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Hurricane Floyd / Hurricane Matthew Empirical Disaster Resilience Study

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and

The University of North Carolina–Chapel Hill Coastal Resilience Center of Excellence
100 Europa Drive, Suite 540
Chapel Hill, NC 27517

Prepared by:

AECOM
12420 Milestone Center Drive
Suite 150
Germantown, MD 20876

T: +1 (301) 820 3000
F: +1 (301) 820 3009
aecom.com

Abstract

Two types of studies were conducted. An exploratory study examined whether 17 theoretical indicators of resilience demonstrate whether communities saved time and money as they recovered from Hurricane Matthew. The other study, a losses avoided study, examined whether the acquisition of flood-prone properties by county and municipal governments increased resilience following Hurricane Matthew. The hazard mitigation projects in the study were implemented after Hurricane Floyd, which struck the coast of North Carolina in 1999 and caused $2 billion of damage, and before Hurricane Matthew, which struck the coast of South Carolina in 2016 and moved north, causing $967 million in North Carolina.

Exploratory Study

The exploratory study used empirical measures of pre-Hurricane Matthew conditions (indicators of resilience) and Hurricane Matthew outcomes in six eastern North Carolina counties. Measures of 17 indicators of resilience (independent variables) were compared to post-Hurricane Matthew outcomes (dependent variables) (dependent variables. Each hypothesized outcome was that higher levels of an indicator of resilience led to less damage to privately owned structures or public infrastructure and a less time-consuming recovery from Hurricane Matthew. The study analyzed 88 paired comparisons of measures of an indicator of resilience and measures of Hurricane Matthew outcomes. A paired comparison approach was selected because the sample size of six counties was insufficient to use simple linear regression.

The findings of the exploratory study suggest that, as hypothesized:

- A lower percentage of low- to moderate-income households makes a community more resilient.
- A higher percentage of homeownership makes a community more resilient.
- A lower percentage of mobile homes makes a community more resilient.
- A larger number of road and bridge projects completed after Hurricane Floyd (measured as completed with FEMA Public Assistance funding) made communities more resilient than communities with fewer projects completed.

The findings are based on a sample of only six counties and cannot be used to infer that one or more indicators of resilience led to reduced time for recovery or reduced costs of recovery. The results of other paired comparisons were statistically insufficient to draw conclusions.

Losses Avoided Study

More than 1,000 flood-prone properties in the study areas were acquired and demolished or relocated after Hurricane Floyd and before Hurricane Matthew using five sources of funding. The losses avoided study used flood event data from Hurricane Matthew to develop estimates of the flood losses that were avoided in Hurricane Matthew. By comparing acquisition cost data with avoided flood loss data, the study showed that losses avoided in just Hurricane Matthew were greater than the investment in the acquisitions. Future flood events will increase the benefit to cost ratio.

Lessons Learned and Recommendations

Both studies identified numerous data collection challenges related to both pre- and post-hurricane conditions. Recommendations are similar to those made in published literature. The recommendations are to (1) improve data by collecting and saving it on a day-to-day basis in the weeks and months after a disaster, (2) codify data collection as part of existing post-event procedures to improve comparability of measures across different jurisdictions, and (3) include post-disaster funding in data collection to document the rapidity with which post-disaster grants are implemented. Only with reliable data can resilience be examined more closely in the future.

Table of Contents

Appendices

Figures

Tables

Acronyms

ACS	American Community Survey (U.S. Census Bureau)
BCA	Benefit-Cost Analysis
BRR	Building Resilient Regions
CAMRA	Creating a More Disaster Resilient America
CDBG-DR	Community Development Block Grant – Disaster Recovery
CRS	Community Rating System
DFIRM	Digital Flood Insurance Rate Map
DHS	Department of Homeland Security
DR	Disaster Declaration Number
DRC	Disaster Recovery Center
FEMA	Federal Emergency Management Agency
FIMAN	North Carolina Flood Inundation Mapping and Alert Network
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
GSA	General Services Administration
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
HUD	Housing and Urban Development
IHP	Individuals and Households Program
LAS	Losses Avoided Study
LiDAR	Light Detection and Ranging
Mit-FLG	Mitigation Framework Leadership Group
NC	North Carolina
NCFRIS	North Carolina Flood Risk Information System
NFIP	National Flood Insurance Program
NIST	National Institute of Standards and Technology
PA	Public Assistance
RAVON	Resiliency and Vulnerability Observatory Network
RFC	Repetitive Flood Claims
ROI	Return on Investment
USDA	United States Department of Agriculture

1. Introduction

This report summarizes the results of a study performed by AECOM for the Department of Homeland Security (DHS) Science and Technology Directorate Flood Apex Program and UNC-CH Coastal Resilience Center. This section describes the Flood Apex Program, the study purpose, research approaches, and the organization of the report.

1.1 Flood Apex Program

The DHS Science and Technology (S&T) Directorate created the Flood Apex Program in 2014 at the request of the Federal Emergency Management Agency (FEMA) Administrator. The Flood Apex Program brings together new and emerging technologies designed to increase communities' resilience to flood disasters and provide flood-predictive analytic tools. The Flood Apex Program supports the DHS S&T Directorate's visionary goal of resilient communities.

Flood Apex Program

Additional information on the Apex program can be found at the following links;

- https://www.dhs.gov/science-and-technology/flood-apex
- https://www.dhs.gov/sites/default/files/publications/Flood-Apex-Overview-Rethinking-Americas-Costliest-Disaster_v1-508_0.pdf

The key objectives of the Flood Apex Program are to reduce fatalities and property losses from future flood events; increase community resilience to disruptions caused by flooding; and develop better investment strategies to prepare for, respond to, recover from, and mitigate against the effects of flood hazards. The Flood Apex Program delivers its objectives by building on existing programs and efforts at the federal, state, and community levels; operationalizing new forecasting and alert methods and technologies; and empowering communities with the right data and decision support tools to enable pre- and post-event flood resilience planning.

Work under the Flood Apex Program will provide products, processes, and standards to:

1. Reduce flood fatalities
2. Reduce uninsured losses
3. Improve mitigation investment decisions
4. Improve flood data and data access
5. Improve predictive flood analytics
6. Enhance community resilience

A major priority of the Program is to integrate the concept of resilience into flood risk management planning and investment decisions at all levels of government, especially at the local community level. This includes using quantitative measures of vulnerability, risk, and recovery.

1.2 Study Purpose

The purpose of this study is to improve the understanding of the impacts of state and local level mitigation actions intended to enhance community resiliency, support effective and equitable recovery, and reduce flood fatalities and losses by providing an empirical analysis of the post-Hurricane Floyd (1999) statewide mitigation actions and consequences of Hurricane Matthew (2016). This study supports the Flood Apex Program objective by examining how indicators of resilience and flood hazard mitigation efforts relate to the experience of communities damaged by those two hurricanes.

The study examines the impacts of Hurricane Matthew in light of flood hazard mitigation actions implemented in each of six study counties in North Carolina after Hurricane Floyd in 1999. The study builds on the theory developed by the scientific community about community resilience. In this study, the term "community" refers to a county.

Hurricane Floyd led to the implementation of flood hazard mitigation projects supported, fully or in part, with federal funds. To mitigate the potential for damage due to flooding, mitigation projects included acquiring properties and either demolishing structures or moving structures to safer, less flood-prone, locations.

Resilience

Resilience is generally described in academic and professional papers as the ability of a community to recover from an adverse occurrence that caused hardship, destruction, and loss.

Community

The term "community" is not defined in resilience literature and may refer to something as small as a business or as large as an economic or geographic region.

1.3 Research Approaches

The study used two research approaches: an exploratory examination of indicators of resilience and an examination of losses avoided due to hazard mitigation in six North Carolina counties. The six hurricane-prone counties selected for the study were Bertie, Columbus, Edgecombe, Lenoir, Robeson, and Wayne. For each approach, independent and dependent variables were identified.

Exploratory Study

Independent variables used in the exploratory examination of resilience are measures of numerous pre-hurricane conditions suggested in theory to indicate resilience. The study also examines flood hazard mitigation accomplishments as a potential indicator of resilience.

Dependent variables used in the exploratory examination are measures of Hurricane Matthew outcomes. The exploratory examination consisted of paired comparisons of independent variables with dependent variables across the six counties to learn whether indicators of resilience led to less damage and faster recovery.

Losses Avoided Study

For the losses avoided study, the independent variable measures were the dollars spent and locations where the risk of flooding was mitigated prior to Hurricane Matthew through acquisition and demolition of structures, as well as estimated depths of flooding due to Hurricane Matthew.

For the losses avoided study, the dependent variable measures were estimates of losses avoided due to having mitigated the risk of flooding. The method used to conduct the losses avoided study was developed by FEMA (2009).

1.4 Organization of Report

Table 1-1 summarizes the content of each section of the report.

Table 1-1: Section Contents

Section of Report		Section Contents
Section 1	Introduction	Description of the Flood Apex Program, discusses the purpose of the study, and briefly describes the two research approaches used in the study
Section 2	Hurricanes Floyd and Matthew	Brief description of Hurricanes Floyd and Matthew, both of which caused damage throughout eastern North Carolina
Section 3	Overview of Study Counties	Overview of the six counties selected for the study
Section 4	Exploratory Study of Resilience	Describes the independent variables, dependent variables, and analytic method, and the findings for the exploratory study of resilience.
Section 5	Losses Avoided Study	Effectiveness of property acquisitions projects completed after hurricane Floyd, and qualitative case studies of two counties
Section 6	Lessons Learned	Lessons learned based on the experience of conducting both the exploratory and losses avoided portions of the study
Section 7	Recommendations	Recommendations for collecting data that can be used to conduct future research on resilience
Appendix A	References and Sources Consulted	References and sources consulted for the study
Appendix B	State-Level Flood Risk Information	State-level flood risk information dissemination programs instituted after Hurricane Floyd
Appendix C	County Maps	Maps of each study county showing locations of the acquired properties used in the losses avoided analysis

2. Description of Hurricanes and Impacts

Hurricanes Floyd and Matthew were selected as the two end points for this study. Hurricane Floyd occurred in 1999 and Hurricane Matthew in 2016. Hurricanes Floyd and Matthew followed similar paths from the tropics to North Carolina, and both occurred within weeks of earlier heavy rainfall events. Impacts of these two hurricanes were similar, but not identical. After Hurricane Floyd struck the area, but before Hurricane Matthew, eastern North Carolina counties experienced several other hurricanes. The major hurricanes affecting the region and leading to disaster declarations between 1999 and 2016 were Hurricanes Isabel (2003), Ivan (2004), Ophelia (2005), Earl (2010), and Irene (2011). After Hurricane Matthew, eastern North Carolina experienced another major damaging hurricane: Hurricane Florence, which struck in in September 2018. Hurricane Florence is not considered in this study because the study began prior to 2018. Additional details regarding each disaster event are presented in Sections 2.1.1 and 2.2.1.

Counties and communities took action after each disaster event as part of recovery and building resiliency. The FEMA Public Assistance (PA) program funded numerous recovery and mitigation projects in each county. The categories of damages to public facilities and associated recovery costs for each disaster are described in Sections 2.1.2 and 2.2.2.

2.1 Hurricane Floyd

Hurricane Floyd, which struck the coast of North Carolina in September 1999, resulted in more than $2 billion in losses in the State (General Assembly of NC, 1999).

2.1.1 Event Description

Hurricane Floyd made landfall on September 16, 1999, at Cape Fear, North Carolina, as a Category 2 hurricane with 105 mph winds. Hurricane Floyd’s rains caused widespread flooding throughout eastern North Carolina that lasted for several weeks (National Weather Service, 2018a).

Less than a month before Hurricane Floyd, eastern North Carolina experienced heavy rainfall due to Hurricane Dennis. The extensive rainfall saturated much of the soil, which made eastern North Carolina more susceptible to flooding when Hurricane Floyd arrived (National Weather Service, 2018). Rainfall from Hurricane Floyd generally ranged from 7 to 15 inches across the six study counties, as shown in Figure 2-1 (National Weather Service,2018a). Robeson County received less precipitation than the other study counties during Hurricane Floyd.

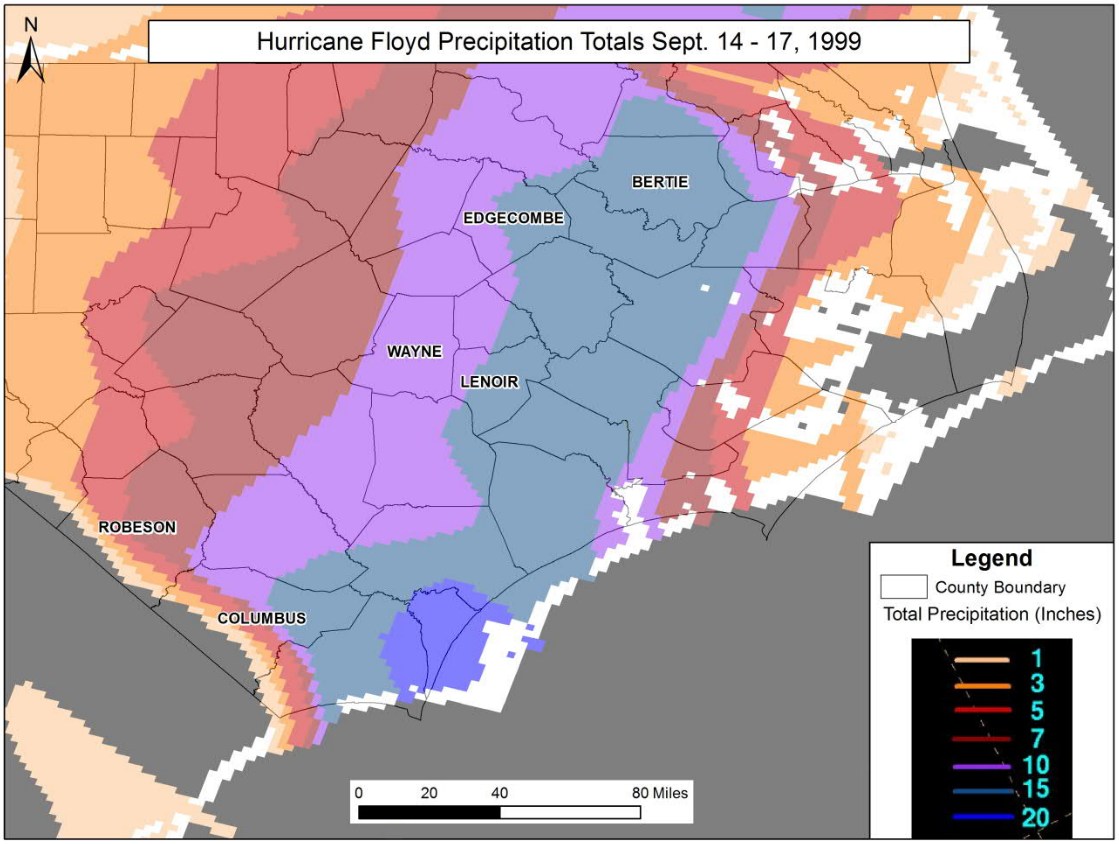


Figure 2-1: Hurricane Floyd precipitation (the six study counties are identified by name)

Source: Adapted from https://www.wpc.ncep.noaa.gov/tropical/rain/floyd1999.html

2.1.2 Damage Description

Following Hurricane Floyd, FEMA obligated over $76 million in Public Assistance (PA) Program funds to assist the six study counties to resume normal functioning (FEMA, 2018a). Hurricane Floyd PA Program funds were distributed as shown in Table 2-1.

Table 2-1: Hurricane Floyd PA Program Project Costs

	Project Cost by County					
PA Category	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
A Debris Removal	$675,902	$549,638	$8,623,931	$4,472,846	$673,053	$3,685,428
B Protective Measures	$262,616	$262,727	$1,683,474	$915,425	$102,861	$629,466
C Roads and Bridges	$47,669	$287,292	$344,679	$127,089	$70,948	$69,681
D Water Control	$4,500	$11,311	$0	$33,960	$70,948	$1,898,730
E Public Buildings	$242,151	$29,567	$12,707,436	$622,554	$33,101	$547,616
F Public Utilities	$1,114,856	$135,367	$2,055,800	$38,023,014	$1,031,114	$1,026,198
G Recreational or Other	$16,697	$46,774	$794,547	$211,486	$68,477	$206,150
Total by County	**$2,364,391**	**$1,322,676**	**$26,209,867**	**$44,406,374**	**$2,050,502**	**$8,063,269**

Source: FEMA, 2018a

As part of an unprecedented state-level effort, North Carolina partnered with FEMA to elevate or acquire and demolish hundreds of homes.

After Hurricane Floyd, state policies were modified to support the recovery and increase disaster resilience. The General Assembly of NC authorized over $281 million to assist in relocating homeowners and renters (General Assembly of NC, 1999). The General Assembly of NC established a Hurricane Floyd Disaster Relief Commission, and this commission recommended that, among other things, the state:

- Create a disaster reserve fund for relief;
- Establish a disaster studies institute to facilitate and coordinate research on disaster planning, response, recovery, and mitigation;
- Integrate long-term recovery into emergency operations; and
- Strengthen the performance and accountability of local emergency management teams (Legislative Study Commission on Disaster Response and Recovery, 2001).

Following Hurricane Floyd, the State of North Carolina embarked on the remapping of its floodplains as a participant in the FEMA Cooperating Technical Community Partnerships Initiative. North Carolina committed to updating and maintaining Flood Insurance Rate Maps (FIRMs) statewide and created digital FIRMs (DFIRMs) after conducting flood hazard analyses as old FIRMs were outdated or inaccurate. The updated DFIRMs were easy to use and showed current information about flood risk. The NC Floodplain Mapping Initiative is described in Appendix B.1. DFIRMs are based on data gathered through Light Detection and Ranging (LiDAR), which is described in Appendix B.2.

North Carolina developed additional programs and platforms to further share information about flood risk with local officials and the general public. These include:

- iRISK
- North Carolina Flood Risk Information System (NCFRIS)
- North Carolina Flood Inundation Mapping and Alert Network (FIMAN)

Each of these platforms is described in Appendices B.3 through B.5 of this report.

2.2 Hurricane Matthew

Hurricane Matthew, which struck the coast of South Carolina in October 2016 moved north and resulted in over $967 million damage in North Carolina (General Assembly of NC, 2016).

2.2.1 Event Description

Hurricane Matthew made landfall on October 8, 2016 in McClellanville, South Carolina, as a Category 1 hurricane. In North Carolina, approximately 88,000 homes were damaged in the hurricane with a total loss of almost $967 million, of which as much as 68 percent was “not expected to be covered by insurance or FEMA assistance” (General Assembly of NC, 2016).

Weeks before Hurricane Matthew occurred, eastern North Carolina received several inches of rain from Tropical Storms Julia and Hermine that saturated soils. Riverine flooding began several days after Hurricane Matthew passed and lasted more than 2 weeks (General Assembly of NC, 2016).

Rainfall from Hurricane Matthew generally ranged from 10 to 15 inches across the six study counties as shown in Figure 2-2 (National Weather Service, 2018b). Bertie, Edgecombe, and Lenoir Counties generally received less rain than Columbus, Robeson, and Wayne during Hurricane Matthew.

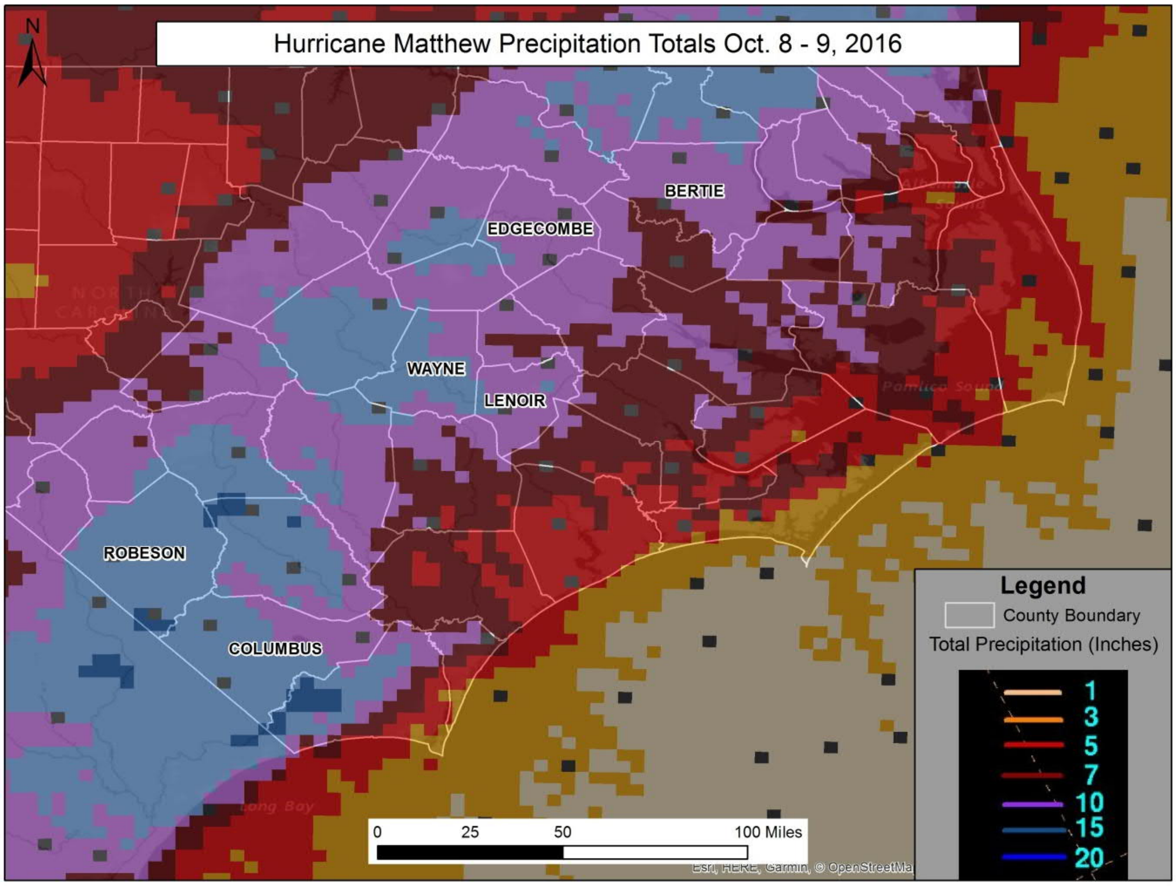


Figure 2-2: Hurricane Matthew precipitation (the six study counties are identified by name)

2.2.2 Damage Description

Hurricane Matthew caused a great deal of damage to housing as well as to public facilities. Table 2-2 summarizes the number of houses impacted by Hurricane Matthew based on claims made to FEMA's Individual Assistance (IA) Program.

Table 2-2: Hurricane Matthew IA Program Claims

County	Number of Claims
Bertie	1,025
Columbus	5,189
Edgecombe	3,139
Lenoir	3,291
Robeson	18,482
Wayne	6,695

Source: FEMA 2018b

By August 2018, the State of North Carolina and FEMA had committed over $81 million in Hazard Mitigation Grant Program (HMGP) funds to rebuild, elevate, or acquire privately owned structures flooded by Hurricane Matthew (North Carolina, 2018). As of December 6, 2018, FEMA had committed over $63 million in PA Program funds to help the six study counties resume normal functioning (FEMA, 2018a). Hurricane Matthew PA Program funds were distributed as shown in Table 2-3.

Table 2-3: Hurricane Matthew PA Program Project Costs

	Project Cost by County					
PA Category	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
A Debris Removal	$104,358	$813,941	$518,830	$1,217,803	$3,674,622	$1,514,704
B Protective Measures	$401,993	$1,107,224	$1,144,433	$1,488,015	$6,584,275	$1,361,424
C Roads and Bridges	$29,450	$31,181	$810,053	$180,574	$546,476	$1,106,930
D Water Control	$3,972	$489,326	$109,638	$6,386	$0	$1,226,776
E Public Buildings	$83,847	$1,056,944	$4,161,209	$1,043,952	$17,630,445	$690,193
F Public Utilities	$487,877	$183,546	$1,838,585	$2,310,582	$6,090,036	$2,482,063
G Recreational or Other	$62,144	$54,595	$212,120	$55,087	$241,899	$290,327
Total Down	**$1,173,641**	**$3,736,757**	**$8,794,868**	**$6,302,399**	**$34,767,753**	**$8,672,417**

Source: FEMA, 2018a

Following Hurricane Matthew, the General Assembly of NC enacted the Disaster Recovery Act of 2016 to aid in meeting “critical needs not met by existing state and federal programs and funds” (General Assembly of NC, 2016, page 2). The act declared that over $11 million would be allocated to the State Division of Emergency Management to conduct resilient redevelopment planning and over $66 million to provide a state match for Federal disaster assistance programs.

3. Overview of Study Counties

This section provides a brief overview of the six study counties. Each county is in eastern North Carolina, but none are on the coast. Locations of the study counties are shown in Figure 2-1 and Figure 2-2.

Tables 3-1 to 3-3 summarize key information for each of the six counties, as follows:

- Table 3-1 summarizes key geographic features of each of the six study counties
- Table 3-2 summarizes American Community Survey (ACS) population and housing information about counties
- Table 3-3 summarizes flood hazard mitigation information about the counties
  Table 3-3 shows that each county developed, updated, and adopted a hazard mitigation plan prior to Hurricane Matthew in 2016; the table also shows that each county participated in the National Flood Insurance Program (NFIP) and adopted standards for construction in designated flood hazard areas well before Hurricane Floyd, and had adopted FIRMs that were revised after Hurricane Floyd.

Table 3-1: Geographic Overview of Study Counties

County	River Basin	Total Square Miles[(a)]	Percentage Land Designated as SFHA on FIRM[(b)]	Percentage Agricultural Land[(c)(d)]
Bertie	Tar-Pamlico	741	56.11%	30.95%
Columbus	Lumber	954	7.08%	26.08%
Edgecombe	Tar-Pamlico	507	23.79%	39.03%
Lenoir	Neuse	402	17.83%	47.46%
Robeson	Lumber	951	22.50%	43.63%
Wayne	Neuse	557	12.73%	53.63%

[(a)] U.S. Census, 2007
[(b)] FEMA, 2018c
[(c)] USDA, 2012
[(d)] SFHA and agricultural land are not mutually exclusive categories
SFHA = special flood hazard area

Table 3-2: Population and Housing Overview of Study Counties

County	2016 Estimated Population	2016 Estimated Total Housing Units	2016 Estimated Occupied Housing Units
Bertie	20,324	9,759	7,673
Columbus	57,015	25,935	22,108
Edgecombe	54,669	24,684	21,103
Lenoir	58,343	27,319	23,015
Robeson	134,576	52,318	45,914
Wayne	124,447	53,202	47,013

Source: U.S. Census Bureau, 2016

Table 3-3: Flood Hazard Mitigation Overview of Study Counties

County	Hazard Mitigation Plan Update (Year) Adopted Prior to Hurricane Matthew[(a)]	Year Joined NFIP[(b)]	Date of FIRM Adopted Prior to Hurricane Matthew[(b)]
Bertie	2016	1985	8/3/2009
Columbus	2015	1991	2/16/2007
Edgecombe	2015	1981	6/2/2015
Lenoir	2015	1983	4/16/2013
Robeson	2012	1989	7/7/2014
Wayne	2011	1991	4/16/2013

Sources: (a)Bertie, Hyde, Martin, Tyrrell, Washington Counties. 2016; Bladen / Columbus County. 2015; Holland Consulting Planners/SEPI Engineering and Construction. 2015; Nash, Edgecombe, Wilson Counties. 2016; Robeson County, 2017;
(b)FEMA, 2019

4. Exploratory Study of Resilience

This section describes the independent variables, dependent variables, and analytic method, and the findings for the exploratory study of resilience.

- Section 4.1 explains the independent variables or pre-Hurricane Matthew conditions used in the exploratory study of resilience. In this study, variables are categorized as social, economic, physical, or disaster management indicators of resilience.
- Section 4.2 discusses the dependent variables, or post-Hurricane Matthew factors used. Dependent variables relate to the amount of time required and the costs necessary to return to normal functioning after the hurricane.
- Section 4.3 explains the method used to conduct the exploratory study of resilience.
- Section 4.4 presents the findings.

4.1 Independent Variables Used in the Study

This section shows how indicators of resilience (i.e., the independent variables, which are pre-Hurricane Matthew conditions and characteristics) used in the study were selected and how empirical measures or data were collected for each independent variable for the exploratory research approach used in this resiliency study.

This section describes how the number of potential indicators of resilience was reduced before identifying the specific indicators of resilience used in the study. Each of the indicators of resilience used in the study is described, as are the four categories into which they are grouped. The section identifies the theoretical basis for using each indicator of resilience and explains how each indicator is measured. It further presents study-specific indicator data for the six counties used in the study.

Two caveats apply:

1. It is recognized that the categories into which the indicators are organized could have been described differently, and some indicators could have been sorted into multiple categories.
2. Many of the indicators presented measure very closely related concepts. However, since the analysis does not employ multiple regression analyses, multi-collinearity is not a concern, so the closely related indicators were included in the study.

4.1.1 Selection of Indicators of Resilience for the Exploratory Study

A review of resilience theory identified approximately 100 different indicators of resilience. These indicators relate to various characteristics of a community, including its physical environments, disaster management experience and capabilities of the local governments, and economic and social conditions.

To reduce the number of indicators of resilience used in the study, those that could not be measured empirically or did not pertain to a county were removed from consideration. Table 4-1 shows reasons why some types of proposed indicators of resilience were eliminated from the study and provides one or more examples for each type of reason.

Table 4-1: Examples of Eliminated Indicators of Resilience

Elimination Reason	Example of an Indicator of Resilience	Comments
Insufficient variation across the study area	Building code	The State of North Carolina has a building code that is applied statewide, so there is no variation across the six counties.
	Freeboard regulations	Each of the six study counties requires structures in Special Flood Hazard Areas to be elevated at least 2 feet above the NFIP-designated base flood elevation.
	Participation in state disaster recovery meetings	While no data were readily available on attendance at state meetings, representatives of each county were assumed to have participated in post-disaster recovery meetings following Hurricane Matthew.
	Regular updating of county hazard mitigation plans	Each of the six study counties developed a hazard mitigation plan after Hurricane Floyd and updated it at least once before Hurricane Matthew.
	Good quality, publicly available information about flood risk	Each of the six study counties had access to similar, high-quality flood risk information through the NC Floodplain Mapping Initiative, the NC Risk Management Portal, or iRISK the NC Flood Risk Information System, and the NC Flood Inundation Mapping and Alert Network. These programs are described in Appendix B.
Data unavailable at the county level	Experience with participation in HUD's CDBG-DR program	Data on participation in the CDBG-DR program after Hurricane Floyd (1999) were found at the state level, but not the county level.
Concept for which no empirical measure can be readily defined	Local economic base	Descriptions of this indicator found in resilience literature do not specify whether it refers to the number of employers in a county, the largest types of employers in a county, the types of employers, or degree to which goods manufactured in a county are exported. However, the study did examine some indicators of economic health.
Includes variables difficult to measure across the study area	Number of community organizations	The number of community organizations could not be reliably determined because official documents from counties list organizations differently. For instance, one county might list only the number of nonprofit organizations with offices in the county and another might include church organizations, school groups, and business and neighborhood associations.
	Comprehensive land use plan or capital improvement plan that addresses flood risk	Such plans vary greatly in presentation and content from one county to another and are not comparable.

HUD = Department of Housing and Urban Development
CDBG-DR = Community Development Block Grant – Disaster Recovery
NFIP = National Flood Insurance Program

Using the selection considerations described, the number of indicators of resilience was reduced to 17, shown on Table 4-2. The selection of each indicator is supported by literature, as shown.

Table 4-2: Selected Indicators of Resilience and Literature Support

Indicator of Resilience	Literature Support
Individual wealth	
Percent of households having low to moderate income	Morrow (2008); Norris et al. (2008); Cutter et al. (2010); Peacock (2010); BRR (2011); Mit-FLG (2018)
Per capita income	
Median monthly household income Individual wealth	
Homeownership rate	Prevention Institute (2004); Morrow (2008); Wagner et al. (2008); Norris et al. (2008); Cutter et al. (2010); Peacock (2010); BRR (2011); Cutter et al. (2014)
Health of population	
Healthcare availability	Mit-FLG (2016), Cutter et al. (2014), Rockefeller Foundation (2014), Cutter et al. (2010), Peacock (2010), Prevention Institute (2004)
Food insecurity	Cutter et al. (2010), Peacock (2010)
Availability of parks	Burby et al. (2000); Cutter et al. (2010), Peacock (2010), Prevention Institute (2004)
Unemployment	Flanagan et al. (2011); Cutter et al. (2014); Mit-FLG (2016)
Educational attainment	Cutter et al. (2010); Peacock (2010)
Access to a vehicle	Prevention Institute (2004); Cutter et al. (2010); Peacock (2010); Tierney (2009); Flanagan et al. (2011); Cutter et al. (2014); Berke et al. (2015)
Housing stock type	Berke et al. (2015); Cutter et al. (2014); Flanagan et al. (2011)
Housing constructed before the county joined NFIP	Burby (2001)
Value of owner-occupied housing units	Morrow (2008); Norris et al. (2008); Cutter et al. (2010); Peacock (2010); BRR (2011)
Road and bridge projects completed after Hurricane Floyd (funded by the FEMA PA program)	Berke and Campanella (2006); Cutter et al. (2010); Peacock (2010); Sempier et al. (2010)
FEMA-funded housing hazard mitigation projects	Berke and Campanella (2008); Cutter et al. (2010); Peacock (2010); Sempier et al. (2010); Committee on Increasing National Resilience to Hazards and Disasters (2012)
Integration of planning mechanisms	Flynn (2014); Berke et al. (2015)
Flood insurance coverage	Burby (2001)

NFIP= National Flood Insurance Program
PA = Public Assistance

These 17 indicators of resilience were then categorized as pertaining to the social, economic, and physical environment, and disaster management capacity of a community as shown in Table 4-3.

Table 4-3: Categories Used for Selected Indicators of Resilience

Category	Indicator of Resilience
Social	Individual wealth • Percent of households having low to moderate income • Per capita income • Median monthly household income Individual wealth • Homeownership rate
	Health of population • Healthcare availability • Food insecurity • Availability of parks
Economic	Unemployment Educational attainment Access to a vehicle
Physical	Housing stock type Housing constructed before the county joined NFIP Value of owner-occupied housing units Road and bridge projects completed after Hurricane Floyd (funded by the FEMA PA program)
Disaster Management	FEMA-funded housing hazard mitigation projects Integration of planning mechanisms Flood insurance coverage

NFIP= National Flood Insurance Program
PA = Public Assistance

Data collection on indicators of resilience was limited to internet research to obtain publicly available information and data provided by FEMA and the DHS. Table 4-4 lists the indicators of resilience, the measure used for each indicator, and the data source for the measure. Limitations that apply to the quality of measures used for indicators of resilience are shown in Table 4-5.

Table 4-4: Measures of Indicators of Resilience

Indicator of Resilience	Measures	Source of the Measure
Individual wealth	Percent of households having low to moderate income	HUD Exchange for FY 2017
	Per capita income	American Community Survey (U.S. Census)
	Median monthly household income	American Community Survey (U.S. Census)
	Homeownership rate (percentage of owner-occupied housing units)	American Community Survey (U.S. Census)

Indicator of Resilience	Measures	Source of the Measure
Healthcare availability	The number of primary care physicians per 100,000 residents in each study county and the counties adjacent to it	Department of Health and Human Services GIS data provided by DHS and FEMA showing the number of primary care physicians by county
Food insecurity	Percent of population defined as food insecure	Southeastern University Consortium on Hunger, Poverty, and Nutrition (2015)
Availability of parks	Number of parks maintained by the county by either the state or the county	Information provided on individual county websites and by the NC 2015–2016 Official State Transportation Map
Unemployment	Average of rates of unemployment during 2014, 2015, and 2016	American Community Survey[a]
Educational attainment	Percentage of residents over the age of 25 who have completed high school or higher levels of education	American Community Survey
Access to a vehicle	Percentage of households with access to at least one vehicle	American Community Survey
Housing stock type Non-mobile homes	Percent housing units not mobile housing	American Community Survey
Housing constructed before decade in which county joined the NFIP	Percent of housing built in decades before a county joined the NFIP	American Community Survey
Value of owner-occupied housing units	Median value of owner-occupied housing units	American Community Survey
Road and bridge projects completed after Hurricane Floyd	Number of road and bridge projects completed after Hurricane Floyd using funds from FEMA's PA program	Data provided by FEMA
FEMA-funded housing hazard mitigation projects	Number of structural mitigation actions supported with FEMA HMA program funds	Data provided by FEMA[b]
Integration of planning mechanisms	Sum of the number of identified planning mechanisms (subdivision ordinance, zoning ordinance, density of land use policy, capital improvements plan, policy to use flood-prone land for parks, Coastal Area Management Act plan, and participation in FEMA's CRS program)	Publicly available websites
Flood insurance coverage	Percentage of homes covered by an NFIP policy	Data provided by FEMA

(a) The American Community Survey is from the U.S. Census
(b) Spreadsheet titled "All NC HMA Projects"
CRS = Community Rating System
FY = fiscal year
HUD = Department of Housing and Urban Development
NFIP = National Flood Insurance Program
PA = Public Assistance

Table 4-5: Limitations on Quality of Measures

Indicator of Resilience	Limitation
Food insecurity	The method used by a source of information that provided food insecurity data was not reviewed in detail for this study.
Educational attainment	The original metric suggested for the resilience study for educational attainment was the difference between percent population with a college degree and percent of population with less than high school. The metric was modified to be consistent with the U.S. Census Bureau metric for "educational attainment," which is percent of population completing high school or higher levels of education.
Housing constructed before the county joined NFIP	Census data list the decade in which housing units were built, not the exact year; therefore, the number of houses constructed per decade before the decade in which a county joined the NFIP is a rough estimate of the number of units built before the county began participating in the NFIP.
Integration of planning mechanisms	Desktop internet research was used to identify most of the listed planning mechanisms for a county. Some relevant documents may not have been identified.
	Although the indicator of resilience uses the term "integration of planning mechanisms," the study did not evaluate the degree to which the various plans were integrated with resilience goals.
	The number of planning mechanisms identified for counties varies; Bertie is the only county required to develop a Coastal Area Management Act plan.
Flood insurance coverage	Flood insurance coverage data show the percentage of homes covered by an NFIP policy in 2017, the year after Hurricane Matthew occurred. Data for 2016 would have been preferable.

NFIP = National Flood Insurance Program

4.1.2 Social Indicators of Resilience

Resilience is "the capacity of a social entity (e.g., a community) to 'bounce back' or respond positively to adversity" (Maguire and Hagan, 2007). Theorists suggest that resilience is a product of the individual wealth and health of residents of a community (Mit-FLG, 2018; Cutter et al., 2014; BRR, 2011; Cutter et al., 2010; Peacock, 2010; Norris et al., 2008, Morrow, 2008; Wagner et al., 2008).

Social indicators of resilience examined in this study are indicators of individual wealth and the health of the population.

4.1.2.1 Individual Wealth Indicators

This study uses four social indicators of resilience as measures of individual wealth or resources: percent of households categorized as having a low to moderate income level, per capita income, and median monthly household income, and homeownership rate. The individual wealth indicators are described below. Table 4-6 shows a summary of the individual wealth indicators for each of the six counties.

Table 4-6: Individual Wealth Indicators by County

County	Percent Households Low to Moderate Income[(a)]	Per Capita Income in 2016[(b)]	Median Monthly Household Income[(b)]	Homeownership in 2016[(c)]
Bertie	34.6%	$17,244	$2,594	73.6%
Columbus	39.1%	$21,133	$2,987	69.4%
Edgecombe	49.0%	$18,009	$2,692	59.6%
Lenoir	41.3%	$20,773	$3,080	61.8%
Robeson	49.4%	$16,221	$2,608	64.0%
Wayne	38.9%	$21,674	$3,371	59.7%

All income percentages are in 2017 dollars
Sources:
(a) HUD Exchange, 2018
(b) U.S. Census Bureau, 2018
(c) Percentage of owner-occupied housing units

Percent of households having low to moderate income. The first measure of individual wealth is percent of population categorized as having a low to moderate income level. This indicator is expected to have a negative relationship to resilience because households that spend more than 30 percent of income on rent or mortgage payments may have difficulty in supporting the costs of repair and rebuilding necessitated by a hurricane.

In this study, the percent of households having a low to moderate income indicator was measured using data published by HUD (HUD Exchange, 2018). Table 4-6 shows the percentage of households in the study area counties classified as having a low to moderate income level.

Per capita income. The second measure of individual wealth is per capita income. This indicator is expected to have a positive relationship to resilience because individuals with greater income will have more money to spend on post-hurricane repairs and rebuilding. Table 4-6 shows per capita income in 2016 in the study area by county.

Median monthly household income. The third measure of individual wealth is median monthly household income. This indicator is expected to have a positive relationship to resilience because households with greater income will have more money to spend on post-hurricane repairs and rebuilding. Table 4-6 shows median monthly household income for 2016 in the study area by county.

Homeownership rate. The fourth indicator of individual wealth is homeownership rate, which is defined as the proportion of households in owner-occupied housing units. This indicator is expected to have a positive relationship to resilience because homeowners will be highly motivated to repair damage and return to their homes following a disaster. In this study, the homeownership rate in 2016 was measured as the percentage of owner-occupied housing units. Table 4-6 shows the percentage of homeownership in 2016 in the study area counties.

4.1.2.2 Health of Population Indicators

This study uses three indicators that are measures of the health of the population: healthcare availability, food insecurity, and availability of parks Table 4-7 shows a summary of the health indicators for each of the six counties. Each of the individual health of population indicators is described in the text that follows.

Table 4-7: Health of Population Indicators by County

County	Primary Care Physicians per 100,000 Population[(a)]	Food Insecure Population[(b)]	Availability of Parks (total)[(c)]
Bertie	46	26%	9
Columbus	50	22%	25
Edgecombe	69	27%	15
Lenoir	65	22%	27
Robeson	56	23%	28
Wayne	38	19%	15

(a) FEMA, 2018d
(b) Southeastern University Consortium on Hunger, Poverty, and Nutrition (2015)
(c) Individual county websites (refer to Table 4-8 for specific sources); NC 2015-2016 Official State Transportation Map

Healthcare availability. The first indicator of health is healthcare availability. This indicator is expected to have a positive relationship to resilience because with improved access to healthcare services, residents of a community will be healthier and more able to respond to the effects of a disaster.

In this study, the healthcare availability indicator was measured as the number of primary care physicians per 100,000 residents in each study county and the counties adjacent to it. Adjacent counties were included because regional hazard mitigation plans indicate that residents of the study counties regularly use facilities in nearby counties. Data for the number of primary care physicians were obtained using geographic information system (GIS) data provided by the U.S. Department of Health and Human Services through FEMA for this study. Table 4-7 shows the number of primary care physicians per 100,000 residents in the study area counties.

Food insecurity. The second indicator of health is food insecurity. Greater food insecurity is expected to be negatively related to resilience because the population will be less healthy and less able to respond to the effects of a disaster.

In this study, data for food insecurity were obtained from the Southeastern University Consortium on Hunger, Poverty, and Nutrition (2015). Table 4-7 displays the percent of the population in the study area counties defined as food insecure.

Availability of parks. The third indicator of health is the availability of parks. This indicator is expected to have a positive relationship to resilience because if residents have improved access to parks for recreation and exercise, they will be healthier and better able to respond to the effects of a disaster.

The availability of parks indicator was measured using information provided on individual county websites and by the North Carolina 2015–2016 Official State Transportation Map. Table 4-8 shows the number of parks maintained by the county and by the state in each county of the study area.

Table 4-8: Availability of Parks by County

	Number of Parks		
County	**County**	**State**	**Total**
Bertie	7	2 (Roanoke River Wildlife Refuges)	9
Columbus	24	1 (Lake Waccamaw State Park)	25
Edgecombe	15	0	15
Lenoir	27	0	27
Robeson	27	1 (Lumber River State Park)	28
Wayne	14[6]	1 (Cliffs of the Neuse State Park)	15

Sources:
Bertie County: retrieved 6/10/18 from http://www.co.bertie.nc.us/departments/rec/pics/parks/pgs.html
Columbus County: retrieved 6/10/18 from http://www.columbusco.org/Departments/Recreation/Facilities
Edgecombe County: retrieved 6/10/18 from http://www.edgecombecountync.gov/Departments/Health%20Department/Environmental%20Health/edgecombe%20county%20cha%20final%20report%20(3).pdf
Lenoir County: retrieved 6/10/18 from http://kinstonrec.com/Facilities?clear=False
Robeson County: retrieved 6/18/18 from https://www.co.robeson.nc.us/robeson-county-parks-recreation.
Wayne County: retrieved 6/10/18 from https://www.waynecounty.com/departments/publicservices/home.aspx
State Park data obtained from North Carolina Department of Transportation 2015–2016 Official State Transportation Map retrieved 2/4/19 from https://www.ncdot.gov/travel-maps/maps/Pages/state-transportation-map.aspx

4.1.3 Economic Indicators of Resilience

Economic resilience is the ability of a community to resume normal economic activity following a disaster (Rose, 2004). Theorists suggest that this ability is related to returning to work and accessing jobs.

Economic indicators of resilience examined in the study are rate of unemployment, educational attainment, and access to a vehicle. The economic indicators are described below. Table 4-9 shows a summary of the economic indicators for each of the six counties.

Table 4-9: Economic Indicators of Resilience and Sources

County	3-Year (2014, 2015, 2016) Average Percent Unemployment	Percentage of Residents Completing High School or Beyond in 2016	Percentage of Households with Access to a Vehicle in 2016
Bertie	7.5%	74.8%	94.8%
Columbus	7.3%	80.7%	97.6%
Edgecombe	4.7%	77.4%	95.8%
Lenoir	6.2%	80.3%	95.6%

County	3-Year (2014, 2015, 2016) Average Percent Unemployment	Percentage of Residents Completing High School or Beyond in 2016	Percentage of Households with Access to a Vehicle in 2016
Robeson	8.7%	76.4%	96.4%
Wayne	6.9%	83.0%	97.0%

Source: U.S. Census Bureau, 2018

Rate of unemployment. The first economic indicator of resilience examined is the rate of unemployment. A higher rate of unemployment in a community is expected to have a negative relationship to resilience because fewer residents will have an incentive to return to their jobs if they are temporarily displaced by an event.

This study uses a 3-year average of unemployment rate as suggested by the Mitigation Framework Leadership Group (Mit-FLG, 2016). In this study, this rate of unemployment indicator is measured using the 2006–2010 ACS data from the U.S. Census Bureau and is presented as the average of rates of unemployment during 2014, 2015, and 2016. Table 4-9 shows the average unemployment rate in the study area counties.

Educational attainment. The second economic indicator of resilience is educational attainment. A higher level of educational attainment is expected to have a positive relationship to resilience because more residents will have jobs and an incentive to return to their jobs following a disaster.

In this study, educational attainment in 2016 is measured using 2006–2010 ACS data from the U.S. Census Bureau and is presented as the percentage of residents over the age of 25 who have completed high school or higher levels of education (definition is per the U.S. Census Bureau). Table 4-9 shows the educational attainment percentages for residents in the study area counties.

Access to a vehicle. The third economic indicator of resilience is access to a vehicle. A higher percentage of residents with access to a vehicle is expected to have a positive relationship to resilience because residents will be able to return to their jobs even if they are temporarily displaced by an event.

In this study, the access to a vehicle indicator is measured using 2006–2010 ACS data from the U.S. Census Bureau and is presented as the percentage of households with access to at least one vehicle. Table 4-9 shows the percentage of households with access to a vehicle in the study area counties.

4.1.4 Physical Indicators of Resilience

Physical resilience is the ability of the built environment (buildings and infrastructure), as well as of the natural environment, to withstand the effects of a natural hazard. With greater physical resilience, recovery time decreases (NIST, 2016).

Physical indicators of resilience examined in the study are housing stock type, housing constructed before the decade in which the county joined the NFIP, value of owner-occupied housing units, and road and bridge projects completed after Hurricane Floyd using FEMA Public Assistance funds. The physical indicators are described below. Table 4-10 shows a summary of the physical indicators for each of the six counties.

Table 4-10: Physical Indicators of Resilience

County	Housing Stock Type – Percent Not Mobile Homes in 2016[(a)]	Housing Built Before County Joined NFIP[(a)]	Value of Owner-Occupied Housing Units – Median in 2016[(a)]	Road and Bridge Projects* Completed After Hurricane Floyd [(b)]
Bertie	67.4%	48.8%	$79,900	4
Columbus	67.5%	66.7%	$84,800	23
Edgecombe	78.1%	52.8%	$82,200	18
Lenoir	77.0%	56.5%	$93,400	9
Robeson	60.9%	43.3%	$71,000	3
Wayne	74.7%	59.2%	$114,200	5

Note:
* Projects completed using FEMA PA Program funds
Sources:
(a) U.S. Census Bureau, 2018
(b) FEMA, 2017

Housing stock type. The first physical indicator of resilience is housing stock type, which is measured as the percent of homes in the County that are not mobile homes. Mobile homes are often more susceptible to damage by high winds and floodwater than other types of structures. Therefore, a higher percentage of housing stock that is not mobile homes is expected to have a positive relationship to resilience.

In this study, the housing stock indicator is measured using 2006–2010 ACS data from the U.S. Census Bureau as the percent of housing units that are not mobile home units. Table 4-10 shows the percentage of housing units that are not mobile home units in the study area counties.

Housing constructed before the county joined the NFIP. The second physical indicator of resilience is the number of homes built in the decades before the county joined the NFIP. Although this indicator of resilience is not commonly mentioned in the literature, it is used in this study as a measure of flood-resistant construction. A higher number of homes built before the county joined the NFIP is expected to have a negative relationship to resilience because housing units built after the county joined the NFIP were required to comply with flood-resistant construction standards per the NFIP.

The study counties joined the NFIP and began to enforce flood resistant standards as follows: Bertie in 1985, Columbus in 1991, Edgecombe in 1981, Lenoir in 1983, Robeson in 1989, and Wayne in 1991.

In this study, the percent of housing built in decades before a county joined the NFIP indicator was estimated using 2006–2010 ACS data from the U.S. Census Bureau to identify the number of housing units built before 1980 (for Bertie, Edgecombe, Lenoir, and Robeson Counties) and before 1990 (for Columbus and Wayne Counties). Table 4-10 shows the percentage of housing units built in the study area counties before the decade in which the county joined the NFIP.

Value of owner-occupied housing units. The third physical indicator of resilience is the value of owner-occupied housing units. A higher median value of owner-occupied housing units is expected to have a positive relationship to resilience because higher-value housing units are expected to better withstand the impacts of a hurricane.

In this study, the value of owner-occupied housing units indicator is measured using 2006–2010 ACS data from the U.S. Census Bureau. Table 4-10 displays the median value of owner-occupied housing units in each of the study area counties.

Road and bridge projects completed after Hurricane Floyd. The fourth physical indicator of resilience is the number of road and bridge projects completed after Hurricane Floyd using funds from FEMA's PA program (for more information on the PA program, see Section 2.1.2).

Although FEMA's PA program is not specifically mentioned in the literature, the program is used in this study as a measure of flood-resistant construction, which is mentioned in the literature. A higher number of road and bridge projects completed after Hurricane Floyd is expected to have a positive relationship to resilience because a community that has addressed road flooding and bridge damage due to flooding will experience less flooding and damage during subsequent flood events.

In this study, the number of road and bridge projects funded by FEMA's PA program that were completed after Hurricane Floyd is measured using 2017 FEMA PA funding data. Table 4-10 displays the number of completed projects funded by the program.

4.1.5 Disaster Management Indicators of Resilience

Disaster management resilience relates to a community's ability and preparation to manage the impact of a hurricane. With better planning, a community should be able to recover from the impacts of a hurricane more quickly (Berke et al., 2015).

Disaster management indicators of resilience examined in the study are FEMA-funded housing hazard mitigation projects, integration of planning mechanisms, and federal flood insurance coverage. The individual disaster management indicators of resilience are described below. Table 4-11 shows a summary of the disaster management indicators for each of the six counties.

Table 4-11: Disaster Management Indicators of Resilience

County	FEMA-Funded Housing Hazard Mitigation Projects[(a)] (percent receiving funds)	Integration of Planning Mechanisms[(a)] – Total County-Level Mechanisms	Flood Insurance Coverage – Percent of occupied housing units[(c)]
Bertie	0.42%	4	3.05%
Columbus	0.18%	0	1.94%
Edgecombe	1.39%	3	7.30%

County	FEMA-Funded Housing Hazard Mitigation Projects[a] (percent receiving funds)	Integration of Planning Mechanisms[a] – Total County-Level Mechanisms	Flood Insurance Coverage – Percent of occupied housing units[c]
Lenoir	3.38%	4	2.60%
Robeson	0.22%	2	2.65%
Wayne	1.19%	4	2.22%

(a) FEMA 2018; North Carolina, 2017; U.S. Census Bureau, 2018
(b) Various sources. Refer to Table 4-12 for detailed source information.
(c) FEMA, 2018d

FEMA-funded housing hazard mitigation projects. The first disaster management indicator of resilience is the completion of FEMA-funded hazard mitigation projects in housing units. A higher rate of completing housing hazard mitigation projects is expected to have a positive relationship to resilience because a community with more homes that have taken actions to reduce the potential for flood damage will experience less damage overall. Mitigation actions include, but are not limited to, community acquisition and demolition of flood-prone structures.

In this study, the housing hazard mitigation projects indicator is measured as the number of properties in the county that received FEMA funds between 1996 and 2015 to perform mitigation projects, based on information from the State of North Carolina. The number of properties where acquisition mitigation projects were implemented was then divided by the average number of housing units in the county as identified by U.S. Census data in 2000 and 2010. Table 4-11 shows the percent of housing mitigation in the study area counties.

Integration of planning mechanisms. The second disaster management indicator of resilience is the integration of planning mechanisms such as development regulations, policies, financial incentives, and permitting processes. Integration of these mechanisms is critical for building resilience (Berke et al., 2015). A higher number of relevant planning mechanisms that have been integrated into a community's master plan is expected to have a positive relationship to resilience because a community that uses more planning mechanisms to reduce the potential for flood damage will experience less flood damage.

All six study counties have a flood damage prevention ordinance, have an emergency operations plan, have adopted policies to acquire flood-prone properties to prevent future development on them, have a comprehensive land use plan, and adhere to the State Building Code and State Stormwater Management regulations. The hazard mitigation plan for each county addresses the value of integration with other planning mechanisms and each county's comprehensive plan addresses flood risk. Additionally, each of the six study counties, in conjunction with the individual municipalities in the counties, uses a variety of other mechanisms.

In this study, the number of planning mechanisms beyond those described previously is used as an indicator of resilience. Table 4-11 shows a summary of the total number of county-level planning mechanisms identified for the project and Table 4-12 shows details of the planning mechanisms used by the study area counties.

Table 4-12: Integration of Planning Mechanisms

	County					
Planning Mechanism	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
Subdivision Ordinance	Yes	No	No	Yes	No	No
Zoning Ordinance	Municipal level only	Municipal level only	Yes	Yes	Yes	Yes
Density of Land Use Policy	No	No	Yes	No	No	Yes
Capital Improvements Plan	Yes	Municipal level only	Municipal level only	No	No	No
Policy to Use Flood-Prone Land for Parks	Yes	Municipal level only	Yes	Yes	Yes	Yes
Coastal Area Management Act Plan	Yes	Not required	Not required	Not required	Not required	Not required
Community Rating System Participation	No	No	No	Yes	No	Yes
Total County-Level Mechanisms Identified	4	0	3	4	2	4

Sources:
Bertie, Hyde, Martin, Tyrrell, Washington Counties. Northeastern NC Regional Hazard Mitigation Plan. 2016.
Bladen / Columbus County. Regional Hazard Mitigation Plan. 2015.
Nash, Edgecombe, Wilson Counties & Municipalities North Carolina. N.E.W. Regional Hazard Mitigation Plan. 2015.
Holland Consulting Planners/SEPI Engineering and Construction. Neuse River Basin Regional Hazard Mitigation Plan. Neuse River Basin Regional Hazard Mitigation Plan. Greene, Jones, Lenoir, Pitt and Wayne Counties. 2015.
Robeson County. Multi-Jurisdictional Hazard Mitigation Plan. 2017.
Wayne County NC Code of Ordinances. Retrieved June 5, 2018 from https://library.municode.com/nc/wayne_county/codes/code_of_ordinances?nodeId=COOR_CH38FLPR.
Wayne County. Subdivision Ordinance. Retrieved June 9, 2018 from https://library.municode.com/nc/wayne_county/codes/code_of_ordinances?nodeId=COOR_CH70SU.

Flood insurance coverage. The third disaster management indicator of resilience used in the study is the percentage of homes in the county with NFIP flood insurance coverage. While flood insurance policies are purchased at the individual level, the percentage of coverage within a community can be used as an indication of the effectiveness of local officials in communicating flood risk to residents. A higher percentage of flood insurance coverage is expected to have a positive relationship to resilience because homeowners will be better able to repair and rebuild homes after flooding.

In this study, the percentage of households in the County with flood insurance coverage is measured for the year 2017, which is after Hurricane Matthew occurred. These were the best available data. Table 4-12 shows the percentage of households with NFIP coverage in the study area counties.

4.1.6 Hypotheses about Independent Variables

This section presents the many hypotheses made about how the independent variables would affect the resilience of the study counties following Hurricane Matthew.

4.1.6.1 Hypotheses about Social Indicators of Resilience

The study examined the following hypotheses about social indicators of resilience that:

- A higher rate of low- to moderate-income households makes a community less resilient
- A higher per capita income level makes a community more resilient
- A higher median monthly household income makes a community more resilient
- A higher rate of homeownership makes a community more resilient
- Greater availability of primary care physicians makes a community more resilient
- Greater food insecurity makes a community less resilient
- Greater availability of parks makes a community more resilient

Indicator data presented in this section are shown ranked in Table 4-13. The county expected to be the most resilient relative to the other counties in the study for each indicator received a score of 6, and the county expected to be the least resilient for each indicator received a score of 1. The summed ranking for each county is its expected social resilience relative to the other counties. Based on the sum of the social indicators of resilience of each county in the study, Edgecombe County was expected to be the least resilient after Hurricane Matthew.

Table 4-13: Social Indicators of Resilience Composite Scores

	County (Rank)					
Indicators	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
Percent of low- to moderate-income households	6	4	2	3	1	5
Per capita income	2	5	3	4	1	6
Median monthly household income	1	4	3	5	2	6
Homeownership rate	6	5	1	3	4	2
Healthcare availability(1)	2	3	6	5	4	1
Food insecurity(2)	2	4	1	4	3	5
Parks(3)	1	4	3	5	6	3
Sum of Rankings	**20**	**29**	**19**	**29**	**21**	**28**

(1) Primary care physicians per 100,000 population
(2) Percent of food insecure population
(3) Total number

4.1.6.2 Hypotheses about Economic Indicators of Resilience

The study examined the following hypotheses about economic indicators of resilience that:

- A higher rate of unemployment makes a community less resilient
- A higher level of educational attainment makes a community more resilient
- A higher percentage of residents with access to a vehicle makes a community more resilient

Data related to economic indicators of resilience presented in this section are shown ranked in Table 4-14. The county expected to be the most resilient relative to the other counties in the study for each indicator received a score of 6, and the county expected to be the least resilient for each indicator received a score of 1. The summed ranking for each county is its expected economic resilience relative to the other counties. Based on the sum of the economic indicators of resilience of each county in the study, Bertie and Edgecombe Counties were expected to be the least resilient after Hurricane Matthew.

Table 4-14: Economic Indicators of Resilience Composite Scores

	County (Rank)					
Indicators	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
Rate of unemployment(1)	5	4	1	2	6	3
Educational attainment(2)	1	5	3	4	2	6
Access to a vehicle(3)	1	6	3	2	4	5
Sum of Rankings	**7**	**15**	**7**	**8**	**12**	**14**

(1) 3-year average
(2) Percent completing high school or beyond
(3) Percent of households

4.1.6.3 Hypotheses about Physical Indicators of Resilience

The study examined the following hypotheses about physical indicators of resilience that:

- A higher percentage of housing stock that is not mobile homes makes a community more resilient
- A higher number of homes built before a community joined the NFIP makes a community less resilient
- A higher median value of owner-occupied housing units makes a community more resilient
- A higher number of road and bridge projects completed after Hurricane Floyd makes a community more resilient

Indicator data related to physical resilience presented in this section are shown ranked in Table 4-15. The county expected to be the most resilient relative to the other counties in the study for each indicator received a score of 6, and the county expected to be the least resilient for each indicator received a score of 1. The summed ranking for each county is its expected physical resilience relative to the other counties. Based on the sum of the economic indicators of resilience of each county in the study, Robeson County was expected to be the least resilient after Hurricane Matthew.

Table 4-15: Physical Indicators of Resilience Composite Scores

	County (Rank)					
Indicators	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
Housing stock type (1)	2	3	6	5	1	4
Housing constructed before county joined	5	1	4	3	6	2

	County (Rank)					
Indicators	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
the NFIP[(2)]						
Value of owner-occupied housing units[(3)]	2	4	3	5	1	6
Road and bridge projects completed after Hurricane Floyd[(4)]	2	6	5	4	1	3
Sum of Rankings	**11**	**14**	**18**	**17**	**9**	**15**

(1) Percent not mobile homes
(2) Percent units
(3) Median
(4) Funded using FEMA PA program grants

4.1.6.4 Hypotheses about Disaster Management Indicators of Resilience

The study examined the following hypotheses about disaster management indicators of resilience that:

- A higher rate of completing FEMA-funded housing hazard mitigation projects makes a community more resilient
- A greater number of planning mechanisms makes a community more resilient
- A higher rate of flood insurance coverage makes a community more resilient

Indicator data related to physical indicators of resilience presented in this section are shown ranked in Table 4-16. The county expected to be the most resilient relative to the other counties in the study for each indicator received a score of 6, and the county expected to be the least resilient for each indicator received a score of 1. The summed ranking for each county is its expected disaster management resilience relative to the other counties. Based on the sum of the disaster management indicators of resilience of each county in the study, Columbus County was expected to be the least resilient after Hurricane Matthew.

Table 4-16: Disaster Management Indicators of Resilience Composite Scores

	County (Rank)					
Indicators	**Bertie**	**Columbus**	**Edgecombe**	**Lenoir**	**Robeson**	**Wayne**
FEMA-funded hazard mitigation projects	3	1	5	6	2	4
Integration of planning mechanisms [(1)]	4	1	3	4	2	4
Flood insurance coverage[(2)]	5	1	6	3	4	2
Sum of Rankings	**12**	**3**	**14**	**13**	**8**	**10**

(1) Based on the total county-level planning mechanisms
(2) Percent of households with NFIP coverage

4.2 Dependent Variables Used in the Study

This section describes how dependent variables, or post-Hurricane Matthew factors, used in the study were selected and how data (the empirical measures) were collected for each dependent variable.

While resilience theory does not specify a set of potentially useful dependent variables but instead focuses on indicators of resilience, it does provide numerous definitions of resilience suggesting that a more resilient community should experience less damage and recover from the effects of a natural disaster more quickly than a less resilient community.

4.2.1 Selection of Dependent Variables for Exploratory Research

Several potential measures of damage and the time required for recovery were considered for the study.

Table 4-17 lists the dependent variables or outcomes considered for the study, as well as the issues or challenges encountered with data collection. If challenges could not be overcome and reliable outcome measures of a variable were not available for the study, that variable was eliminated from consideration.

Table 4-17: Dependent Variables Considered for the Study

Dependent Variables Considered	Issues/Challenges Encountered
Included in the Study	
Number of days schools were closed	Data not available for some, but not all, school districts
Number of days of Disaster Recovery Center operated	
Number of road closures due to Hurricane Matthew	
Percent of occupied housing units that received NFIP flood insurance payments after Hurricane Matthew	
Average NFIP payment	
Percentage of housing units that received housing damage assistance through FEMA's Individuals and Households Program (IHP)	
Average IHP housing damage assistance payment	
Total FEMA PA program award, by county	
Not Included in the Study	
Utility disruption	Data not available for municipal water/wastewater treatment facilities; in rural areas, residents rely on wells and septic tanks, so the outcome is not relevant throughout the study areas
Displacement	Data available at the state level, but not county level; comparable data not available across the six study counties
Emergency rescue	Data available at the state level, but not county level; comparable data not available across the six study counties

4.2.2 Dependent Variable Measures

This section describes the measures of the dependent variables used in the study and identifies the source of each measure. Raw data were adjusted for differences in the population of each of the study counties using population or total housing unit estimates for 2016 available through the U.S. Census Bureau American Fact Finder. The individual dependent variable measures are described below. Table 4-18 shows a summary of the dependent variable measures.

Table 4-18: Outcome Measures

County	No. Days Schools Were Closed	No. Days DRC Operated	No. Road Closures Due to Matthew	Occupied Housing Units[a] Rec'd NFIP Payments after Matthew	Avg. NFIP Payment	Occupied Housing Units[a] Rec'd Housing Damage Assistance through IHP	Avg. IHP Housing Damage Assistance Payment	Total FEMA PA Program Award after Matthew
Bertie	9	45	26	2.15%	$32,526	8.07%	$1,052	$866,485
Columbus	NA	79	43	0.46%	$40,393	12.70%	$1,628	$2,821,106
Edgecombe	19	122	59	1.49%	$47,664	8.57%	$3,751	$6,619,322
Lenoir	16	60	60	1.13%	$92,852	6.52%	$1,802	$4,767,807
Robeson	23	122	184	0.89%	$50,353	21.07%	$1,750	$26,080,608
Wayne	12	95	161	0.95%	$64,406	6.47%	$2,223	$6,531,370

(a) U.S. Census Bureau, 2016
DRC = Disaster Recovery Center; NA = not available; IHP = Individuals and Households Program; PA = Public Assistance

Days schools were closed. Emails and calls with local school officials revealed the number of days after Hurricane Matthew until all public schools re-opened in five of the six study counties. The number of days until all public schools in a county re-opened is a measure of the amount of time needed for hurricane recovery. Table 4-18 displays these data.

Days of disaster recovery center operations. FEMA opened a Disaster Recovery Center (DRC) in each of the study counties following Hurricane Matthew. FEMA generally closes a DRC when the number of residents seeking post-disaster recovery assistance program information slows. Desktop research identified the number of days each DRC was open in each of the study counties; it is assumed DRCs were open on weekends as well as week days. The number of days the DRC was kept open is a measure of the amount of time needed for hurricane recovery. Table 4-18 displays these data.

Road closures due to Hurricane Matthew. The State of North Carolina provided GIS data showing road closures in each of the study counties following Hurricane Matthew. The number of roads closed is a measure of the costs of hurricane damage. Table 4-18 displays the number of road closures reported for each study county.

Percentage of homes with NFIP flood insurance claims. FEMA provided the number of NFIP payments made following Hurricane Matthew. For the study, to adjust for differences in population, the number of NFIP payments was divided by the total number of occupied housing units in the county according to 2016 U.S. Census ACS estimates. In this study, even though NFIP payments offset the costs of repair and rebuilding borne by property owners, the percentage of occupied housing units receiving NFIP payments is a measure of the costs or the extent of hurricane damage. Table 4-18 displays these data.

Average NFIP payment. FEMA provided the total value of NFIP payments made after Hurricane Matthew. For the study, the total value was divided by the total number of NFIP payments to calculate the average NFIP payment in each of the study counties. The average NFIP payment in a county is a measure of the costs or the extent of hurricane damage. Table 4-18 displays these data.

Percentage of households receiving housing damage assistance. FEMA provided the number of households receiving a housing damage assistance award through the IHP following Hurricane Matthew. For the study, to adjust for differences in populations, the number of households receiving a housing damage assistance award was divided by the total number of occupied housing units in a county according to 2016 U.S. Census estimates. The percentage of occupied housing units receiving housing damage assistance is a measure of the costs of hurricane damage. Table 4-18 displays these data.

Average housing damage assistance payment. FEMA provided the total amount of IHP housing damage assistance paid per county. For the study, the total was divided by the total number of housing damage assistance payments to calculate the average housing damage assistance award made in a county. The housing damage assistance payment is a measure of the costs of hurricane damage. Table 4-18 displays these data.

Total FEMA PA Program payments. FEMA provided the total amount of FEMA PA program payments made to each of the six study counties following Hurricane Matthew. The total PA program award to a county is a measure of the costs of hurricane damage. Table 4-18 displays these data.

4.3 Analytic Method

This section describes the method used in the exploratory portion of the study of resilience. For the exploratory study, resilience theory provided a set of hypotheses to explore. Each hypothesis suggests that higher levels of an indicator of resilience should have led to less damage to privately owned structures or to the public infrastructure and a less time-consuming recovery from Hurricane Matthew. This section explains the method used to examine the hypotheses summarized in Section 4.1.6.

Eighty-eight paired comparisons were made between measures of an indicator of resilience and measures of Hurricane Matthew outcomes. Thirty-two comparisons were made relative to the time required for recovery from Hurricane Matthew, 56 paired comparisons made relative to the costs associated with recovery from Hurricane Matthew.

The study did not use simple linear regression because the sample size of six counties is too small to conduct statistically sound simple linear regression analysis for inferring relationships between an indicator of resilience and a measure of Hurricane Matthew outcomes. However, the paired comparison approach is like that used in simple linear regression studies.

4.3.1 Paired Comparison Method

For comparisons, the five or six measures (one per county depending on data availability) of an independent variable, an indicator of resilience, were represented on a horizontal axis, and the corresponding five or six outcome measures of a dependent variables were represented on a vertical axis.

Next, a scatter plot was created and a trendline was inserted on the scatter plot using Microsoft Excel.

Finally, the data were analyzed to determine if a conclusion could be drawn. Before drawing a tentative conclusion about whether the data supported the theory, consideration was given to:

- Whether there was too little variation in measures of either the dependent or independent variable and the data points were clustered together. If several data points were clustered together, no conclusion was drawn about a hypothesis.
- Whether there was too much variation in measures and data points were far from the trendline. If several data points were far from the trendline, no conclusion was drawn about a hypothesis.
- Whether the trendline was relatively flat. If the slope of the trendline appeared to be close to zero or nearly horizontal, no conclusion was drawn about a hypothesis.

This simple technique provided an opportunity to examine hypotheses identified in Section 4.1.6 of this report and to determine if an indicator of resilience seemed to be associated with improved outcomes following Hurricane Matthew.

4.3.2 Time Required for Recovery

Table 4-19 shows the 32 paired comparisons made relative to the time required for recovery from Hurricane Matthew.

Table 4-19: Thirty-Two Comparisons with Measures of the Time Required for Recovery

Each of the 16 Indicators of Resilience…	… was compared to each of these 2 measures of the time required for recovery
1. Percent of households having low to moderate income 2. Per capita income 3. Median monthly household income 4. Percent homeownership 5. Primary care physicians per 100,000 population 6. Percent of food insecure population 7. Total number of parks 8. 3-year average rate of unemployment 9. Percent completing high school or beyond 10. Percent of households with access to a vehicle 11. Number of road and bridge projects completed after Hurricane Floyd 12. Number of mitigated housing units divided by average number of housing units 2000–2010 13. Composite score for social indicators of resilience 14. Composite score for economic indicators of resilience 15. Composite score for physical indicators of resilience 16. Composite score for disaster management indicators of resilience	• Number of days DRC was opened • Number of days until all public schools re-opened

4.3.3 Costs Associated With Recovery

Table 4-20 shows the 56 paired comparisons made relative to the costs associated with recovery from Hurricane Matthew.

Table 4-20: Fifty-Six Comparisons with Measures of the Costs of Recovery

Each of the11 indicators of resilience listed below…	…was compared to each of these 5 measures of the cost of recovery
1. Percent not mobile homes 2. Percent housing units built in decades before county joined NFIP 3. Median value of owner-occupied housing units 4. Number of mitigated housing units divided by average number of housing units 2000–2010 5. Integration of planning mechanisms score 6. Percent of occupied housing units with flood insurance coverage 7. Number of road and bridge projects completed after Hurricane Floyd 8. Composite score for social indicators of resilience 9. Composite score for economic indicators of resilience	• Percentage of households receiving housing damage assistance • Average housing damage assistance award • Percent of occupied housing units with Hurricane Matthew NFIP claims • Average NFIP payment • Dollar value of Hurricane Matthew PA awards

Each of the11 indicators of resilience listed below…	…was compared to each of these 5 measures of the cost of recovery
10. Composite score for physical indicators of resilience 11. Composite score for disaster management indicators of resilience	
The indicator of resilience listed below …	... was also compared to this measure of the cost of recovery
• Number of road and bridge projects completed after Hurricane Floyd (using FEMA PA funds)	• Number of road closures due to Hurricane Matthew

4.4 Findings of Analyses

This section presents the findings of the paired comparisons of indicators of resilience with Hurricane Matthew outcomes.

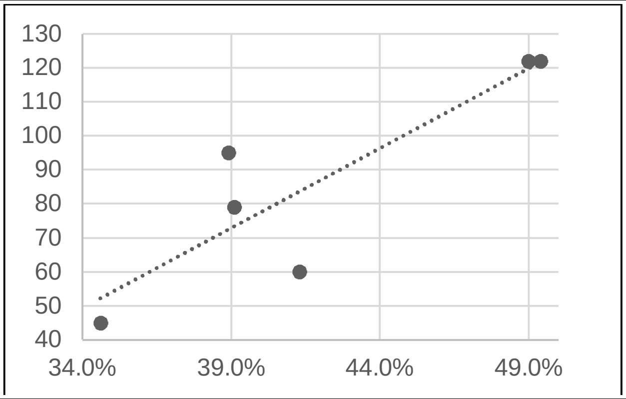
4.4.1 Examination of Social Indicators of Resilience

Each of the hypotheses about social indicators of resilience presented in Section 4.1.6.1 was examined relative to measures of the time required for recovery from Hurricane Matthew.

Data support the hypothesis that a higher rate of low- to moderate-income households makes a community less resilient. Having a higher rate of low- to moderate-income households seems to be associated with both a slower recovery from a disaster measured as the number of days the DRC was kept open and the number of days until public schools re-opened (see Figure 4-1).

Graph showing paired comparisons of measures of one indicator of resilience with one Hurricane Matthew outcome measure

County	Households having low to moderate income	Number of days the DRC was kept open
Bertie	34.6%	45
Wayne	38.9%	95
Columbus	39.1%	79
Lenoir	41.3%	60
Edgecombe	49.0%	122
Robeson	49.4%	122



Graph showing paired comparisons of measures of one indicator of resilience with one Hurricane Matthew outcome measure

County	Percent of households having low to moderate income	Number of days until all public schools re-opened
Bertie	34.6%	9
Lenoir	41.3%	16
Edgecombe	49.0%	19
Robeson	49.4%	23
Wayne	38.9%	12

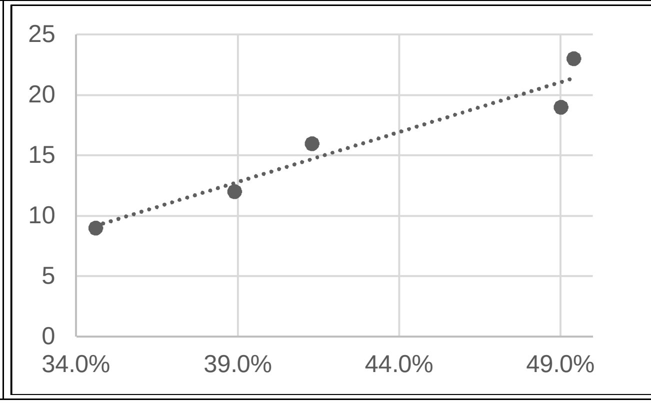
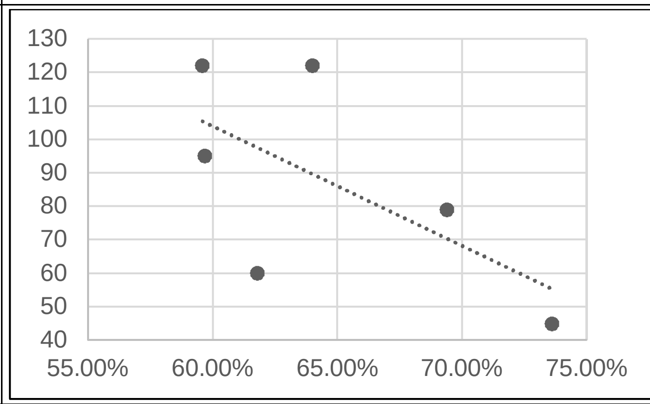


Figure 4-1: Graphs showing Paired Comparisons for Percent Low- to Moderate-Income

Data also support the hypothesis that a higher rate of homeownership makes a community more resilient. Having a higher rate of homeownership seems to be associated with both a quicker recovery from a disaster measured as the number of days the DRC was kept open and the number of days until public schools re-opened (see Figure 4-2).

Graph showing paired comparisons of measures of one indicator of resilience with one Hurricane Matthew outcome measure

County	Percent homeownership	Number of days the DRC was kept open
Edgecombe	59.60%	122
Wayne	59.70%	95
Lenoir	61.80%	60
Robeson	64.00%	122
Columbus	69.40%	79
Bertie	73.60%	45



County	Percent homeownership	Number of days until all public schools re-opened
Edgecombe	59.60%	19
Wayne	59.70%	12
Lenoir	61.80%	16
Robeson	64.00%	23
Bertie	73.60%	9

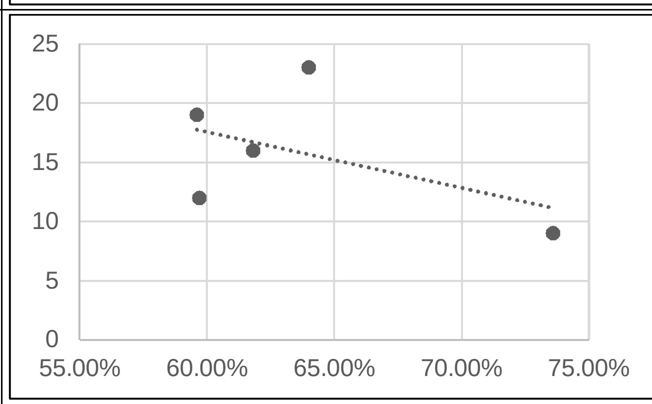


Figure 4-2: Graphs showing Paired Comparisons for Percent Homeownership

Data were insufficient to suggest conclusions about other hypotheses about social indicators of resilience.

Composite scores for social indicators of resilience displayed in Table 4-13 were also examined relative to measures of the time and costs needed for Hurricane Matthew recovery. The six data points were insufficient for drawing a conclusion about the meaning of the composite scores.

4.4.2 Examination of Economic Indicators of Resilience

Each of the hypotheses about economic indicators of resilience presented in Section 4.1.6.2 was examined relative to the time required for recovery from Hurricane 5Matthew. Data were insufficient to suggest conclusions about hypotheses about economic indicators of resilience.

Composite scores for economic indicators of resilience displayed at in Table 4-14 were also examined relative to the time and costs needed for Hurricane Matthew recovery. The six data points were insufficient for drawing a conclusion about the meaning of the composite scores.

4.4.3 Examination of Physical Indicators of Resilience

Each of the hypotheses about physical indicators of resilience presented in Section 4.1.6.3 was examined relative to the costs required for recovery from Hurricane Matthew. The data provided some support for some of the proposed hypotheses.

Before determining if physical indicators of resilience are associated with reduced costs of recovery, two possible meanings of one measure of the costs of Hurricane Matthew recovery—increased NFIP payments—were considered:

- Increased NFIP payments may indicate greater damage, increased costs of recovery, and reduced resilience.
- Alternatively, increased NFIP payments may indicate reduced costs for recovery and increased resilience because homeowners must pay less to repair and rebuild.

For this discussion, increased average NFIP payments are interpreted as being associated with greater damage, increased costs of recovery, and reduced resilience.

Data suggest support for the hypothesis that a lower number of mobile homes makes a community more resilient. Having fewer mobile homes seems to be associated with a smaller percentage of households receiving housing damage assistance awards, which suggests increased resilience (see Figure 4-3).

County	Percent Not Mobile Homes	Percentage of households receiving housing damage assistance
Robeson	60.90%	21.07%
Bertie	67.40%	8.07%
Columbus	67.50%	12.70%
Wayne	74.70%	6.47%
Lenoir	77.00%	6.52%
Edgecombe	78.10%	8.57%

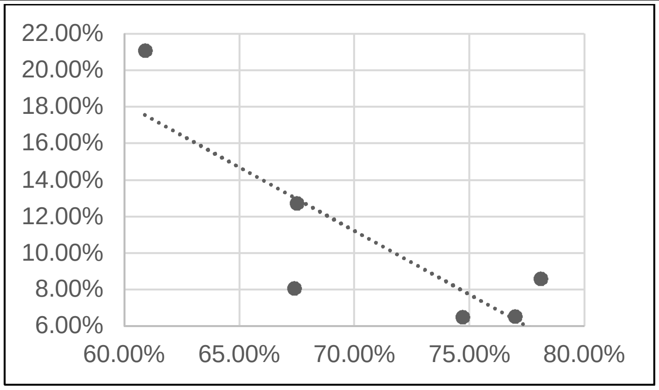


Figure 4-3: Graph showing Paired Comparisons for Percent Not Mobile Homes

However, having fewer mobile homes also seems to be associated with a larger average NFIP payment and greater average housing damage assistance awards, which suggests reduced resilience. These findings may be explained by the fact that, in general, mobile homes have lower value than other types of homes.

Data also suggest support for the hypothesis that having completed more road and bridge projects following Hurricane Floyd with FEMA PA funds made a community more resilient (see Figure 4-4). Having completed more road and bridge projects after Hurricane Floyd seems to be associated with having fewer road closures following Hurricane Matthew. However, the exploratory study did not account for confounding factors such as the amount of rainfall; it is important to note that Robeson County received less rainfall than the other study counties in Hurricane Floyd and more rainfall than the others in Hurricane Matthew, as shown in Figure 2-1 and Figure 2-2.

County	Road and bridge projects completed after Hurricane Floyd	Number of road closures due to Hurricane Matthew
Robeson	3	184
Bertie	4	26
Wayne	5	161
Lenoir	9	60
Edgecombe	18	59
Columbus	23	43

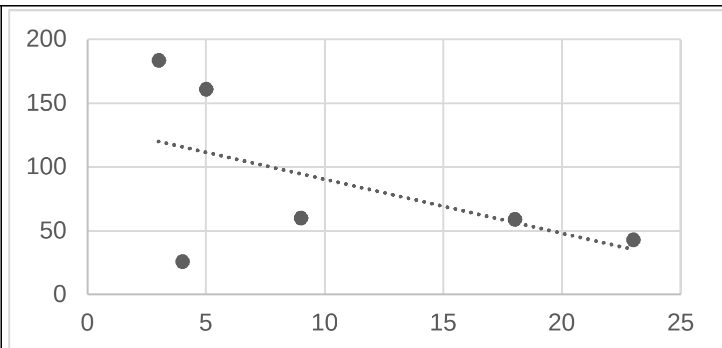


Figure 4-4: Graph showing Paired Comparisons for Road and Bridge Projects Completed after Hurricane Floyd

Data were insufficient to suggest conclusions about other hypotheses about physical indicators of resilience.

Composite scores for physical indicators of resilience displayed in Table 4-15 were also examined relative to the time and costs needed for Hurricane Matthew recovery. The six data points were insufficient for drawing a conclusion about the meaning of the composite scores.

4.4.4 Examination of Disaster Management Indicators of Resilience

Each of the hypotheses about disaster management indicators of resilience presented in Section 4.1.6.4 was examined relative to the cost required for recovery from Hurricane Matthew. Data were insufficient to suggest conclusions about hypotheses about physical indicators of resilience.

Composite scores for disaster management indicators of resilience displayed in Table 4-16 were also examined relative to the time and costs needed for Hurricane Matthew recovery. The six data points were insufficient for drawing a conclusion about the meaning of the composite scores.

4.4.5 Limitations of the Exploratory Study

As an exploratory study, findings are not statistically valid. Findings are based on a sample of only six counties. The findings presented in this report cannot be used to infer that one or more indicators of resilience led to reduced time for recovery or reduced costs of recovery.

Additionally, as an exploratory study, findings are based on comparisons of only two factors. Potentially associated conditions or factors were not considered simultaneously, as would have happened if the sample size was large enough to use a multiple linear regression research approach.

5. Losses Avoided Study

In addition to exploratory study of resilience described in Chapter 4, the project team conducted a study to examine the losses that were avoided as a result of the implementation of mitigation measures taken by counties and communities in the study area. This losses avoided study was performed as a quantitative analysis based on property acquisitions in each county (Section 5.1) and a qualitative discussion that describes other types of mitigation measures that resulted in unquantified losses avoided (Section 5.2).

5.1 Quantitative Analysis

According to FEMA, a losses avoided analysis is completed in three phases (FEMA, 2009). These are:

- Phase 1: Gather measures of the independent variables (Section 5.1.1).
  - Independent variables are location, cost, and flood depth.
- Phase 2: Conduct a storm event analysis and a flood inundation analysis (Section 5.1.2).
  - A storm event analysis is an examination of storm damage data to determine if a storm was severe enough to have caused damage at the locations that had been acquired.
  - A flood inundation analysis uses FEMA flood depth grids after a storm to estimate the depth of flooding inside buildings that would have occurred at the locations of buildings that were acquired.
- Phase 3: Estimate losses and calculate Return on Investment (ROI) (Section 5.1.3).
  - The dollar value of losses that would have occurred at the locations of the acquired properties was estimated. In lieu of exact data, assumptions were made about the structures that were acquired. The damages that would have occurred are the losses avoided. For acquisitions, the damages that did occur are valued at zero dollars.
  - The ROI is calculated by dividing the losses avoided by project costs.

The losses avoided analysis was performed by collecting study inputs, determining outcome measures, performing the analysis, and preparing the findings.

Background

Each of the six study counties has completed many acquisitions of flood-prone properties to remove structures from flood-prone locations. The property acquired by the county or another entity cannot be developed after acquisition. The acquired property must be converted to open or forested space that can be used for active or passive recreation or to provide safe storage for floodwater.

Table 5-1 displays the number of property acquisitions completed by each county with the support of FEMA Hazard Mitigation Assistance (HMA) funds prior to Hurricane Matthew that were included in the quantitative losses avoided analysis. The locations of the areas where the properties included in Table 5-1 are located are shown on maps in Appendix C.

Table 5-1: Property Acquisitions Included in Losses Avoided Analysis

County	Number of Property Acquisitions Completed Between 1996 and 2016[(a)]
Bertie	25
Columbus	10
Edgecombe	170
Lenoir	450
Robeson	87
Wayne	396
Total	**1,138**

[(a)] Includes only properties considered in this losses avoided analysis

5.1.1 Phase 1 – Losses Avoided Study Inputs and Outcome Measures

This section describes the study inputs or independent variables as well as the outcome measures used to evaluate losses avoided during Hurricane Matthew due to property acquisition.

5.1.1.1 Study Inputs

This section describes the independent variables, or the inputs, used to conduct the examination of losses avoided due to acquisition of properties at risk of flooding. This section also describes limitations in the data used for the study.

Most of the acquired properties included in this analysis used funds that became available as a result of four disaster declarations. The names of these disasters, their disaster declaration (DR) numbers, and years are:

- Hurricane Fran, DR-1134, 1996
- Hurricanes Floyd and Irene, DR-1292, 1999
- Hurricanes Floyd and Irene Supplemental Funding, DR-4292, 1999
- North Carolina Winter Storm, DR-1312, 2000

One property was acquired using funds available through the HMA Repetitive Flood Claims program in 2008.

Some property acquisitions in the six study counties were paid for using funds outside of FEMA or funds associated with other disaster declarations or other HMA programs. Data about these additional property acquisitions were not available for this study.

Location

FEMA HMA provided the latitude and longitude coordinates of properties acquired in each of the six study counties using funds available through FEMA programs.

*Data Limitations Related to Location***.** Some of the location data made available for the study were not accurate, and the latitude and/or longitude coordinates supplied were for locations outside of the county that received funding for the acquisition. The locations for which these data seemed to be incorrect were eliminated from the examination of losses avoided. The numbers of locations by county where the latitude and/or longitude coordinates for acquisitions funded through the four disaster funding sources listed above were incorrect are:

- Bertie: 15
- Columbus: 1
- Edgecombe: 21
- Lenoir: 41
- Robeson: 1
- Wayne: 124

Acquisition Costs

FEMA HMA provided the property acquisition costs for the study (FEMA, 2018d). Cost estimates for the properties included in the study total $116,842,353. A project may result in the acquisition of a few or of over a hundred individual properties. Table 5-2 shows the cost of the acquisition projects by county.

Table 5-2: Acquisition Costs Used in the Study

County	Number of Acquisition Projects (Projects Involved Multiple Properties)	Total Cost of Acquisition Projects
Bertie	15	$1,115,988
Columbus	1	$1,295,756
Edgecombe	21	$44,192,216
Lenoir	41	$38,904,477
Robeson	1	$2,876,084
Wayne	124	$28,457,832
Total	**203**	**$116,842,353**

Data Limitations Related to Cost. Acquisition costs used in the study are not necessarily exact. Cost data provided by HMA were for cost estimates developed at the time of application for funding rather than the exact expenditures for property acquisition, and may not have included demolition of structures, removal of debris, and other associated costs or for relocations of structures to a new, safer location.

Moreover, cost data were limited in accuracy because, while costs for acquisitions in five of the six study counties were provided by property, costs for property acquisition in Robeson County were summed for several properties acquired together under a single grant award rather than for individual properties.

Flood Depth

Geographic information for approximate flood depths for Hurricane Matthew was obtained from raster data downloaded from https://data.femadata.com/NationalDisasters/HurricaneMatthew (October 12, 2016 version).

5.1.1.2 Outcome Measures

The outcome measure used in the examination of losses avoided is the number of structures that would have been flooded in Matthew had they not been acquired.

The locations of mitigated properties were mapped using ArcGIS for Desktop v10.2.2. Using the Interpolate Shape geoprocessing tool, the approximate flood depth at the location of each acquired property was estimated as less than 2 feet, 2 to 5 feet, or more than 5 feet.

Table 5-3 displays the number of acquired structures by county where flooding occurred in Hurricane Matthew that would have resulted in building damage had it not been acquired and demolished. The estimated flood depth is based on the flood depth data described in Section 5.1.1.1.

Table 5-3: Estimated Number of Structures That Would Have Been Flooded If Not Acquired

County	Depth of Estimated Flooding			Total Number of Structures That Avoided Damage
	< 2 Feet	2 to 5 Feet	> 5 Feet	
Bertie	7	3	15	25
Columbus	0	1	9	10
Edgecombe	71	56	43	170
Lenoir	273	136	41	450
Robeson	2	69	16	87
Wayne	16	108	272	396
Total	**369**	**373**	**396**	**1,138**

Source: FEMA, 2018d

5.1.2 Phase 2 - Losses Avoided Analysis

The losses avoided study includes an analysis of the storm event and the flood inundation, as described in this section. Also described are the assumptions and estimates used in the study and the depth-damage parameters.

5.1.2.1 Storm Event Analysis

To conduct a storm event analysis, the project team reviewed the number of residential structures in each county that were damaged in some way by Hurricane Matthew. Table 2-2 summarizes the claims made to FEMA's Individual Assistance (IA) Program after Hurricane Matthew. Based on the claim data, at least 37,821 residential structures were damaged by Hurricane Matthew.

The conclusion of the storm event analysis is that had structures not been acquired, Hurricane Matthew would have caused flood damage to them, too, as the acquired properties were in identified flood hazard areas.

5.1.2.2 Flood Inundation Analysis

The results of the flood inundation analysis are the estimated depths of flooding in the 1,138 locations where properties were acquired and where properties experienced flooding due to Hurricane Matthew (see Table 5-3).

5.1.2.3 Assumptions for Costs and Percent Damage

To perform the losses avoided study, various costs associated with the acquired structures must be assumed and percent damage (based on depth of flooding) must be calculated.

Cost Assumptions

Some cost assumptions were needed to conduct the losses avoided analysis, as described.

Building details. All buildings in this analysis were assumed to have been of average quality, to have one story, occupy 1,600 square feet of space, and have 2 feet of ground clearance.

Construction cost. Research using a national building valuation guide showed that the average construction cost for a new house in 2016 in the Hurricane Matthew-impacted areas of North Carolina was at least $100 per square foot (International Code Council, 2018). Thus, the replacement value for each acquired structure would have been about 1,600 square feet*$100/square foot = $160,000.

Content value. For conducting a benefit-cost analysis, FEMA literature suggests that content value is 50 percent of structural value (FEMA, 2018e), which this study assumed. Thus, the estimated value of contents for each acquired structure would have been about $80,000.

Displacement cost. To estimate displacement cost due to flood damages, the 2016 General Services Administration (GSA) per diem rate of $91 per hotel night per household was used; similarly, to estimate the per diem cost of food, the 2016 GSA rate for eastern North Carolina of $51 per person was used (General Services Administration, 2018). To estimate household size, this study used the 2016 U.S. Census average household size of 2.48 persons per household. Thus, the daily cost of displacement per acquired structure would have been about $91 + ($51*2.48) = $217.

Depth Damage Parameters

In order to estimate the percentage of damage that one-story buildings and building contents will sustain when they are flooded, FEMA has developed Depth-Damage Functions (DDF). The DDFs estimate the percent damage when a structure is flooded to a depth of less than 2 feet, between 2 and 5 feet, and more than 5 feet. The DDFs also provide estimates of the number of days that residents will be displaced or required to use alternative housing because of building damage. Table 5-4 shows the parameters calculated by the FEMA's DDFs.

Table 5-4: Parameters Calculated by DDFs for One-Story Residences

Depth of Flooding	Structural Damage	Contents Damage	Displacement
Less than 2 feet	23.3%	13.3%	45 days
Between 2 and 5 feet	40.1%	22.0%	135 days
Greater than 5 feet	58.6%	31.5%	270 days

(FEMA, 2018e)

5.1.3 Phase 3 - Losses Avoided Study Findings

The losses avoided study findings include the calculation of the amount of avoided losses and then the subsequent calculation of the ROI.

5.1.3.1 Avoided Losses

Using the assumptions and information described in Sections 5.1.1 and 5.2.2, it is possible to calculate the losses that were avoided by removing the structures from areas that were flooded during Hurricane Matthew. Table 5-5 shows the dollar value of losses that were calculated to have been avoided in Hurricane Matthew because of prior acquisitions of flood-prone structures. As shown on the table, the calculated total dollar value of losses avoided was over $133 million.

Table 5-5: Losses Avoided During Hurricane Matthew

County	Number of Structures(1)	Avoided Building Damages(2)	Avoided Contents Damages(3)	Avoided Displacement Cost(4)	Total Losses Avoided
Bertie	25	$1,859,840	$505,280	$1,037,380	**$3,402,500**
Columbus	10	$908,000	$244,400	$557,836	**$1,710,236**
Edgecombe	170	$10,271,520	$2,824,640	$4,863,940	**$17,960,100**
Lenoir	450	$22,747,360	$6,331,520	$9,072,178	**$38,151,058**
Robeson	87	$6,001,760	$1,638,880	$2,984,913	**$10,625,553**
Wayne	396	$33,028,480	$8,925,440	$19,299,175	**$61,253,095**
				Total	**$133,102,542**

(1) From Table 5-3, these are structures that were acquired and demolished, but would have experienced less than 2, between 2 and 5, or more than 5 feet of flooding during Hurricane Matthew
(2) Multiply number of buildings with less than 2, 2 to 5, and more than 5 feet of flooding by building value ($160,0000) and by percent of structural damage from Table 5-3 and sum for each county.
(3) Multiply number of buildings with less than 2,2 to 5, and more than 5 feet of flooding by content value ($80,000) and by percent of contents damage from Table 5-3 and sum for each county.
(4) Multiple number of buildings with less than 2, 2 to 5, and more than 5 feet of flooding by daily cost of displacement ($217) and by number of days of displacement from Table 5-3 and sum for each county.

5.1.3.2 Return on Investment

The final step in conducting a losses avoided study is the calculation of the ROI, which is a ratio of the amount spent on the mitigation versus the amount of avoided damages. The ROI formula is:

- Total Losses Avoided / Total Mitigation Project Cost = ROI

The ROI result for the six study counties is calculated as:

- Total Losses Avoided = $133,102,542 (see Table 5-5)
- Total Mitigation Project Cost = $116,842,353 (see Table 5-2)
- ROI: $133,102,542 / $116,842,353 = 1.14

Based on the information obtained for the losses avoided study, the investment of over $116 million saved approximately $133 million in damages from Hurricane Matthew.

An ROI greater than one indicates that the acquisition investment was cost effective to mitigate the damages expected for Hurricane Matthew. The ROI is expected to increase through time because the region in which the study counties are located experiences hurricanes or tropical storms almost every year. With each hurricane, the ROI will increase due to the accumulation of losses avoided.

5.2 Qualitative Discussion

> Approximately 5 months after Hurricane Matthew, North Carolina Governor Roy Cooper said that the impacts of Matthew could have been worse if measures had not been put in place after Hurricane Floyd to reduce flood damages
>
> *Source: Harper, 2017*

This section provides two brief case studies describing hazard mitigation measures implemented in Edgecombe and Lenoir Counties to reduce flood losses. The counties were selected to be representative of the six study counties. Both Edgecombe and Lenoir Counties have implemented numerous acquisition and demolition projects that have turned once occupied properties into open space. Additionally, Edgecombe County has implemented elevation of buildings as a mitigation measure. The case studies show that, despite the effectiveness of acquisition in reducing the risk of flooding, the value of acquisition to a community remains a topic for debate.

5.2.1 Edgecombe County Case Study

Edgecombe County is in eastern North Carolina and is part of the Tar River watershed. The location is shown on Figure 2-2. Edgecombe County has a history of hurricanes and flooding and the county, along with its incorporated municipalities, has worked to mitigate the potential for flood damages by completing residential flood hazard mitigation projects.

5.2.1.1 Participation in NFIP, Flood History, and Public Assistance Projects

To reduce the potential for flood damage and allow residents and business owners to purchase flood insurance, Edgecombe County and nine incorporated municipalities located in Edgecombe County (Leggett, Macclesfield, Pinetops, Princeville, Rocky Mount, Sharpsburg, Speed, Tarboro, and Whitakers) participate in the NFIP. The county and most of these municipalities joined the NFIP prior to Hurricane Floyd; Leggett joined by the end of 1999. Participating communities meet locally adopted standards for building in designated Special Flood Hazard Areas. By 2017, residents and business owners in Edgecombe County had received approximately $53.6 million in flood insurance payments on 1,264 claims (FEMA, 2018c).

Table 5-6 shows that the costliest flood disaster in Edgecombe County as of January 2019 was due to Hurricane Floyd in 1999. In 2016, the county received between 6 and 11 inches of rain during Hurricane Matthew, resulting in the second-most costly flood disaster.

Table 5-6: FEMA Public Assistance Projects - Edgecombe County

Year	Event	FEMA PA Funds (2000 dollars)	Number of PA Projects
1999	Hurricane Floyd	$26 million	179 projects
2016	Hurricane Matthew	$8.8 million	91 projects

PA = Public Assistance Program (FEMA)
Source: FEMA 2018a

5.2.1.2 Mitigation Measures Implemented by Edgecombe County

FEMA-funded flood mitigation measures implemented in Edgecombe County include property acquisition/demolition and building elevation projects.

Property Acquisitions. FEMA HMA funds, in conjunction with state and local funds and in cooperation with neighboring Nash and Wilson Counties, have been used to acquire over 300 properties since 1999. The total cost of these HMA-supported projects was over $50.5 million; the federal government's share was over $37.9 million (FEMA, 2018d).

Building Elevations. More recently, following Hurricane Matthew in 2016, Edgecombe County was awarded more than $1.7 million from FEMA to complete additional flood hazard mitigation by elevating 15 residences near the Tar River that were flooded. To comply with Edgecombe County's current Flood Damage Prevention ordinance, the homes will be raised to 2 feet above the base flood elevation (FEMA, June 27, 2018).

5.2.1.3 Town of Princeville

Data show that the Town of Princeville was the most severely damaged county municipality following Hurricane Matthew. Princeville has a population of over 2,000 or almost 4 percent of the county population (U.S. Census Bureau, 2018). Yet the town submitted almost 29 percent of the applications for FEMA PA funds and approximately 66 percent of the applications for residential acquisition projects in Edgecombe County (Edgecombe County, May 2018).

Mitigation of Public Schools

The Princeville Elementary School flooded after Hurricane Floyd and again after Hurricane Matthew. The school board voted to rebuild the school using FEMA PA funds to lessen the risk of flood damage following Hurricane Matthew. Repairs included elevating air conditioning units, installing tile rather than carpet in classrooms, and replacing some drywall with masonry (Harper, November 1, 2017).

According to David Coker, director of maintenance and transportation at Edgecombe County Public Schools, "The circumstances after Hurricane Floyd were much different than they are now. There was no hazard mitigation planned in 1999. Since this is the second time the school has flooded, we are being more cautious about the plans to rebuild" (Harper, September 18, 2018). Mitigation improvements will be paid for with $270,000 in FEMA PA funds, and insurance payments will be used to cover the estimated $4 million needed to repair the building and replace furniture, technology, and equipment (Harper, November 1, 2017).

Effect of Property Acquisitions on Town of Princeville

The effect of property acquisition and demolition on the Town of Princeville has been significant and residents have different opinions regarding it.

One Princeville resident said "I am taking the buyout. This property was flooded. This is the second time, in 1999, now 2016. And it's going to flood again" (Inge, 2017 quoting Stephanie Cherry). However, other residents want to re-build and move back into their homes (Inge, 2017).

Princeville's Town Manager, Daniel Gerald, said residents “shouldn’t have to go through this again and again and again." However, the Town Manager was worried that if too many people left, there wouldn’t be enough property tax dollars to support the town (Inge, 2017).

To mitigate the problem of reduced tax dollars, consideration has been given to the possibility of allowing the Town of Princeville to purchase adjacent land owned by the North Carolina Department of Transportation that is less susceptible to flooding (Harper, March 17, 2017). This would make it possible for residents to move away from areas at greater risk of flooding but to still live within town boundaries.

Opponents of acquisition and demolition of flood-prone structures also cite the historic significance of Princeville. Princeville Mayor Bobbie Jones said, “We are the oldest town started by blacks in America, and no one else can make that claim. We need to preserve what we have—and the only way we can preserve it is that we keep the town as it is and grow instead of reducing our citizens. The buyout of course will knock all the houses down, and we can’t bring anymore citizens in.” Ella Pettaway, a supporter of the mayor’s stance said, “I’m not interested in a buyout, and I’m more about wanting to get my home elevated… When [Hurricane] Floyd happened, I lost everything. But for me God gave me this house and until God tells me it’s time to move on, I’m staying put. If God wants you to move, he will let you know it” (Davis, 2016).

5.2.2 Lenoir County Case Study

Lenoir County is in eastern North Carolina and is part of the Neuse River watershed. The location is shown on Figure 2-2. Lenoir County has a history of hurricanes and flooding and the county and its incorporated municipalities have worked to mitigate the potential for flood damages by completing residential flood hazard mitigation projects.

In 2016, the county received between 6 and 11 inches of rain during Hurricane Matthew. Hurricane Matthew led to record water levels in the Neuse River.

5.2.2.1 Participation in NFIP, Flood History, and Public Assistance Projects

To reduce the potential for flood damage and allow residents and business owners to purchase flood insurance, Lenoir County and its incorporated municipalities (Grifton, Kinston, LaGrange, and Pink Hill) participate in the NFIP. The county and two of the municipalities joined the NFIP prior to Hurricane Floyd; LaGrange joined in 2004 and Pink Hill, which does not have any designated flood-prone areas, joined in 2012. Participating communities meet locally adopted standards for building in designated Special Flood Hazard Areas. Since the inception of the NFIP, residents and business owners in Lenoir County have received approximately $36 million in flood insurance payments on 697 claims (FEMA, 2018c).

Table 5-7 shows that the costliest flood disaster in Lenoir County as of January 2019 was due to Hurricane Floyd in 1999, followed by Hurricane Matthew.

Table 5-7: FEMA Public Assistance Projects - Lenoir County

Year	Event	FEMA PA Funds (2000 dollars)	Number of PA Projects
1999	Hurricane Floyd	$44 million	200 projects
2016	Hurricane Matthew	$6 million	54 projects

PA = Public Assistance Program (FEMA)
Source: FEMA, 2018a

5.2.2.2 Mitigation Measures Implemented by Lenoir County

The primary FEMA-funded flood mitigation measure implemented in Lenoir County is property acquisition/demolition projects. FEMA HMA funds, in conjunction with state and local funds and in cooperation with neighboring Pitt County, have been used to acquire and demolish over 900 properties since 1996. The total cost of these HMA-supported projects was over $18.4 million; the federal government's share was over $13.8 million.

Lenoir County plans to acquire and demolish 83 additional homes flooded by Hurricane Matthew. Residents will "relocate to homes outside the floodplain" and the county "will create public open space where their flooded homes were" according to State Emergency Management Director, Mike Sprayberry (North Carolina Department of Public Safety, July 10, 2018). The acquisition projects will be partially funded with a FEMA mitigation grant of over $5.9 million (FEMA, July 23, 2018).

5.2.2.3 City of Kinston

The City of Kinston was severely damaged in 1996 by Hurricane Fran and in 1999 by Hurricane Floyd. The city implemented several flood hazard mitigation projects by acquiring and demolishing flood-prone residential structures. As a result of these actions, the floodplain within Kinston city limits is now mostly open space. A total of 1,600 homes have been acquired and demolished, leaving 73 percent of the city's floodplain as open space that has largely reverted to its natural, forested state (NOAA, 2018). Other flood-prone areas in Kinston have been converted to a park and nature center and a large dog park (Coastal Resilience Center, 2016).

> According to Kinston Mayor B.J. Murphy, approximately "90 percent of Kinston's residential areas that were affected by Floyd had been bought out by FEMA and were demolished by the city or county"
> *Source: Cioffi, 2016*

Despite the measures taken after Hurricanes Fran and Floyd, 49 owner-occupied homes and 132 rental housing units in Kinston received severe damage in Hurricane Matthew (North Carolina, 2017). Data show that the City of Kinston, the most populous in Lenoir County, was the most severely damaged county municipality following Hurricane Matthew. Kinston's population is about 21,677 representing about 36 percent of the county population, yet Kinston received approximately 48 percent of the damage in the county from Hurricane Matthew (Lenoir County, 2018).

Effect of Property Acquisitions on City of Kinston

Despite a record of 20 years of experience with property acquisition and demolition, debates about the approach continue.

One concern is over the loss of old neighborhoods and the social connections they afforded. Yet Kinston officials worked to relocate residents away from flood-prone areas but to locations near former neighbors that would allow children to attend school with classmates from their previous neighborhoods (NOAA Office for Coastal Management, 2018).

There is some discontent with restrictions on use of the floodplain where development is severely restricted. Kinston officials have developed parts of the floodplain for active and passive recreation to protect water quality and to maintain the flood storage capacity of the land (NOAA Office for Coastal Management, 2018).

There is also concern that despite flood hazard mitigation efforts, the footprint of the flood zone continues to grow because of substantial new growth and development of impervious surfaces upstream. Kinston Mayor B.J. Murphy explained that “all the water from [upstream] is coming all the way to Kinston. It’s just getting here a lot faster and there’s a lot more of it.” (WUNC, October 25, 2017).

6. Lessons Learned

This section presents lessons learned based on both the exploratory examination of indicators of resilience and the examination of losses avoided due to mitigation. It discusses the challenges encountered when gathering and measuring data and includes some recommendations for overcoming them.

6.1 Challenges in Measuring Pre-Hurricane Conditions

Some difficulties encountered in measuring pre-hurricane conditions were like those encountered when developing other studies of social science phenomena, specifically related to determining the unit of analysis and finding accurate data.

Unit of Analysis

(1) The initial sample for the study was to be six small municipalities. However, it was difficult to find measures of many of the theoretical indicators of resilience for small municipalities.

- *Solution implemented in this study*: This challenge was overcome by changing the unit of analysis to a county.

(2) Some of the data that HMA provided for this study were not connected to specific acquired properties but rather to grant awards for acquisition of several properties.

- *Solution implemented in this study*: This study relied on the best available cost data.
- *Proposed solution*: To overcome this obstacle, first HMA cost estimate data should be attached to specific properties, rather than to aggregations of properties that are mitigated under a single grant award. Second, cost data should be updated to reflect actual, rather than just proposed or estimated, costs.

Accuracy of Measures

(1) The difficulty encountered in measuring pre-hurricane conditions was data accuracy. It was difficult to find data that were comparable across the six sample counties. Data found in local plans, reports, or other documents were not necessarily comparable across communities and counties. Reports included data for different size areas, and the methods used for gathering the data are not necessarily recorded.

- *Proposed solution*: The only way to overcome this obstacle would be to define measures of interest very carefully and to conduct detailed research in each county to be certain that data across counties are comparable.

(2) Some of the data provided for this study, such as HMA location data for some acquired properties, proved to be inaccurate.

- *Solution implemented in this study*: This study eliminated the locations of acquired properties where location data showed a property located outside of the boundaries of the county that implemented the acquisition. To overcome this obstacle, HMA latitude and longitude data must be recorded accurately. This study used only properties for which latitude and longitude showed the property as being located within the boundaries of the county that acquired it.

6.2 Challenges in Measuring Post-Hurricane Conditions

Challenges encountered in measuring post-hurricane conditions were due in part to the approach used to gather data and in part to the timeframe in which this study was conducted.

Data Gathering Approach

Local officials of the six study counties were contacted by email and asked questions about Hurricane Matthew outcomes. The first emails were sent approximately 17 months after the storm; follow-up questions were asked when the first emails weren't answered.

(1) No responses were received relative to questions about "displacement."

- *Proposed solution*: This challenge could potentially be overcome by better defining the requested measure. In that way, a concept such as displacement, which initially seemed clear to researchers, but which is a multi-faceted problem to local emergency managers, could be examined. To overcome this obstacle, researchers could have specified, for example, the need to know the number of days emergency shelters were opened, the number of people in emergency shelters each day, the number of uninhabitable housing units each day, and the number of days until the last of the uninhabitable housing units was again occupied. However, even with better definition, data on displacement would not likely be available after an event unless the data were formally recorded on a day-to-day basis during and after the event.

(2) Some responses were obtained only after repeated contacts with local officials. Researchers learned that some data are difficult for local officials to retrieve. When asked about school closures due to Hurricane Matthew approximately 17 months after the storm, the data could not be quickly retrieved by school officials, although most replied to inquiries following several follow-up emails and phone calls.

- *Proposed solution:* This obstacle might be overcome by having state and local officials or researchers record outcome data daily during hurricane recovery and save it for several years.

Lack of Long-Term Impact Data

(1) Additional outcomes proposed for inclusion in the study were related to long-term impacts of the hurricane. However, it was not possible to determine long-term impacts of Hurricane Matthew because the study was undertaken approximately 17 months after Hurricane Matthew occurred.

- *Proposed Solution* Conduct future studies to examine the long-term impacts of Hurricane Matthew when newer U.S. Census data become available, FEMA data are updated to show changes in flood insurance coverage or participation in the CRS, information about

HMGP expenditures following Hurricane Matthew is available, and data are available about new construction in flood-prone areas of study counties.

A study of the long-term impacts of a hurricane could include dependent variables such as those listed in Table 6-1.

Table 6-1: Dependent Variables for Measuring Long-Term Recovery

Long-Term Outcome	Potential Source of the Long-Term Outcome
Change in proportion of population that is employed by sector pre- and post-Matthew	2020 U.S. Census
Change in percentage of homes covered by flood insurance	Future NFIP data
Change in participation in CRS program	Future FEMA and State Emergency Management data
Number and type of mitigation actions completed based on both county recovery plans and available FEMA data relative to mitigation and insurance payments	Hurricane Matthew Recovery Plans and HMGP/CDBG-DR funding
Change in percentage of residents in owner-occupied housing units	2020 U.S. Census
Change in median housing value	2020 U.S. Census
Change in number of buildings in flood-prone areas	Future local building department permit data

6.3 Complexity of Examining Social Conditions

However, when data on long-term changes in the study counties become available, it will be critical that causation of changes not be attributed only to Hurricane Matthew. Other factors should be examined, such as trends in the state, regional, and national economy; the changing capacity of the state and local governments to administer post-disaster grants; and the devastation caused by Hurricane Florence in 2018.

This resilience study underscores the fact that resilience research will always be a complicated concept to explore empirically. This is because, in addition to the proposed indicators of resilience, numerous other factors affect the impact of a potentially damaging storm on a community.

For example, since rainfall amount and wind speed vary across a region, a single potentially damaging storm does not affect an entire region in the same way. Another example is that personnel involved in response and recovery operations have individual strengths and weaknesses that will not be reflected in a set of indicators of community resilience.

As with any social science study, numerous other variables affect changes in demographics, economics, and the decisions of government leaders at all levels. These include not just weather-related phenomena, but also interest rates, global market trends, and international trade policy.

7. Recommendations

Monitoring and assessing progress toward building more resilient communities is a stated aim of the Disaster Mitigation Act of 2000 planning requirements. Only with systematic collection and sharing of relevant data by federal, state, and local government agencies can progress be monitored and assessed. The question is, how can we clearly codify the means by which systematic collection and sharing of data occurs and assign responsibility for collecting and sharing the data? The solution is both a technical and administrative challenge that requires the attention of federal, state, and local levels of government. As more relevant empirical data are collected and analyzed, the number of potential indicators of resilience can be reduced to only those that have been shown to be effective in reducing the amount of time, level of effort, and costs required to recover from a disaster. Such information will ultimately allow communities to focus resources on developing those specific characteristics that can effectively improve resilience.

The findings of this study are consistent with those of other studies and suggest that better data, particularly on outcomes of a damaging storm at the local rather than state level, will provide better opportunities for empirical examination of resilience theory. The report provides three recommendations to improve future data collection efforts and build progress toward achieving the aim of the Disaster Mitigation of 2000.

7.1 Relationships of Recommendations to Other Studies

The findings of this study show that it is difficult to find data about the outcomes of a damaging storm and the response and recovery phases of disaster management. These findings are consistent with conclusions of the 2008 report, *Toward a Resiliency and Vulnerability Observatory Network (RAVON)*, which suggests that the scientific community "promote the development of data sets on a variety of units of analysis" (Peacock et al., 2008, page14). The findings of this study are also consistent with the report titled *Creating a More Disaster Resilient America (CAMRA): The Findings from a Workshop on a New Cross-Directorate Program on Disaster Resilience, Vulnerability, and Risk Reduction*, which cites the need for systematic collection of data and standardization of data collection protocols (Peacock et al., 2011).

The 2008 RAVON report says that research on "resiliency and vulnerability demands long-term sustained data collection activities to monitor and model change and the complex factors influencing these changes" and that "the episodic nature of post-disaster and hazards research has generally resulted in it being carried out in a rather ad hoc manner employing different measurement, research, and sampling strategies, yielding incompatible and inconsistent findings, and limiting comparability and generalizability" (Peacock et al., 2008, page 6).

To facilitate data collection and overcome these challenges, the 2008 RAVON report recommends institutionalization of "long-term systematic data collection activities in multiple locations monitoring vulnerability and resiliency" and "the development of common measurement protocols, instruments and data collection strategies that will promote comparative research across locations" (Peacock et al., 2008, page14). Similarly, the 2011

CAMRA report recommends development of a network of multidisciplinary observatories that will "serve as platforms for integrated data collection across various disciplines to enable model development" (Peacock et al., 2008, page 11).

7.2 Recommendations for Future Data Collection

The following three recommendations for future data collection are provided for consideration.

Recommendation No. 1: Collect Data on a Day-to-Day Basis

To successfully examine community resilience following a disaster, relevant data must be collected and saved on a day-to-day basis during the days and months following the event. Such data collection could be done by a designated local official or by researchers with a plan for using the data. Ideally, data requirements, as well as a means to collect, analyze, and archive the data, would be codified by the state. The process and associated data should be incorporated into state and local hazard mitigation plans to better track the degree to which resilience is changing over time. This recommendation aligns with a stated purpose of the Disaster Mitigation Act of 2000, which is to monitor how risk is mitigated over time.

Recommendation No. 2: Codify Data Collection as Part of Existing Post-Event Documentation Procedures

The most effective method to obtain pertinent data would be to gather the information as part of the existing documentation collected during and after disaster events. During disaster response and recovery, local officials are accustomed to filing reports. Existing reports could be modified to capture information to document the length of time, the level of effort, and costs associated with recovery. This information would thereby be saved daily at the local or state level as part of the event documentation.

For example, Situation Reports are commonly developed each day to describe damages and needs for assistance. These reports could be expanded to document daily conditions at the county or even municipal level to obtain information that would be useful in performing resiliency studies. Data that could be collected, recorded, and archived daily might include:

- Number of public schools closed
- Number of shelters opened and number of residents in shelters
- Number of housing units deemed uninhabitable due to the storm
- Number of residents without water/wastewater service or electric power
- Number of emergency rescues performed
- Number of businesses closed due to the storm

Recommendation No. 3: Include Post-Disaster Funding in Data Collection

Given that key themes of resilience include the speed and quality of recovery, the data collected should include the rapidity with which post-disaster grants are implemented, including both traditional disaster recovery programs such as PA and IHP and post-disaster hazard mitigationfocused grants like HMGP and CDBG-DR. Similarly, additional jurisdiction-based measures undertaken after a disaster event, such as changes in codes, ordinances, and land use policies, should be documented.

Appendix A: References and Sources Consulted

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Appendix B: State-Level Flood Risk Information

State-level flood risk information systems were developed after Hurricane Floyd to better inform property owners and local officials about their flood potential. The purpose of each information system is to improve resilience; reduce the time needed for recovery in future disasters; and to allow local officials, residents, and business owners to readily identify and understand their flood risk. The systems are:

- NC Floodplain Mapping Initiative
- LiDAR
- iRISK
- NC Flood Risk Information System (NCFRIS)
- NC Flood Inundation Mapping and Alert Network (FIMAN)

Because these information systems are state-based, there is no variation across the six counties, so they could not be examined in this study. The following paragraphs describe each initiative and are included here to explain the situation in the study counties prior to Hurricane Matthew.

B.1 NC Floodplain Mapping Initiative

Shortly after Hurricane Floyd, FEMA and the State of North Carolina entered into a Cooperating Technical Partnership contract making North Carolina the first state to manage and produce its own National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRMs). The NC Floodplain Mapping Initiative entailed investment in high-resolution terrain data; updated engineering studies; and the development of an Information Technology (IT) infrastructure to store, disseminate, and archive updated GIS data. The initiative involved updating FIRMs and developing real-time flood forecasting and inundation mapping platforms. Figure B-1 displays one of the updated FIRMs.

The updated flood data allow community officials and property owners to make sounder siting and design decisions when rebuilding after a flood, when building new structures and infrastructure, and when retrofitting existing structures. The purpose of the investment was to drastically reduce the long-term losses in North Carolina by alerting property owners with an identified flooding risk for the need to buy flood insurance, providing all data freely to the public and community leaders, and allowing the updated information to be used for engineering and planning applications, including site design, stormwater management, transportation planning and design, and spill response.

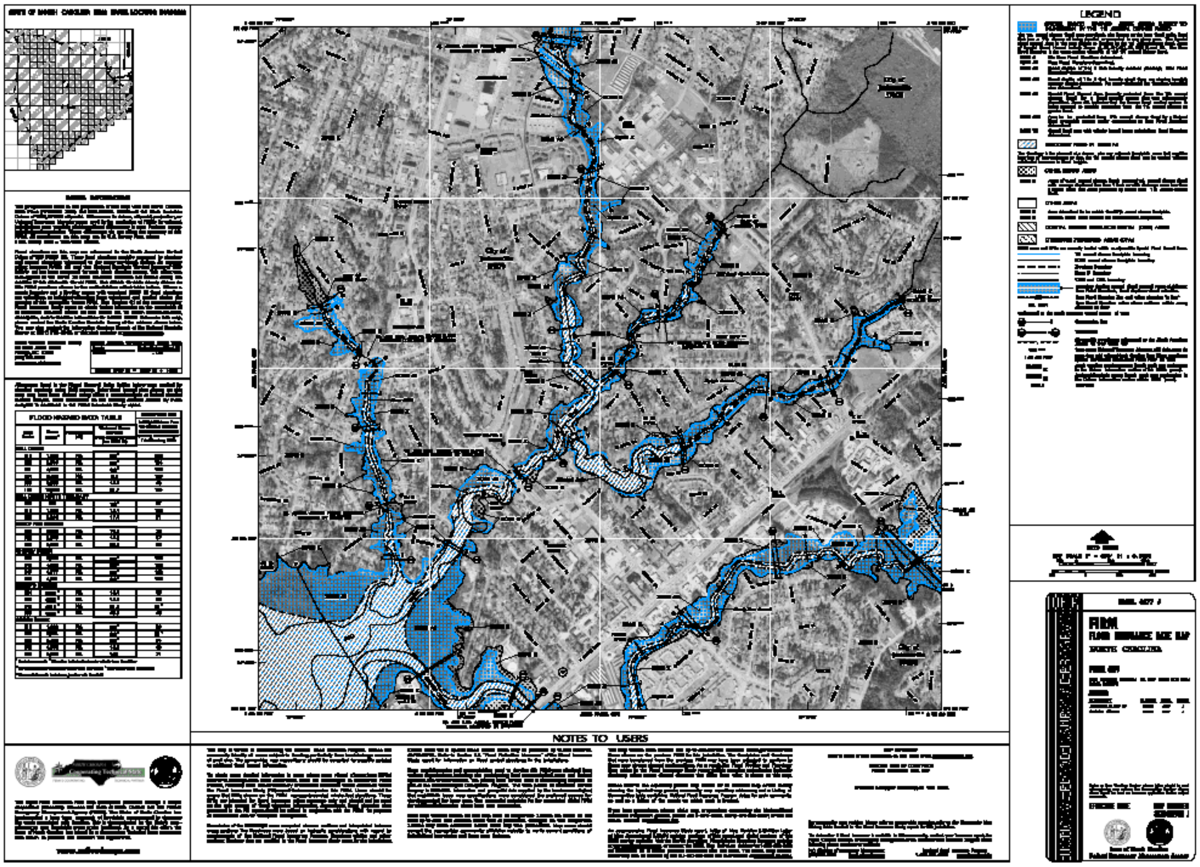

Figure B-1: New digital FIRM developed for the NC Floodplain Mapping Initiative

B.2 LiDAR

Light Detection and Ranging (LiDAR) is a surveying technique that measures distances using a laser. This method was used in the NC Floodplain Mapping Initiative to acquire accurate, high-resolution elevation data across the state.

LiDAR was used because it is more cost effective and more precise than traditional photogrammetric methods for obtaining mass points, spot elevations, and breaklines. Accuracies obtained using LiDAR meet the National Map Accuracy Standards for 2-foot contours. The accuracy of the LiDAR data was assessed using 120 surveyed checkpoints for each county, or 12,000 checkpoints in total across all 100 counties in North Carolina. The study counties are in the Neuse, Tar-Pamlico, and Lumbar River Basins; LiDAR data for these counties were gathered as part of Phase I of the effort. Figure B-2 illustrates the locations of the three phases of the NC Floodplain Mapping Initiative.

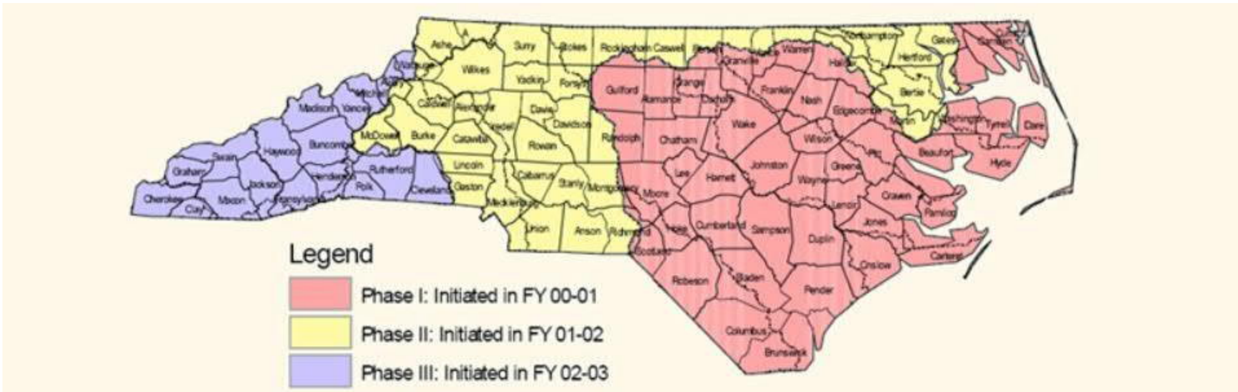

Figure B-2: LiDAR data were initially gathered in three phases

B.3 iRISK

iRISK is an online tool that identifies hazards to which a specific property or community is vulnerable, performs a risk assessment for a specific area and hazard, and communicates the results of the risk assessment. iRISK uses multiple models and methods commonly used by government risk assessors, including FEMA's Hazus software, which estimates potential losses for floods, hurricanes, earthquakes, and tsunamis, and FEMA benefit-cost analysis (BCA) software, which calculates the benefit achieved by implementing hazard mitigation projects. iRISK can be used to develop a local or county hazard mitigation plan.

The iRISK tool analyzes and communicates flood hazards, including coastal and riverine flooding, coastal erosion, and flooding from levee or dam failure. Analyses determine the potential for direct physical damage to buildings, contents, and infrastructure; direct economic losses associated with physical damage from the hazard, including loss of utilities and disruption of employment; and indirect economic losses, which include upstream and downstream business and industry disruption associated with the hazards. Community officials use this information to make determinations about mitigation projects and plan for future disasters. Figure B-3 displays the opening page of the online tool.

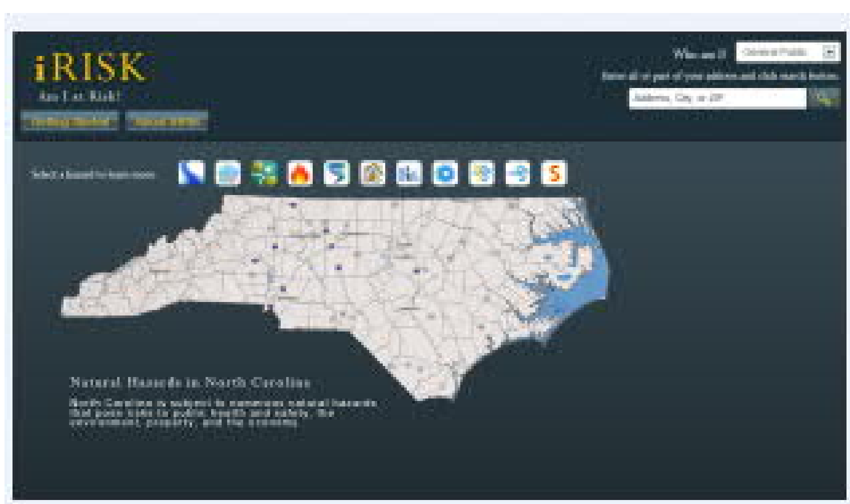

Figure B-3: Opening page of iRISK, an online hazard identification tool available to the public

B.4 North Carolina Flood Risk Information System (NCFRIS)

NCFRIS is an online flood risk platform that gives the public access to current flood risk information, as well as to preliminary, new flood study information. The NCFRIS site contains digitally available flood hazard data, models, maps, and flood risk assessment reports for specific locations. Geospatial data on the site include base maps, LiDAR, imagery, and results of hydrologic and hydraulic models that can be downloaded. NCFRIS is updated regularly with new data and information.

Emergency management specialists, community officials, and the general public can access the site to determine the flood risk of a specific area. Information provided includes the flood zone, flood source, Base Flood Elevation, political area, FIRM number, and effective date of the FIRM. This information can help residents know their risk, determine if they should purchase flood insurance, and estimate their flood insurance premium. Users can also find structure-specific information, such as assessed value, number of stories, square footage, foundation type, and occupancy type. Structure-specific information can help emergency management specialists and planners with future land use planning, as well as with developing applications for grant funds. Figure B-4 displays the opening page of the online tool.

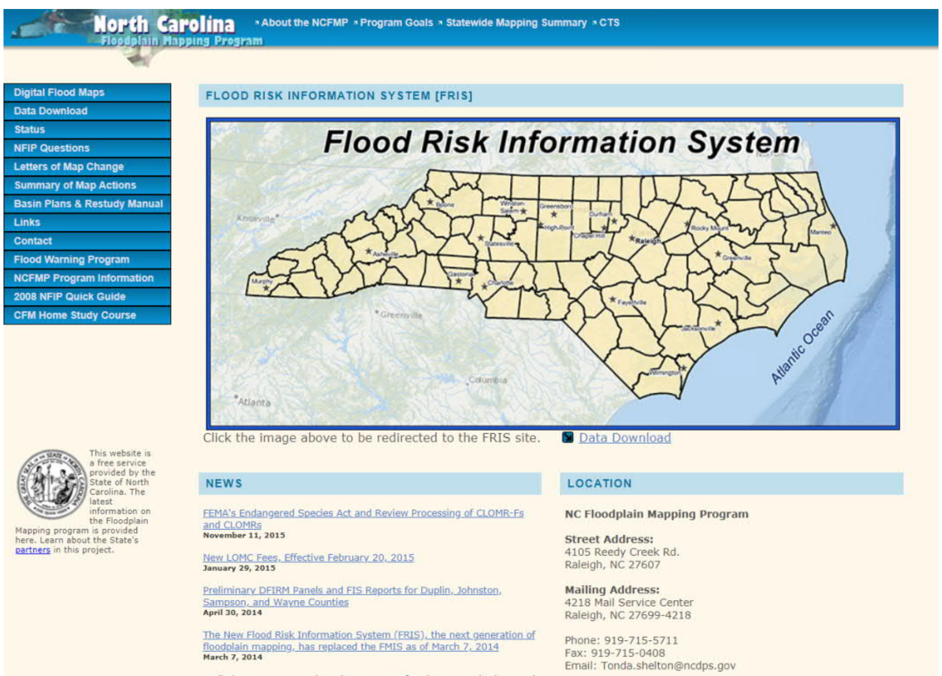

Figure B-4: Opening page of NCFRIS, an online flood risk tool available to the public

B.5 North Carolina Flood Inundation Mapping and Alert Network (FIMAN)

FIMAN is a network of gages that provide real-time data on stream elevation, rainfall, and weather parameters for over 550 locations across the state. This information is used to create live flood inundation maps, estimate flooding impacts, and disseminate alert notifications to support risk-based decision-making. The gages are managed by a combination of the North

Carolina Division of Emergency Management, U.S. Geological Survey, local government agencies, and private organizations.

Established in 2006, North Carolina's FIMAN is one of the most sophisticated and technologically advanced flood warning systems in the United States. FIMAN allows users to select specific gage alerts relevant to their community to stay up to date on the current conditions in their area. Through FIMAN, emergency managers and planners have access to different flooding scenarios for future planning and can use the network to identify specific buildings in their community at risk of flood damage. Figure B-5 illustrates the opening page of the online tool.

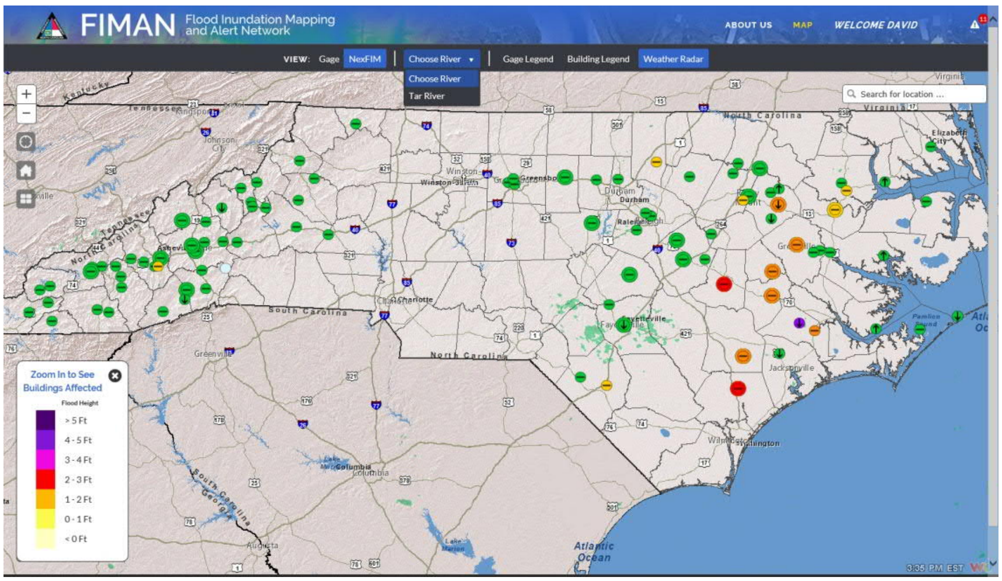

Figure B-5: Opening page of FIMAN, an online flood mapping tool available to the public

Appendix C: County Maps

Geographic Information Systems (GIS) data were used to develop maps for each of the six counties showing the locations of properties used to evaluate the losses avoided in Hurricane Matthew due to acquisition. The maps also indicate sites where relocation and elevation projects occurred. Locations are generally close to major waterways. Locations of several property acquisition projects are indicated by just one dot on the maps because locations were often close to one another. This appendix displays, in alphabetical order, the maps used in the Losses Avoided Study (LAS) for Bertie, Columbus, Edgecombe, Lenoir, Robeson, and Wayne Counties.

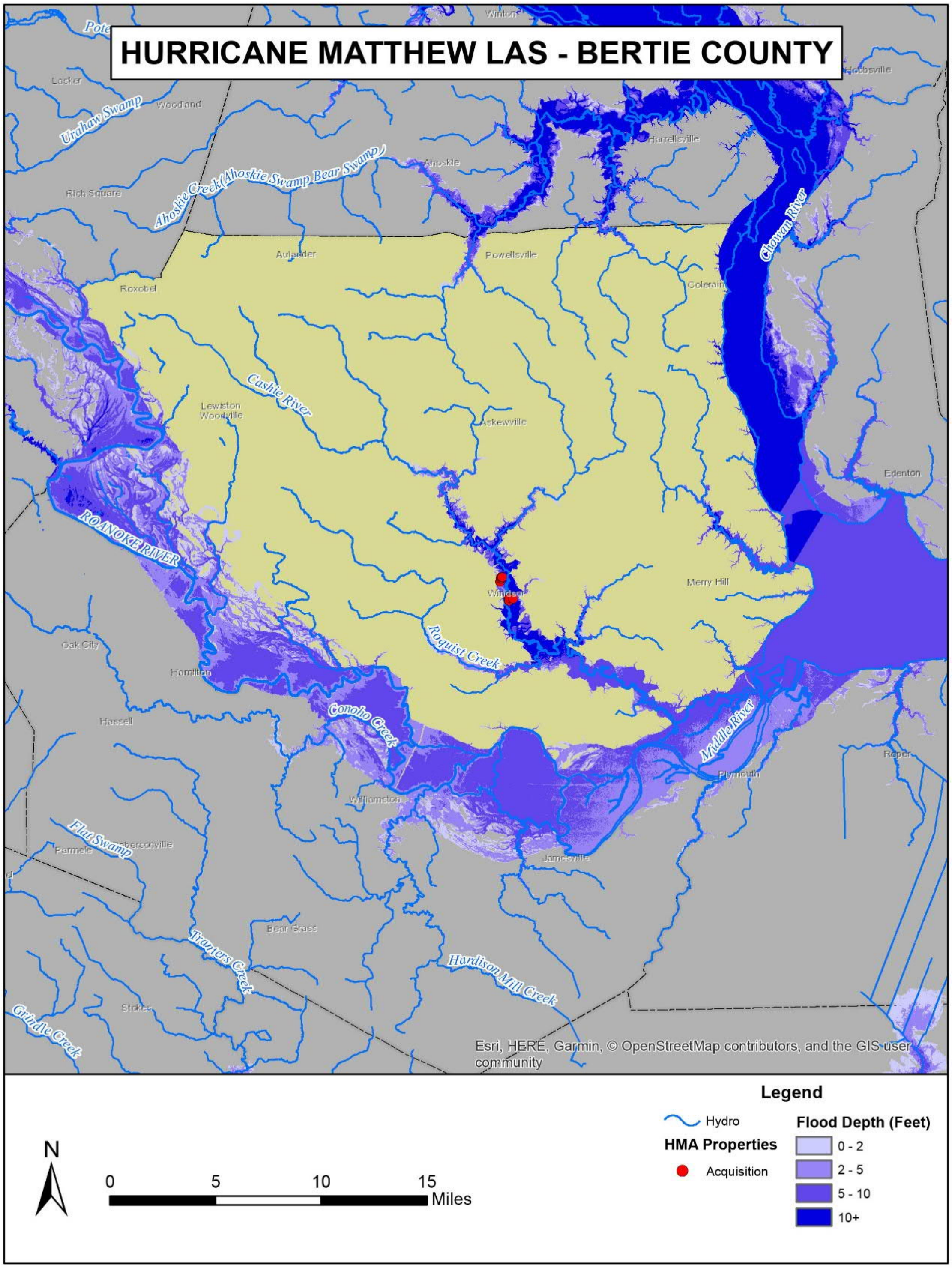

Figure C-1: Hurricane Matthew LAS – Bertie County

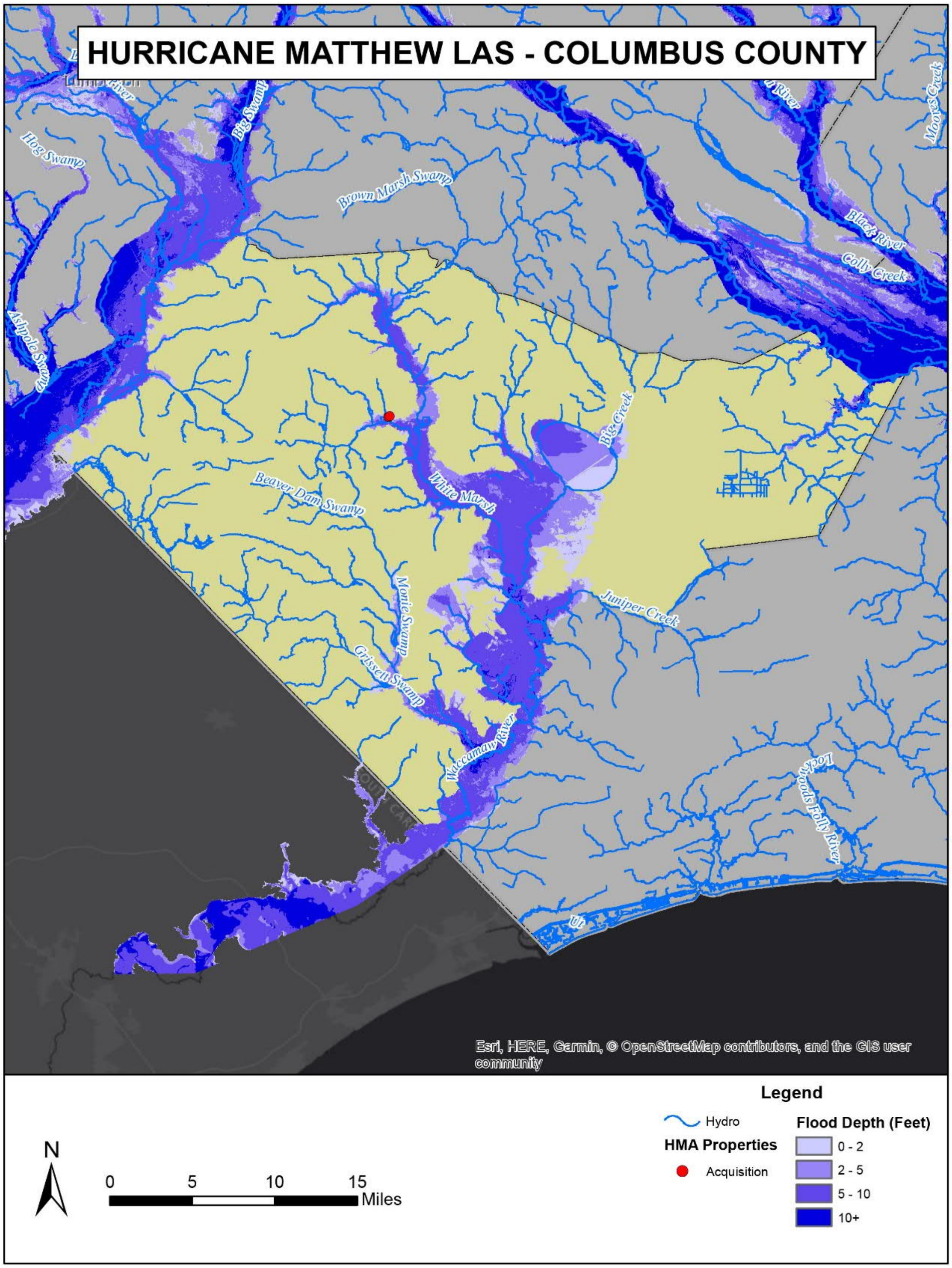

Figure C-2: Hurricane Matthew LAS – Columbus County

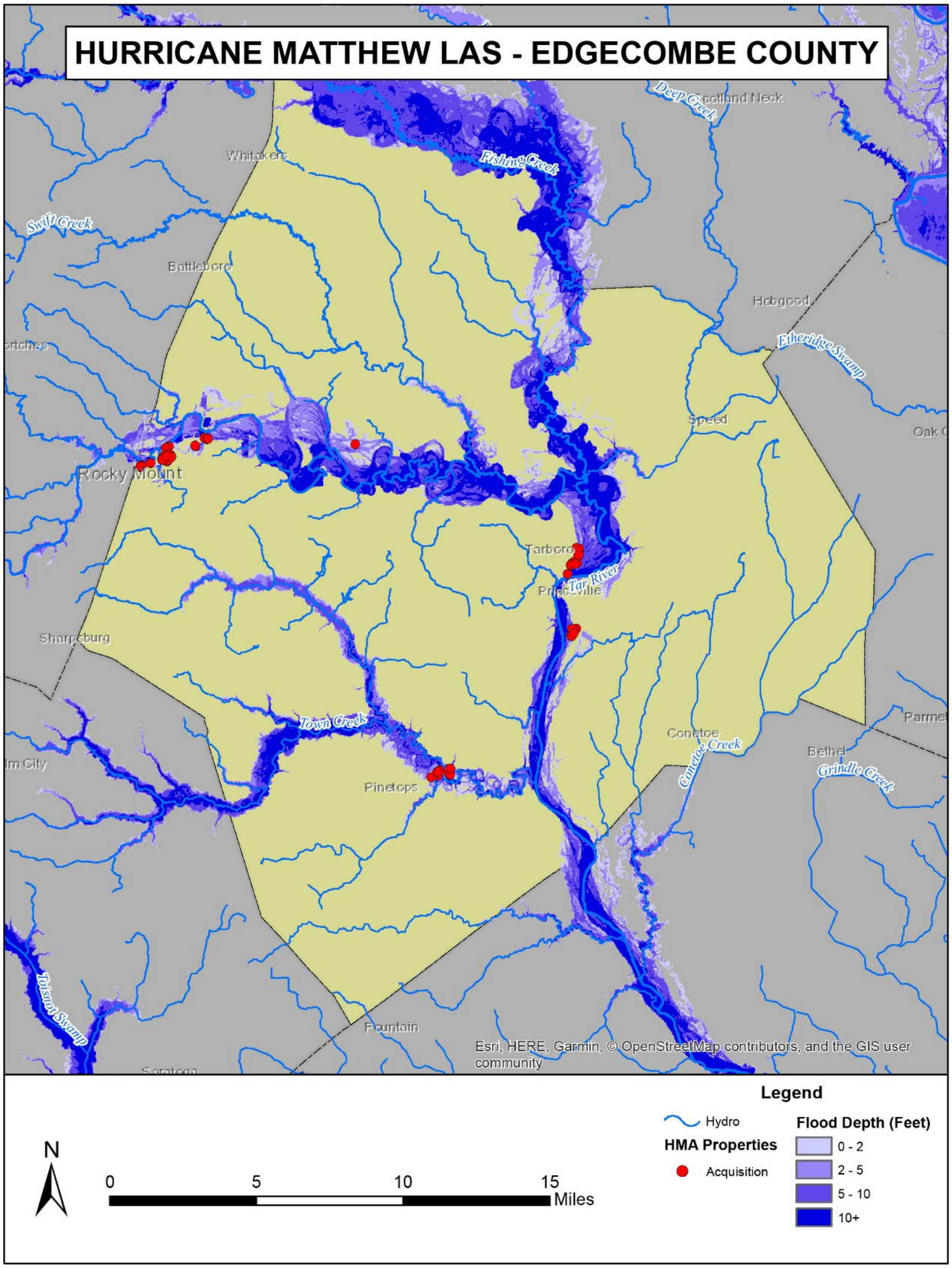

Figure C-3: Hurricane Matthew LAS – Edgecombe County

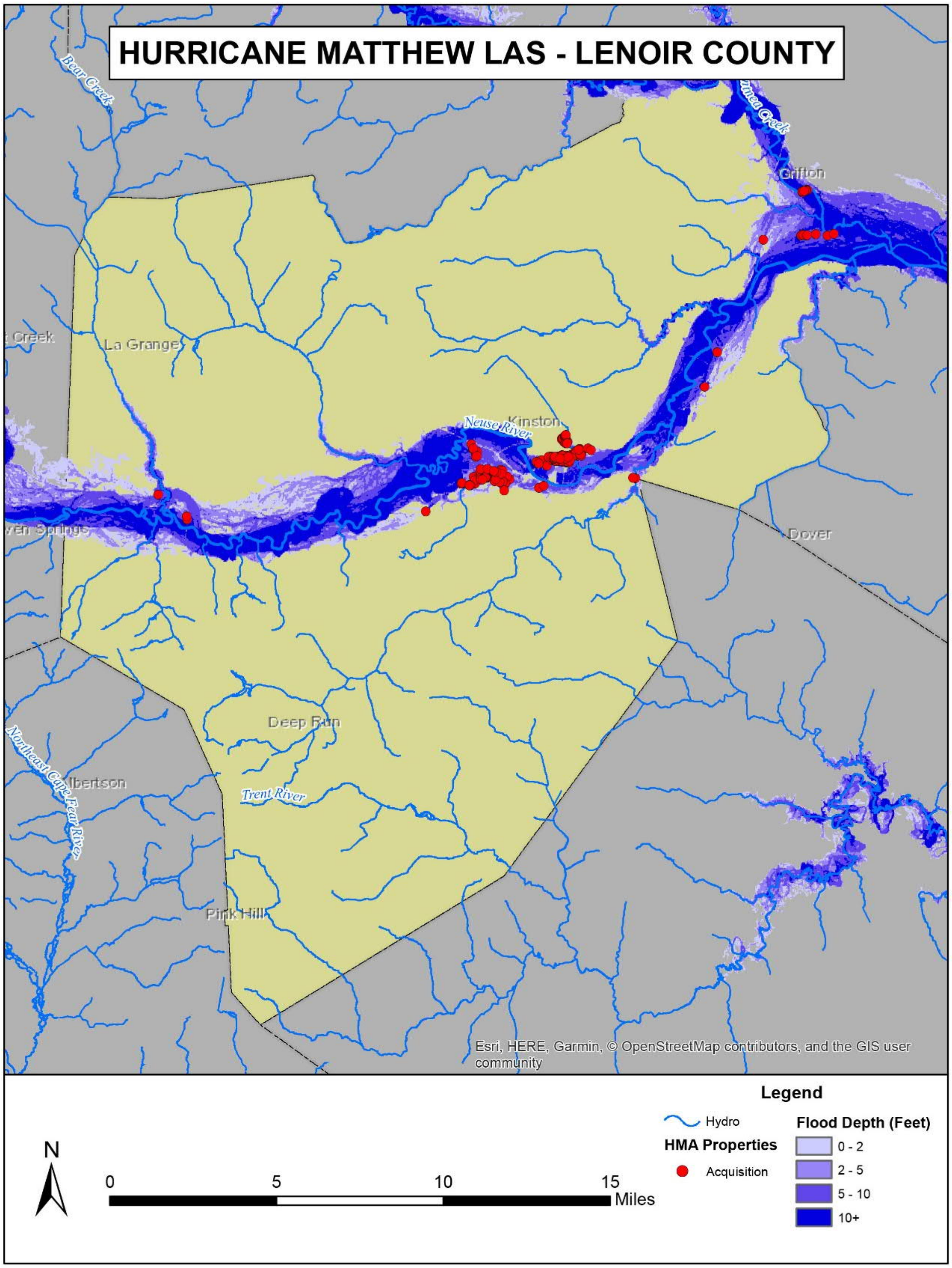

Figure C-4: Hurricane Matthew LAS – Lenoir County

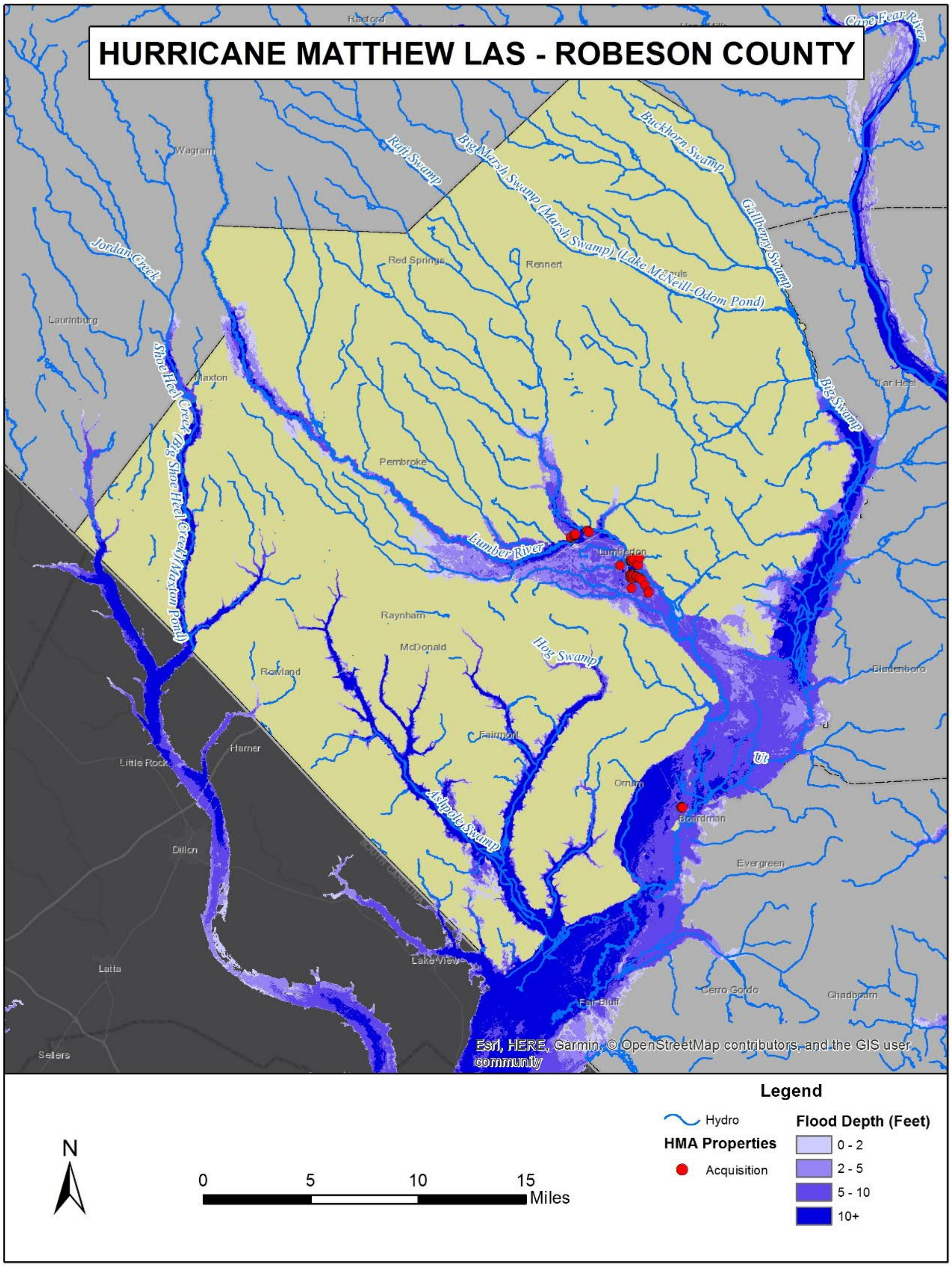

Figure C-5: Hurricane Matthew LAS – Robeson County

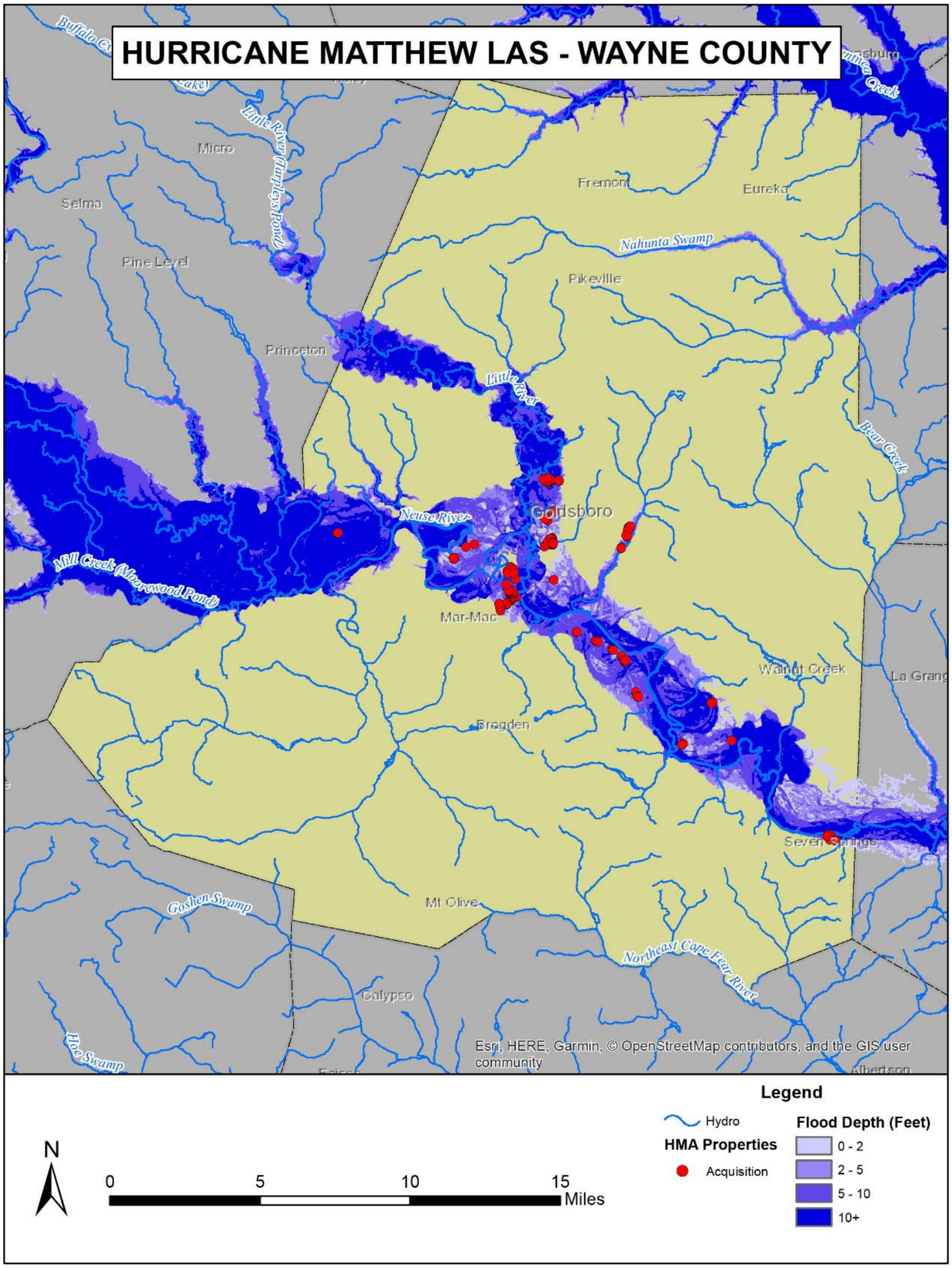

Figure C-6: Hurricane Matthew LAS – Wayne County

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