2020, <https://www.eia.gov/state/print.php?sid=RQ>; Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’.”

³⁴² New York Power Authority et al., 8.

lines across the service territory, and 334 substations.”³⁴³ PREPA generates power primarily via facilities located on the northern and southern shores of the island; the two largest and most vital generating facilities, Aguirre and Costa Sur, are located on the southern shore, connected to the north by high-voltage transmission lines traversing mountainous terrain.³⁴⁴ This form of transmission proved problematic when those lines collapsed under hurricane force winds in remote hard-to-reach areas leading to grossly extended power restoration timelines and system repair costs.³⁴⁵

At the time of Hurricane Maria, the Puerto Rican government was estimated to have been \$74 billion dollars in public debt and had an economy that retracted 15% over ten years prior to Hurricane Maria.³⁴⁶ PREPA was no exception. In the years preceding Hurricane Maria, Puerto Rico’s electrical grid had deteriorated after losing nearly a 20% demand for power between 2007 and 2017 due to the sun-setting of tax haven legislation, Section 936, which led to a gradual exodus of major corporations operating in Puerto Rico that were large industrial power consumers. When large major corporations pulled up stakes, energy demand decreased significantly; revenue and system maintenance followed downward. One month before Hurricane Maria, in August 2017, Puerto Rican authorities estimated that PREPA required \$1.6 billion in systemwide upgrades to avoid bankruptcy. One month prior, in July 2017, the Financial Oversight and Management Board (PROMESA by the Spanish acronym) had filed a petition requesting bankruptcy protection for PREPA.³⁴⁷ Puerto Rico’s broader financial prospects look bleak as well. In 2016, public debt accounted for 93% of the island’s GDP, and Puerto Rico’s fiscal future hinges largely on the viability and success of a variety of debt restructuring maneuvers, the outcomes of which remain to be seen.³⁴⁸

³⁴³ New York Power Authority et al., 8.

³⁴⁴ New York Power Authority et al., 9.

³⁴⁵ New York Power Authority et al., 31.

³⁴⁶ Federal Emergency Management Agency, *2017 Hurricane Season*, 11.

³⁴⁷ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 30.

³⁴⁸ Tranchau (Kris) T. Nguyen and David Gootnick, *U.S. Territories: Public Debt Outlook—2019 Update*, GAO-19-525 (Washington, DC: Government Accountability Office, 2019), <https://www.gao.gov/products/GAO-19-525>.

It is nearly impossible to consider any disaster impact on Puerto Rico without also discussing its link to the collapse of the power grid. Not only was the power grid devastated by Hurricane Maria, norther portions of the island were also struck just two weeks prior by Hurricane Irma that knocked out power to one million customers. It is estimated that 70% of power was restored prior to Hurricane Maria’s impact; however, the remaining 30% of customers without power were already anticipated to wait months for power restoration.³⁴⁹ On September 21, the day after Hurricane Maria’s landfall, FEMA reported 1.5 million customers without power, which represents roughly 100% of PREPA’s customers, and noted a waiting period for the deployment of power trucks to the island vital for restoration operations.³⁵⁰ Complicating matters, the submarine transmission line feeding the island of Vieques was damaged in the storm and cut off the island.³⁵¹ It is estimated that 80% of all utility poles on the main island were destroyed.³⁵² Over the following three weeks, no more than 16% of customers’ power was restored; for those that did have power once again, it remained unreliable.³⁵³

Post-impact, it became immediately apparent that PREPA lacked the capacity to restore the island’s power grid fully.³⁵⁴ The USACE estimated that 80% of the island’s grid was *destroyed* and the power restoration mission would take many months to complete.³⁵⁵ The poor prognosis of Puerto Rico’s power grid led to the largest USACE power mission ever with an estimated 2,300 generator installations completed by the 249th Engineer Battalion.³⁵⁶ Particular emphasis was placed on powering critical facilities, such as hospitals, water plants, communication towers, police and fire stations, and 911 call centers—as allowed under the Stafford Act—that in many cases, either

³⁴⁹ New York Power Authority et al., *Build Back Better*, 10.

³⁵⁰ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017.”

³⁵¹ New York Power Authority et al., *Build Back Better*, 17; Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’.”

³⁵² National Hurricane Center, *Hurricane Maria Cyclone Report*, 7.

³⁵³ Palin, “Learning from H.I.M. (Harvey, Irma, Maria).”

³⁵⁴ Holland, “Responding to the Perfect Storm,” 21.

³⁵⁵ Holland, 21.

³⁵⁶ Holland, 19.

lacked generators or had inoperable generators.³⁵⁷ Many generators across the island were aging and not designed for long-term use (i.e., months at a time), which led to frequent mechanical failures that contributed to infrastructure fragility for a long period of time.³⁵⁸ When the USACE completed its mission in May 2018, the Corps had restored roughly 99% of pre-existing customers' power service.³⁵⁹ The USACE noted that the response in Puerto Rico was the "most difficult and complicated task" on the island and mentioned that in other disasters on the U.S. mainland, transportation into the disaster area remains viable or is minimally impacted.³⁶⁰ As a result, the USACE is now reviewing how it provides support in remote island environments, and is prioritizing transportation assets and the ability to track personnel and resources deployed to an incident in real-time.³⁶¹ FEMA has also determined a need for improvements to include adding 300 more emergency generators to its inventory, and a need to update its existing Caribbean transportation contract.³⁶²

Utter collapse of the Puerto Rican power grid plunged Puerto Ricans into the second longest power outage in recorded history and profoundly altered their daily lives for many months following Hurricane Maria. Puerto Rico's blackout underpinned the failure of multiple other vital community services, such as communications, water systems reliant on electrically powered water pumps, grocery stores, banks, hospitals, clinics, and threatened residents reliant upon power for medical devices.³⁶³ For nearly a year, Puerto Ricans who remained without power flocked to the few homes and

³⁵⁷ Federal Emergency Management Agency, *2017 Hurricane Season*, 36.

³⁵⁸ Robin Respaut and Nick Brown, "In Puerto Rico, Lives Depend on Volunteer Doctors and Diesel Generators," Reuters, October 6, 2017, <https://in.reuters.com/article/us-usa-puertorico-healthcare-idINKBN1CB28W>.

³⁵⁹ Holland, "Responding to the Perfect Storm," 21.

³⁶⁰ Holland, 21.

³⁶¹ Holland, 23.

³⁶² Federal Emergency Management Agency, *2017 Hurricane Season*, 32.

³⁶³ Umair Irfan, "9 Months after Hurricane Maria, Thousands of Puerto Ricans Still Don't Have Power," Vox, June 20, 2018, <https://www.vox.com/energy-and-environment/2018/6/13/17413828/puerto-rico-blackout-power-grid-hurricane-maria>.

community facilities that had temporary generator power, and began drawing water from natural sources despite potentially high levels of contamination.³⁶⁴

After initial restoration, rolling outages remain frequent. In March 2018, 970,000 customers lost power due to the shutdown of two major substations.³⁶⁵ This outage followed another by three weeks caused by a fire at a major power station.³⁶⁶ To this day, recurring blackouts are common and the grid remains fragile to minor mechanical issues, weather impacts, and the island's seismic threat. For example, In January 2020, Puerto Rico suffered a 6.5 earthquake in the south of the island that led to widespread power outages.³⁶⁷ The island has suffered multiple other outages of varying durations in areas all over the island, and illustrates the ongoing threats posed to Puerto Rico and the continued fragility of the power grid.

In light of Puerto Rico's energy challenges, several communities stand out as models of independence and resilience. Around the island, a variety of self-sufficient solar microgrids and energy co-ops are springing up and offering potentially scalable models. In Puerto Rico's mountainous interior, the rural community of Adjuntas was served by a community organization known as Casa Pueblo. Founded in 1980 as a cultural center, Casa Pueblo remains dedicated to ecological interventions, clean energy, education, and environmental activism.³⁶⁸ Immediately following Hurricane Maria, Casa Pueblo was the only powered location in Adjuntas and quickly became an organizing hub for self-help community relief efforts. Residents converged on the solar-powered facility

³⁶⁴ Dorell, "With Long Lines for Food, Water and Fuel and No Electricity"; Irfan, "9 Months after Hurricane Maria."

³⁶⁵ Danica Coto, "Blackout Hits Puerto Rico after 2 Power Plants Shut Down," *Seattle Times*, March 1, 2018, <https://www.seattletimes.com/business/blackout-hits-puerto-rico-after-2-power-plants-shut-down/>.

³⁶⁶ Coto.

³⁶⁷ Patricia Mazzei, Ivan Penn, and Frances Robles, "With Earthquakes and Storms, Puerto Rico's Power Grid Can't Catch a Break," *New York Times*, January 10, 2020, <https://www.nytimes.com/2020/01/10/us/puerto-rico-electricity-power-earthquake.html>; "Puerto Rico Struck by Biggest Earthquake yet, Island-Wide Power Outage Reported," *New York Post*, January 7, 2020, <https://nypost.com/2020/01/07/puerto-rico-struck-by-biggest-earthquake-yet-island-wide-power-outage-reported/>.

³⁶⁸ "Casa Pueblo Adjuntas Puerto Rico," Casa Pueblo: Proyecto de Autogestión Comunitaria, 2020, <https://casapueblo.org/>.

to compile and exchange information, supplies, and charge necessary electronics.³⁶⁹ In some ways, Casa Pueblo also became a vital healthcare clinic as those dependent upon electronic medical devices arrived to power their life-sustaining equipment.³⁷⁰ Casa Pueblo was also able to continue broadcasting on its self-owned radio station, which served as a vital source of information for local residents.³⁷¹ In telling Casa Pueblo's story, author Naomi Klein said that visiting the organization was "a vertiginous experience—a bit like stepping through a portal into another world, a parallel Puerto Rico where everything worked and the mood brimmed with optimism."³⁷²

Since Hurricane Maria, Casa Pueblo has partnered with The Honnold Foundation to scale a solar microgrid, currently producing 220 kW on a solar micro grid, returning energy profits to the local community, and powering 17 small businesses.³⁷³ Casa Pueblo has also been able to scale its storage to one-megawatt capacity based upon second-life electric car batteries procured in cooperation with The Honnold Foundation.³⁷⁴

Other energy independent examples exist around the island in Utuado, Ciales, Jayuya, Vieques, and others. In Utuado, the Hydroelectric Cooperative of the Mountain energy co-op seeks to create a more cost-effective energy model that is also environmentally sustainable.³⁷⁵ Near to Utuado, solar community hubs are springing up in Jayuya currently centered upon a gas station, health clinic, and a blended coffee roasting and ice-making facility.³⁷⁶ The gas station serves as a quasi-community hub, similar to Casa Pueblo that bridges the communities of Utuado and Jayuya. The solar-

³⁶⁹ Klein and Feeney, "Puerto Ricans and Ultrarich 'Puertopians'."

³⁷⁰ Klein and Feeney.

³⁷¹ Klein and Feeney.

³⁷² Klein and Feeney.

³⁷³ "Casa Pueblo," Honnold Foundation, 2020, <http://www.honnoldfoundation.org/partners/casa-pueblo>.

³⁷⁴ Honnold Foundation.

³⁷⁵ Emma Fiala, "Behind the Veil: Enhancing Resilience in Rural Puerto Rican Communities," *Global Convergence Lab* (blog), May 1, 2019, <https://www.umnconvergencepuertorico.org/research-posts-1/2019/5/1/enhancing-resilience-in-rural-puerto-rican-communities>.

³⁷⁶ Fisher, Reineccius, and Engstrom, "Solar Opportunities in Jayuya."

powered health clinic in Jayuya is operated by a community organization known as COSSAO aimed at improving access to healthcare regardless of financial or insurance status of patients.³⁷⁷ The facility offers a surprisingly wide range of services including dental, prenatal care, dentistry, surgery, pharmaceuticals, and urgent care.³⁷⁸ The clinic opened in 2018 in response to a void of medical services for local residents.³⁷⁹

On the island of Vieques, east of the main island, a non-profit organization called Footprint based in Vieques focuses upon solar energy systems to power communications, refrigeration, and lighting.³⁸⁰ In conjunction with the local emergency management office, the Footprint team assesses the needs and designs programs to serve the local community.³⁸¹ In addition, in the community of Toro Negro, in Ciales, the community has come together to establish a solar microgrid management by a local cooperative, and to secure safe alternate drinking water sources after enduring over eight months without power and potable water.³⁸² Other examples of grassroots community resilience endeavors exist in Puerto Rico; however, these organizations are offered as examples of the ongoing migration toward community-led initiatives responding to shortcomings of state and federal government service provisions.

a. Discussion

Power outage durations in Puerto Rico were extensive, which made response and recovery of communities exceptionally challenging. On average, Puerto Rican residents

³⁷⁷ Fisher, Reineccius, and Engstrom.

³⁷⁸ Fisher, Reineccius, and Engstrom.

³⁷⁹ Fisher, Reineccius, and Engstrom.

³⁸⁰ Fiala, "Behind the Veil."

³⁸¹ Fiala.

³⁸² "Comunidad Solar Toro Negro Takes Energy Independence by the Horns: Stories of Resilience," Center for Puerto Rican Studies, January 30, 2020, YouTube, video, 3:34, <https://www.youtube.com/watch?v=0QicrhZDoaQ>; Simeng Deng et al., "Evaluating Viability of Community Solar Microgrids for Resilience in Puerto Rico" (master's project, Nicholas School of the Environment of Duke University, 2019), 3, <https://dukespace.lib.duke.edu/dspace/handle/10161/18460>; Porta, "Lessons in Community Resilience"; Christine Ayala, "The Community Effort to Bounce Back from Puerto Rico's Eight-Month Blackout," *The Hill*, September 30, 2018, <https://thehill.com/opinion/energy-environment/409135-the-community-effort-to-bounce-back-from-puerto-ricos-eight-month>; Tim Johnson, "Weary of Blackouts, More Puerto Ricans Are Turning to Solar Energy," *Mcclatchy DC*, accessed October 8, 2020, <https://www.mcclatchydc.com/news/nation-world/national/article217653250.html>.

went 84 days without electricity; many residents sustained outages well over the average, closer to one year, which positively correlated with the remoteness of the customer.³⁸³ The initial response priority to Puerto Rico's destroyed power grid was to repair the existing system rapidly, at the expense of neglecting a long-term, energy independent, or otherwise resilient model for future energy resilience.³⁸⁴ In 2017, the existing disaster legislation, the Robert T. Stafford Act, only allowed FEMA to fund permanent work insofar as it restores to pre-disaster conditions, which did not account for the poor condition of Puerto Rico's electrical grid prior to Hurricane Maria.³⁸⁵ This situation led former FEMA Administrator, Brock Long, to Capitol Hill to plead the case that Puerto Rico was an exception to this long-standing rule.³⁸⁶ In 2018, the Bipartisan Budget Act made an exception to this rule to allow FEMA to "restore disaster-damaged facilities or systems that provide the specifically identified critical services to an industry standard without regard to pre-disaster condition" in both Puerto Rico and the U.S. Virgin Islands for damages incurred by Hurricanes Irma and Maria.³⁸⁷

b. Review

Puerto Rico's power grid was undoubtedly in serious disrepair when Maria struck that contributed to high levels of structural damage and prolonged power outages. However, beginning in 2015, PREPA had outlined strategic goals in its Integrated Resource Plan (IRP) aimed at migrating away from oil as a primary fuel and moving

³⁸³ Kishore et al., "Mortality in Puerto Rico after Hurricane Maria," 165.

³⁸⁴ American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 28.

³⁸⁵ Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, Title 42 United States Code 192 (1988), <https://www.fema.gov/robert-t-stafford-disaster-relief-and-emergency-assistance-act-public-law-93-288-amended>.

³⁸⁶ "FEMA Funding," November 30, 2017, C-SPAN, video, 1:41:42, <https://www.c-span.org/video/?437909-1/fema-administrator-brock-long-testifies-capitol-hill>.

³⁸⁷ Federal Emergency Management Agency, *Implementing Section 20601 of the 2018 Bipartisan Budget Act through the Public Assistance Program*, FEMA Recovery Policy FP-104-009-5 (Washington, DC: Federal Emergency Management Agency, 2018), 1, https://www.fema.gov/media-library-data/1537374589131-e5048390675525d0bc84812759eba5fe/BBA_Policy_9-14-2018_508_FINAL.pdf.

toward renewable energies and natural gas as primary power sources.³⁸⁸ Under this plan, Puerto Rico would achieve 20% renewable generation by 2035.³⁸⁹ The IRP was updated via the Puerto Rico Energy Public Policy Act in April 2019 and emplaced more aggressive goals. Under this act, Puerto Rico is to achieve the elimination of coal as an energy source by 2028, utilize 40% renewable energy by 2025, and 100% renewable energy generation by the year 2050.³⁹⁰

Clean energy and microgrids remain key components of Puerto Rico’s future energy strategy. Several clean energy and microgrid projects have been developed since Hurricane Maria. Microgrids offer a grid structure that allows for the isolation of impacts to prevent large-scale and long-term outages, and potentially faster restoration timelines.³⁹¹ In Maria’s wake, much of the investment in such technology has come via private sector philanthropy, such as Tesla installing microgrid technology in several small communities around the island.³⁹² While these investments are viewed as positive steps in the right direction toward energy resiliency, some experts remain skeptical that these approaches will solve Puerto Rico’s power problem on grounds of scalability and sustainability.³⁹³ In addition to ongoing microgrid initiatives, FEMA has increased its on-island stock of available generators from 90 to 268 as of August 2020.³⁹⁴

Amid tectonic aspirations of clean energy, Puerto Rico has legislated annual power rate increases from \$.22 per/kWh up to \$.32 per/kWh, and requires even those operating solely on solar panels to pay into funds designed to pay down PREPA’s

³⁸⁸ Puerto Rico Electric Power Authority, “Integrated Resource Plan—Puerto Rico Energy Bureau,” Puerto Rico Energy Bureau, 2020, <https://energia.pr.gov/en/integrated-resource-plan/>; New York Power Authority et al., *Build Back Better*, 5–6.

³⁸⁹ New York Power Authority et al., 7.

³⁹⁰ Puerto Rico Energy Public Policy Act, Public Law 17-2019 (2019), <https://energia.pr.gov/wp-content/uploads/2019/05/Act-17-2019.pdf>; Umair Irfan, “Puerto Rico Is Targeting 100% Renewable Energy. The Trump Administration Has Other Ideas,” *Vox*, April 17, 2019, <https://www.vox.com/2019/4/17/18306417/puerto-rico-renewable-energy-natural-gas>.

³⁹¹ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 28.

³⁹² American Society of Civil Engineers, 32.

³⁹³ American Society of Civil Engineers, 32.

³⁹⁴ Federal Emergency Management Agency, “Hurricane Maria by the Numbers.”

existing debt.³⁹⁵ Moreover, as the ASCE point out, these fees are to pay down PREPA's old debt, not to invest in the island's aggressive clean energy goals.³⁹⁶ Energy price hikes make market entry difficult, and are a strong disincentive to transition to cleaner, more sustainable forms of energy. Such price structuring stifles migration toward renewable energy solutions.

Unfortunately, based upon historical storm track data, similar storm paths leading to high levels of damage to infrastructure are likely to reoccur in the future.³⁹⁷ This data, along with the other challenges outlined, places Puerto Rican communities at a high likelihood of repeated long-term power loss and isolation. However, the perennial threat of catastrophic disasters offers an opportunity for government agencies, NGOs, and community organizations to maintain community engagement and fundamentally prepare Puerto Ricans in ways that increase resiliency. The Puerto Rican experience also affords other communities the ability to study impacts and challenges of power loss in resource-constrained environments for a comparative analysis of applicable circumstances to communities everywhere. Communities, such as Adjuntas, Utuado, and Jayuya, and organizations, such as Casa Pueblo and the Hydroelectric Cooperative of the Mountain, and COSSAO offer models for energy independence, accessible and affordable healthcare, and community resilience that other jurisdictions may seek to replicate in the interest of reducing long-term vulnerability against catastrophes.

The uprising and solidification of decentralized and community-based organizations, and their growing role in community resilience, align with the ODNI's Global Trends assessment of a future in which "advocacy groups, charities, and local governments prove nimbler than national governments" as the government and the public renegotiate roles and responsibilities in providing public services, also noting that "tomorrow's successful states will probably be those that invest in infrastructure,

³⁹⁵ American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 31.

³⁹⁶ American Society of Civil Engineers, 31.

³⁹⁷ New York Power Authority et al., *Build Back Better*, 17.

knowledge, and relationships resilient to shock.”³⁹⁸ Furthermore, resilient community hubs are likely to play an increasing role in communities’ response and recovery efforts. In 1960, Nobel Prize winner, Thomas Schelling, discovered that in the absence of information, people will “people will coordinate by selecting a focal point that seems natural, special or relevant to them,” and this scenario appears to hold true in Puerto Rico following Hurricane Maria.³⁹⁹

2. Fuel

Fuel supply to Puerto Rico presents a vulnerability given the power grid’s reliance on imported fuel for electricity generation. Roughly, 75% of Puerto Rico’s energy production is derived from petroleum products obtained via fuel imports through the ports of San Juan, Guayanilla, and Ponce, and arrive mostly on foreign-flagged vessels from non-U.S. ports of origin.⁴⁰⁰ In fiscal year 2017, Puerto Rico received 212 fueling ships to supply its power production.⁴⁰¹ By one estimation, Hurricane Maria may have driven diesel demand by as much as 500% by a large-scale transition to generator power across the three inhabited islands.⁴⁰² Fuel shipments bound for Puerto Rico were met with significant delays as a result of Hurricanes Irma, Jose, and Maria as they sought safe passage around each system.⁴⁰³ Once shipments arrived, off-loading fuel products remained problematic. While fuel supply sources remained unaffected by the storm, the ability to distribute fuel was crippled for a significant period of time. For example, the FEMA Daily Brief for September 27, one week post-landfall, noted, “bulk fuel is on the island, but there is limited capability to distribute.”⁴⁰⁴ The same briefing on September

³⁹⁸ Office of the Director of National Intelligence, “The Future Summarized,” Global Trends: Paradox of Progress, 2019, <https://www.dni.gov/index.php/global-trends/the-future-summarized>; National Intelligence Council, *Global Trends*, 67.

³⁹⁹ As discussed in Warigia Bowman and L. Jean Camp, “Protecting the Internet from Dictators: Technical and Policy Solutions to Ensure Online Freedoms,” *The Innovation Journal* 18, no. 1 (2013): 6.

⁴⁰⁰ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 35; Palin, *Out of the Whirlwind*, loc. 162.

⁴⁰¹ American Society of Civil Engineers, 35.

⁴⁰² Palin, “Learning from H.I.M. (Harvey, Irma, Maria).”

⁴⁰³ Palin, *Out of the Whirlwind*, loc. 157.

⁴⁰⁴ Federal Emergency Management Agency, “FEMA Daily Situation Report Archive 2017.”

28 estimated 18 days of fuel were available on the island and noted distribution remained challenging due to debris issues. With fuel in port, truck drivers who deliver the product to final destinations were unable to get to the port either due to blocked transportation routes or a need to ensure their own families were safe before reporting to work.⁴⁰⁵ FEMA's AAR noted that competing demands for fuel transfer from vessels to trucks created a need to develop a fuel truck shipment route priority and necessitated the contracting of additional trucks and drivers.⁴⁰⁶ Retrospectively, the fuel shortages experienced on Puerto Rico following Hurricane Maria appear to be an issue of demand and delivery, not of supply.⁴⁰⁷ In the moment, the issue appeared to be resource scarcity, which led to very high levels of resource ordering, further crowding the overwhelmed distribution system.⁴⁰⁸

Regardless of cause, endpoint fuel scarcity sent Puerto Ricans everywhere scrambling with vehicles and gas cans to wait in hours-long lines to get what little fuel they could from the island's 1,100 gas stations.⁴⁰⁹ For residents of the interior municipalities, sourcing fuel became a day-long venture.⁴¹⁰ For residents fortunate enough to have access to both generators and fuel, the costs of fuel exacerbated financial woes as they quickly became unaffordable to operate for long periods, driving some resident to eat very basic foods and pool funds to source precious gasoline.⁴¹¹ For residents with generators that could afford fuel, rationing was common and was typically capped at five gallons of fuel per individual.⁴¹² Residents throughout the island would often flock to locations with generators to charge their telephones and other electronics

⁴⁰⁵ Klein and Feeney, "Puerto Ricans and Ultrarich 'Puertopians'."

⁴⁰⁶ Federal Emergency Management Agency, *2017 Hurricane Season*, 10.

⁴⁰⁷ The pre-Maria on-island fuel estimate is between 30-60 days' worth of fuel stocks. Within 9 days post-impact, 2.4 million barrels of fuel were brought into the island. Palin, *Out of the Whirlwind*, loc. 622.

⁴⁰⁸ Palin, loc. 303.

⁴⁰⁹ Fischbach et al., "After Hurricane Maria," 211.

⁴¹⁰ Dorell, "With Long Lines for Food, Water and Fuel and No Electricity."

⁴¹¹ Oxfam America, *Far from Recovery*, 5; Caitlin Dickerson and Luis Ferré-Sadurní, "'Like Going Back in Time': Puerto Ricans Put Survival Skills to Use," *New York Times*, October 24, 2017, <https://www.nytimes.com/2017/10/24/us/hurricane-maria-puerto-rico-coping.html>.

⁴¹² Palin, loc. 649.

then go in search of what limited cell phone connectivity could be found to coordinate helping their family, friends, and putting their lives back together.

a. Discussion

Puerto Rico’s reliance on imported fuels creates the need for particularly resilient airport, seaports, and ground transportation infrastructure.⁴¹³ Should a single port of entry fail, securing a resupply of fuel in support of temporary power generation and daily use will be in peril.

b. Review

However, the experience of Hurricane Maria also indicates that post-disaster, fuel supply shortages are more likely to be related to issues of distribution, not limited supply.⁴¹⁴ Distribution issues consisted of physical impact to, and blockage of, vital transportation routes, and the unplanned need for the USACE and FEMA to support such a massive temporary power generation mission.⁴¹⁵ In the interest of long-term vulnerability reduction and disaster resilience, the community organizations discussed under the energy component that are based upon sustainable micro grid energy models reduce the need for high-volume fuel shipments in the days and weeks following a major disaster and afford a resilient model that extends a lifeline to communities, particularly in rural areas. Scaling this model to other communities throughout Puerto Rico may relieve the stress on the logistics supply chain amid future disasters.

3. Conclusion

The widespread destruction Puerto Rico’s power grid made the stabilization of all other critical infrastructure extremely challenging, and nearly impossible, for a significant period of time. In much the same way that the island’s underlying health conditions exacerbated issues found in the health and medical lifeline, the island’s pre-existing

⁴¹³ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 29.

⁴¹⁴ Palin, *Out of the Whirlwind*, loc. 303.

⁴¹⁵ Holland, “Responding to the Perfect Storm”; Federal Emergency Management Agency, *2017 Hurricane Season*, 37.

decrepit power grid also served as an amplifier to Hurricane Maria's destructive power. With a collapsed grid, the island quickly became many times more dependent on the import of fuel that also proved problematic due to the widespread collapse of the resource distribution networks discussed in the transportation lifeline. Without a power supply across the island, it also proved essentially impossible for communities and responders to communicate effectively as well.

E. COMMUNICATIONS LIFELINE

FEMA defines the communications lifeline as:

Infrastructure owners and operators of broadband internet, cellular and landline telephone networks, cable services, satellite communications services, and broadcast networks (radio/television). These systems encompass diverse modes of delivery, often intertwined but largely operating independently. Services include alerts, warnings, and messages, 911 and dispatch, and access to financial services.⁴¹⁶

The components of this lifeline include infrastructure, responder communications, alerts, warnings, and messages, finance, and 911 dispatch.⁴¹⁷

The most evident gap in Puerto Rico's communications capabilities was the lack of survivable communications primarily due to a lack of a resilient infrastructure, scarce equipment redundancy, lack of temporary power generation, and a general void of catastrophic preparedness initiatives both in the private and public sphere. A full two days after landfall of Hurricane Maria, the Puerto Rico government still had negative contact with 40 of its 78 municipalities.⁴¹⁸ FEMA's AAR indicated that local, state, and federal governments suffered from an inability to communicate, which resulted in poor resource coordination, and identified that ensuring the future continuity of communications as an agency high priority.⁴¹⁹ Without functioning communications, jurisdictions found it impossible to request outside resources or receive offers of

⁴¹⁶ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6.

⁴¹⁷ Federal Emergency Management Agency, 6.

⁴¹⁸ Deibert, *When the Sky Fell*, 105.

⁴¹⁹ Federal Emergency Management Agency, *2017 Hurricane Season*, 38.

assistance from other jurisdictions. Puerto Rico authorities could not communicate with the outside world for a significant period of time, particularly in regard to off-island EMAC resources from different states.⁴²⁰ Many Puerto Rican responders at both the local and Commonwealth levels reported that the inability to communicate was the biggest challenge to mounting an effective response.

1. Infrastructure

Puerto Rico's communications network is comprised of fiber internet, microwave towers, cable television, broadcast radio, and cellular sites. In total, the island has a network of 1,600 cell sites supporting the primary means of individual communication via voice and text.⁴²¹ In 2018, the island had an estimated 703,266 fixed line customers, and 3,330,286 wireless customers, which represented a 21% and 101% saturation rate, respectively.⁴²² AT&T, T-Mobile, Claro, Sprint, and Open Mobile serve as the primary providers, and cellular service is the majority source of internet for many on the island.⁴²³ A vast majority of communications on the island is achieved via wireless, cellular technology, whereby 80% of residents exclusively use cell phones for routine communications.⁴²⁴ Much like other sectors, the communications infrastructure was in ill-repair and vulnerable before Hurricane Maria made landfall. Many cell towers were overloaded with equipment, which made them top-heavy and susceptible to high winds, and many cell sites were poorly maintained and difficult to access for routine upkeep.⁴²⁵

Hurricane Maria decimated the island's communication infrastructure and rendered 95.6% of all cell sites non-operational. All municipalities experienced at least 75% outages, and peak communications outages left 48 of the island's 78 municipalities

⁴²⁰ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 46.

⁴²¹ Deibert, *When the Sky Fell*, 105.

⁴²² Central Intelligence Agency, "Central America: Puerto Rico."

⁴²³ Robin Respaut and David Graham, "With Cell Service Crippled, Puerto Ricans Look Skyward for a Signal," Reuters, September 27, 2017, <https://www.reuters.com/article/us-usa-puertorico-communication-idUSKCN1C30FA>.

⁴²⁴ Fischbach et al., "After Hurricane Maria," 159.

⁴²⁵ Fischbach et al., 161–2.

with 100% cellular outages for extended periods.⁴²⁶ Maria also rendered an estimated 85% of both above and below ground cable and fiber-optic networks inoperable.⁴²⁷ Services were incrementally restored over the following six months at which point 4% of cell sites remained completely inoperable.⁴²⁸ The Federal Communications Commission (FCC) noted these impacts were “considerably longer than for any other storm” and the networks in both Puerto Rico and neighboring U.S. Virgin Islands were “almost completely destroyed” in its 2018 report.⁴²⁹ It is important to note that the damage wrought by Hurricane Maria overlaps that inflicted by Hurricane Irma just two weeks prior. Although the U.S. Virgin Islands bore the brunt of Hurricane Irma, Puerto Rico was substantially impacted as well.⁴³⁰ For example, the day after Irma’s impact, Puerto Rico recorded 39% cell site outages; nearly a week later on September 14, 2017, Puerto Rico was still experiencing 6% cell site outages.⁴³¹ According to the FCC’s Disaster Information Reporting System (DIRS), cellular outages were concentrated east-to-west along the northern two-thirds of the island.⁴³² Hurricane Maria would strike five days later and knocked out nearly all communications islandwide.

In an attempt to stem widespread outages, Google’s X lab, operated by its parent company, Alphabet, devised a plan to launch telecommunication balloon platforms designed to provide communications capability to remote areas in October 2017. Prior to Hurricane Maria, the solar-powered balloon platforms had undergone testing in New

⁴²⁶ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact on Communications Report and Recommendations*, Public Safety Docket No. 17-344 (Washington, DC: Federal Communications Commission, 2018), 6, <https://docs.fcc.gov/public/attachments/DOC-353805A1.pdf>.

⁴²⁷ Deibert, *When the Sky Fell*, 105.

⁴²⁸ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 15.

⁴²⁹ Federal Communications Commission, 15, 5.

⁴³⁰ The islands of St. Thomas and St. John bore the brunt of Hurricane Irma’s impact. Exact storms tracks and other archival data are available via the National Hurricane Center.

⁴³¹ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 9.

⁴³² A DIRS screenshot is available in the FCC report. Federal Communications Commission, 9.

Zealand, Peru, and Brazil.⁴³³ Performing this mission required that the FCC grant Alphabet an experimental license.⁴³⁴

By November, Alphabet reported that it was providing communications services to as many as 100,000 residents of the island via its stratospheric balloons that delivered internet service to areas that remained without functioning cellular towers.⁴³⁵ Each balloon operated via AT&T and T-Mobile networks and covered 5,000 square kilometers, supplying as much as a 10 megabyte per second connection that allowed residents to send texts and emails.⁴³⁶ While this technology provided some communications relief, they offered daytime services only as the balloons are solar-powered, and Project Loon remains experimental technology.⁴³⁷

a. Discussion

According to one study, on average, Puerto Rican residents went without cellular phone service for 41 days; those who resided in more remote areas strongly correlated with longer service outages.⁴³⁸ This number is significant given the central role communication plays in the coordination of all other disaster response and recovery functions. J. Brian Houston et al. describe communication systems and resources as “reservoirs in which community meaning-making, information exchange, interactions, and connections can occur.”⁴³⁹

⁴³³ Nick Lavars, “Project Loon Balloons to Connect Storm-Ravaged Puerto Rico,” *New Atlas*, October 8, 2017, <https://newatlas.com/project-loon-puerto-rico/51666/>.

⁴³⁴ Lavars.

⁴³⁵ Guynn, “Google Parent’s Project Loon Delivers Internet to 100,000 in Puerto Rico.”

⁴³⁶ Guynn; Thomas Hedger, “How to Bring the Internet to Everyone—The Possibility Report,” *The Atlantic*, October 2017, <https://www.theatlantic.com/sponsored/vmware-2017/internet-for-everyone/1542/>.

⁴³⁷ Guynn.

⁴³⁸ Kishore et al., “Mortality in Puerto Rico after Hurricane Maria,” 165.

⁴³⁹ J. Brian Houston et al., “The Centrality of Communication and Media in Fostering Community Resilience: A Framework for Assessment and Intervention,” *American Behavioral Scientist* 59, no. 2 (February 2015): 270–83, <https://doi.org/10.1177/0002764214548563>.

b. Review

Alphabet’s balloon technology represents what is possible for public and private partnerships in challenging environments. Deployments of Alphabet’s balloons was not a pre-planned action but perhaps should be, particularly in areas known to suffer major communications impacts, and long restoration timelines. Pre-planning such capability may afford technology providers the ability to scale operations further and provide higher levels of services in the future.

The role of the ARRL in supporting first response operations and the ARC’s *Safe and Well* program also portray what is possible when non-governmental and informal actors are brought into alignment with government response frameworks and their resources are applied to common problems facing disaster-impacted areas. Greater pre-planning for non-governmental actors may have also expanded each organization’s ability to provide disaster relief services.

2. Responder Communications

Responder communications largely rely on the same physical infrastructure as the public and therefore were as heavily impacted as other forms of communication. FEMA defines responder communications as the LMR networks that first responders use to communicate with dispatch centers and with each other in the field.⁴⁴⁰ First response repeaters, antennas, and other communications hardware are affixed to commercial towers and government facilities exposed to Hurricane Maria’s high winds over an extended period of time. When well over 90% of cellular communications went offline, a vast majority of responder communications capability did so as well.

Many regional authorities reported an inability to communicate with the central government, and lacked the clear authority under those circumstances to respond to the disaster’s impacts.⁴⁴¹ Therefore, during the initial days and weeks following Hurricane Maria, communications resorted to old ways via the use of runners between

⁴⁴⁰ Federal Emergency Management Agency, *FEMA Stabilization Guide*, E-2.

⁴⁴¹ Fischbach et al., “After Hurricane Maria,” 130.

municipalities and the San Juan, Puerto Rico’s capital city. For instance, Caguas Mayor, William Miranda Torres, reported driving to San Juan with hand-written supply requests often times staying for four to five hours each day to plead for disaster relief supplies for his town.⁴⁴² This practice was common with the mayors of nearly all 78 municipalities in Puerto Rico. According to Puerto Rico’s Chief Information Security Officer, Luis Arocho, “no one prepares for the complete loss of the communication network...what happened in Puerto Rico has never happened with a major disaster in the United States.”⁴⁴³ Most disasters have an edge where the destruction stops and disaster aid resources can amass and be used as operational hubs. As an island, Puerto Rico posed unique challenges because the entire island was heavily impacted with nowhere left to stage resources.

When standard cellular and internet connectivity was lost, Puerto Rico sought support from a variety of actors with the primary sources being FEMA, the DOD private sector providers, and volunteer organizations, such as the ARRL. Immediately following Hurricane Maria, FEMA deployed its Mobile Emergency Response Support (MERS) units. By September 23, the agency had deployed 34 MERS teams, which left only 5.5% of MERS capacity remaining in reserve.⁴⁴⁴ MERS provided “mobile satellite, mobile radio, and logistics support services to provide command and control communications, situational awareness, and program delivery.”⁴⁴⁵ For the capability that FEMA was not able to offer organically, the agency contracted services via the private sector and coordinated delivery of DOD and Secret Service assets.⁴⁴⁶ FEMA also eventually issued satellite phones to both municipal mayors and hospitals; however, they proved to be largely ineffective in facilitating communications. FEMA reported that poor weather conditions, user inexperience, and phone activation issues were the culprits hindering the

⁴⁴² Hernández, “A Tale of Two Puerto Ricos.”

⁴⁴³ Jack Corrigan, “How Puerto Rico Is Rebuilding Its Network Three Months after Maria,” Nextgov, December 19, 2017, <https://www.nextgov.com/emerging-tech/2017/12/how-puerto-rico-rebuilding-its-network-three-months-after-maria/144686/>.

⁴⁴⁴ Federal Emergency Management Agency, *2017 Hurricane Season*, 16.

⁴⁴⁵ Federal Emergency Management Agency, 35.

⁴⁴⁶ Federal Emergency Management Agency, 35.

use of satellite phones.⁴⁴⁷ The agency also noted that some satellite phones “could not correctly operate” in the Caribbean.⁴⁴⁸ Anecdotally, in other words, the overhead satellite infrastructure was either not positioned properly over the area, or held insufficient bandwidth to process a sudden surge in satellite communications traffic.⁴⁴⁹ Unfortunately, for Mayor Torres, and many other mayors in his position, communicating needs to San Juan would not substantially improve until cellular networks were restored.

Military units also aided substantially in emergency communications coming from both Title 32 (National Guard) and Title 10 (Federal) forces from around the country. By September 30, the DOD had received requests for two theater communications packages, and three others for communications support packages inclusive of Broadband Global Area Networks (BGAN) with operators.⁴⁵⁰ The DOD’s primary focus was to support “government and FEMA Joint Field Office efforts to engage the mayors of the 78 municipalities and ascertain needs” with the intent to bolster governmental communications capability to facilitate command and control over response efforts.⁴⁵¹ The DOD also deployed a number of Civil Affairs Information Support Element (CAISE) teams.⁴⁵² These teams performed a variety of functions but one of the most vital was aiding in the restoration of radio broadcast stations, which allowed the government to communicate more effectively with the communities it served.

Given the extensive damage to the infrastructure, satellite-based solutions played a vital role in establishing reliable responder communications. One major provider, Hughes Network Solution LLC, carried a majority of the satellite internet and Voice over

⁴⁴⁷ Federal Emergency Management Agency, 34–5.

⁴⁴⁸ Federal Emergency Management Agency, 35.

⁴⁴⁹ This information was relayed to the author in person when operating in Puerto Rico shortly after Hurricane Maria.

⁴⁵⁰ This order: “Directs the Secretary of Defense to oversee the development, testing, implementation, and sustainment of national security and emergency preparedness communications that are directly responsive to the national security needs of the President, Vice President, and senior national leadership.” Larson et al., *U.S. Army North in the Hurricane Maria Response*, 50.

⁴⁵¹ Larson et al., 130.

⁴⁵² Larson et al., 41.

Internet Protocol (VOIP) communications.⁴⁵³ Hughes offers a variety of satellite-based communications platforms. The company reported supporting FEMA, the NWS, the DOD, and Customs and Border Protection (CBP), as well as many private sector clients totaling 1,500 individual terminal connections between Puerto Rico and the Virgin Islands in the first three months post-disaster.⁴⁵⁴ One of the most commonly used devices are known as very small aperture terminals (VSATs) that allow for the sending and receiving of information in areas with no existing networks.⁴⁵⁵ Other assistance came from random sources able to provide assistance, such as when Massachusetts and Rhode Island provided Puerto Rico with satellite communications and radios as part of a much broader joint effort to prop up the island's communications infrastructure.⁴⁵⁶ These sources primarily originated via the EMAC network managed by NEMA.

As primary means of communications were degraded or destroyed, and local and state responders began using alternative means of communications, one such resource was amateur radio networks.⁴⁵⁷ Unsurprisingly, grassroots communications platforms, such as HAM radios, displayed the high levels of resiliency in this disaster and were able to fill vital communications capability gaps. While a HAM network existed on Puerto Rico (and mutual-aid operators on the mainland), scant evidence is available that shows that the networks were well integrated in Commonwealth emergency response plans as an asset to the island. The ARRL, however, comprised of volunteer radio operators capable of operating a wide range of communications technology, was able to be of great assistance nevertheless.⁴⁵⁸ Private HAM radio operators and members of ARRL's

⁴⁵³ In the month of November 2017, Hughes reported supporting in excess of 30,000 VOIP calls. Corrigan, "How Puerto Rico Is Rebuilding Its Network."

⁴⁵⁴ Hughes Network Systems, *Lessons from Disaster Relief: The Importance of Communications Resiliency and Preparedness* (Germantown, MD: Hughes Network Systems, 2018), 1, https://www.hughes.com/sites/hughes.com/files/2018-04/Lessons-from-Disaster-Relief_H60300_HR%20%281%29.PDF.

⁴⁵⁵ Corrigan, "How Puerto Rico Is Rebuilding Its Network."

⁴⁵⁶ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 30.

⁴⁵⁷ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 21.

⁴⁵⁸ The FCC recognized a lack of engagement with the emergency management community as well and took that lesson as an area of improvement in the commission's AAR.

subsidiary component, ARES, teamed with first responders to provide communications via handheld HAM radios, and other operators (approximately 12) PREPA manned trucks.⁴⁵⁹ Early in the response, the ARC partnered with the ARRL and mobilized approximately 50 radio operators to Puerto Rico where they aided ARC's *Safe and Well Program* that reunites separated family members following disasters.⁴⁶⁰ The ARRL radio operators also supported 51 community hospitals by issuing and installing very high frequency (VHF) communications that allowed them direct radio communications to the Puerto Rico Emergency Operations Center, which aided greatly in coordinating resources.⁴⁶¹ The ARRL, as a grassroots organization, filled vital communications gaps in many other ways at a time when government and private sector frameworks could not. Unfortunately, the ARRL was only able to be of such assistance in spite of, not because of, pre-disaster planning and strong local and state government coordination.⁴⁶²

a. Discussion

Restoring functioning responder communications required that numerous ad hoc measures be performed and supported by a massive amount of resources. While FEMA and the DOD maintains standard capabilities, their employment in Puerto Rico was not pre-planned which posed a challenge and caused FEMA to nearly exhaust all its MERS capability.⁴⁶³

⁴⁵⁹ Suzanne Gamboa, "Without Phones, Puerto Rico Turns to Amateur Radio Operators at Worst Moments," NBC News, September 28, 2017, <https://www.nbcnews.com/news/latino/puerto-rico-amateur-radio-operators-are-playing-key-role-puerto-n805426>.

⁴⁶⁰ Gamboa; American Radio Relay League, *ARRL 2017 After-Action Report*, 23; Paul Murphy and Michelle Krupa, "HAM Radio Operators Are Saving Puerto Rico," CNN, September 27, 2017, <https://www.cnn.com/2017/09/27/us/puerto-rico-maria-ham-radio-operators-trnd/index.html>.

⁴⁶¹ American Radio Relay League, 18.

⁴⁶² The ARRL indicated in its AAR that its members needed to have a clearer affiliation with the ARRL, a presence in the federal JFO to coordinate communications, and a need for a communications strategy. American Radio Relay League, 51.

⁴⁶³ Federal Emergency Management Agency, *2017 Hurricane Season*, 16.

b. Review

Hurricane Maria also highlighted both the lack of survivable communications and the importance of having such contingencies in place pre-disaster impact. Government entities often struggled to distribute satellite phones and VSAT technologies in a manner that comparably supported response operations as primary communications systems. Securing such contingency technology is often cost-prohibitive, which may suggest Puerto Rico build out more economical capabilities by further incorporating volunteer actors, such as ARRL’s HAM radio operations into future response and recovery plans.

3. Alerts, Warnings, and Messages

Extensive damage to physical infrastructure, such as wind damage to radio and microwave towers, downed utility poles, and other similar impacts brought cable and radio broadcast capability to a standstill for a matter of months as well. As late as December 2017, only 5% of Puerto Rico’s 100 television stations were reporting themselves as operational and nearly 33% of both amplitude modulation (AM) and frequency modulation (FM) radio stations remained inoperable.⁴⁶⁴ Additionally, the FCC reports that cable system and traditional landline services were “generally non-existent” primarily due to the widespread and long-term lack of power.⁴⁶⁵ These impacts made communicating information to the public difficult in all cases and impossible in many others. Radio broadcasting stations proved to be rather resilient considering the circumstances; however, this communication medium only afforded responders a one-way method of communication that did little to alleviate the inability to communicate resource needs, and apply available resources in a timely manner.⁴⁶⁶ On September 22, 2020, Puerto Rico’s Guajataca Dam was in eminent danger of collapsing, which resulted in the need to evacuate 70,000 residents. This evacuation prompted the NWS alerting

⁴⁶⁴ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 17.

⁴⁶⁵ Federal Communications Commission, 17.

⁴⁶⁶ Bruno Takahashi, Yadira Nieves, and Manuel Chavez, *Radio Practices and Their Impacts during Hurricane Maria in Puerto Rico* (Boulder, CO: Natural Hazards Center, 2018), <https://hazards.colorado.edu/quick-response-report/radio-practices-and-their-impacts-during-hurricane-maria-in-puerto-rico>.

procedures. However, due to widespread communications outages, authorities had little means actually to reach the intended audience, which prompted first responders to alert area residents physically via PA systems on emergency vehicles to urge people to evacuate immediately.⁴⁶⁷ Despite shortcomings, in the following days and weeks, FEMA continued to try to implement novel solutions to maintain alert and warning capability. The agency's Integrated Public Alert and Warning System (IPAWS) Office, responsible for such things as emergency alerts, amber and silver alerts, partnered with SiriusXM to emplace satellite radios to keep what are known as "primary entry point" (PEP) stations broadcasting.⁴⁶⁸

Void of widespread service restoration, residents were often traveling long distances seeking locations and buildings that could offer cell phone signals and Wi-Fi connectivity to allow them to connect to family and resources on the island, as well as the mainland.⁴⁶⁹ One other notable connection to the outside world was radio station WAPA 680 of San Juan that continued to employ analog equipment requiring less energy to operate than other stations that had migrated solely to modern digital equipment requiring greater generator power; thus, WAPA 680 provided continuity of services when others ceased to function.⁴⁷⁰ Not only did WAPA 680 operate as a radio station, it also took the initiative to field initial calls for emergency assistance for those becoming isolated by rising floodwaters before the communication network collapsed.⁴⁷¹ Following the storm, the radio station also hosted medical professionals who offered residents medical and psychological advice over the airwaves.⁴⁷² The station's continuity served as a lifeline of information for residents otherwise in the dark. Other stations that were able to remain on

⁴⁶⁷ Ellis, "Puerto Rico Dam."

⁴⁶⁸ Antwane Johnson, "Written Testimony of FEMA Office of Continuity Communications Director Antwane Johnson for a House Committee on Homeland Security, Subcommittee on Emergency Preparedness, Response, and Communication Hearing Titled 'Ensuring Effective and Reliable Alerts and Warnings'," Department of Homeland Security News, February 16, 2018, <https://www.dhs.gov/news/2018/02/06/written-testimony-fema-house-homeland-security-subcommittee-emergency-preparedness>.

⁴⁶⁹ Associated Press, "Puerto Ricans Hunt for Precious Wi-Fi."

⁴⁷⁰ Deibert, *When the Sky Fell*, 107–8.

⁴⁷¹ Deibert, 108.

⁴⁷² Deibert, 108.

the air often operated in a limited capacity, such as only being able to operate on the FM band, and for those who had generators, fuel began to become scarce, which forced many stations to cease broadcasts at 5 p.m. daily.⁴⁷³ These stations also served vital roles, such as helping reunite families and perform welfare checks on loved ones.⁴⁷⁴ These examples illustrate the value of several truths: citizens maintained radios capable of connecting them to local broadcast stations, analog communications equipment is often more reliable amid catastrophes than more sophisticated hardware, WAPA 680 was able to operate on generator power, which allowed it to continue to broadcast in austere conditions in the immediate aftermath when residents needed it most, and local broadcasting stations should be viewed as a vital response resource when preparing for disasters.

On a community level, the environmental activist organization, Casa Pueblo, was also able to maintain operations of its radio station broadcasting in Adjuntas due to its focus on pre-disaster preparedness and abundant solar power generation. By remaining on the air, Casa Pueblo was able to serve the vital function of keeping the local community abreast of important updates and information pertaining to disaster response and recovery.⁴⁷⁵

a. Discussion

Once again, the capabilities of non-governmental actors proved most resilient amid catastrophic disaster as evidenced by entities, such as Casa Pueblo and WAPA 680's ability to maintain communications capabilities. It remains important for government entities to identify, support these community resources, and join as partners in disaster response. Doing so would serve as a force-multiplier to strengthening the island's resilience against future catastrophic disasters.

⁴⁷³ Takahashi, Nieves, and Chavez, *Radio Practices and Their Impacts during Hurricane Maria in Puerto Rico*.

⁴⁷⁴ Respaut and Graham, "With Cell Service Crippled."

⁴⁷⁵ Klein and Feeney, "Puerto Ricans and Ultrarich 'Puertopians'."

b. Review

Hurricane Maria's threat to the Guajataca Dam also highlighted the need for functioning secondary and tertiary means of communicating risk to communities. If the NWS' warnings are the primary means, and audible stationary alert systems are a secondary, this need will remain problematic in hurricane scenarios that extensively affect the operability of both of these systems and methods of communication. Perhaps a tertiary means of notification is necessary, such as a PA system affixed to rotary wing aircraft or a ground strategy whereby first responders go door-to-door or utilize PA systems to warn residents to evacuate. Such capability would likely negate predictable hurricane impacts.

4. Finance

Loss of power, internet connectivity, and physical infrastructure rendered Puerto Rico a cash economy for a significant period of time. While many residents withdrew cash prior to Hurricane Maria's impact, the protracted nature of the response resulted in many quickly running low on cash to buy what critical supplies were available, such as food, water, and petroleum products.⁴⁷⁶ According to Zoime Alvarez, Vice President of the Association of Banks of Puerto Rico, by October 3, roughly 40% of bank branches were at least partially operational.⁴⁷⁷ This reduction in operations resulted in many residents spending much of their time using precious fuel, or walking long distances, in an attempt to find working ATMs so they could buy the necessary provisions for continued survival. The issues surrounding the functioning of banks was also multi-faceted; many branches did not have available drivers to deliver cash, each relied on generator power to operate, and their employees were subjected to the same disaster impacts as everyone else on the island.⁴⁷⁸

⁴⁷⁶ Ben Fox and Danica Coto, "Now Even Money Is Running Out in Hurricane-Hit Puerto Rico," AP News, September 28, 2017, <https://apnews.com/d98021c8616a451e9eca958638099abd>.

⁴⁷⁷ Patrick Gillispie and Jill Disis, "Puerto Rico Is Still in a Major Cash Crunch," CNN Money, October 3, 2017, <https://money.cnn.com/2017/10/03/news/puerto-rico-hurricane-banks-cash/index.html>; Danica Coto, "Puerto Rico Still Stumbles in the Dark a Month after Maria," *Seattle Times*, October 19, 2017, <https://www.seattletimes.com/business/puerto-rico-still-stumbles-in-the-dark-a-month-after-maria/>.

⁴⁷⁸ Gillispie and Disis.

a. Discussion

Finance is not often a frontline disaster response topic, however, a lack of access to cash or credit card services can be devastating to impacted communities.

b. Review

Luckily, Puerto Rico saw a plurality, if not a majority, of banking services back online within a reasonably short period of time; however, many throughout the island struggled to access their financial resources to provide for the essentials. Emergency financing and cash access must be a governmental disaster planning consideration, while storing cash reserves, when possible, remains the responsibility of all citizens.

5. 911 Communications

High winds and resulting damage to physical infrastructure also impacted other forms of communications, such as public safety answering points (PSAPs), or more commonly referred to as 911 call centers, cable providers, and radio broadcast stations. The morning after Hurricane Irma's impact, the two PSAPs in Puerto Rico were degraded in capability; the centers were able to receive 911 calls for service but without automatic location identifiers (ALIs), it was difficult to map calls and direct resources.⁴⁷⁹ By the time Hurricane Maria impacted Puerto Rico, the island's PSAPs were once again fully operational.⁴⁸⁰ Remarkably, the PSAPs continued to operate throughout Hurricane Maria's impact although ALI issues re-emerged along with others, which prompted dispatchers to resort to old analog methods of information gathering and recordkeeping.⁴⁸¹

As of 2019, it was reported that the PSAPs still lack ALIs and that 911 computer-aided dispatch systems still contained old mapping software that had not been updated

⁴⁷⁹ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 14–5.

⁴⁸⁰ Federal Communications Commission, 15.

⁴⁸¹ Federal Communications Commission, 17.

with new roads, businesses, and housing developments. 911 Commissioner, Yazmín González Morales, disagreed on the accuracy of this report.⁴⁸²

In addition to aforementioned outside responders and resources, the island also was afforded a great deal of regulatory relief via the FCC. For instance, the FCC offered support to the ARRL to alter broadcast intensity to facilitate better communications with the mainland. The FCC also afforded temporary provisions to reduce record-keeping requirements, permitted atypical bandwidth use, and waived interoperability requirements all in the interest of facilitating a rapid communications recovery.⁴⁸³

However, as power outages initially spread and communications capability degraded, citizens had little means of soliciting help from first responders. This unavailability forced many to resort to signaling “help” and messages, such as “send food” in large letters either on the ground or rooftops in hopes they would be spotted from the air.⁴⁸⁴ Residents also began using relays and word-of-mouth, a method even local governments were resorting to at the time.⁴⁸⁵ As late as October 30, 2017, just “12 of 78 police stations, 14 of 56 emergency medical service stations, and none of the 93 fire stations was able to relay 911 calls.”⁴⁸⁶ In practical terms, this inability meant that residents fortunate enough to be able to place a call to 911 may still not receive emergency services due to the lack of connectivity at responding stations.⁴⁸⁷

Amid the response, FEMA procured or issued satellite phones for many first responders, such as police, fire, and ambulance services, but 911 operators reported not having the numbers to the devices. Communications and coordination therefore remained a challenge.⁴⁸⁸ Satellite phones are typically expensive to procure and keep active service on, and are generally more complicated to use than a standard cellular phone that

⁴⁸² Robles, “New Emergency Sirens Sat in Storage.”

⁴⁸³ Federal Communications Commission, *2017 Atlantic Hurricane Season Impact*, 21.

⁴⁸⁴ Respaut and Graham, “With Cell Service Crippled.”

⁴⁸⁵ Respaut and Graham.

⁴⁸⁶ Fischbach et al., “After Hurricane Maria,” xxvii.

⁴⁸⁷ Fischbach et al., xxvii.

⁴⁸⁸ Robles, “New Emergency Sirens Sat in Storage.”

nearly everyone is now accustomed to using. This difficulty may lead to situations, such as Puerto Rico not having pre-planned satellite communications capabilities.

a. Discussion

In summary, 911 emergency communications capabilities in Puerto Rico proved able to work with FCC regulators to establish workarounds under exigent circumstances that ensured some baseline capability remained in place throughout the initial response.

b. Review

Hurricane Maria illustrated that a total loss of communication remains possible in the modern age, and local communities can take continuity of communications into their own hands. If each community had maintained HAM radios and operators, they each would have had a reliable means of communicating needs to the outside world. Not being able to communicate directly contributed to an inability to coordinate response and recovery personnel and resources. Gaining and maintaining situational awareness was a monumental task void of standard communications technology, and void of awareness, responders could not effectively apply disaster aid resources.

The scope and scale of damage to Puerto Rico's communications infrastructure is difficult to capture in its entirety; however, the issues discussed in this section offer insight into the major challenges that disaster responders, local community leaders, and residents contended with in the days, weeks, and months that followed Hurricane Maria. Writ large, communities throughout the island struggled to communicate needs and coordinate resources until cellular networks were reliably restored, which took a record-setting period of time. The ways in which Puerto Rico was able to cope with the consequences of Hurricane Maria can be instructive to other communities that may also find themselves isolated due to severe disaster impacts. Puerto Rico illustrates that solutions can be found and brought to bear even in extreme circumstances, and that many of those solutions can be found at the community-level.

6. Conclusion

Puerto Rico's pre-disaster communications infrastructure was beset with delayed maintenance issues, much like the power grid. Vulnerable communications infrastructure suffered severe damages amid Hurricane Maria that severely limited responders of all types from understanding the situation in communities across the island, and from coordinating and de-conflicting their actions. These issues naturally led to delayed responses, duplicative efforts, and a myriad of inefficiencies until temporary field communications could be erected, or hasty infrastructure repairs could be effected. However, the long-term power outage necessitated that most communications infrastructure operate on regular fuel resupply, which proved difficult to manage effectively.

As seen in other lifelines, non-governmental actors proved able to fill critical voids in government capability. The ARRL volunteers were able to establish themselves with key government actors and afford urgent communications bridges that may have not otherwise been possible under the same timelines.⁴⁸⁹ Likewise, the private sector proved able and interested in piloting new technologies, such as balloon platforms capable of providing cell and basic internet service, with mixed success, as an unconventional means of rapidly restoring communications.⁴⁹⁰ Adding another layer of complexity to the situation, essentially all transportation routes throughout the island were negatively impeded or impacted in some way by Hurricane Maria, which also contributed to the initial inability to distribute vital supplies to impacted communities.⁴⁹¹

⁴⁸⁹ American Radio Relay League, *ARRL 2017 After-Action Report*, 20.

⁴⁹⁰ "An Experimental New Project Is Helping Bring LTE Connectivity to Puerto Rico," NBC News, accessed October 5, 2020, <https://www.nbcnews.com/mach/video/google-is-helping-bring-lte-connectivity-to-puerto-rico-with-project-loon-1066391107923>; Jack Morse, "Google Officially Flips on Project Loon in Puerto Rico," Mashable, October 20, 2017, <https://mashable.com/2017/10/20/puerto-rico-project-loon-internet/>; Guynn, "Google Parent's Project Loon Delivers Internet to 100,000 in Puerto Rico"; Lavars, "Project Loon Balloons to Connect Storm-Ravaged Puerto Rico."

⁴⁹¹ See section on Bottlenecks in Palin, *Out of the Whirlwind*, loc. 1273; Federal Emergency Management Agency, *2017 Hurricane Season*, 29; Bessette-Kirton et al., "Landslides Triggered by Hurricane Maria,"; Karl Kim and Lily Bui, "Learning from Hurricane Maria: Island Ports and Supply Chain Resilience," *International Journal of Disaster Risk Reduction* 39 (October 2019): 101244, <https://doi.org/10.1016/j.ijdr.2019.101244>; Palin et al., *Supply Chain Resilience and the 2017 Hurricane Season*, 27.

F. TRANSPORTATION LIFELINE

FEMA defines the transportation lifeline as “Multiple modes of transportation that often serve complementary functions and create redundancy, adding to the resilience in overall transportation networks. This includes roadway, mass transit, railway, aviation, maritime, and intermodal systems.”⁴⁹² The components of this lifeline include highway/roadway/motor vehicle, mass transit, railway, aviation, and maritime.

This lifeline narrative offers little in terms of community preparations for disasters other than to highlight transportation impact challenges that communities are likely to face in catastrophic disasters. Communities appeared to play a less active role in managing and resolving transportation lifeline impacts during and after Hurricane Maria. This information however may be informative as communities develop their own catastrophic disaster plans and strategies. For this reason, this lifeline is addressed despite the paucity of data suggesting direct community involvement.

1. Highway/Roadway/Motor Vehicle

Puerto Rico has 18,358 miles of roadway spanning three categories: the National Highway System (NHS), state highways, and municipal roadways. The roadways are classified as follows: 284 miles are NHS-interstate highways, 496 miles are NHS non-interstate roadways, 4,296 miles are non-NHS roadways, and 13,280 miles are municipal road systems.⁴⁹³ Not all roadways are uniformly cataloged at the Commonwealth level; therefore, other sources indicate fewer miles of roadway, such as RAND’s estimation of 16,500 miles of roadway networks, and 2,222 bridges across the island.⁴⁹⁴ Regardless of the exact miles of roadways, Puerto Rico maintains a ring-route of highways that circumnavigate the island and serve as the primary over-the-road access points.⁴⁹⁵ In the aftermath of Hurricane Maria, some 6,000 incidents were reported to the island Department of Transportation (DTOP) including “landslides and collapsed and seriously

⁴⁹² Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 6.

⁴⁹³ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 38.

⁴⁹⁴ Fischbach et al., “After Hurricane Maria,” 211.

⁴⁹⁵ Fischbach et al., 211.

weakened bridges.”⁴⁹⁶ Hurricane Maria is estimated to have generated an astounding six million cubic yards of debris that resulted in just 400 miles of the island’s total roadways remaining passable.⁴⁹⁷

Importantly, in the context of Hurricane Maria, the municipality manages the municipal roadways. They exist, but are not under the central government, and therefore, are not required to meet federal or Puerto Rico Highway and Transit Authority (PRHTA) standards unless the project utilizes federal funding.⁴⁹⁸ Similar to other critical infrastructure sectors, the island’s roadways are plagued by a variety of issues including a lack of dedicated funding, poor construction standards, and laws allowing heavy freight leading to early roadway damage.⁴⁹⁹ Heavy structural impacts to Puerto Rico’s network of roadways, coupled with a near total loss of communications, degraded the island’s ability to coordinate response operations and deliver vital commodities via multi-modal transportation.⁵⁰⁰ For reference, Hurricane Maria triggered an estimated 40,000 landslides in three-fourths of the island’s 78 municipalities, which were two orders of magnitude greater than any previous experiences.⁵⁰¹ Blocked and collapsed roadways and bridges crippled the island’s ability to distribute commodities. Massive transportation impacts spurred FEMA to assume a leading role in not just supplying resources to the island’s ports and RSAs, but also ensuring the onward movement of supplies to final destinations, such as local points of distribution (PODs). Operating as the sole distributor was not a pre-planned role for FEMA, which led to supply chain breakdowns, staffing shortages, and an inability to source enough truck drivers.⁵⁰² Severe roadway and bridge damage across the island led FEMA, in partnership with the DOD, to begin an air reconnaissance of damages, and delivery of commodities to isolated areas as early as

⁴⁹⁶ Fischbach et al., 216.

⁴⁹⁷ Fischbach et al., 216.

⁴⁹⁸ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 43.

⁴⁹⁹ American Society of Civil Engineers, 38.

⁵⁰⁰ Federal Emergency Management Agency, *2017 Hurricane Season*, 27–8; Palin, “Learning from H.I.M. (Harvey, Irma, Maria).”

⁵⁰¹ Bessette-Kirton et al., “Landslides Triggered by Hurricane Maria.”

⁵⁰² Federal Emergency Management Agency, *2017 Hurricane Season*, 29.

three days post-hurricane impact.⁵⁰³ However, FEMA noted that information gleaned from damage assessment flights was difficult to communicate to those on the ground and therefore had limited impacts on improving the common operating picture of the response.⁵⁰⁴ Additionally, it remains unclear how effective supply airdrops were in terms of what percentage of needs was met, or if areas of highest priority received deliveries first.

The island also suffered from insufficient debris management contracting capability, which prolonged the inability to transport resources and commodities over-the-road. In 2018, the GAO found that the response to the 2017 hurricanes, particularly in the U.S. Virgin Islands and Puerto Rico, highlighted “longstanding issues,” including shortages in available debris removal contractors that delayed crucial recovery steps and “a lack of trained personnel with program expertise.”⁵⁰⁵ This deficiency led to long delays and an inability to reach the most impacted areas of the island, which in turn, led some municipalities to organize ad hoc debris removal crews comprised of local residents. For instance, in the town of Aibonito, crews would work during the daylight hours and convene on the town center by evening, the only area with power restored.⁵⁰⁶ This scenario serves as one example of a community coming together to fill a void by performing a public service at a time when their government and private contractors fell short of fulfilling disaster response and recovery obligations.

a. Discussion

Much like the health and medical lifeline, access and situational awareness were major challenges in the early response phase as it related to transportation. Amid significant roadway and bridge impacts, ARRL HAM radio operators were once again the “eyes and ears” as they had VHF radio operators spread throughout the island that allowed them to construct an incident map of open and closed routes, and other damages

⁵⁰³ Federal Emergency Management Agency, 29.

⁵⁰⁴ Federal Emergency Management Agency, 34.

⁵⁰⁵ Currie, *2017 Hurricanes and Wildfires*, 3.

⁵⁰⁶ Deibert, *When the Sky Fell*, 119.

impacting the response operation.⁵⁰⁷ In total, 131 local radio operators and 22 mutual-aid operators supported the island’s communication and situational awareness needs.⁵⁰⁸ This capability proved pivotal at a time when governmental elements struggled to gain and maintain island-wide situational awareness.

b. Review

Crowdsourcing information from individuals regarding transportation impacts also proved vital in Puerto Rico. FEMA alone noted that 5,400 “digital volunteers” provided information on roadway and bridge closures, hospital status, and food and fuel availability.⁵⁰⁹ This latent community capability, combined with the role of ARRL HAM radio operators, illustrates the critical role non-governmental actors play in disaster response, and secondarily, indicates a need to plan for leveraging these capabilities, particularly in catastrophic disasters.

Additionally, NGOs proved able to access hard-to-reach areas of the island and render aid. For example, an organization called Visit Rico was able to gain access to rural farms and support their owners with funding and by organizing debris removal volunteers.⁵¹⁰ In the days, weeks, and months following Hurricane Maria, Farm Aid was able to work through Visit Rico to get cash in farmers’ hands and organize a “Farm to Farm” fundraiser in which mainland farms supported those impacted by the hurricane in Puerto Rico.⁵¹¹ Additionally, the COSSAO organization focused on clearing debris, opening roadways, and conducting emergency bridge repairs in concert with other organizations.⁵¹²

⁵⁰⁷ American Radio Relay League, *ARRL 2017 After-Action Report*, 3.

⁵⁰⁸ American Radio Relay League, 3; Murphy and Krupa, “HAM Radio Operators Saving Puerto Rico.”

⁵⁰⁹ Federal Emergency Management Agency, *FEMA After-Action Report*, 34.

⁵¹⁰ Tess Bonn, “Puerto Rico Governor: Private Sector, Nonprofits Better Positioned than Government to Help with Rebuilding,” *TheHill*, September 20, 2018, <https://thehill.com/hilltv/rising/407571-hurricane-maria-one-year-later>.

⁵¹¹ Sophie Friedman, “Hurricane Maria: A Look at the Family Farm Disaster Fund in Puerto Rico,” *Farm Aid*, August 3, 2018, <https://www.farmaid.org/blog/family-farm-disaster-fund-puerto-rico/>.

⁵¹² Holladay et al., “Utuado,” 11.

The experience of Puerto Rico calls for a recognition of the limitations of contractual and governmental ability to provide for all services, particularly concerning debris clearance and the rapid re-opening of critical pathways in communities. An inability to open roadways rapidly inhibits the ability to provide medical aid, to deliver food and water provisions, to conduct fuel deliveries, as well as other critical response functions. Delays in services and physical isolation indicate a need to re-evaluate latent community capability and reimagine the role of residents in extreme times of needs amid catastrophic disaster impacts. In some instances, municipalities may be required to mobilize able-bodied citizens rapidly to perform emergency route clearance for the greater good of the community, which may be a difficult subject that raises questions as to the role and capacity of the government to be the public service provider.⁵¹³

2. Mass Transit

Puerto Rico has limited mass transit capability that suffers from financial deficits. The systems the island does maintain are primarily centered on San Juan, managed by the Integrated Transit Authority (ATI, by its Spanish acronym) under the PRHTA.⁵¹⁴ Tren Urbano is a fully automated rapid transit system consisting of 74 Siemens heavy rail transit vehicles that service the municipalities of San Juan, Guaynabo, and Bayamon, via a 10.7-mile track with 16 stops.⁵¹⁵ The system is operated by Alternate Concepts Incorporated and is capable of a max speed of 62 miles-per-hour with a capacity of 144 seated and 216 standing passengers per each two-car unit.⁵¹⁶ ATI indicates that it provides 166-weekday trips, 138-weekend trips, services 26,500 trips per day on a schedule spanning from 5:30 AM to 11:30 PM.⁵¹⁷ A variety of proposals have been made over the years to expand this system, but none have come to fruition. Following

⁵¹³ Fjäder, “The Nation-State, National Security and Resilience,” 127–8.

⁵¹⁴ “Rail Services,” Alternate Concepts Inc., 2020, <http://www.acitransportation.com/services-rail.html>.

⁵¹⁵ Alternate Concepts Inc.; Fischbach et al., “After Hurricane Maria,” 211.

⁵¹⁶ “Tren Urbano,” Railway Technology, 2020, <https://www.railway-technology.com/projects/tren/>.

⁵¹⁷ Alternate Concepts Inc., “Rail Services.”

Hurricane Maria, Tren Urbano services were suspended until December 19, 2017 due to substations not having power.⁵¹⁸

San Juan also maintains the Metropolitan Bus Authority and the Cataño, Culebra, and Vieques Ferries. The public bus service provides connections via 31 routes between the areas of San Juan, Carolina, Cataño, Guaynabo, Trujillo Alto, and Bayamón that services approximately 80,000 riders on workdays.⁵¹⁹ The fleet reportedly contains only 26 metrobuses. Approximately 28 other municipalities report providing some type of public transportation service on either fixed or demand-based schedules.⁵²⁰ Additionally, prior to Hurricane Maria, an estimated 1,884 privately owned public transport vehicles throughout the entire Commonwealth provided some imprecise level of community service.⁵²¹ By September 29, 21 of the 23 metropolitan bus routes were back in service.⁵²²

The Cataño Ferry consists of one line connecting Cataño on the western shore of the Bay of San Juan to the city of Old San Juan and is operated by AcuaExpreso.⁵²³ The Culebra and Vieques ferries are operated out of the Ceiba Ferries Terminal Building on the island's eastern shore and provide services to residents and tourists living on or visiting each island. The government of Puerto Rico allocated just over \$1 million in routine maintenance funds for the ferry terminal in its FY 2019–2022 plan under the Statewide Transit Improvement Program (STIP), \$3 million for ferry maintenance,

⁵¹⁸ Fischbach et al., “After Hurricane Maria,” 217.

⁵¹⁹ “Amenazan con dejar a pie a usuarios de transporte público,” *Primera Hora*, November 21, 2014, <https://www.primerahora.com/noticias/gobierno-politica/notas/amenazan-con-dejar-a-pie-a-usuarios-de-transporte-publico/>. See bus routes in Integrated Transit Authority, *Plan de servicio: folleto informativo rutas de servicio* (San Juan, PR: Estado Libre Asociado de Puerto Rico, n.d.), 4–32, accessed September 8, 2020, <https://311prkb.respondcrm.com/respondweb/AMA-D004%20Folleto%20Informativo%20Rutas%20de%20Servicio/AMA-D004%20Folleto%20Informativo%20Rutas%20de%20Servicio.pdf>.

⁵²⁰ Fischbach et al., “After Hurricane Maria,” 211.

⁵²¹ Fischbach et al., 211.

⁵²² The author was unable to locate the original source as cited by the RAND Corporation. Fischbach et al., 217.

⁵²³ “Cataño Ferry/Old San Juan Ferry,” San Juan Puerto Rico, accessed September 8, 2020, <https://sanjuanpuertorico.mystagingwebsite.com/catano-old-san-juan-ferry/>.

\$90,000 for waterway dredging, and \$25 million for the development of a cargo ferry system connecting out of the military base, Roosevelt Roads.⁵²⁴

a. Discussion

A 2016 DTOP fiscal year report indicated a transportation infrastructure operating at a fiscal deficit.⁵²⁵ Issues pertaining to the solvency of the public transportation infrastructure partially stem from declining credit ratings—linked to long-term, island-wide divestment—and has been addressed via proposing fuel tax increases on the island.⁵²⁶ The struggles of public transportation in Puerto Rico are a pertinent reminder that disasters do not occur in socioeconomic vacuums, but instead, overlay and often exacerbate existing local dynamics. Collectively, financial strain and insolvency combined with disaster result in lower resiliency of such public services.

b. Review

Massive transportation infrastructure impacts led many Puerto Ricans to travel long distances on minimal fuel supplies in search of bare life essentials in the days and weeks following the storm.⁵²⁷ This situation highlights a need for substantial community-level lifeline resources that build resiliency into the infrastructure network. In areas of extreme isolation, heavy impacts, and long delays, surrounding the influx of key resources, becomes a central consideration when preparing for and mitigating against future catastrophic disasters.

⁵²⁴ Puerto Rico Department of Transportation and Public Works and Puerto Rico Highway and Transportation Authority, *Statewide Transportation Improvement Program (STIP): Fiscal Year 2019–2022* (San Juan, PR: Government of Puerto Rico, 2019), 60, <https://act.dtop.pr.gov/wp-content/uploads/2019/03/Final-STIP-2019-2022-March-1.pdf>.

⁵²⁵ Puerto Rico Department of Treasury, *Commonwealth of Puerto Rico: Basic Financial Statements and Required Supplementary Information* (San Juan, PR: Government of Puerto Rico, 2016), 37.

⁵²⁶ *Primera Hora*, “Amenazan con dejar a pie a usuarios de transporte público.”

⁵²⁷ Steven Mufson, “A Cry from Puerto Rico: ‘In My Life, I Have Never Seen Anything So Mismanaged,’” *Washington Post*, September 29, 2017, <https://www.washingtonpost.com/news/wonk/wp/2017/09/29/a-letter-from-puerto-rico-no-fuel-no-cash-no-food/>; Associated Press, “Puerto Ricans Hunt for Precious Wi-Fi.”

3. Railway

Puerto Rico no longer maintains a cargo rail system since the decline of the agricultural sector and the widespread use of the automobile and over-the-road freight hauling. Instead, personal vehicles and semi-trucks are utilized for the daily transport of persons and materials.

4. Aviation

Puerto Rico has 29 airports or airstrips, 17 of which are paved, and just two are longer than 3,000 meters.⁵²⁸ The Puerto Rico Ports Authority (PRPA) oversees the island's air and seaports.⁵²⁹ Rapid airport assessments became a critical factor in re-establishing passenger and cargo air transports into the island following Hurricane Maria. Once the re-opening of airports occurred, most operated at limited capacity for at least one week post-landfall, increasing supply transit times, and limiting the ability to receive disaster aid.⁵³⁰ Despite heavy transportation impacts and the limited capacity of airports, FEMA reports that the first aircraft carrying relief supplies landed in San Juan on September 23, one day after landfall. The agency coordinated daily flights until October 19.⁵³¹

a. Discussion

The ASCE noted in 2019 that because of Puerto Rico's isolated position, it is vital that its infrastructure become more resilient than the mainland infrastructure.⁵³² However, communities have a limited role in aviation operations in Puerto Rico other than being politically active and partaking in community mitigation decision-making and prioritization practices that may impact the resiliency of such infrastructure.

⁵²⁸ Central Intelligence Agency, "Central America: Puerto Rico."

⁵²⁹ American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 34.

⁵³⁰ Federal Emergency Management Agency, *2017 Hurricane Season*, 25.

⁵³¹ Federal Emergency Management Agency, 26.

⁵³² American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 32.

b. Review

The larger responsibility for resilient air transport infrastructure falls to local, state, and federal governments. Notwithstanding, residents of heavily impacted areas will bear the brunt of a degraded supply chain, whether issues of supply or distribution plague it, or both when infrastructure disruptions do occur. However, these disruptions are both predictable and amenable by risk mitigation in the form of pre-planning and building of self-reliance that allows slack—in the form of time and resources—in critical supply chains until services can be restored to reasonable pre-disaster levels. Citizens can be active participants in how their local and state governments approach mitigation planning, and can use the impacts of Hurricane Maria to inform future planning assumptions for catastrophic disasters.

5. Maritime

Puerto Rico imports at least 80–85% of its food, and 98% of its electricity is derived from imported petroleum, natural gas, and coal products.⁵³³ Although the island maintains port facilities in Isla Grande, Ponce, Mayaguez, Puerto Nuevo Army Terminal, Arecibo, Yabucoa, Guyanilla, and Guánica, the Port of San Juan receives the bulk to maritime shipments and nearly all cargo.⁵³⁴ In 2017, the island received 212 maritime fuel shipments, and the Port of San Juan received 164 cargo shipments holding over 1.3 million containers.⁵³⁵ As of 2017, and since 2015, most port calls to San Juan were performed by just 16 vessels.⁵³⁶ Prior to this period, roughly 22 U.S. vessels regularly resupplied the island, which was a decline from years prior.⁵³⁷ This surviving fleet comes following years of corruption and bankruptcy of major shipping providers.⁵³⁸ As

⁵³³ Mares, “Cultivating Comida”; American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 8; American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*, 34; Palin, *Out of the Whirlwind*, loc. 105.

⁵³⁴ American Society of Civil Engineers, *2019 Report Card for Puerto Rico’s Infrastructure*; Central Intelligence Agency, “Central America: Puerto Rico.”

⁵³⁵ American Society of Civil Engineers, 35.

⁵³⁶ Palin, *Out of the Whirlwind*, loc. 163.

⁵³⁷ Palin, loc. 163.

⁵³⁸ Palin, loc. 163.

noted under the food, water, and shelter lifeline, most cargo containers arriving in the Port of San Juan following Hurricane Maria were generically labeled from their JAXPORT, Florida point of embarkation as “FEMA Freight,” on the bill of lading, and “Disaster Relief” on the containers.⁵³⁹

Nine additional vessels were allocated to routes from the mainland to San Juan, which increased shipment capacity by 40% to support the surge of supplies to Puerto Rico.⁵⁴⁰ While successfully getting additional needed resources and commodities to the island, it did little to solve the distribution bottleneck plaguing the response mission. In many ways, supply shortages during Hurricane Maria in Puerto Rico, initially misdiagnosed as supply issues, were later discovered to be more related to problems of distribution. The result for Puerto Rican communities was the same, causing widespread resource shortages, such as food, water, fuel, power, telecommunications, and medical treatment.

a. Discussion

Puerto Rico is heavily reliant on maritime-imported products of all types to support daily life on the island, which presents a vulnerability, as well as also creates a need to “buy time” by stockpiling critical resources ahead of time for periods of massive disaster impacts.

b. Review

Foreknowledge of the island’s dependency on regular supply shipments can also inform the actions of the community and volunteer organizations active in disaster relief by setting realistic expectations of time delays in the restoration of routine community lifeline services compared to other less geographically challenging locales.

⁵³⁹ Palin, loc. 165.

⁵⁴⁰ Palin, loc. 312.

6. Conclusion

Puerto Rico's geographically isolated position ensures that the timely and effective flow of all commodities and resources is particularly vulnerable to disruption. Without substantial on-island stockpiles, Puerto Rico is wholly reliant on an uninterrupted flow of goods to communities. However, the island's highways, mass transit, aviation, and maritime infrastructure were often in disrepair and structurally vulnerable prior to Hurricane Maria's impacts.⁵⁴¹

Supply shortages in Puerto Rican communities resulted primarily from issues of distribution.⁵⁴² As Hurricane Maria approached, standard maritime supply shipments were halted, to be replaced temporarily with disaster relief shipments. Ports became quickly overloaded with containers, particularly when road networks proved incapable of supporting over-the-ground shipments due to roadway and bridge damage, and a record-setting number of landslides.⁵⁴³ Complicating impacts to road network impacts, debris contractors proved incapable to executing contracts, which spurred some communities to pool resources to tackle common problems, such as determining the locations of isolated homes, forming cooperative teams to perform debris and route clearance, and pooling available tools and heavy equipment from machetes to bulldozers.⁵⁴⁴

Short of supplies, communities were left to pool their own resources within families and communities, and go in search of scant available commodities.⁵⁴⁵ This search often entailed transiting dangerous roadways, and developing creative solutions to

⁵⁴¹ American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 7; Fischbach et al., "After Hurricane Maria," 12.

⁵⁴² See section on Bottlenecks in Palin, *Out of the Whirlwind*, loc. 1273.

⁵⁴³ Palin, loc. 239; Fischbach et al., "After Hurricane Maria," 130; Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*.

⁵⁴⁴ Anais Delilah Roque, David Pijawka, and Amber Wutich, "The Role of Social Capital in Resiliency: Disaster Recovery in Puerto Rico," *Risk, Hazards & Crisis in Public Policy* 11, no. 2 (April 2020): 217, <https://doi.org/10.1002/rhc3.12187>.

⁵⁴⁵ Dickerson and Ferré-Sadurní, "'Like Going Back in Time'"; Karl Vick, "A Land They No Longer Recognize," *Time*, accessed July 13, 2020, <https://time.com/a-land-they-no-longer-recognize/>; Allen, "'I Don't Feel Safe'"; Rios, "In Puerto Rico"; Dickerson, "Stranded by Maria"; Allen, "To Build Resilience"; Holladay et al., "Utuado," 6; Dorell, "With Long Lines for Food, Water and Fuel and No Electricity."

navigate damaged bridges connecting communities to the outside world.⁵⁴⁶ In addition, as residents ventured outside, the risk of exposure to a wide range of HAZMAT was ever-present.

G. HAZARDOUS MATERIALS LIFELINE

FEMA defines the hazardous material lifeline as “systems that mitigate threats to public health or the environment. This includes facilities that generate or store hazardous substances, as well as all specialized conveyance assets and capabilities to identify, contain, and remove pollution, contaminants, oil, or other hazardous materials and substances.”⁵⁴⁷ The components of this lifeline include facilities, and HAZMAT, pollutants, and contaminants.⁵⁴⁸

Due to a paucity of data pertaining to this community lifeline, this chapter only briefly outlines the HAZMAT impacts created by Hurricane Maria. While communities play a vital role in all community lifelines, information pertaining to the specific impacts and adaptations to HAZMAT in relation to community actions are scarce and is reflected in the level of detail provided as follows.

1. Facilities

Gaining and maintaining situational awareness of the HAZMAT facility status proved challenging for FEMA. One week into the response, on September 27, the agency still only had awareness of the status of 24 of the 52 wastewater treatment facilities serving communities across the island.⁵⁴⁹ By January 2018, the Environmental Protection Agency (EPA) reported 284 personnel on the ground in Puerto Rico.⁵⁵⁰ According to an EPA news release, the agency was focused upon debris management,

⁵⁴⁶ Porta, “Lessons in Community Resilience”; Dickerson, “Stranded by Maria.”

⁵⁴⁷ Federal Emergency Management Agency, *FEMA Incident Stabilization Guide*, 7.

⁵⁴⁸ Federal Emergency Management Agency, 6.

⁵⁴⁹ Federal Emergency Management Agency, *2017 Hurricane Season*, 33.

⁵⁵⁰ U.S. Environmental Protection Agency, *News Release: EPA Hurricane Maria Update* (Washington, DC: U.S. Environmental Protection Agency, 2018), 1, <https://response.epa.gov/sites/12403/files/Maria%20Update%20January%204%20FINAL%20ENGLISH.pdf>.

hazardous household materials, marine operations, drinking and wastewater management, and water safety.⁵⁵¹

The EPA's primary role consisted of coordinating with local governments, assessing the status of drinking water, providing analysis and test lab support, and identifying strategies to return wastewater facilities to functional statuses.⁵⁵² This type of coordination was a challenging endeavor due to the widespread and long-term loss of the power grid, which in turn, impacted the ability to source and supply fresh, safe drinking water for communities across the island.⁵⁵³

Particular EPA attention was paid to serving some 76,000 residents in approximately 200 communities served by non-PRASA, independent water systems.⁵⁵⁴ In September 2018, the EPA further strengthened ties with seven organizations including NGOs and universities under a memorandum of understanding to bolster the safety and performance of independent, non-PRASA water systems serving communities in Puerto Rico.⁵⁵⁵ Many of these systems exist in remote areas of the island. By focusing on building the capacity of non-PRASA water systems, residents served by these systems can become more water resilient over the long-term. It also remains important for Puerto Rico to apply resources to building the safety, reliability, and resiliency of PRASA systems that serve millions of Puerto Rico before, during, and after disasters.

a. Discussion

Puerto Rico's substandard water and wastewater facilities are partly due to long-term infrastructure neglect due to divestment and subsequent financial strains throughout

⁵⁵¹ U.S. Environmental Protection Agency.

⁵⁵² U.S. Environmental Protection Agency, *EPA Year in Review: 2017–2018* (Washington, DC: U.S. Environmental Protection Agency 2018), 18, <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100YAC2.PDF?Dockey=P100YAC2.PDF>.

⁵⁵³ Oxfam America, *Far from Recovery*, 6.

⁵⁵⁴ U.S. Environmental Protection Agency, *News Release: EPA Hurricane Maria Update*, 3.

⁵⁵⁵ U.S. Environmental Protection Agency, *Year in Review: 2018* (Washington, DC: U.S. Environmental Protection Agency, 2018), 32, <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100WFZH.PDF?Dockey=P100WFZH.PDF>.

the island since the early 2000s.⁵⁵⁶ Void of long-term reinvestment in water infrastructure, Puerto Ricans are very likely to remain vulnerable to similar infrastructure vulnerabilities and contaminant exposures in future disasters.

b. Review

The underlying vulnerable status of Puerto Rican critical infrastructure serves as a vital planning consideration as communities consider their role in future catastrophic disasters, community risks, and strategies to increase resiliency. Nationwide, residents of all communities benefit from legislation known as Superfund Amendments and Reauthorization Act (SARA) Title III, Emergency Planning and Community Right-to-Know Act (EPCRA). Under this legislation, entities storing and using chemicals identified as extremely hazardous substances (EHS) must abide by regular public reporting requirements, such as submitting material safety data sheets (MSDSs) to local governments, are encouraged to participate in emergency planning with concerned local governments, must report chemical releases, and requires that states form emergency response commissions (SERCs), emergency planning districts, and local emergency planning committees (LEPCs) for each district.⁵⁵⁷

In Puerto Rico, the state Environmental Quality Board manages reporting requirements and industry is required to submit information regularly to the SERCs, LEPCs, and local fire departments.⁵⁵⁸ This submission offers citizens an opportunity to become aware of what threats exist within their own communities, have a dialogue with local governments, and craft community plans to increase safety post-disaster. No data were located that would suggest the impact that either the SERC or LEPCs had on the HAZMAT response to Hurricane Maria, but SARA Title III, and the EPCRA serve as

⁵⁵⁶ American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 23–6.

⁵⁵⁷ “What Is SARA Title III?,” Indiana Department of Homeland Security, 2020, <https://www.in.gov/dhs/2526.htm>; Environmental Protection Agency, “Summary of the Emergency Planning & Community Right-to-Know Act,” Overviews and Factsheets, Laws and Regulations, December 27, 2018, <https://www.epa.gov/laws-regulations/summary-emergency-planning-community-right-know-act>; “What Is EPCRA? Overviews and Factsheets,” Environmental Protection Agency, October 1, 2020, <https://www.epa.gov/epcra/what-epcra>.

⁵⁵⁸ “State Tier II Reporting Requirements and Procedures,” Environmental Protection Agency, September 28, 2020, <https://www.epa.gov/epcra/state-tier-ii-reporting-requirements-and-procedures>.

inroads to community involvement in understanding, planning for, and mitigating against hazards contained in their own communities.

2. HAZMAT, Pollutants, Contaminants

Throughout Puerto Rico, drinking and wastewater facilities present poor safety track records, and HAZMAT from a number of industries, such as farming, pharmaceutical production, petroleum facilities, coal plants, and others, and serve as major sources of pollution posing public risk. Over the years, Puerto Rico has struggled within HAZMAT facility federal safety compliance. In 2016, PRASA was issued a consent decree by the EPA due to violations of sections 301 and 402 of the Clean Water Act in connection with the island's wastewater treatment plants (WWTPs) and drinking water treatment plants (DWTPs).⁵⁵⁹ On December 19, 2016, PRASA entered a guilty plea on 15 felony counts of violating the Clean Water Act specific to nine WWTPs, and five DWTPs.⁵⁶⁰ These violations indicate a baseline, pre-disaster struggle with ensuring clean and safe drinking water to island residents as an underlying context that was then heavily impacted by Hurricane Maria.

Puerto Rico's groundwater is potentially affected by a multitude of contaminants, but many stem from the coal industry, poultry farms, pesticides, and septic systems. The Aguirre power plant alone burns tons of coal that results in massive amounts of coal ash, which is difficult to dispose of safely from an island environment. As a result, huge mounds of coal ash remain on-site and are subject to rain and runoff. These sites are concentrated in the southeast of the island near communities with high rates of poverty and unemployment that potentially exposes some of the island's most vulnerable to toxins.⁵⁶¹

⁵⁵⁹ Environmental Protection Agency, *Consent Decree: Puerto Rico Aqueduct and Sewer Authority Clean Water Act Settlement* (Washington, DC: Environmental Protection Agency, 2016), <https://www.epa.gov/sites/production/files/2013-09/documents/prasa-cd060706.pdf>.

⁵⁶⁰ Environmental Protection Agency, "Puerto Rico Aqueduct and Sewer Authority Settlement," EPA Enforcement, December 19, 2016, <https://www.epa.gov/enforcement/puerto-rico-aqueduct-and-sewer-authority-settlement>.

⁵⁶¹ Fischbach et al., "After Hurricane Maria," 354.

A recent groundwater analysis indicated that selenium, lithium, and molybdenum exceeded EPA maximum limits by a factor of four to 14 times.⁵⁶² A follow-up study claims that despite the pollution, drinking water reserves have not been penetrated, and therefore present no drinking water health impact to island residents.⁵⁶³ While this assertion may or may not be factual, it is well known that floodwaters greatly increase the potential to spread dangerous chemicals over large areas, which makes community exposure more likely. Additionally, nitrogen runoff from poultry farms, pesticides, and septic systems pose water safety challenges to the island.⁵⁶⁴

On a community level, contaminated water posed a public health risk that was difficult to avoid in light of widespread power and subsequent water outages that led residents to seek alternative sources, such as rivers, rainwater runoff, and spring water from nearby sources.⁵⁶⁵ Despite FEMA and the DOD undertaking the largest food and water mission in U.S. disaster aid history, many residents were without fresh water for considerable periods of time, most for a matter of weeks.⁵⁶⁶ In the interim, contact with and consumption of contaminated water is credited with a witnessed rise in diseases, such as leptospirosis, across the island in the weeks and months following the storm.⁵⁶⁷ These

⁵⁶² Alexander Kaufman, “Puerto Rico’s Next Big Crisis Is Water,” *HuffPost*, updated December 16, 2019, https://www.huffpost.com/entry/puerto-rico-water_n_5dd2e6e9e4b0d2e79f917f43?guccounter=1&guce_referrer=aHR0cHM6Ly9kdWNrZHVja2dvLmNvbS8&guce_referrer_sig=AQAAAGgxufzL2bA4vV-ZfV_IyP3hkuZYaOo8XndeYwq7f_O2CgO9_CkyHl_q7Vs6gOuiirdQF_xtS7b4rzjmHa-iBe4E7EHy9S0BLRjEzi_OGskAROm9ST3N5xzCFYZwY0hImbAYa2WS3IulYik9KCrjaRBLszh546JC1yg20jJjQEIC; DNA-Environment, LLC, *2018 CCR Annual Groundwater Monitoring Report* (Guaynabo, PR: AES Puerto Rico, 2019), http://aespuertorico.com/wp-content/uploads/2019/03/180161r_AES_2018_Groundwater_Monitoring_Report.pdf.

⁵⁶³ Kaufman, “Puerto Rico’s Next Big Crisis Is Water”; Haley Aldrich, *Summary of the Haley & Aldrich Groundwater Risk Evaluation for AES Puerto Rico in Guayama* (Guaynabo, PR: AES Puerto Rico, 2019), 2, 4, https://www.aespuertorico.com/wp-content/uploads/2019/03/2019-0325_AES-PR_FactSheet_F.pdf.

⁵⁶⁴ Kaufman.

⁵⁶⁵ Fiala, “Behind the Veil”; Schmidt and Hernández, “Trapped in the Mountains.”

⁵⁶⁶ Dickerson, “Stranded by Maria.”

⁵⁶⁷ By November 2017, 99 suspected cases of leptospirosis, 18 confirmed cases, and four fatalities had resulted; the island typically sees between 63 and 95 cases over a 12-month period. Deibert, *When the Sky Fell*, 112; Irfan, “9 Months after Hurricane Maria”; Cordero, “Aumenta la cantidad de casos sospechosos y confirmados de leptospirosis en puerto rico”; Oxfam America, *Far from Recovery*, 6; Nedelman, “Suspected Leptospirosis Cases on Rise in Puerto Rico.”

cases provide one example of the elevated health risks communities face in the wake of disasters. Although a major spike in the spread of diseases does not appear to have occurred in Puerto Rico following Hurricane Maria, the potential is always an important consideration for resident safety and wellbeing as floodwaters often contain dangerously high levels of toxic chemicals, operate as vectors for diseases, and standing water also aids in proliferating mosquito populations that carry a variety of diseases, such as malaria, chikungunya, dengue, and zika.⁵⁶⁸ Recognizing that floodwaters serve as a primary threat that hurricanes pose to communities, the CDC publicly warns that contact with floodwaters risks exposure to chemicals, household waste, sewage, wild or stray animals, and may result in a wide variety of medical conditions from leptospirosis, skin rashes, wound infections, tetanus, and others.⁵⁶⁹

a. Discussion

Risks posed by these hazards are important for residents to understand *before* disasters so they can take sensible protective measures in the wake of the next catastrophic disaster.

b. Review

Puerto Rico presents an urgent need to build “slack” into the water supply chain to minimize contact with, and consumption of, potentially contaminated water sources following disasters, such as hurricanes. When communities lack access to fresh, safe water supplies post-disaster, residents are forced to source water from nearby rivers, streams, and lakes that have a great potential of being contaminated by natural pathogens, dangerous industrial chemicals, or both. Areas known to be difficult to access, and slow to receive disaster aid, are likely at an elevated risk of contaminant exposure as they await emergency fresh water distribution networks to mature either in the form of water bottle distribution, water trailers, or other methods. Building “slack” into the water supply chain would necessarily entail building pre-disaster water stockpiles, and

⁵⁶⁸ Hernandez, “In Puerto Rico.”

⁵⁶⁹ U.S. Centers for Disease Control, “Floodwater after a Disaster or Emergency,” September 2020, <https://www.cdc.gov/disasters/floods/floodsafety.html>.

developing alternative means of safe water storage, such as cisterns resistant to wind or seismic damage.

3. Conclusion

Puerto Rico is home to a large number of HAZMAT facilities from wastewater treatment plants to coal and gas-fired power plants that present a risk of contamination to surrounding communities. Disasters, such as Hurricane Maria, have an expanding effect on existing HAZMAT and present other threats, such as contaminated floodwaters, and compromising drinking water supplies.⁵⁷⁰ Additionally, Puerto Rico has a long-standing track record of questionable water quality under normal circumstances.⁵⁷¹

Regardless of the typical water safety standards, the lack of primary water systems and basic supplies forced many Puerto Ricans to drink from, and bath with, clearly unsafe water sources, such as streams, rivers, and mountain runoff for long periods of time, and necessitated repetitive contact with contaminated floodwaters as residents aided each other and went in search of supplies.⁵⁷² Research did not indicate that largescale water stockpiles or alternative water sources were an element of disaster preparedness efforts prior to Hurricane Maria. This situation was particularly problematic, as the distribution of water bottles and generators to support drinking water facilities were plagued by slow and complex distribution.⁵⁷³

⁵⁷⁰ Lin Yishan et al., “Impact of Hurricane Maria on Drinking Water Quality in Puerto Rico,” *Environmental Science and Technology* 54, no. 15 (July 8, 2020): 9495–9509; “In Puerto Rico, One Community Leader Prepares for What’s Next,” Mercy Corps, January 7, 2019, <https://www.mercycorps.org/blog/puerto-rico-community-leader-hurricane-maria>; Mekela Panditharatne, “New Data: 2 Million Puerto Ricans Risk Water Contamination,” NRDC, December 11, 2017, <https://www.nrdc.org/experts/mekela-panditharatne/over-2-million-puerto-ricans-risk-bacteria-water>; Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’,”; Michael Melia, “Puerto Rico Contaminated with Raw Sewage After Hurricane Maria,” *The Weather Channel*, October 16, 2017, <https://weather.com/en-CA/canada/news/news/puerto-rico-raw-sewage>; Kaufman, “Puerto Rico’s Next Big Crisis Is Water”; “Raw Sewage Contaminating Water in Puerto Rico after Maria,” *CBS News*, October 17, 2017, <https://www.cbsnews.com/news/raw-sewage-contaminating-water-puerto-rico-hurricane-maria/>; Aldrich, *Summary of the Haley & Aldrich Groundwater Risk Evaluation*.

⁵⁷¹ Natural Resources Defense Council, *Threats on Tap*; Yishan et al., “Impact of Hurricane Maria on Drinking Water Quality in Puerto Rico”; Hernandez, “In Puerto Rico; Heredia Rodriguez, “Water Quality in Puerto Rico.”

⁵⁷² Fiala, “Behind the Veil”; Schmidt and Hernández, “Trapped in the Mountains.”

⁵⁷³ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*; Fischbach et al., “After Hurricane Maria.”

H. SUMMARY

In sum, major preparedness gaps were both evident and substantial across all community lifelines. In a majority of cases, outside resources met disaster relief needs, as per the NRF, either by state mutual-aid resources, NGOs, the DOD, or other federal agencies. However, in many instances, disaster relief was delayed or inadequate in the early stages of the disaster. Many communities thus experienced critical resource deficits for weeks post-impact with the most concerning shortfalls pertaining to food, water, and medical services. Communities in rural and mountainous areas were often cutoff from resupply and aid by collapsed roadways and bridges after the island experienced a record-setting number of landslides. Overall, Puerto Rico's experience illustrated a situation in which the outer boundaries of the NRF were reached, and how, in such circumstances, when the framework began to fray, communities were compelled to fill the void. It is possible to consider future scenarios in which the NRF may be degraded further and suffer collapse, and as a result, isolate communities for longer periods of time, which is a potentiality that should drive future preparedness initiatives.

Despite devastating impacts and substantial resource shortfalls across the community lifelines and throughout the island, the study of Puerto Rico also indicated the presence of close-knit communities coming together to provide each other impromptu mutual-aid, emergent ingenuity, as well as a vibrant community-based organization network. Hurricane Maria also appears to have served as a catalyst to revive grassroots partnerships and preparedness initiatives from community healthcare to agrotherapy.

Puerto Rico's experience with Hurricane Maria displayed many formal and informal actors coming together, rising to the occasion, but also exposes a lack of pre-planning and integration of unconventional disaster actors. Documenting these instances affords a blueprint and ample future opportunity to reconsider how the island plans and prepares for disasters, and may inform future disaster resiliency benchmarks.

All disasters begin and end locally. If disaster programs can serve as gardener of the grassroots from the bottom-up, while also aligning top-down disaster plans and resources, then federal, state, local, and community actors can meet in the middle within

a more resilient Puerto Rico. The following chapter synthesizes themes present within all community lifelines, and provides lifeline-specific conclusions that can inform a path forward for Puerto Rico, and other communities seeking to achieve similar disaster preparedness goals.

IV. THEMES AND CONCLUSIONS

A. THEMES

Throughout the course of this study, several themes became apparent across all community lifelines. Each theme is presented as an element for consideration for a future in which Puerto Rico is resilient and prepared for catastrophic disasters, and may serve as key considerations for other communities seeking to achieve the same goal. These themes also serve as the lens for conclusions provided in the next section.

1. Holistic Disaster Preparedness

Disaster preparedness is about far more than food and water stockpiles, having a response plan, emergency sheltering, and power crews. Puerto Rico's precarious infrastructure, financial burdens, and public health crises appear to have compounded the impacts of Hurricane Maria.⁵⁷⁴ Puerto Rico also suffered from substandard water quality, failing roads and bridges, and a frail power grid, which all served as disaster amplifiers.⁵⁷⁵ When disasters overlay struggling populations, many pre-existing conditions are exacerbated and recovery can take much longer than in areas operating with more health and balance pre-disaster. Balanced budgets, sound infrastructure, and healthy, well-connected, and cooperative communities are also considered disaster preparedness. How communities conceptualize and actualize preparedness will serve as influential factors in disaster outcomes. A myopic view of what it means to be prepared will not prove as beneficial as a more holistic approach to preparedness.

A 2020 RAND study indicated that “in the longer term (the next decade or so), Puerto Rico will need to focus on key resilience challenges,” such as “economic conditions that precipitated population loss, worsened storm damage, and currently

⁵⁷⁴ See sections relating to pre-hurricane conditions in Fischbach et al., “After Hurricane Maria.”

⁵⁷⁵ See sections relating to pre-hurricane conditions in Fischbach et al.; American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*; Palin, “Learning from H.I.M. (Harvey, Irma, Maria)”; Russell and Blair, “Puerto Rico Recovery Inches On,” 7–8.

inhibit recovery.”⁵⁷⁶ After RAND researchers conducted roundtable discussions with municipal leadership in all 12 emergency management zones, the data indicated a lack of preparedness for Hurricane Maria despite years of planning. Mayors indicated that pre-disaster actions did not account for the devastation wrought by Hurricane Maria that resulted in a complete system collapse.⁵⁷⁷ Municipal leadership uniformly reported completely overwhelming circumstances, which indicates a need for focusing on building resilience by increasing the density of networks, and catastrophic disaster preparedness from the community-level up to the state-level, and from the federal government down to the state-level.

No matter how robust a federal disaster response is, deferred maintenance of infrastructure, and a near total reliance on FEMA and its partners, will result in unmet public needs. Successful disaster response requires a “whole of community” response.⁵⁷⁸ According to former FEMA Administrator, Brock Long, “the 2017 hurricane season showed that all levels of government—and individual families—need to be much better prepared with their own supplies, particularly in remote or insular areas where commodities take longer to deliver.”⁵⁷⁹ While this advice may not account for high levels of poverty across Puerto Rico and other American communities, it seemed apparent amid Hurricane Maria that even those with few resources fared better when they banded together as one community to share information and what resources were available.⁵⁸⁰ This outcome is particularly true in isolated areas, such as Morovis, that did not see first responders for weeks, in areas that became cutoff because of collapsed roadways and bridges, but is also true in more urban areas, such as Las Carolinas, where

⁵⁷⁶ Fischbach et al., “After Hurricane Maria,” https://www.rand.org/pubs/research_reports/RR2595.html.

⁵⁷⁷ Fischbach et al., 123–5.

⁵⁷⁸ Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management*, 3.

⁵⁷⁹ Robles, “FEMA Was Sorely Unprepared.”

⁵⁸⁰ Rios, “In Puerto Rico”; Dickerson, “Stranded by Maria”; Allen, “To Build Resilience”; Dorell, “With Long Lines for Food, Water and Fuel and No Electricity.”

disaster survivor needs outstripped available supplies.⁵⁸¹ However, individual and familial preparation also needs to remain a function that residents are cognizant of, and build over long periods of time in ways that are both affordable and sustainable. A focus on building strong communities can reduce the burdens amid future disasters.

Since Hurricane Maria, a strong move toward community-centric solutions with a more holistic view of disaster preparedness appears to have resulted. Such efforts include COSSAO's free community health clinics, Tetuan Reborn's agrotherapy and disaster preparedness projects, Casa Pueblo's continued commitment to solar energy, other communities, such as Toro Negro, migrating to solar energy independence, the establishment of community kitchens, and ARRL's continued efforts to support first responder communications needs.⁵⁸² Some of these efforts have benefited from external NGO support, such as Mercy Corps' network of resilience hubs across the island.⁵⁸³ With continued momentum, the disaster preparedness aperture can be broadened in Puerto Rico to be more encompassing of other preparedness factors, and can expand the focus on communities.

2. Integration of Non-governmental Actors

Non-governmental actors capable of affording disaster response and recovery resources and services were not well-integrated into the response to Hurricane Maria.

⁵⁸¹ Deibert, *When the Sky Fell*, 113–4; Dickerson and Ferré-Sadurní, “‘Like Going Back in Time’,”; Dickerson, “Stranded by Maria”; Allen, “‘I Don’t Feel Safe’.”

⁵⁸² Fisher, Reineccius, and Engstrom, “Solar Opportunities in Jayuya”; Holladay et al., “Utuado”; The Honnold Foundation, “Casa Pueblo”; Casa Pueblo: Proyecto de Autogestión Comunitaria, “Casa Pueblo Adjuntas Puerto Rico”; Higgins, “A Fire Department in Puerto Rico”; Center for Puerto Rican Studies, *Comunidad Solar Toro Negro Takes Energy Independence by the Horns*; Alleen Brown, “Energy Insurrection: Puerto Rico’s Power Failures Inspired a Rooftop Solar Movement. But Officials Are Undermining It—in Favor of Natural Gas,” *The Intercept* (blog), February 9, 2020, <https://theintercept.com/2020/02/09/puerto-rico-energy-electricity-solar-natural-gas/>; See Toro Negro in Deng et al., “Evaluating Viability of Community Solar Microgrids for Resilience in Puerto Rico,” 32–58; Ana Campoy, “Hurricane Maria Has Made Puerto Rico the Land of Opportunity for Solar Power,” Quartz, November 11, 2017, <https://qz.com/1119528/the-multi-billion-dollar-scramble-over-who-will-keep-the-lights-on-in-darkened-puerto-rico-2/>; Irfan, “Puerto Rico Is Starting to Take Solar Power More Seriously”; Lewis Milford, *Resilient Power Recovery Plan for Puerto Rico: A Proposal to Use Community Development Block Grant—Disaster Relief Funds to Create a Dedicated Solar and Storage Incentive Program* (Montpelier, VT: Clean Energy Group, 2018), <https://www.cleangroup.org/wp-content/uploads/PR-Incentive-Note.pdf>; Allen, “To Build Resilience.”

⁵⁸³ Mercy Corps, “In Puerto Rico, One Community Leader Prepares for What’s Next.”

Organizations, such as the ARC and other community groups appeared not to have functional pre-disaster relationships with government actors, or effective plans for integration in a major disaster response.⁵⁸⁴ In contrast, while the ARRL appeared to have better integration, establishing formal volunteers and integration at the JFO levels was still identified as an area of improvement in the organization’s Hurricane Maria AAR.⁵⁸⁵ The successful integration of non-governmental actors is not an issue unique to Puerto Rico, but has been broadly recognized over time and across the nation.⁵⁸⁶

Amid Hurricane Maria, formal local and state government response networks experienced overload and relied heavily upon state mutual-aid and federal resources to perform their roles as disaster responders.⁵⁸⁷ Outside formal networks, such as state-to-state mutual aid via the EMAC system, and employment of federal resources under major disaster declaration mission assignments, infused Puerto Rico with much needed additional capability. Notwithstanding, many disaster survivor needs went unmet for considerable periods of time, which prompted informal networks to fill the void. Whether it was neighbor helping neighbor, residents affording crowd-sourcing capability, HAM radio operators assisting first responders with communications and situational awareness, a local church opening a feeding or medical mission, or a local organization, such as Casa

⁵⁸⁴ Larin, *Disaster Response*, 27–34; Denigan-Macauley, *Disaster Response*, 32–4; Rios, “In Puerto Rico.”

⁵⁸⁵ American Radio Relay League, *2017 After-Action Report*, 49–52.

⁵⁸⁶ William Jenkins, *Emergency Preparedness and Response: Some Issues and Challenges Associated with Major Emergency Incidents*, GAO-06-467T (Washington, DC: Government Accountability Office, 2006), 1, 4–5, 15–6, <https://www.gao.gov/products/GAO-06-467T>; Government Accountability Office, *Emergency Preparedness: FEMA Faces Challenges Integrating Community Preparedness Programs into Its Strategic Approach*, GAO-10-193 (Washington, DC: Government Accountability Office, 2010), 16–20, <https://www.gao.gov/products/GAO-10-193>; William Jenkins, *Emergency Management: Preliminary Observations on FEMA’s Community Preparedness Programs Related to the National Preparedness System*, GAO-10-105T (Washington, DC: Government Accountability Office, 2009), 13–5, <https://www.gao.gov/products/GAO-10-105T>; William Jenkins, *Emergency Management: Observations on DHS’s Preparedness for Catastrophic Disasters*, GAO-08-868T (Washington, DC: Government Accountability Office, 2008), 8–10, <https://www.gao.gov/products/GAO-08-868T>; Government Accountability Office, *Forces That Will Shape America’s Future: Themes from GAO’s Strategic Plan, 2007–2012*, GAO-07-467SP ((Washington, DC: Government Accountability Office, 2007), 31, <https://www.gao.gov/products/GAO-07-467SP>.

⁵⁸⁷ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 27–30; Federal Emergency Management Agency, *2017 Hurricane Season*, 25, 33; Fischbach et al., “After Hurricane Maria,” xviii.

Pueblo, serving as a community hub, informal networks rose to the occasion. Many informal networks appeared capable of filling, at least in part, large gaps in resource provision although precise measurements of their individual contributions were not tracked. This disparity is due, in part, to the lack of pre-disaster integration of informal networks that makes post-disaster response activities difficult to account for accurately. When facing catastrophic threats and hazards, the role of informal networks becomes key before, during, and after catastrophic disasters, least of all, because pre-existing community organizations often occupy positions of trust, and are well positioned to understand community needs best, and to aid in provisioning commodities and key resources.⁵⁸⁸

A Heritage Foundation AAR of Hurricane Maria made several recommendations. One recommendation noted a need for deeper connections between disaster response organizations via routine training and coordination.⁵⁸⁹ Another key recommendation offered that governmental organizations active in disaster should pre-plan how to cooperate with, and mobilize, informal or “ad hoc” civilian responders, and suggested incorporating faith-based entities into local and state disaster response plans.⁵⁹⁰ The GAO specifically echoed this observation pertaining to a greater inclusion of non-governmental actors that provide disaster-sheltering assistance. The GAO offered six recommendations, all centering around better understanding the capabilities of community groups, incorporating them into disaster plans, and developing mechanisms for their inclusion in future disaster responses.⁵⁹¹ This study has revealed that communities performed far more functions than providing shelter, and therefore, should be considered for integration and inclusion spanning all disaster operations. Although unrelated to Hurricane Maria, the ODNI has noted in *Global Trends: Paradox of*

⁵⁸⁸ Olivia Patterson, Frederick Weil, and Kavita Patel, “The Role of Community in Disaster Response: Conceptual Models,” *Population Research and Policy Review* 29, no. 2 (April 1, 2010): 127–41, <https://doi.org/10.1007/s11113-009-9133-x>; Aldrich, *Building Resilience*, loc. 157–448.

⁵⁸⁹ David Inserra et al., *After the Storms: Lessons from Hurricane Response and Recovery in 2017*, Special Report 201 (Washington, DC: The Heritage Foundation, 2018), 2, 20, <https://www.heritage.org/sites/default/files/2018-04/SR-201.pdf>.

⁵⁹⁰ Inserra et al., 2, 20.

⁵⁹¹ Larin, *Disaster Response*, 36–7.

Progress that “the most resilient societies will also be those that unleash the full potential of individuals—including women and minorities—to create and cooperate.”⁵⁹²

Similarly, RAND offered recommendations based on research aimed at two areas, community resilience, and statewide plans. RAND indicated, “at the community level, stronger social ties are associated with better mental health, immediate survival, and community-level outcomes—in a word, resilience.”⁵⁹³ Researchers further recommended that FEMA and its partners “build partnerships across organizations before disaster strikes, empower community groups to mitigate risks, and identify and address the needs of vulnerable populations.”⁵⁹⁴ Broader incorporation of non-governmental actors in disaster preparedness, response, and recovery can greatly promote resiliency.

3. Decentralization

By integrating community-level capability into local government and state response plans in the preparedness phase, collective disaster response and recovery capabilities are decentralized into more resilient forms. Puerto Rico has long held a decentralized governmental emergency management structure by maintaining 12 state emergency management zones, and 78 municipal EOCs. However, as noted under the safety and security lifeline, much of this structure collapsed. It proved difficult from publicly available data to determine what level of functionality remained at the municipal or emergency management zone levels.⁵⁹⁵ What is apparent is that FEMA, other federal agencies, and state EMAC resources played an outsized role of first responder for an overwhelmed Puerto Rican response system.⁵⁹⁶

Due to the lack of functional decentralization pre-disaster, many entities morphed into decentralized postures amid the response to Hurricane Maria. For instance, the HHS

⁵⁹² National Intelligence Council, *Global Trends*, 69.

⁵⁹³ Barnosky, Roberts, and Acosta, “What Can FEMA Learn,” February 3, 2020.

⁵⁹⁴ Barnosky, Roberts, and Acosta.

⁵⁹⁵ Hernández, Lamothe, and Achenbach, “When Hurricane Maria Hit Puerto Rico.”

⁵⁹⁶ National Emergency Management Association, *Emergency Management Assistance Compact (EMAC) Response*, 27–30; Federal Emergency Management Agency, *2017 Hurricane Season*, 25, 33; Fischbach et al., “After Hurricane Maria,” xviii.

DMATs reconfigured the typical team composition into smaller “health medical taskforce teams” to reach remote areas; US&R teams also divided into smaller, more agile configurations to cover larger areas as they faced an unconventional search and rescue mission.⁵⁹⁷ Much of this decentralization was spurred by a lack of communications, a destroyed transportation infrastructure, a lack of power, and an overpowering need for services among communities. Large, centralized structures were not capable of operating quickly or dynamically in response to Hurricane Maria.

Hurricane Maria also necessitated the decentralization of critical infrastructure and equipment as well, such as communications gear, generators, and stockpile warehouses. For instance, FEMA and the USACE set forth the largest temporary power generation mission in the agencies’ histories that involved the installation of some 2,300 generator across the island to supply critical power requirements.⁵⁹⁸ Similarly, FEMA facilitated the distribution of satellite communications technology to key personnel and facilities throughout the island post-impact.⁵⁹⁹ Post-Maria, FEMA also set forth to grossly expand its disaster warehousing capabilities by a factor of seven across the island in a greater number of geographically dispersed facilities.⁶⁰⁰

Decentralization, in this context, also means ensuring disaster preparedness and resilience at the lowest levels possible. The SW-RAMC’s ability to continue providing medical care to patients in a critical moment served as an example of what organizations can achieve on their own accord by prioritizing disaster preparedness.⁶⁰¹ The SW-RAMC’s capability to continue operations reduced the burdens on outside resources,

⁵⁹⁷ Denigan-Macauley, *Disaster Response*, 16; Jesse Roman, “‘A Whole Lot of Good for a Whole Lot of People in a Whole Lot of Need’,” NFPA, November 1, 2017, <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2017/November-December-2017/Features/Storm-Season/Joe-Jardin>; and Federal Emergency Management Agency, *2017 Hurricane Season: FEMA After-Action Report* (Washington, DC: Federal Emergency Management Agency, 2018), 3, <https://www.hsd1.org/?abstract&did=812985>.

⁵⁹⁸ Federal Emergency Management Agency, *2017 Hurricane Season*, 36–8; Holland, “Responding to the Perfect Storm,” 19.

⁵⁹⁹ Federal Emergency Management Agency, *2017 Hurricane Season*, 34–5; Hughes Network Systems, *Lessons from Disaster Relief*; Corrigan, “How Puerto Rico Is Rebuilding Its Network.”

⁶⁰⁰ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*, 33.

⁶⁰¹ de Arzola, “Emergency Preparedness and Hurricane Maria.”

such as federal DMATs and field medical units. On the community level, Hurricane Maria revealed the existence of what the Urban Sustainability Directors Network (USDN) refers to as community “resilience hubs” that are “community-serving facilities” that “support residents” and “coordinate resource distribution and services before, during, or after a natural hazard event.”⁶⁰² Casa Pueblo in Puerto Rico is the most straightforward example of the role resilience hubs can play in communities.⁶⁰³ Casa Pueblo also aligns to what the Electromagnetic Pulse Special Interest Group synonymously refers to as “resilient community islands,” which is borrowed from grid restoration terminology and transferred to the context of community resiliency.⁶⁰⁴ Resilient community islands offer a community meeting place to share information and resources, and may transition into “recovery islands” that carry a community forward post-disaster.⁶⁰⁵

Resilience hubs that serve as community resources before, during, and after disasters collectively reduce disaster vulnerability.⁶⁰⁶ Another such example in Puerto Rico resides in the municipality of Cataño. The Asociación Pro Juventud y Comunidad de Barrio Palmas (APJ), has long been a social hub for the area, but now the executive director of the association is transforming the organization into a disaster resilience hub that “freshly grown food from community gardens, emergency supplies, clean water and supplemental power to assist the community.”⁶⁰⁷ Additionally, under one Mercy Corps project alone, roughly 15 resilience hubs are being established around the island with a primary focus on providing vulnerable areas with reliable backup power and water

⁶⁰² Kristin Baja, *Resilience Hubs: Shifting Power to Communities and Increasing Community Capacity* (Urban Sustainability Directors Network, n.d.), 2, accessed October 5, 2020, https://www.usdn.org/uploads/cms/documents/usdn_resiliencehubs_2018.pdf.

⁶⁰³ Klein and Feeney, “Puerto Ricans and Ultrarich ‘Puertopians’”; The Honnold Foundation, “Casa Pueblo.”

⁶⁰⁴ Mary Lasky et al., *Powering through: From Fragile Infrastructures to Community Resilience* (Philadelphia: Curtis 1000, 2016), 83.

⁶⁰⁵ Lasky et al., 83.

⁶⁰⁶ “Resilience Hubs Shifting Power to Communities and Increasing Community Capacity,” Urban Sustainability Directors Network, 2020, <https://www.usdn.org/resilience-hubs.html>.

⁶⁰⁷ Mercy Corps, “In Puerto Rico, One Community Leader Prepares for What’s Next.”

systems.⁶⁰⁸ Resilience hubs are of particular importance in post-disaster environments that will challenge the ability of government resources to respond effectively by building grassroots resilience.

Decentralized networks also afford greater access to impact areas and serve the vital purpose of reducing the time and distance between resource needs and resource delivery. In other words, disaster needs and resources are brought into closer proximity for more rapid application, which was most evident in Puerto Rico as it pertained to the food, water, and shelter, and the health and medical lifelines. Communities that had more robust and resilient food, water, shelter, and medical providers in close proximity to their homes appeared, at least anecdotally, abler to meet their own basic needs post-disaster, as was also true of provisioning power and telecommunications. Restoration occurred more quickly when residents were closer to urban centers.⁶⁰⁹

Lastly, decentralization supports what Ramos refers to as “deep-security” in *Age of the Unthinkable: Why the New World Disorder Constantly Surprises Us* whereby mindsets pivot away from protecting against all possible threats, and instead focus on building the density of networks, and raising their collective ability to absorb the shocks of disasters and a rapid return to normalcy.⁶¹⁰ This approach may be a sensible path forward in Puerto Rico as the island experiences frequent compounding disasters. As Patrick Roberts, author of *Disaster and the American State* says, “FEMA is not the cavalry...The roots of vulnerability to disaster are in communities. The neighbors, the residents, the city, the state—they are going to be the first to respond and they are going to do the bulk of the rebuilding.”⁶¹¹ Disaster resilience must be built in this area.

⁶⁰⁸ Betty Cortina-Weiss, “Puerto Rico, Still in Hurricane Recovery, Focuses on Resilience,” The Miami Foundation, May 16, 2018, <https://miamifoundation.org/puerto-rico-still-in-hurricane-recovery-focuses-on-resilience/>.

⁶⁰⁹ Kishore et al., “Mortality in Puerto Rico after Hurricane Maria,” 165.

⁶¹⁰ Ramo, *The Age of the Unthinkable*, 172.

⁶¹¹ Gabrielle Canon, “The U.S. Won’t Be Prepared for the Next Natural Disaster,” *The Guardian*, sec. World News, January 18, 2019, <https://www.theguardian.com/world/2019/jan/18/natural-disaster-preparation-fema-hurricanes>.

4. Redundant Systems

FEMA's *2017 Hurricane Season AAR* indicated that, "continuity planning and resilient all-hazards communications capabilities must be built into FEMA and its partners' plans and guidance for catastrophic disasters," and further recommended that FEMA more aggressively support continuity of government planning for state and local jurisdictions.⁶¹²

While the concept of redundancy is certainly applicable to communications capabilities, back-up systems must be built into all other lifelines as well, such as community-based search and rescue capability, medical care, food and water supplies, energy sources, debris removal, and other functions. Each of these areas suffered collapse in Puerto Rico after Hurricane Maria. Many communities were isolated for weeks, and went without reliable food and water supplies for months that caused residents and informal actors to seek emergency interventions to provide for basic needs. Amid future catastrophic disasters, each of these primary capabilities are likely to collapse once again, which necessitates some type of redundant systems be emplaced before the next catastrophe.

Amid an ongoing budget crisis, Puerto Rico will likely need to rely upon cost-effective NGOs, community organizations, and volunteer services for such redundancy, which links this theme closely with the issue of integrating non-governmental actors into disaster response and recovery plans, as well as preparedness functions. Organizations, such as the ARRL, for instance, offer cost-effective means of ensuring continuity of communications, which in turn, affords the ability to maintain situational awareness and coordination operations amid disasters.⁶¹³ Other groups, such as COSSAO, Tetuan Reborn, Casa Pueblo, Center of Mutual Support, and many others, are successful examples of communities overcoming resource scarcity to be more resilient together.

Other communities throughout the nation are also likely to be in similar financial positions as budgets shrink and states face massive financial challenges as a result of

⁶¹² Federal Emergency Management Agency, *2017 Hurricane Season*, 38.

⁶¹³ American Radio Relay League, *2017 After-Action Report*.

decades of stressed fiscal policy, and most recently, the impacts of COVID-19. Due to these challenges, communities across the nation will likely have to consider how to do more with less in the coming years amid financial hardships, and increasing disaster frequency. Therefore, Puerto Rico may serve as a prime example of what is possible when primary response and recovery systems falter, and many of those examples are likely to come from organizations that emerged post-Hurricane Maria.

B. CONCLUSIONS

The conclusion summarizes the study and offers opportunities for future discussion and research. Where possible, the recommendations of reputable and authoritative sources are provided for consolidated consideration.

1. Safety and Security Lifeline

The near total collapse of disaster response capabilities in Puerto Rico suggests the island ought to reimagine community safety and security by reaching deeply into communities and involving them in disaster preparedness so they can operate as assets at times when government resources are overwhelmed. To that end, Robert Bach and David Kaufman wrote a 2009 article proposing a “social infrastructure” that brings “the American people fully into strengthening their own preparedness.”⁶¹⁴ The article articulated that top-down approaches have largely excluded citizens and their communities from being active participants in their own preparedness. While speaking specifically in terms of homeland security, the recommendations provided are also more broadly applicable to all-hazards disaster preparedness. The authors suggested sharing more risk information with the public, including involving local communities in decision making. FEMA regions should be the facilitator and not a hierarchical federal monitor of communities, and the United States should establish a “National Institute of Preparedness.”⁶¹⁵ This concept is particularly applicable to Puerto Rico as the

⁶¹⁴ Robert Bach and David Kaufman, “A Social Infrastructure for Hometown Security: Advancing the Homeland Security Paradigm,” *Homeland Security Affairs* 5, no. 2 (May 2009): 1–13.

⁶¹⁵ Bach and Kaufman, 7.

Commonwealth government continues to struggle with fiscal deficits, pension shortfalls, and challenges in staffing key departments.

In a recent FEMA Prep Talk, speaker Aaron Titus shared similar sentiments as part of his presentation titled “Let the Community Lead: Rethinking Command and Control Systems” in which he described a governmental structure serving as a facilitator for community-led disaster response and recovery.⁶¹⁶ In many ways, communities did lead in Puerto Rico for a period of time; however, non-governmental, and informal community actor involvement was not pre-planned and was therefore ad hoc and born out of necessity. It is possible that as the island considers its future, it also evaluates how to incorporate informal actors better who fill the void when governmental resources are overwhelmed.

In another Caribbean nation with very different political and societal constructs, Cuba has proven able to leverage the horsepower of communities to perform such functions as evacuating neighbors from coastal and flood prone areas, community debris removal functions, community sheltering, and care of community members, particularly the disabled and the frail.⁶¹⁷ The island has accomplished this process through building a preparedness culture, risk mitigation planning, lifelong community education, community organizing, and bolstering underlying social capital.⁶¹⁸ Given Puerto Rico’s apparent high levels of bonding social capital, and recent disaster experience, it remains likely that residents can be leveraged to support vital disaster response and recovery capabilities, as well, and can be done affordably.⁶¹⁹

⁶¹⁶ “PrepTalks: Aaron Titus “Let the Community Lead Rethinking Command and Control Systems,” December 10, 2019, Federal Emergency Management Agency, YouTube, video, 26:46, <https://www.youtube.com/watch?v=Ny3pC4entl8>.

⁶¹⁷ Holly Sims and Kevin Vogelmann, “Popular Mobilization and Disaster Management in Cuba,” *Public Administration and Development* 22, no. 5 (2002): 389–400, <https://doi.org/10.1002/pad.236>.

⁶¹⁸ Martha Thompson and Izaskun Gaviria, *CUBA Weathering the Storm: Lessons in Risk Reduction from Cuba* (Washington, DC: Oxfam America, 2004), https://web.archive.org/web/20070927023654/http://www.oxfamamerica.org/newsandpublications/publications/research_reports/art7111.html/OA-Cuba_Weathering_the_Storm-2004.pdf; Kirk, “Alternatives–Dealing with the Perfect Storm,” 93–101.

⁶¹⁹ Kirk attributes Cuba’s success to effective “low-cost measures and determination.” Kirk, “Alternatives–Dealing with the Perfect Storm,” 101.

2. Food, Water, and Shelter Lifeline

Hurricane Maria clearly indicated that government resources at times would prove insufficient in disaster response, specifically when amid compounding or close-proximity major disasters.⁶²⁰ As FEMA struggled to keep pace with near-simultaneous major disasters in Texas, Florida, California, the U.S. Virgin Islands, and Puerto Rico, the outer limits of the largely government-centric NRF became apparent. Although many states were able to provide aid to Puerto Rico, and dozens of federal government entities responded, communities still struggled to obtain the basic necessities needed for survival and recovery.

Food and water provision following Hurricane Maria was primarily an issue of distribution, but was not linked to supply shortages.⁶²¹ The 69-day average FEMA delivery time was not a matter of not having supplies in the pipeline, but rather of having a clogged distribution system.⁶²² Regardless, the end result was communities in need of basic food and water provisions for extended periods of time.⁶²³ To reduce future distribution issues, FEMA reported to the OIG that the agency has undertaken massive efforts to correct and bolster its logistics management capabilities to include improving contracting capabilities, technical enhancements to its LSCMS platform and over the ocean tracking of shipments, and has increased commodity stockpiles “seven-fold” in both its Caribbean and Pacific area distribution centers, and has achieved a greater geographic dispersion of these stockpiles around the islands.⁶²⁴ Moreover, in rebuttal to OIG criticisms, FEMA indicated that it had surplus commodities not capable of being accepted by impacted communities due to a lack of need; these items were redirected to storage.⁶²⁵ However, it is difficult to know with certainty if these shipments represented

⁶²⁰ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*.

⁶²¹ Palin, *Out of the Whirlwind*, loc. 1273; Palin, “Learning from H.I.M. (Harvey, Irma, Maria).”

⁶²² Palin, loc. 1273; Palin; Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*, 7, 20.

⁶²³ Venes, “Starving Puerto Rican Towns Sharing Food”; Deibert, *When the Sky Fell*.

⁶²⁴ Office of Inspector General, *FEMA Mismanaged the Commodity Distribution Process*, 33.

⁶²⁵ See FEMA’s comments in Office of Inspector General, 27–37.

a “too little, too late” situation because the private sector had come back online, or if they truly surpassed needed disaster supplies.

What is known is that many communities went without vital supplies for extended periods, which is a reality that highlights a need to bolster community-level resiliency. Despite FEMA’s drastic logistics capability enhancements, which are commendable, the agency will never be resourced or postured to be the sole provider of vital commodities, such as food and water to millions of disaster survivors. Programs focusing on social capital and food security in both rural and urban areas, but particularly focusing on marginalized communities and rural communities known to have physical access challenges, can raise a community’s ability to access physical capital post-disaster.⁶²⁶ Several working examples of what is possible in Puerto Rico can be found in organizations, such as Tetuan Reborn, CASSAO, and Casa Pueblo, as grassroots organizations with a community-centric focus on providing critical services, such as food, water, power, and basic medical care before, during, and after disasters.⁶²⁷ In addition, each may serve as an example for expansion across the island.

Following Hurricane Maria, many community shelters sustained significant damage and endured the same loss of power and water services experienced across the island.⁶²⁸ Since 2018, the ARC has boosted the resilience of schools doubling as hurricane shelters by installing solar panels.⁶²⁹ The panels can reportedly withstand 160 mph winds and flying debris while providing 50kW of power over a 10-year life span.⁶³⁰ This ARC project, along with others focused on communities, represents a step in the right direction toward building ground-level resilience against future disasters.

⁶²⁶ Chriest and Niles, “The Role of Community Social Capital for Food Security,” 89.

⁶²⁷ Holladay et al., “Utuaado”; Fisher, Reineccius, and Engstrom, “Solar Opportunities in Jayuya”; Casa Pueblo: Proyecto de Autogestión Comunitaria, “Casa Pueblo Adjuntas Puerto Rico”; The Honnold Foundation, “Casa Pueblo.”

⁶²⁸ Fischbach et al., “After Hurricane Maria,” 346–7.

⁶²⁹ American Red Cross, *Hurricane Maria: Two-Year Update* (Washington, DC: American Red Cross, 2019), 3, <https://www.redcross.org/content/dam/redcross/about-us/publications/2019-publications/hurricane-maria-2-year-update.pdf>.

⁶³⁰ American Red Cross, 3.

Agriculture represents another key area in which resiliency should be a priority. In Cuba, a country requiring a high level of agricultural self-reliance, citizens often come together to harvest crops rapidly preceding hurricanes, and aid farmers in planting short-yield crops afterward to minimize agricultural losses.⁶³¹ Organizations in Puerto Rico, just as with Tetuan Reborn’s agrotherapy approach, may serve as a catalyst for cultivating such community capability aimed at reducing burdensome agricultural losses in disasters.⁶³² Minimizing future disaster losses to Puerto Rico’s agricultural sector will contribute to food supply chain resilience that is critical to positive disaster outcomes.⁶³³

3. Health and Medical Lifeline

Hurricane Maria laid bare the underlying population vulnerabilities and other public health issues present in Puerto Rico, since 39.5% of those 65 and older live below the poverty line, and 84% of children live in census tracts with poverty rates of 30% or more since 2012.⁶³⁴ Overall, 43.1% of Puerto Ricans live in poverty, 21.3% are over the age of 65, the average household income is just \$20,166, 15.1% under the age of 65 have a disability, and 7.9% live without health insurance coverage.⁶³⁵ In light of these challenges, any workable solution will likely be long-term and multi-pronged, and also focused on health promotion against preventable diseases, while also tackling the current reality of an impoverished, aging population with high rates of chronic diseases.

Solutions going forward must be tailored to the realities of the island. Adequately planning to support the medically vulnerable in disasters will necessarily be a joint effort with different health sector actors. The GAO offered seven recommendations, each centered upon the HHS exploring ways to rely more on partners in the interest of medical force-multiplication by better understanding partner capabilities, developing memorandums of agreement, and incorporating entities that can meet the appropriate

⁶³¹ Sims and Vogelmann, “Popular Mobilization and Disaster Management in Cuba,” 397–8.

⁶³² Holladay et al., “Utuado,” 9–13.

⁶³³ Chriest and Niles, “The Role of Community Social Capital for Food Security,” 89.

⁶³⁴ Fischbach et al., “After Hurricane Maria,” 363.

⁶³⁵ U.S. Census Bureau, “QuickFacts: Puerto Rico.”

standards of care into HHS plans.⁶³⁶ One recommendation in particular addressed reducing the agency's reliance upon DOD assets should they prove unavailable at any future point.⁶³⁷

As a sizeable medical network in Puerto Rico, the SW-RAMC stands as an example of what is possible when organizations prioritize and insist on high levels of preparedness. The SW-RAMC network held a fully developed and well-considered disaster plan that included backup power generation, satellite communications, employee safety, fuel provision, and accountability, etc.⁶³⁸ The end result was that the SW-RAMC remained functional and able to serve communities amid a catastrophic disaster. If the federal or Commonwealth government were to utilize the SW-RAMC as a model for other healthcare networks, or if other networks were to emulate SW-RAMC, each would require an understanding of how the medical network funded, planned, and staffed its preparedness posture.

Hurricane Maria also highlighted the importance of proximity to care as a key factor in successful medical interventions. "Bringing the Hospital Home" is a community paramedicine model whereby trained paramedics serve communities' urgent care needs by going to them.⁶³⁹ This model presents another adaptation that makes it possible to access underserved or remote communities in times of disasters, and is essentially what the HHS' DMATs aimed to do by dividing into smaller, more mobile "health medical taskforce teams" to reach remote communities, cover larger areas, assess community health needs, provide medical triage and treatment, and evacuate patients as necessary.⁶⁴⁰

As a community-led model, COSSAO stands as an example of community medicine meeting the needs of vulnerable communities.⁶⁴¹ In addition to focusing on

⁶³⁶ Denigan-Macauley, *Disaster Response*, 34–5.

⁶³⁷ Denigan-Macauley, 35.

⁶³⁸ de Arzola, "Emergency Preparedness and Hurricane Maria."

⁶³⁹ Cahill, "Community Paramedicine."

⁶⁴⁰ Cahill; Office of the Assistant Secretary for Preparedness and Response, "Disaster Medical Assistance Teams."

⁶⁴¹ Fisher, Reineccius, and Engstrom, "Solar Opportunities in Jayuya."

sustainable economic development, community rebuilding projects, agrotherapy, and other areas, COSSAO also coordinates a network of medical volunteers to serve underserved communities at no cost.⁶⁴² Organizations, such as COSSAO, appear well-connected and in tune with the needs of the communities they serve, and operate as a force-multiplier in close proximity to impacted communities.

Effective health and medical provision in Puerto Rico will need to be long-term, multi-pronged, and layered from the ground level in organizations, such as COSSAO, to island-wide formal medical networks, such as the SW-RAMC, up to the Commonwealth public health networks, and with the support of federal agencies, such as the HHS and its partners. Lastly, medical NGOs, such as Americares, will continue to serve as vital conduits between government actors, medical networks, and communities in need.

4. Energy Lifeline

Puerto Rico's power infrastructure still faces systemic and existential challenges that will lead to continued disaster vulnerability. Following earthquakes in January 2020, the Costa Sur power plant was knocked out of commission. To this day, the power plant remains on backup generators to keep the island powered, which illustrates the continued peril to Puerto Rico's power infrastructure.⁶⁴³ PREPA, the island's power provider, filed for bankruptcy shortly before the dual impacts of Hurricanes Irma and Maria destroyed the grid that resulted in one of the nation's costliest repairs, and more importantly, the longest blackout in recorded U.S. history.⁶⁴⁴ Drastic impacts to the island's power grid made it impossible to consider a myriad challenges to any other community lifeline without first recognizing the compounding impact of the total loss of power. Therefore, any catastrophic disaster plan devised going forward must plan for, and expect, widespread and long-term power outages as part of the equation.

⁶⁴² Fisher, Reineccius, and Engstrom; Holladay et al., "Utuaado," 6.

⁶⁴³ Costa Sur supplies roughly 25% of the island's power supply. Brown, "Energy Insurrection."

⁶⁴⁴ President's National Infrastructure Advisory Council, *Surviving a Catastrophic Power Outage*, 69; American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 28; New York Power Authority et al., *Build Back Better*, 11.

In the wake of Hurricane Maria, the energy sector at both the federal and state mutual-aid levels have offered substantive recommendations to PREPA to address and reduce recovery, long-term sustainability, and vulnerability. The U.S. Department of Energy made its recommendations across four areas: transmission and distribution, generation, microgrids, and systems operations, management, and planning.⁶⁴⁵ To summarize, the recommendations involve long-term infrastructure investments, segmenting the power grid, which contributes to stability and resilience, the installation of microgrids for largely the same purpose to provide power to the island, and the faster regeneration of a damaged grid while also buying time for large overland transmission lines, traversing from the island’s south to the north, to be restored.⁶⁴⁶

Similarly, the NY Power Authority (NYPA)—a major supplier of mutual-aid assistance—offered recommendations pertaining to the transmission and distribution system, the capability to generate power, system operations, as well as an implementation roadmap for the island complete with cost-projections.⁶⁴⁷ In total, the plan costs in excess of \$17.6 billion, which is an extremely tall order for a bankrupt utility facing compounding disasters, even after considering ongoing and massive amounts of federal investments.⁶⁴⁸ Much like the DOE, the NYPA also suggested the development of microgrids to allow “energy to become abundant, affordable, and sustainable to improve the way of life for the citizens of Puerto Rico.”⁶⁴⁹

Notwithstanding, nor specific to Puerto Rico, the Electromagnetic Pulse Special Interest Group in *Powering Through: From Fragile Infrastructure to Community Resilience*, highlighted the utility of micro-grids offering stability during restoration and may be essential for catastrophic disasters impacting the electrical grid. The authors recommend beginning their development locally with a “clear understanding of

⁶⁴⁵ U.S. Department of Energy, *Energy Resilience Solutions for the Puerto Rico Grid* (Washington, DC: U.S. Department of Energy, 2018), 18–41, <https://www.hsdl.org/?abstract&did=812312>.

⁶⁴⁶ U.S. Department of Energy, 18–41.

⁶⁴⁷ New York Power Authority et al., *Build Back Better*, 12–41.

⁶⁴⁸ See Appendix B in New York Power Authority et al.

⁶⁴⁹ New York Power Authority et al., 1, 5.

user requirements, environmental constraints, and reliability standards for interconnections.”⁶⁵⁰

In regard to beginning locally, many examples already exist in Puerto Rico, from the Honnold Foundation’s partnership with Casa Pueblo, to the ARC installing storm-resistant solar panels on multiple schools that double as shelters, to other organizations that also recognize solar as a means of reducing energy dependence and disaster vulnerability while also increasing affordability, and access to communities that need it the most.⁶⁵¹ In line with both federal, state, and non-profit recommendations, the Clean Energy Group proposed in September 2018 that the federal government apportion recovery funds for a community development block grant that allows communities to apply recovery dollars to sustainable solar and energy storage capabilities as a means to reduce long-term vulnerability.⁶⁵²

While solar may not be scalable to solve all of Puerto Rico’s power ailments, the sensible promotion and support of the technology may well afford some baseline capability to provide communities with enough power supply to meet their basic needs in critical post-disaster time periods, or effectively “buying time” for bulk power restoration to occur. However, such a transition will require political will and financial support. If left to corporate philanthropy, programs aimed at long-term resiliency are subject to the waxing and waning interest of corporate sponsors, such as Tesla, which stands accused of abandoning a large-scale solar project on Puerto Rico’s eastern island of Vieques.⁶⁵³ Only with serious, long-term commitment can Puerto Rico reach its energy goals of producing 20% of its energy sustainably by 2022, and 40% by 2025, and energy

⁶⁵⁰ Lasky et al., *Powering Through*, 57.

⁶⁵¹ Honnold Foundation, “Casa Pueblo”; Campoy, “Hurricane Maria Has Made Puerto”; American Red Cross, *Hurricane Maria*, 3; Irfan, “Puerto Rico Is Starting to Take Solar Power More Seriously”; “ResilientPowerPR,” RPPR, accessed April 2, 2020, <https://resilientpowerpr.org>; Fisher, Reineccius, and Engstrom, “Solar Opportunities in Jayuya”; Allen, “To Build Resilience”; Fiala, “Behind the Veil.”

⁶⁵² Milford, *Resilient Power Recovery Plan for Puerto Rico*, 1–3.

⁶⁵³ Alexander Kaufman, “On Puerto Rico’s ‘Forgotten Island,’ Tesla’s Busted Solar Panels Tell a Cautionary Tale,” *HuffPost*, updated May 17, 2019, https://www.huffpost.com/entry/elon-musk-tesla-puerto-rico-renewable-energy_n_5ca51e99e4b082d775dfec35.

independence by 2050.⁶⁵⁴ However, unfortunately, the probability of such a commitment remains uncertain as Puerto Rico's leadership appears in favor of natural gas expansion as a primary fuel source, and thereby draining political support for a renewable energy future.⁶⁵⁵

5. Communication Lifeline

Much like the energy sector, Puerto Rico's communications sector suffered extensive storm damages and near total destruction that rendered commercial communications "almost non-existent" post-impact, and it remains fragile to future disaster impacts.⁶⁵⁶ Not only were first responders inhibited from communicating resource needs, and coordinating operations, it also inhibited residents as well from calling for help, checking on loved ones, and coordinating community collaboration. Later, communications outages also made it difficult for residents to apply for disaster benefits.⁶⁵⁷ Additionally, due to largely centralized governmental decision-making processes, the inability of regional authorities to reach counterparts in the island's capital reportedly led to uncertainty and delays in the disaster response.⁶⁵⁸

RAND, commissioned by the DHS, has made several straightforward, albeit expensive, recommendations for improving Puerto Rico's communications resilience. In sum, the recommendations center around making the necessary immediate repairs to infrastructure, ensuring adequate backup power generation on each site, replacing outdated infrastructure, and ensuring broadband connectivity for all residents.⁶⁵⁹ While these recommendations appear to be rather sensible, it is also unlikely affordable for Puerto Rico to implement save for massive federal investments in system upgrades.

⁶⁵⁴ Puerto Rico Energy Public Policy Act, Public Law 17-2019 (2019), <https://energia.pr.gov/wp-content/uploads/2019/05/Act-17-2019.pdf>; Umair Irfan, "Puerto Rico Is Targeting 100% Renewable Energy. The Trump Administration Has Other Ideas," Vox, April 17, 2019, <https://www.vox.com/2019/4/17/18306417/puerto-rico-renewable-energy-natural-gas>; and Kaufman; Brown, "Energy Insurrection."

⁶⁵⁵ Brown, "Energy Insurrection."

⁶⁵⁶ Fischbach et al., "After Hurricane Maria," 163.

⁶⁵⁷ Fischbach et al., 155–173.

⁶⁵⁸ Fischbach et al., 130.

⁶⁵⁹ Fischbach et al., 173.

The most resilient communications capabilities evident in Puerto Rico after Hurricane Maria were AM radio stations and HAM radio networks. These networks are also the most affordable to sustain and expand for future disasters. A post-disaster study of the role of radio journalism found that many stations require greater disaster resilience, such as continuity plans accounting for damages to the infrastructure, and a need to be able to generate power temporarily.⁶⁶⁰ Researchers indicated that the ability to broadcast via radio, particularly to vulnerable communities, provided timely, pertinent information on the situation, as well as how to obtain needed resources.⁶⁶¹ These observations align with another study considering the role of communication in disaster resilience, in addition to how it can be leveraged to help communities overcome disasters via “communication systems and resources, [fostering] community relationships, [establishing] strategic communication processes, and [considering] community attributes.”⁶⁶² Hurricane Maria clearly indicated that the ability to communicate among responders and with the public is a critical precursor to effective disaster response and recovery.

Amid the void, the ARRL proved agile and adaptable and provided support to key governmental response agencies that served as a bridge during a critical time. The ARRL’s AAR supplied multiple post-disaster recommendations with the common themes centering on a need to solidify and grow the HAM radio network in Puerto Rico, a need to integrate better with communications regulators, as well as other government actors at all levels, and with private industry.⁶⁶³ While RAND’s recommendations are most holistic, void of cost consideration, ARRL’s recommendations likely more closely align with what is possible and most pragmatic in the context of Puerto Rico.

⁶⁶⁰ Yadira Nieves-Pizarro, Bruno Takahashi, and Manuel Chavez, “When Everything Else Fails: Radio Journalism during Hurricane Maria in Puerto Rico,” *Journalism Practice* 13, no. 7 (2019): 799–816, <https://doi.org/10.1080/17512786.2019.1567272>.

⁶⁶¹ Nieves-Pizarro, Takahashi, and Chavez, 15.

⁶⁶² Houston et al., “The Centrality of Communication and Media in Fostering Community Resilience,” 279.

⁶⁶³ American Radio Relay League, *2017 After-Action Report*, 49–52.

Private sector telecommunications providers also have a role to play in catastrophic disaster responses, such as Google X lab's Project Loon. While Tesla's involvement with solar power in Vieques is a "cautionary tale," so too are projects, such as Loon, which can still be integrated into response and recovery plans without being engineered as single points of failure. By layering and decentralizing communications capabilities and redundancies, Puerto Rico can continue to drive toward communications resilience in sustainable ways.⁶⁶⁴

6. Transportation Lifeline

The transportation lifeline represented less community involvement save for communities and community groups banding together to clear debris blocking roadways, and examples of constructing workarounds for washed out bridges and roadways, which therefore contributes less to answering the research questions.⁶⁶⁵ Notwithstanding, as communities begin to consider their own catastrophic disaster preparedness, the ability, or inability, to access key areas is a paramount planning consideration for strategy development and long-term planning. A lack of access to impacted areas will result in longer isolations of such areas, and will require that residents cultivate higher levels of self-reliance to buy time until disaster aid can be adequately delivered. If history is instructive, it is known that by mid-October, Puerto Rico still faced 27 impassable major roadways, 550 debris blockages, and at least 17 damaged major bridges.⁶⁶⁶

This preparedness may entail accruing larger food and water stocks, identifying alternate sources of food and water, and municipalities procuring heavy equipment capable of clearing critical roadways, and organizing community members to perform emergency debris clearance. This method, which Palin refers to as a "tactical" debris removal plan, identifies priority areas and key infrastructure, debris storage sites, and

⁶⁶⁴ Kaufman, "On Puerto Rico's 'Forgotten Island'"; NBC News, "An Experimental New Project Is Helping"; Morse, "Google Officially Flips on Project Loon in Puerto Rico"; Guynn, "Google Parent's Project Loon Delivers Internet to 100,000 in Puerto Rico"; Lavars, "Project Loon Balloons to Connect Storm-Ravaged Puerto Rico."

⁶⁶⁵ Associated Press, "Puerto Ricans Hunt for Precious Wi-Fi"; Holladay et al., "Utuado," 11; Dickerson and Ferré-Sadurní, "Like Going Back in Time"; Dickerson, "Stranded by Maria."

⁶⁶⁶ Palin, "Learning from H.I.M. (Harvey, Irma, Maria)."

ways to manage different types of debris (i.e., vegetative, household, etc.).⁶⁶⁷ The EPA developed a report pertaining to planning for natural disaster debris and included tangible steps communities can take to reduce the amount of debris they produce, such as bracing homes for disaster impacts, vegetation management, limiting the storage of chemicals, securing propane tanks and outdoor objects, etc.⁶⁶⁸ The agency also recommended that the same measures can be taken when identifying the community's critical facilities, such as schools, nursing homes, hospitals, shelters, transportation routes, etc., that are vulnerable to disaster debris issues that may inhibit rapid post-disaster access.⁶⁶⁹ Mobilizing the community is also a common post-disaster practice in Cuba whereby citizens come together to clear key roadways and facilities of debris to allow access for first responders and critical supplies.⁶⁷⁰ This approach may serve as a model and also as the only option for isolated communities to self-organize and open the roads when government or debris contractors are not able to deliver these services.

Both RAND and the ASCE made recommendations following Hurricane Maria centered on roadway repairs, establishing quality control standards, increasing ridership on public transportation platforms, reducing the need to use passenger vehicles, and reducing the island's reliance on the Port of San Juan.⁶⁷¹ While these recommendations appear sensible, many are likely aspirational and out-of-reach of the island's public financing capacity—at least over the near-term—that leaves residents in a vulnerable position in future disasters, a reality they must plan for in advance. Kim and Bui offer recommendations in their study stratified across the tactical, operational, and strategic levels that do offer some community-level involvement, such as pre-staging food and water on the island, pre-disaster mitigation, training and exercises, and building

⁶⁶⁷ Kim and Bui, "Learning from Hurricane Maria," 6.

⁶⁶⁸ U.S. Environmental Protection Agency, *Planning for Natural Disaster Debris* (Washington, DC: U.S. Environmental Protection Agency, 2018), 10, https://www.epa.gov/sites/production/files/2019-05/documents/final_pndd_guidance_0.pdf.

⁶⁶⁹ U.S. Environmental Protection Agency, 10.

⁶⁷⁰ Kirk, "Alternatives—Dealing with the Perfect Storm," 94–9.

⁶⁷¹ Fischbach et al., "After Hurricane Maria," 203–31; American Society of Civil Engineers, *2019 Report Card for Puerto Rico's Infrastructure*, 34–49.

partnerships with a wide variety of community actors to bolster supply chain resilience.⁶⁷² Similarly, the U.S. Committee on the Marine Transportation System created several recommendations to accelerate the restoration and recovery of the transportation infrastructure. Recommendations included the pre-staging of assessment teams and equipment, aiding port facility employees in returning to work, establishing a clear way to communicate a facility’s status, and a need for prioritizing facilities.⁶⁷³ Citizen involvement in hazard mitigation planning, public funding priorities, and in understanding their community’s risk profile and potential for isolation post-disaster, are essential measures for knowing what to expect to plan adequately for disasters.

Puerto Rico maintains some of the densest roadway networks in the nation. By working with local community groups and leaders, communities can plan for likely transportation impacts and structure preparedness strategies around known and likely vulnerabilities to prepare residents for potential periods of isolation, and devise plans to reduce the amount of time their communities remain inaccessible. Residents can also actively participate in driving the decision making of local and Commonwealth leaders on matters of long-term hazard mitigation.

7. Hazardous Materials Lifeline

Puerto Rico faces a variety of HAZMAT risks due largely to long-term infrastructure degradation because of fiscal constraints and divestments from the island.⁶⁷⁴ The poor safety track records of drinking and wastewater facilities and high rates of exposure to HAZMAT from a number of industries, such as farming, pharmaceutical production, petroleum facilities, coal plants, and others, serve as major public risk factors requiring consideration in planning for future catastrophic disasters.

As of February 2018, 96% of drinking water, and 98% of wastewater facilities were still operating below full capacity while non-PRASA systems displayed variant

⁶⁷² Kim and Bui, “Learning from Hurricane Maria,” 6–8.

⁶⁷³ U.S. Committee on the Marine Transportation System, *2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System* (Washington, DC: Department of Transportation, 2018), 42–6, <https://www.hsdl.org/?abstract&did=819864>.

⁶⁷⁴ Fischbach et al., “After Hurricane Maria,” 45–81, 175–99.

water quality.⁶⁷⁵ RAND noted that ill-performing water facilities increase the risk of transmitting waterborne diseases and exposure to toxic compounds.⁶⁷⁶ When considering Puerto Rico’s path to full recovery, RAND suggested prioritizing safe and reliable drinking water via infrastructure re-investment and system maintenance, such as dredging reservoirs in neglect.⁶⁷⁷

Many issues concerning post-disaster HAZMAT exposure can be avoided by avoiding floodwaters when possible, and securing reliable disaster-resilient and community-based alternate water facilities for instances when primary systems fail. At least one community has shown that security safe water sources are possible via community organizing and planning for a resilient future. Residents of Toro Negro, a community in the municipality of Ciales, were without power and potable water for over eight months following Hurricane Maria.⁶⁷⁸ Since that time, the community has been able to secure a safe mountain aqueduct as a disaster-resilient water source to hedge against future isolating and contaminating effects of disasters.⁶⁷⁹

As Puerto Rico considers future disaster preparedness, access to resilient water systems will be a vital consideration in avoiding HAZMAT exposure, particularly in areas that proved difficult to reach after Hurricane Maria. In addition, it is important to note that communities need not wait for the largely government and utility-centric recommendations of such organizations as RAND to be implemented. Communities like Adjuntas, Jayuya, Ciales, and others, show that positive outcomes are possible through community action and the formation of local cooperatives.⁶⁸⁰

⁶⁷⁵ Fischbach et al., 190.

⁶⁷⁶ Fischbach et al., 366.

⁶⁷⁷ Fischbach et al., 199–201.

⁶⁷⁸ Porta, “Lessons in Community Resilience.”

⁶⁷⁹ The Commission for Environmental Cooperation.

⁶⁸⁰ Center for Puerto Rican Studies, *Comunidad Solar Toro Negro Takes Energy Independence by the Horns*; Deng et al., “Evaluating Viability of Community Solar Microgrids for Resilience in Puerto Rico,”; Porta, “Lessons in Community Resilience”; Ayala, “The Community Effort to Bounce Back”; Johnson, “Weary of Blackouts.”

Lastly, it is imperative that communities understand toxic hazards in close proximity that may pose risks amid disaster. By engaging local leaders and becoming active in local emergency planning councils, communities can work cooperatively to understand the risks they face better, identify, and implement mitigating measures pre-disaster. While some mitigating measures may be as complex as working with large industries and local leaders on the cleanup of hazardous chemical storage sites, others will be as simple as messaging fellow community members to wear protective clothing, to avoid floodwaters as much as possible, and establishing a means of securing safe drinking water supplies before future disasters strike, such as Toro Negro and other communities have since Hurricane Maria.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

All research projects are bound by resource availability, with the greatest resource being time. Therefore, the following areas were identified throughout the writing of this thesis as potentially impactful areas for future study based upon their ability to create generalizable conclusions that result in concrete recommendations to further Puerto Rico's disaster resiliency. Conclusions for further research may also inform other resource-constrained communities around the globe, to one degree or another, via a comparative analysis as they seek to build catastrophic disaster preparedness:

- deeper research on specific community lifelines or critical infrastructure sectors
- evolution of community-based organizations of Puerto Rico
- impact of cumulative disasters on overall disaster resiliency
- exploration of the role of social capital in Puerto Rico amid disasters
- examination of how to rebalance the role of disaster preparedness and response from local, state, and federal levels from a policy standpoint

D. SUMMARY

This study aimed to provide readers with a comprehensive examination of Hurricane Maria's impact on the island of Puerto Rico. Utilizing a community lifeline approach, critical preparedness gaps were revealed that could be instructive to ongoing preparedness efforts and the building of long-term disaster resilience. Other communities facing catastrophic threats and hazards may also find comparative lessons in the Puerto Rico's experience and find useful conclusions to put toward their own endeavors.

In addition to substantial preparedness gaps, this study revealed decisive ad hoc measures taken by communities and informal actors to adapt and bridge critical gaps in disaster relief resources, such as food, water, shelter, medical care, power supply, and water provision. In the context of Puerto Rico, considerable opportunities are possible to re-imagine disaster preparedness, and integrate informal actors as a vital part of the solution to wicked preparedness problems as an isolated island commonwealth. In the event of a national catastrophic incident, other communities may also find themselves as literal or figurative islands for substantial periods of time should the NRF partially or completely collapse, and therefore, may find utility in the lessons of Puerto Rico.

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