# Tracking North Carolina's Investments in Flood Resilience:

## An Evaluation of the Spatial Distribution of Funding in the State Budgets between 2018-2022

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## Executive Summary

The purpose of this Master's project is to build a clearer picture of North Carolina's flood resilience investments over the last 5 years. Through an analysis of the communities receiving direct funding through budgetary legislation between 2018-2022, this research supports the North Carolina Office of Recovery and Resiliency (NCORR) and its partners in their efforts to understand the impact of past state funding for flood resilience and to identify the remaining gaps in resources. This project encompasses maps of the existing investment landscape and utilized flood extent, National Risk Index, and rural capacity data to compare the spatial distribution of flood resilience investments and the communities most at risk of flood hazards and those with social and administrative vulnerabilities in need of investment. The analysis in this project identified mismatch in the communities who received funding for flood resilience and those with the great need for financial support, according to their flood risk, vulnerability, and rural capacity. Through this project, I have built a case for a more comprehensive tracking platform of state flood resilience investments and identified several avenues to continue this research.

## Acknowledgements

I would like to acknowledge all of the people who helped me complete this project, including my advisor Dr. Miyuki Hino, the staff at UNC's Department of City and Regional Planning, the Resilience Team at the North Carolina Office of Recovery and Resilience, and my brilliant friends, Jordan April, Eve Lettau, Julia Maron, Viviana Martinez, Kristin Podsiad, Cesar Reyes, Marielle Saunders, Mary Elizabeth Russell, and Emma Vinella-Brusher.

## Background

### *The Necessity for Flood Resilience Investment in North Carolina*

Flooding is one of the most common hazards in North Carolina. With its proximity to the Atlantic Ocean and extensive river system throughout the state, flooding can occur in North Carolina as a result of tropical cyclones, major precipitation events, and dam failures (NC Climate Education, 2020). Every part of the State is susceptible to either direct storms or remnants of storms. Key impacts from tropical cyclones include coastal storm surge, wind damage, and inland riverine flooding due to extensive rainfall (NC Climate Education, 2022). Riverine flooding is particularly damaging and disruptive because of its duration and compounding effects on ill-equipped transportation infrastructure. Floodwaters can remain for weeks as they flow through over-capacity river basins, thus disrupting or even halting the movement of vital goods and services and crippling emergency response efforts and local economic recovery. In particular, the coastal plain river basins of the Neuse, Cape Fear, Lumber, Cashie and Tar-Pamlico rivers have experienced major flooding in the last 20 years, resulting in billions of dollars in damage (Doll et al, 2020).

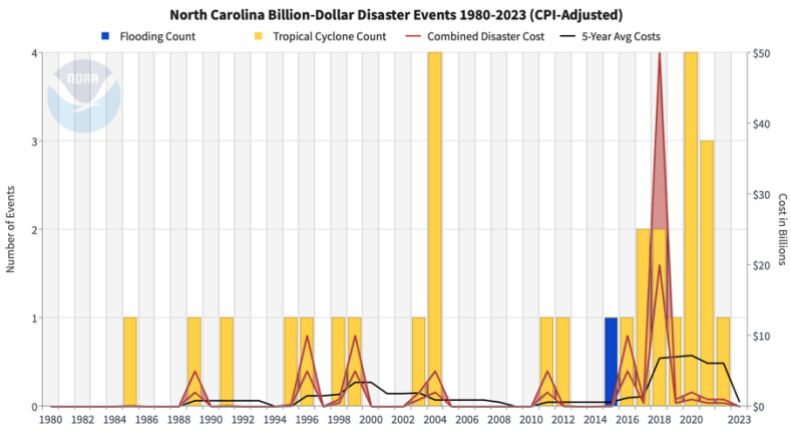


*Figure 1. North Carolina Billion-Dollar Disaster Events (1980-2023)*

Figure 1 displays the cost breakdown of the 28 Tropical Cyclones and 1 Flooding billion-dollar disaster event that affected North Carolina between 1980 and 2023 (NOAA National Centers for Environmental Information, 2023). From 1980 to 2017, the deadliest hurricane was Hurricane Floyd in 1999, which caused 35 fatalities and record–breaking flooding. Hurricane Floyd was nicknamed the "500-year flood" and many had assumed that the unprecedented level of freshwater flooding was an anomaly (Davis, 2021). However, the impacts of the tropical cyclones in the last 5 years, which have been about 2.2 tropical cyclone and flooding events per year and account for a significant proportion (46.4%) of the total cost between 1980 and 2023, have forced a shift in this mindset and catalyzed a greater level of focus and resources toward proactively preparing for and preventing flood-related risks and damages (NOAA National Severe Storms Laboratory, n.d.).

To better understand the shift toward investments in flood resilience, it is beneficial to take a deeper look at the most damaging tropical cyclones that impacted North Carolina in the past five years. Figure 2 depicts the tropical cyclone events that have initiated Emergency and Major Disaster Declaration requests from the North Carolina Governor's Office between 2016-2022 and resulted in supplemental federal emergency public and individual assistance (FEMA, 2023; Ready NC, n.d.)[1].

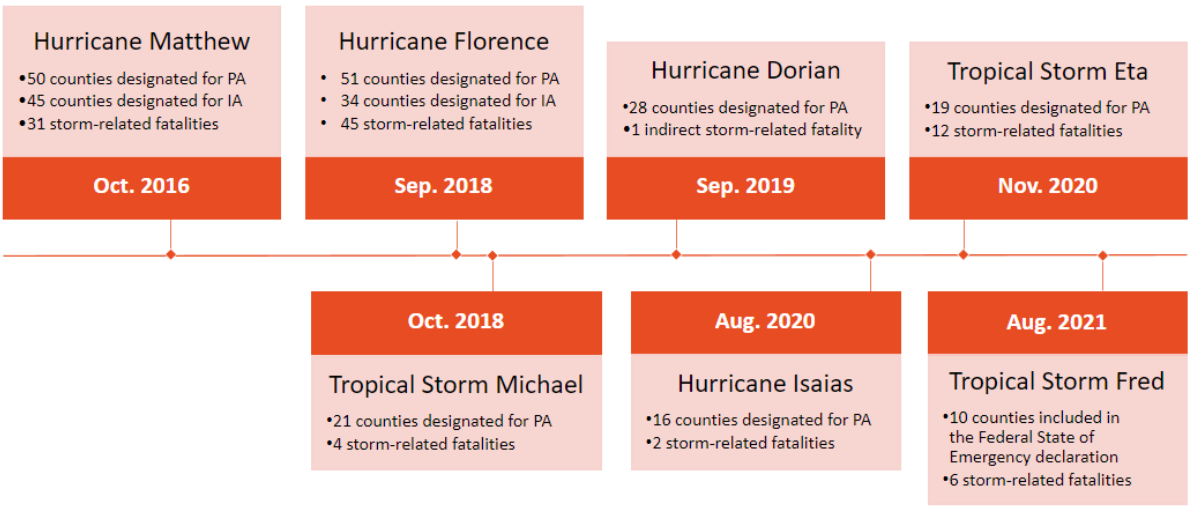


*Figure 2. Timeline of Federally declared Flood-related Disasters*

Hurricane Matthew and Hurricane Florence are often focused on in the discussion of flood resilience in North Carolina because of their unprecedented impacts and overlapping paths. For example, more than 1,760 roads and more than 2,500 roads were flooded during Hurricane Matthew and Florence, respectively, including major interstates like Interstate 40 and Interstate 95 (Davis, 2021).

North Carolina has taken major steps toward facilitating recovery from these storms. While most of the formal actions have been reactive to the storm damage and community disruptions, focusing on recovery and rebuilding, there has been a more recent shift toward proactive investments to strengthen the State's resiliency to future storms.

[1] Emergency declarations supplement State and local or Indian tribal government efforts in providing emergency services with a maximum assistance amount of $5 million. An emergency declaration allows states to access Public Assistance (PA) Categories A (debris removal) and B (emergency protective measures) or Individual Assistance (IA) through the Individuals and Households Program (IHP). However, a Major Disaster Declaration provides a wide range of federal assistance programs for individuals and public infrastructure, including all categories of IA, PA, and Hazard Mitigation Assistance (FEMA). All of the storms depicted in Figure 2 resulted in Major Disaster Declarations.

**2017-2019**

Between July 2017 – June 2019, during the 2017 Biennium budget session, the state passed the State Disaster Recovery Acts of 2017 and 2018. Then, in October 2018, Governor Cooper signed Executive Order 80, a transformative piece of legislation that has set the stage for several forthcoming flood resilience actions at the state level (American Flood Coalition, 2021). Executive Order 80 formalized North Carolina's commitment to address climate change and transition to a clean energy economy, while prompting the creation of the State's Climate Risk Assessment and Resilience Plan and an Action Plan for Nature-Based Stormwater Strategies. Additionally, this Executive Order directed the development of a new state agency, the North Carolina Office of Recovery and Resilience (NCORR). NCORR was formed to better support the distribution of Community Development Block Grant – Disaster Recovery (CDBG-DR) funds to impacted communities and improve on the delivery of hurricane recovery programming. Importantly, it also set aside a small sector of the entity to build and support state policies and actions to enhance North Carolina's resilience to climate hazards.

**2019-2021**

The 2019 Biennium between July 2019 – June 2021 saw the North Carolina Senate pass Senate Bill 429, the "Disaster Recovery Act," (Session Law 2019- 224). This Act appropriated $2,000,000 to the North Carolina Policy Collaboratory to conduct research related to flood resiliency in eastern North Carolina. The research resulting from this Act can be connected to the inclusion of several flood resilience-building programs and projects in future budgets. North Carolina also prepared its first-ever climate resilience plan, the "NC Risk Assessment and Resiliency Plan," propelling state in the direction of building resilience in the face of climate-change risks (Plastrik et al, 2020).

**2021-2022**

For the 2021 Biennium between July 2021 – June 2023, the state government of North Carolina passed a full working budget in November 2021, the first since June 2019, which equated to $25.9 billion. It includes unprecedented funding allocated to flood resiliency, stormwater projects, and upgraded infrastructure. This budget also included a section dedicated to allocations from the State Emergency Response and Disaster Relief Fund (SERDRF), effectively organizing flood resilience the majority of investments into one part of the budget[2]. NCORR also released the most recent iterations of their governing action plans for the 2021-22 utilization of the Hurricane Florence and Matthew disaster recovery and mitigation funds received from the federal government. While NCORR houses critical funding for communities, additional funding for flood resilience exists across state government and is distributed to several departments, visualized in Figure 3. including the Department of Environmental Quality (housing the Department of Mitigation Services), the Department of Commerce, the Department of Natural and Cultural Resources, the Department of Public Safety, the Department of Transportation, and the Office of State Budget and Management.

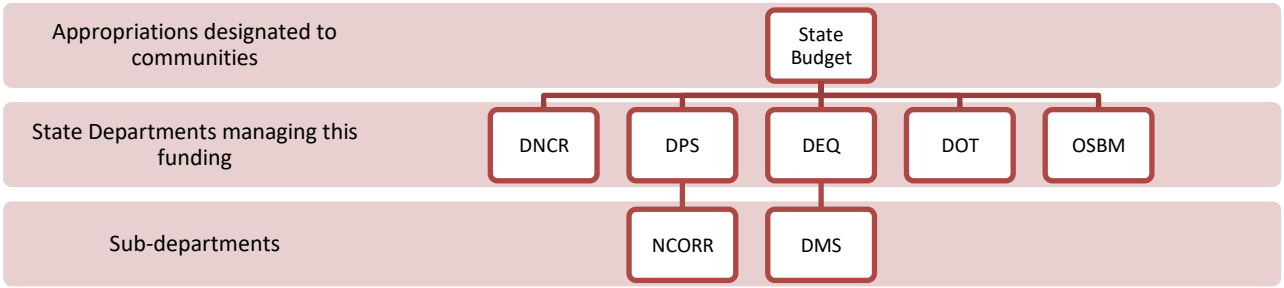


*Figure 3. Funding Flow to State Departments*

[2] According to the case text, although the State Emergency Response and Disaster Relief Fund was added to the North Carolina Emergency Management Act in October 2012, and amended in July 2015, it was not until SL 2021-180 that this section of the budget was created.

# Key Literature

## *Importance of Flood Resilience*

Flooding is an increasingly present hazard impacting most communities in North Carolina and across the United States, whether through coastal flooding, riverine flooding, or increased precipitation of severe storms (Peck et al, 2022; Wombus et al, 2021; Wing et al, 2018). Between 2000 to 2015, floods took more than 100 lives every year (Peck et al, 2022). Riverine floods, which are among the costliest natural disasters in the United States, caused an average of $8 billion in damages each year for the past 30 years (Wombus et al, 2021; Wing et al, 2018).

The literature on climate change has found substantial evidence that floods are likely to increase in frequency and magnitude as climate change worsens (Wombus et al, 2021; Wing et al, 2018). In 2010, the U.S. Geological Survey projected that the number of extreme flooding events could double every five years (US Geological Survey, 2010). First Street Foundation projected that 16.2 million homes in the U.S. will be at substantial risk of flooding by 2050 (First Street Foundation, 2020). Additionally, hurricanes are rapidly intensifying at a pace that diminishes the timeframe for communities to prepare and evacuate (Ting et al., 2019). Hurricanes are also showing a trend of moving slower, according to Kossin (2018), thus increasing the likelihood of extreme amounts of rainfall and the risk of catastrophic riverine flooding.

A combination of land-use patterns and climate change has exposed more people and important development to flood risk (Wing et al. 2018). Expansive development in riverine, estuarine, and coastal floodplains, coupled with traditional flood response efforts (e.g., hardening and accommodation) continue to have negative environmental, economic, and social consequences while also creating a false sense of security for communities near water (Peck et al, 2022; Gittman et al, 2016). The literature also points to lower-income groups, communities of color, and indigenous communities as over-represented within at-risk communities for flooding (Tate et al. 2021, Wing et al. 2022). The perpetuation of historically racist and biased institutional decision-making systems has led to a lack of access to resources and little to no opportunity to participate in decisions about flood management, thus compounding existing social stresses and structural inequities (Peck et al, 2022; Siders, 2019b; Wing et al, 2022).

The literature has shown that the factors increasing the severity and magnitude of floods, especially for vulnerable communities, are evidence that there is deficiency in the flood resilience in the United States. Governments need to designing future flood risk management interventions and in allocating state and federal dollars more effectively by targeting locations with disproportionate risk, or where risk is expected to increase (Peck et al, 2022; Wing et al, 2022).

## *Complexity of Funding Flood Resilience Strategies*

Peck et al (2022) describes the complexity of flood adaptation and resilience planning, which is facilitated by institutional interactions between public and private-sector institutional interactions with entities at the federal government, state government, municipal government, and hyper-local levels. Cigler (2017) describes this complexity as the “intergovernmental paradox of emergency management” in that that states and their local governments will have to bear more responsibility and more costs for disaster, whereas the federal government, which is concerned with the aggregate threat of disaster nationwide, has the most resources. While states may look to the federal government for resources and direction to distribute to local governments, the amount of funding is often subject to change based on the administrative priorities (Cigler, 2017). Federal programs to disrupt flood risk also tend to be reactive and limits extensive access to resources until after a disaster has occurred (such as through FEMA’s post disaster mitigation grants or the National Flood Insurance Program) (Cigler, 2017). Peck at al (2022) also points out that, in a post-disaster setting,

the urgency and politics faced by local governments often favor flood resilience strategies that focus on rebuilding in place (i.e., constructing sea walls and installing other hardened engineering options) instead of considering the broader, systemic implications of these strategies.

While the federal and state governments have begun to reconsider outdated policies and to look for alternatives that support more proactive responses to increasing flood intensities and magnitudes, the reactive approach to flood resilience has become the default (Peck et al, 2022). This conventional approach includes the following sequence, as described by Peck et al (2022): communities first utilize strategies that defend the status quo, typically hardened engineering solutions like sea walls, then aim to accommodate periods of inundation by modifying structures, and finally, if all else fails, retreat from flood-prone areas (Klein et al, 2001, Thomsen et al, 2012, Siders, 2019a; Peck et al, 2022). However, there is strong evidence for movement toward nature-based flood resilience strategies that enable coastal and riverine systems to perform as naturally as possible with little constriction to their dynamism, allowing nature to provide the full suite of direct and indirect benefits to communities, such as flood protection, water filtration, sediment transport, carbon sequestration, and recreation (Peck et al, 2022). Plastrik et al (2020) reiterates the need for flood resilience strategies to generate multiple "co-benefits," adding job creation and prevention of economic disruption to the list of benefits (Plastrik et al, 2020). It is projected that resilience investments can generate $6 in cost savings for every $1 invested (Plastrik et al, 2020).

### *State Funding as a Flood Resilience Investment Pathway*

While crucial to flood resilience capacity of communities, local governments are often lacking financial, managerial, technical, and political capacity to deal with catastrophic flood events (Peck et al, 2022; Plastrik et al, 2020). Additionally, local governments are bound by what powers state governments assign to or deny them; thus, they need their local capacities to be enhanced by flows of state and federal funding and programs (Plastrik et al, 2020).

State governments have powers and resources that local and federal governments do not have and can serve in a capacity builder role for local governments (Cigler, 2017; Plastrik et al, 2020; Peck et al, 2022). Plastrik et al (2020) identified several roles of state governments important to the flood resilience capacity of local government. State governments control and invest in critical physical infrastructure; regulate energy, buildings, insurance and other essential and vulnerable sectors; control funding for water infrastructure, housing, economic development, and energy systems; facilitate the flow of federal funding, including money in response to economic downturns and emergencies; own and manage natural areas; organize and maintain emergency capacities and responses to natural disasters; and shape public opinion and responsiveness to climate risks (Plastrik et al, 2020). State governments also have the ability to increase the flexibility of local governments to systematically consider the application of a comprehensive spectrum of adaptation strategies, recognizing that there is no single-best solution for the environmental, social, and political contexts of local communities experiencing flooding (Peck et al, 2022).

### *Ensuring Equitable Investments*

Environmental equity is defined as the "protection from environmental hazards as well as access to environmental benefits for all, regardless of income, race, and other characteristics" (University of California at Los Angeles Luskin Center of Innovation). The literature suggests that the current flooding paradigms of "defend, accommodate, or retreat" and ecosystem-based adaptation do not fully integrate social equity with flood adaptation (Peck et al, 2022). The literature has also found that income-based inequity was more frequently considered than gender, age, or Indigenous status in adaptation responses, and that ethnic and racial minorities, migrants, and people with disabilities were rarely considered at all (Araos et al, 2021). Additionally, the types of investments do not match promising practices in the literature (Peck et al, 2022; Young et al, 2021). Between 2004 and 2013,

investment in coastal conservation and natural infrastructure was $14 USD billion. This equates to roughly 3% of investments in traditional gray infrastructure, which Young et al (2021) found to be significantly lower than where the investment amount should likely be considering the known benefits of protecting and restoring natural infrastructure (Young et al, 2021). Peck et al (2022) suggest that flood resilience investment should be guided by a framework that identifies the relationships between adaptation strategies and equity and provides guidance on how to consider the challenges and opportunities surrounding equity during application of the framework.

### *Tracking Flood Resilience Investments*

To cope with increasing flooding threats, the literature emphasizes the need for coordinated planning and implementation of flood and storm damage reduction systems that include both natural and gray infrastructure (Peck et al, 2022; Wing et al. 2018; Young et al, 2021). As was mentioned, states play a key role in building capacity for local governments and facilitating coordination and planning of effective and equitable flood resilience investments (Cigler, 2017; Plastrik et al, 2020; Peck et al, 2022). While the literature suggests that investment is increasing, there is a need for more consistent tracking methods for investments (Young et al, 2021; Schroeder et al, 2018). The Pew's Fiscal Federalism Initiative (FFI) found that most states do not have a comprehensive method to track spending across the various agencies involved in disaster preparedness, mitigation, response, and recovery (Schroeder et al, 2018). The literature suggests that a comprehensive investment tracking system would reveal the extent of investments across agencies, help document expansion of understanding of the functions and values of resilience strategies, help demonstrate whether new policies, laws, and programs are facilitating implementation, and would help support strategic decisions about funding of cost-saving mitigation measures (Young et al, 2021; Schroeder et al, 2018). Young et al (2021) suggests building a database with multiple years of state investment data, providing insight into consistency of investments in resilience infrastructure and potentially serving as a tool to advocate for increased investment, especially if compared against other risk analyses tools.

## Central Research Questions

The following research questions have guided my methodology and analysis:

1. Where has the North Carolina State Government invested in flood resilience amongst its communities? Are there notable discrepancies in investments? What are the differences when considering communities with the most vs. least funding?
2. How do communities with designated funding fall within different measures of physical and social vulnerability to flooding? Have any key communities been underfunded for flood resilience?

### *Value of this Research*

It is important to answer these questions because, as it is right now, there is no unified understanding or tracking of state investments in flood resilience, other than segmented reports about different funds within the Budget. Therefore, with a lack of consolidated information, state investments are under analyzed as a means of understanding NC's preparedness and resilience in the face of increased flooding and damage as a result of climate change. Additionally, a geographic breakdown of this data will allow state agencies to know which communities should be prioritized for additional investment.

## Methodology

This project has taken a quantitative approach, utilizing a variety of state documentation. The major steps of this project include developing a definition of state flood resilience investment to guide the project, identifying investments within the budgets, and conducting a geospatial analysis of flood

investments using ArcGIS Pro. This process was informed by consultation with staff at the North Carolina Office of Recovery and Resilience and key literature in the field of flood resilience.

### *Step 1. Identifying the projects that would be considered addressing or building flood resilience*

Using a similar process as Dwyer (2014), I identified **s**earch criteria based on the resilience interventions described in Meng et al (2020) [3]. I used these criteria to collect data from the North Carolina budgetary documents released between 2018-2022[4]. These documents were accessed the budgets through the NC Legislature's website. Each year has budget legislation and summary documents associated with them. I utilized data processing features to build a spreadsheet of information about the funded projects. This spreadsheet includes project identifiers, text associated with the project, an indication about whether the funding was matched by other funding streams, the department/office managing the line item, and the associated state fund.

### *Step 2. Narrowing scope and categorizing flood resilience strategies*

For each funded project, I assigned a Tier, based on Peck et al's (2022) characterization of flood adaptation hierarchy tiers, displayed in Table 1. This categorization process provides a means of understanding the themes in project types and the changes across years[5]. Peck et al's (2022) framework factors in climate change and incorporates equitable considerations, as a means of overcoming the inadequacies of existing frameworks. The framework establishes a tier system for resilience and adaptation strategies that prioritizes the protection and restoration of intact ecosystems over all other adaptation strategies, including nature-based and grey infrastructure. The tiers are prioritized according to the desired purpose or outcome of the project, as well as the capacity for a project to protect and enhance long-term welfare of the nature and people within the community where the project will take place (Peck et al, 2022).

Table 1. Framework for Flood Resilience Strategies, adapted from Peck et al (2022.)

| Tier | Description | Timeframe | Examples[6] |
|---|---|---|---|
| **1** | *Avoid Risk by Protecting and Restoring Natural Floodplains*<br>Measures that protect natural (i.e., undeveloped) floodplains from new development | Long-term (> 100 years) | - Legal protection of natural floodplains (e.g., fee ownership or easement)<br>- Land-use regulations that prevent development in the floodplain<br>- Restoration of existing, degraded floodplains |
| **2** | *Eliminate Risk by Moving Communities* Away from Danger Measures that permanently move people and infrastructure out of floodplains to safe receiving areas and restore floodplain function | Long-term (> 100 years) | - Managed retreat (e.g., voluntary home buyouts)<br>- Restoration of floodplains to natural areas or open space (e.g., parks) that can function as floodplains |
| **3** | Accommodate Water with *Passive* Risk-Reduction Measures that design or upgrade infrastructure to withstand temporary periods of inundation | Medium-term (25–100 years) | - Elevated structures, utilities, and roads<br>- Right-sized culverts and bridges<br>- Stormwater storage tanks<br>- Tidal backflow valves<br>- Dam upgrades/repairs |

[3] The full list of search terms utilized to identify flood resilience projects invested through state budgets can be found in Appendix 2.

[4] The 2017 budget did not contain any flood resilience funding, so analysis was not included in this project. Each state budget has associated documents where sections and line items were amended. I incorporated these changes into my spreadsheet to create the most updated and finalized list of flood resilience projects.

[5] Peck et al (2020) emphasize the ability for a hierarchy framework to assist decision-makers in evaluating strategies within their embedded systems. By assigning values to outcomes, decision-makers are guided in their ability to consider benefits and costs, longevity of a solution, and cohesion with the characteristics of a particular location.

[6] I adapted the framework to include strategies mentioned in the Budgets that met the definition of the tier descriptions. Those additions are shown in red text.

| | | | |
|---|---|---|---|
| **4** | Accommodate Water with *Active* Risk-Reduction Measures that temporarily reduce flood risk by<br>(1) deploying temporary barriers to keep water out<br>(2) temporarily moving people and/or infrastructure out of floodplains<br>(3) temporarily modifying infrastructure to withstand inundation | Short-term (< 50 years) | - Deployable flood protection barriers (e.g., Tiger dams)<br>- Mobile, seasonal recreational structures (e.g., docks, cabins)<br>- Evacuation<br>- Preemptive infrastructure shutdown (e.g., power plants)<br>- Debris Removal<br>- Recovery Activities<br>- Emergency Management Investments |
| **5** | Defend Community Assets Using *Nature-Based Engineering Measures* that alter the natural floodplain system to stabilize it by reducing or withstanding wave energy and/or erosion using primarily living and/or natural (e.g., sand, stone) materials to mimic natural systems. | Short-term (< 50 years) | - Submerged vegetation, oyster or marine mussel beds<br>- Edging<br>- Sills<br>- Beach nourishment<br>- Vegetated dunes<br>- Root wads and boulders<br>- Stream restoration |
| **6** | Defend Community Assets Using *Hardened Engineering Measures* that alter the natural floodplain system to stabilize it by reducing/withstanding wave energy and/or erosion, using primarily nonliving and non-natural materials (e.g., concrete, metal) | Medium-term (25–100 years) | - Groins/jetties<br>- Sea walls<br>- Bulkhead/retaining walls<br>- Revetments (e.g., riprap)<br>- Breakwater<br>- In-water storm surge barriers<br>- Dredging<br>- Repairing or Building Dikes |

### *Step 3. Narrowing scope and categorizing flood resilience strategies*

As I was reviewing the budgets, I made several decisions about the data in order to ensure that my results would stay within my scope.

I categorized projects within a tier or county, based on the following criteria:

- When funding was designated for a community water district, I labeled it based on the proximate county.
- When a funded project included project elements that could be identified with multiple tiers, I categorized it as the largest tier. For example, Red Springs got 3.5 million for debris removal (Tier 4), stream restoration and flood mitigation (Tier 5), and stormwater management (Tier 3). Therefore, I categorized it as Tier 5.
- When a funded project was for a city, I chose the County that it was matched to using the ArcGIS World Geocoding Service.
- I included water and sewer infrastructure projects funded through the Viable Utilities Reserve due to the research on the importance of utilities given the impacts on these systems from flood events (Environmental Finance Center, 2021)
- I classified Coastal Storm Damage Mitigation (CSDM) projects as Tier 5 because of text in the guidelines document[7], which states that the Fund may only be used for costs associated with beach nourishment, artificial dunes, and other projects to mitigate or remediate coastal storm damage to the ocean beaches and dune systems of the State.
- Classified the Coastal Storm Risk Management (CSRM) projects with the U.S. Army Corp of Engineers as Tier 5 because of the focus[8] on beach nourishment.
- I added debris removal/recovery activities, Emergency response activities, stream gauge projects and demolition of damaged buildings to Tier 4 because of their active nature and short-term relief.
- I categorized stream restoration as Tier 5 because it primarily uses natural materials to

[7] More information can be found at NC DEQ's Coastal Storm Damage Mitigation Fund Guidelines for Fiscal Year 2021-2022.

[8] More information can be found at the U.S. Army Corp of Engineer's resources on CSRM.

mimic the existing stream materials.
- When there was little description of the disaster recovery, I categorized it as Tier 4.
- I categorized dredging as Tier 6 because it requires significant engineering processes that involves removing natural materials[9].

My exclusion criteria included the following:
- State university/college flood resilience related projects
- State building improvements
- Funding that went to organizations/non-municipal entities, but did not mention a specific municipality
- Projects that were watershed level, unless a county/municipality was mentioned
- Projects that were intended for hazards other than floods/hurricanes (i.e., freezes, earthquakes, and tornadoes)
- COVID-19 related emergency response funding, unless flood resilience was explicitly the intention
- Water Treatment projects
- Improvements to state and local parks, unless they explicitly mentioned flood resilience

I also researched projects lacking thorough descriptions in order to better understand how they fit into my research. These findings can be found in Appendix 3.

### *Step 4. Build a map of Funded communities and Flood extent*

**Creating Funding Concentration Layer:**
Using ArcGIS Pro, I uploaded my spreadsheet and geocoded the funded cities and counties using the U.S. Geological Service Geolocator. There were 335 total funding line items. When I ran the geo-locator process, the system flagged 46 cities and/or counties that did not match currently to their geographic location. Therefore, I fixed each flagged county and city to the correct location. My next step was to join the geocoded layer to a county boundary layer, which connected the points to the polygons of the counties. This allowed me to conduct analysis with county-level comparison data. I utilized the Spatial Join tool to pull the data from the points into a county polygon layer. When this was successful, I verified my data were included in the table. I then utilized the Summarize Within tool to summarize features within existing polygons, specifically the sum of funding per county and the count of funding line items.

**Creating the Flood extent layer for Florence and Matthew, as a measure of flood inundation:**
To create this layer, I utilized the Flood extent maps[10] for Hurricane Matthew and Hurricane Florence from NC One Map. Since they were in Tiff format, I created a Raster Dataset and then merged the new Raster layers using the Mosaic Tool. I order to compare to the county-level data, I converted the Raster file into a polygon layer. I used the Intersect tool to split the flood extent polygon layer by the county boundaries they intersected. This generated a shape area field within each county that depicted the surface area of the flood extent compared to the square feet of each county. In order to show the differences between counties, I utilized the graduated colors symbology to compare across counties.

[9] More information can be found at NOAA's resources on dredging.
[10] The flood extent maps for Matthew and Florence were created as part of a NatureNet Science Fellowship project initiated in 2018 by The Nature Conservancy and the Arizona State University Center for Biodiversity Outcomes. They used a random forest classification model that leveraged pre- and post-storm synthetic aperture radar from the European Space Agency's Sentinel-1 sensor, in addition to topography, floodplain, and landcover data. The model achieved 92% accuracy against an independent withheld sample.

*Step 5. Build comparison map to identify overlap and gaps*

Flood extent maps for Hurricane Matthew and Hurricane Florence from NC One Map only captured the extent of flooding in the eastern part of the state, and specifically focused on inland flooding in those areas. Therefore, I needed another measure of flooding to "complete" the picture, particularly including coastal flooding and riverine flooding in the Western part of the state. In order to do this, I identified the National Risk Index (NRI) as a source to identify and compare funding amounts to counties with the greatest risk of flooding across the whole state. The National Risk Index is an online mapping tool based on extensive research, cross-disciplinary collaboration, and best practices in the risk assessment fields (Zuzak et al, 2022) [11]. While the tool includes 18 different types of hazards, I focused on the risk measures Coastal Flooding and Riverine Flooding hazards.

**Coastal Flooding:**

The NRI defines Coastal Flooding as "when water inundates or covers normally dry coastal land as a result of high or rising tides or storm surges" (FEMA, 2021). The Coastal Flooding risk measurements are sourced from the National Flood Insurance Program's National Flood Hazard Layer (NFHL), CoreLogic's Special Flood Hazard Area (SFHA) Layer, the NOAA Office for Coastal Management's High Tide Flooding (HTF) Probability, and NOAA's National Hurricane Center (NHC), Sea, Lake, and Overland Surges from Hurricane (SLOSH) raster files. For North Carolina, the counties deemed possible for Coastal Flooding were those that intersected the SLOSH MOM raster layer for Category 5 storms.

**Riverine Flooding:**

The NRI defines Riverine Flooding as "when streams and rivers exceed the capacity of their natural or constructed channels to accommodate water flow and water overflows the banks, spilling into adjacent low-lying, dry land" (FEMA, 2021). The Riverine Flooding risk measurements are sourced from FEMA's NFHL, CoreLogic's SFHA layer, and the NCEI Storm Events Database. For North Carolina, all counties were deemed possible for Riverine Flooding.

**Risk Index Score:**

Available at both the census tract and county level, the scores generated for communities measure the relative risk of a community compared to that of all other communities at the same level. This score combines Expected Annual Loss (EAL), Social Vulnerability, and Community Resilience values by independently normalizing them to a range of 0 (lowest possible value) to 100 (highest possible value). Zuzak et al (2022) explain the flow of this calculation, which is depicted in Figure 4.

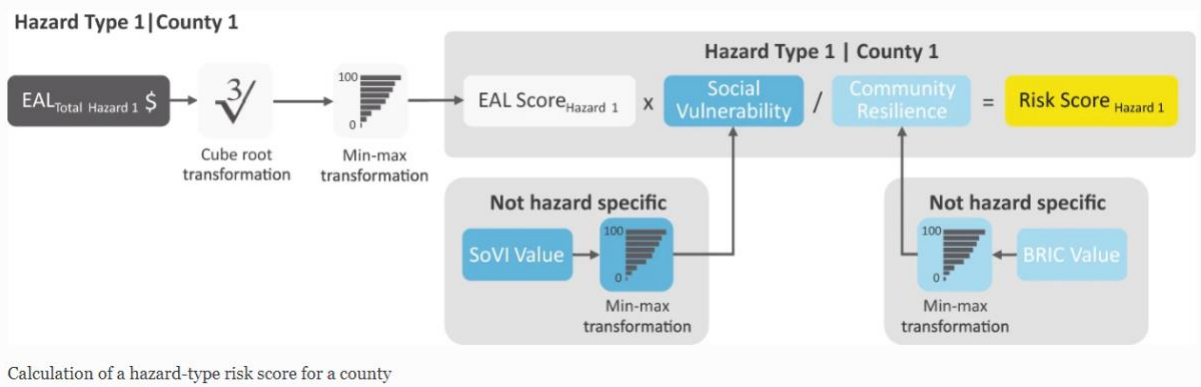


*Figure 4. Zuzak et al (2022)'s depiction of Risk Index Score*

[11] For more information about the National Risk Index, see FEMA (2021). National risk index: technical documentation. FEMA.gov. https://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf.

**Risk Index Value:**
As another way of understanding the risk of counties to Coastal and Riverine Flooding, I utilized NRI's Risk Index Value. The formula is very similar to Risk Index Score, but the units are in dollars, representing a community's average economic loss from a particular hazard each year. I compared the Risk Index Values for Coastal Flooding and Riverine flooding to the Total Flood Resilience Funding for each county.

I also wanted to better understand the factors playing into the Risk Index Scores and Values, so I created a layer from NRI's Expected Annual Loss and Community Risk Factor (CRF) computations.

**Expected Annual Loss:**
Expected Annual Loss quantifies loss for relevant consequence types (i.e., buildings, population, or agriculture). While building and agriculture losses were monetary in the source data, impacts on population were monetized by applying a $7.6 million Value of Statistical Life (VSL) to fatality estimates and adjusting for inflation to 2020 dollars (Zuzak et al, 2022). This measure also factors in annualized frequency of a hazard-type and the historic annual losses associated with each consequence. I compared the EAL total values for Coastal Flooding and Riverine flooding to the Total Flood Resilience Funding for each county.

**Community Risk Factor:**
The CRF reflects the impacts of hazards on communities by incorporating Social Vulnerability and Community Resilience. A community's Social Vulnerability value, sourced from the CDC/ATSDR's Social Vulnerability Index, is divided by its Community Resilience value, sourced from the HVRI's Baseline Resilience Indicators for Communities (BRIC). Therefore, if Social Vulnerability is higher and Community Resilience is lower, relative to all other communities at the same level (county or Census tract), then the resulting Risk Index values will be higher for a given level of EAL. I compared the CRF values for Coastal Flooding and Riverine flooding to the Total Flood Resilience Funding for each county.

Another factor of vulnerability I wanted to understand was Rural Capacity. Since the majority of North Carolina's communities are rural (78 rural counties compared to 22 suburban and urban counties), the impact of rural capacity seems important to understanding the equity implications of the funding distributed to counties[12].

**Rural Capacity Index:**
Headwater Economics' Rural Capacity Index (RCI) is based on 10 variables that can function as proxies for community capacity and help identify communities where investments in staffing and expertise are needed to support infrastructure and climate resilience projects. I compared the RCI values for Coastal Flooding and Riverine flooding to the Total Flood Resilience Funding for each county.

Additionally, for my analysis, I used the NC Prosperity Zones[13] to compare regions, found in Figure 5.

[12] See the North Carolina Rural Center's map for their description of the rural, suburban and urban counties.
[13] For more information, see N.C. Prosperity Zones (n.d.). NC Commerce. https://www.commerce.nc.gov/about-us/nc-prosperity-zones

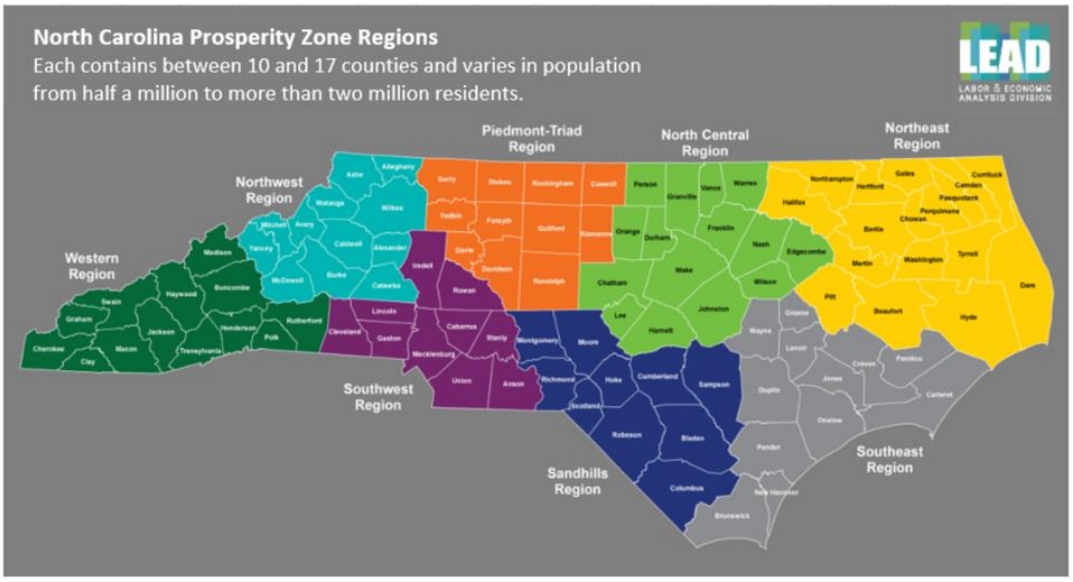


*Figure 5. NC Prosperity Zones*

# Findings

My results are split into two sub-sections. Section 1 contains the excel analysis of flood resilience funding. Section 1 contains the geo-spatial analysis of the flood resilience funding when it is tied to county-level data. For ease of communication, flood resilience funding will be referred to as "funding" in this section.

## *Section 1: Distribution of Flood Resilience Funding*

My analysis of the State's budgets between 2018-2022 yielded 334 instances of funding, totaling $1,688,592,182. The majority of this funding (67%) was allocated to municipalities, while the remaining third (33%) of the funding was allocated to counties[14]. This analysis also discovered that 15 counties did not receive any direct funding for uses that met my flood resilience criteria[15].

Table 2. Funding by Entity Type

| Entity | Count | Sum of Funding | % Total |
|---|---|---|---|
| **County** | 97 | $558,394,472 | 33% |
| **Municipality** | 237 | $1,130,197,710 | 67% |
| **Total** | 334 | $1,688,592,182 | 100% |

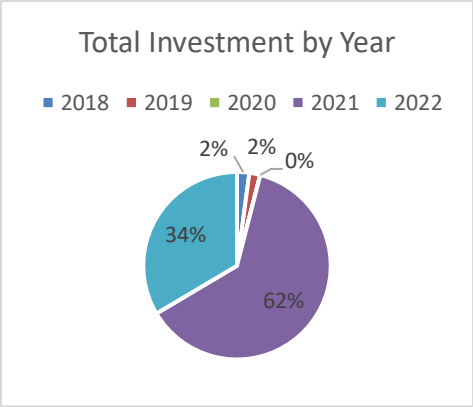


*Figure 6. Distribution of Flood Resilience Funding by Year*

[14] For the purposes of this research, all municipal funding was aggregated to the county level, allowing for the ability to perform county-level vulnerability analyses.

[15] See Step 2 of my methodology section to review my inclusion criteria.

When the flood resilience funding is examined by the year, I found that the majority (62.47%) of the funding over the last 5 years was allocated during 2021, totaling at $1,054,890,138. This finding aligns with the widely discussed designation of the 2021 budget as an unprecedented year for flood resilience investments[16]. Funding during 2022 was the next largest year, at 33.52% or $565,993,044. Years 2018 and 2019 contained much smaller funding allocations, at just 4% of the total funding over the last 5 years. Figure 6 depicts the distribution of flood resilience funding by year.

Table 3. Funding by Year

| Year | Sum of Funding | % Total |
|---|---|---|
| **2018** | $35,741,000 | 2.12% |
| **2019** | $31,668,000 | 1.88% |
| **2020** | $300,000 | 0.02% |
| **2021** | $1,054,890,138 | 62.47% |
| **2022** | $565,993,044 | 33.52% |
| **Total** | $1,688,592,182 | 100% |

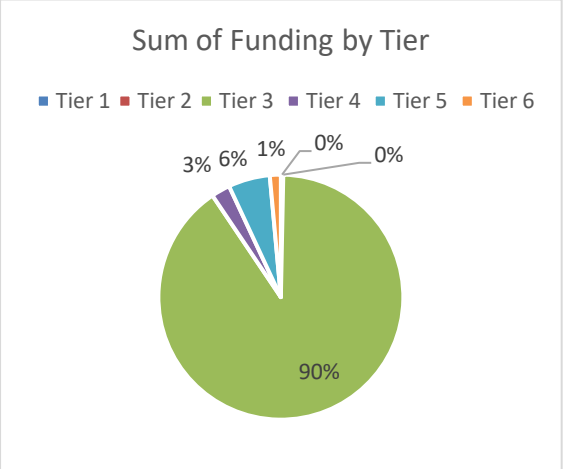


*Figure 7. Distribution of Flood Resilience Funding by Tier*

In Table 4, flood resilience funding is examined by Tier category[17]. The analysis reveals that projects that fell within the Tier 3 criteria received the majority (90.3%) of the total budget funding between 2018-2022, totaling $1,524,027,129. The second largest was Tier 5 with 5.5% of the total budget funding, totaling $92,884,953. The third largest was Tier 4 with 2.5% of the total budget funding, totaling $41,914,600. Tier 6 projects had 1.4% of the funding allocations, totaling $24,465,500. Tier 1 projects received 0.3% of the total funding, totaling $5,300,000. Tier 2 projects did not receive any funding through the 2018-2022 state budgets. Figure 7 depicts the distribution of flood resilience funding by Tier.

Table 4. Total Funding by Year and Tier

| Tier | 2018 | % | 2019 | % | 2020 | % | 2021 | % | 2022 | % | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier 1** | $- | 0.0% | $3,300,000 | 10.4% | $- | 0.0% | $2,000,000 | 0.2% | $- | 0.0% | $5,300,000 | 0.3% |
| **Tier 2** | $- | 0.0% | $- | 0.0% | $- | 0.0% | $- | 0.0% | $- | 0.0% | $- | 0.0% |
| **Tier 3** | $9,640,000 | 27.0% | $8,500,000 | 26.8% | $300,000 | 100.0% | $962,106,685 | 91.2% | $543,480,444 | 96.0% | $1,524,027,129 | 90.3% |
| **Tier 4** | $3,427,000 | 9.6% | $16,500,000 | 52.1% | $- | 0.0% | $1,375,000 | 0.1% | $20,612,600 | 3.6% | $41,914,600 | 2.5% |
| **Tier 5** | $7,674,000 | 21.5% | $3,000,000 | 9.5% | $- | 0.0% | $80,310,953 | 7.6% | $1,900,000 | 0.3% | $92,884,953 | 5.5% |
| **Tier 6** | $15,000,000 | 42.0% | $368,000 | 1.2% | $- | 0.0% | $9,097,500 | 0.9% | $- | 0.0% | $24,465,500 | 1.4% |
| **Total** | $35,741,000 | 100.0% | $31,668,000 | 100.0% | $300,000 | 100.0% | $1,054,890,138 | 100.0% | $565,993,044 | 100.0% | $1,688,592,182 | 100.0% |

**Top Funded Entities for Flood Resilience**[18]

In my analysis of funded counties for flood resilience projects, I identified the ones who received the most funding. The following discussion breaks down the "top-funded" counties and municipalities.

[16] Additional context includes the creation of the State Emergency Response and Disaster Relief Fund (SERDRF) within the 2021 budget, as well as the 2021 budget being the first full-fledged budget since the COVID-19 pandemic.

[17] Information about the Tiers can be found in Table 1.

[18] 11 counties were chosen as the amount because 2019 only included 11 funded projects.

Johnston County and Lee County tied at 6.6% of the total funding allocated in the budgets between 2018-2022. Both counties were allocated at and slightly above $111,000,000. Cleveland County, Brunswick County, and Randolph County sat at 3rd, 4th, and 5th place, respectively, with funding between $69,488,000 and $78,350,000. Table 5 includes the remaining top funded counties[19].

Table 5. Top 11 Funded Counties

| County | Total Funding, 2018-2022 | % Funding |
|---|---|---|
| **Johnston** | $111,593,700 | 6.6% |
| **Lee** | $111,000,000 | 6.6% |
| **Cleveland** | $78,350,000 | 4.6% |
| **Brunswick** | $72,081,599 | 4.3% |
| **Randolph** | $69,488,000 | 4.1% |
| **Harnett** | $66,375,000 | 3.9% |
| **New Hanover** | $62,061,996 | 3.7% |
| **Cabarrus** | $59,976,000 | 3.6% |
| **Rockingham** | $57,475,000 | 3.4% |
| **Stokes** | $53,326,250 | 3.2% |
| **Union** | $49,150,000 | 2.9% |

Table 6. Top 11 Funded Municipalities

| Municipality | Total Funding, 2018-2022 | % Funding |
|---|---|---|
| **Sanford** | $75,000,000 | 6.6% |
| **Asheboro** | $55,000,000 | 4.9% |
| **Clayton** | $49,000,000 | 4.3% |
| **Kings Mountain** | $41,500,000 | 3.7% |
| **Sanford** | $36,000,000 | 3.2% |
| **Newton** | $33,750,000 | 3.0% |
| **Dunn** | $30,950,000 | 2.7% |
| **East Spencer** | $23,349,051 | 2.1% |
| **Jacksonville** | $23,250,000 | 2.1% |
| **Benson** | $22,733,700 | 2.0% |
| **King** | $22,000,000 | 1.9% |

I also analyzed the top funded municipalities. Of the $1,130,197,710 designated directly to municipalities, the top funded communities were Sanford, Asheboro, and Clayton, receiving around 15% of all of the flood resilience funding designated for municipalities between 2018-2022. Table 6 includes the remaining top funded municipalities[20].

When examining the top funded counties by year, there were several communities that repeatedly received the one of the largest amounts of funding for flood resilience between 2018-2022, which can be found in Table 7. The top funded counties during 2 separate years were New Hanover, Surry, Columbus, Edgecombe, Granville, Carteret, Bladen, Johnston and Lee counties. Rockingham, Harnett and Brunswick were top funded counties during 3 separate years.

Table 7. Top 11 Funded Counties for each Year

County = 2 Top Ranks across years

County = 3 Top Ranks across years

| 2018 | | 2019 | | 2020 | | 2021 | | 2022 | |
|---|---|---|---|---|---|---|---|---|---|
| **Top 11 Counties** | **Funding** | **Top 11 Counties** | **Funding** | **Top 11 Counties** | **Funding** | **Top 11 Counties** | **Funding** | **Top 11 Counties** | **Funding** |
| **Dare** | $15,000,000 | **Columbus** | $6,000,000 | **Bladen** | $300,000 | **Johnston** | $82,593,700 | **Lee** | $ 77,000,000 |
| **New Hanover** | $10,936,000 | **Edgecombe** | $6,000,000 | | | **Cleveland** | $65,650,000 | **Randolph** | $ 61,100,000 |
| **Rockingham** | $3,000,000 | **Wayne** | $5,500,000 | | | **New Hanover** | $51,125,996 | **Catawba** | $ 35,250,000 |
| **Beaufort** | $1,125,000 | **Sampson** | $3,500,000 | | | **Harnett** | $48,300,000 | **Johnston** | $ 29,000,000 |
| **Surry** | $1,000,000 | **Carteret** | $3,368,000 | | | **Brunswick** | $48,094,599 | **Brunswick** | $ 23,500,000 |
| **Columbus** | $725,000 | **Surry** | $3,000,000 | | | **Cabarrus** | $48,000,000 | **Alamance** | $ 22,687,000 |
| **Edgecombe** | $700,000 | **Hyde** | $1,800,000 | | | **Union** | $43,400,000 | **Rockingham** | $ 22,375,000 |
| **Granville** | $500,000 | **Wilson** | $1,000,000 | | | **Stokes** | $40,326,250 | **Lincoln** | $ 18,550,000 |

[19] The percentage calculated here uses the total funding, encompassing funding allocated for both counties and municipalities. This total is $1,688,592,182 and is presented in *Table 2. Funding by Entity Type.*

[20] I decided not to explore municipality-specific funding beyond this analysis. The county-level data was utilized as a basis for comparison to the NRI and Rural Capacity Index data.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Harnett** | $500,000 | **Bladen** | $500,000 | | | **Granville** | $35,000,000 | **Wilkes** | $ 18,500,000 |
| **Haywood** | $500,000 | **Jones** | $500,000 | | | **Lee** | $34,000,000 | **Harnett** | $ 17,575,000 |
| **Brunswick** | $487,000 | **Pender** | $500,000 | | | **Rockingham** | $32,100,000 | **Carteret** | $ 13,500,000 |
| **Total Funding for the year** | **$35,741,000** | | **$31,668,000** | | **$300,000** | | **$1,054,890,138** | | **$565,993,044** |

**Top Funded Counties for Flood Resilience without Water and Sewer Infrastructure (WSI)**

Table 8 depicts the breakdown of funding with WSI and without WSI. WSI projects make up 75.9% of the projects funded within the 2018-2022 budget. The total funding amount for projects that do not include WSI is $272,636,686, or 24.1%. Because the WSI projects utilize the majority of the flood resilience funding, I conducted another layer of analysis by evaluating the top funded communities when water and sewer infrastructure related (WSI) projects are excluded from the analysis[21]. Of the Non-WIS funding, the top funded communities are Brunswick, New Hanover, Haywood, Carteret, Dare, Rutherford, Pender, and Cumberland, respectively. Tier 3 received the most amount of funding at $108,071,633. The next highest funded Tiers are Tier 5 and Tier 4, at $92,884,953 and $41,914,600 respectively. Table 9 includes the rest of the breakdown of County funding for non-WSI projects by Tier.

Table 8. Breakdown of Funding with WSI and without WSI

| | **Funding Total** | **% Total** |
|---|---|---|
| **All Funding** | $1,130,197,710 | 100% |
| **Funding without WSI** | $272,636,686 | 24.1% |
| **Funding for WSI** | $857,561,024 | 75.9% |

Table 9. Breakdown of County funding for non-WSI projects, by Tier

| **County Tier Breakdown** | **Tier 1** | **Tier 2** | **Tier 3** | **Tier 4** | **Tier 5** | **Tier 6** | **Funding Total** |
|---|---|---|---|---|---|---|---|
| **Tier Total (without WSI)** | $5,300,000 | $- | $108,071,633 | $41,914,600 | $92,884,953 | $24,465,500 | $272,636,686 |
| **Brunswick** | $- | $- | $14,000,000 | $- | $28,981,599 | $- | $42,981,599 |
| **New Hanover** | $- | $- | $6,092,642 | $2,007,000 | $21,962,354 | $2,000,000 | $32,061,996 |
| **Haywood** | $- | $- | $10,412,041 | $8,300,000 | $500,000 | $1,500,000 | $20,712,041 |
| **Carteret** | $3,300,000 | $- | $250,000 | $12,000,000 | $3,687,000 | $68,000 | $19,305,000 |
| **Dare** | $- | $- | $- | $425,000 | $2,700,000 | $15,000,000 | $18,125,000 |
| **Rutherford** | $- | $- | $16,500,000 | $- | $- | $- | $16,500,000 |
| **Pender** | $- | $- | $500,000 | $- | $14,537,000 | $- | $15,037,000 |
| **Cumberland** | $- | $- | $11,800,000 | $- | $3,000,000 | $- | $14,800,000 |
| **Edgecombe** | $- | $- | $- | $6,700,000 | $- | $5,197,500 | $11,897,500 |
| **Robeson** | $- | $- | $10,125,000 | $- | $- | $- | $10,125,000 |
| **Columbus** | $- | $- | $- | $7,150,000 | $- | $- | $7,150,000 |

[21] As discussed in my literature review, while maintaining and updating water and sewer infrastructure is an important component of flood resilience strategies (Thompson et al, 2021), those projects make up a large portion of the total funding. Therefore, removing the WSI projects allowed me to examine another layer of the funded communities.

*Section 2: Analyzing Geospatial Trends within the Funding Breakdowns*

**Top Funded Counties for Flood Resilience**

Figure 8 depicts the sum of the amount of funding allocated per county. The darkest purple counties have received the most funding for flood resilience projects. The top funded communities align with the analysis in *Table 5. Top 11 Funded Counties*, which were Johnston, Lee, Cleveland, Brunswick, Randolph, Harnett, New Hanover, Cabarrus, Rockingham, Stokes, and Union. The spread of funding shows that the top funded communities are mostly located in the central part of North Carolina.

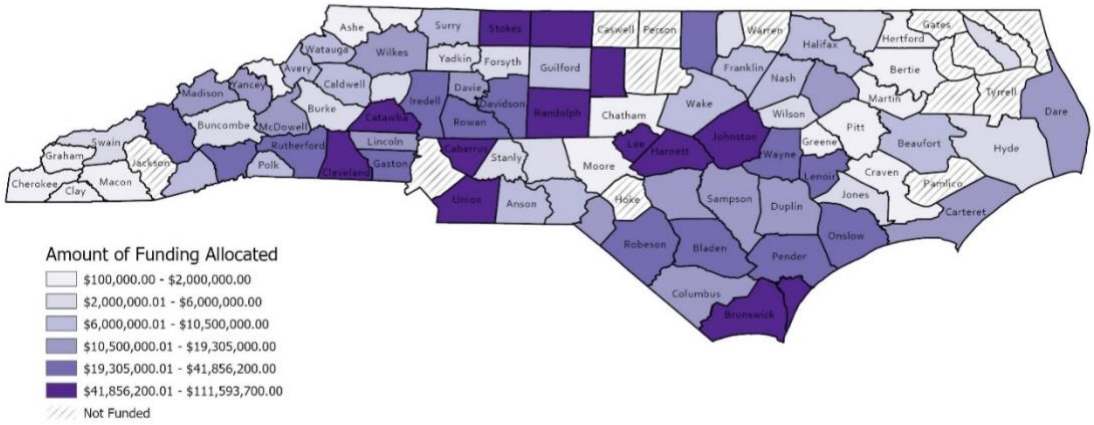


*Figure 8. Flood Resilience Funding by County*

**Flood Extent of Hurricane Matthew and Hurricane Florence**

One question that has guided my analysis is whether the investments in the flood resilience through State budgets is reflective of the flood extent of Hurricane Matthew and Florence, two of the most damaging flood events that have had a traced impact on state funding. Figure 9 depicts the flood extent of Hurricane Matthew and Florence, aggregated by the amount of flood surface area. When comparing to the counties who have received the most flood resilience funding (between $41,856,200 and $111,593,700), there is a no overlap with the counties who experienced the most flood extent. There is some overlap for the second highest funded counties (those who were allocated between $19,305,000 and $41,856,200) and those who experienced the highest tier of flood extent. That overlap can be found in Bladen and Pender counties (20% overlap). A few of the highest funded counties can be identified in the second highest tier of flood extent, specifically Johnson, Brunswick, and Harnett counties.

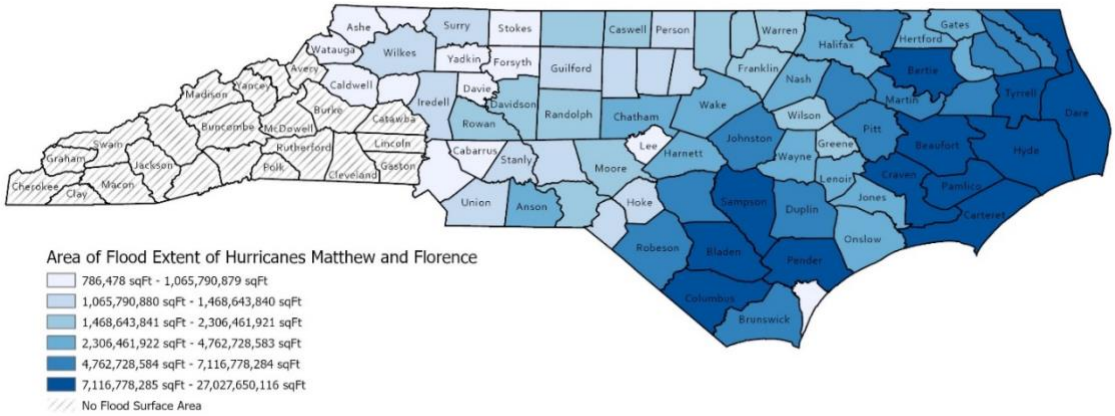


*Figure 9. Extent of Flooding for Hurricanes Matthew and Florence*

**Risk Index Score**

Because the flood extent data only encompassed Hurricane Matthew and Florence, I included the National Risk Index dataset into my analysis to better understand the flood impacts across the state. The National Risk Index splits the flood hazard category into Coastal Flooding and Riverine Flooding. Figure 10 depicts the Risk Index Scores for Coastal and Riverine Flooding for North Carolina Counties. This score represents a county's national percentile ranking relative to all other counties for each type of flood hazard[22]. The higher the score, the more at risk a county is to the respective flood hazard. The counties with the highest risk index score for Coastal Flooding include Beaufort, Hyde, Dare, and Tyrrell. The counties with the highest risk index score for Riverine Flooding are more extensive, with concentrations in the Sandhills, Southeast, North Central, Northeast, Western and Northwest regions. The overlap of the top 10 funded counties and the counties with the highest Risk Index Scores for Coastal and Riverine Flooding include Johnston and Brunswick (20% overlap).

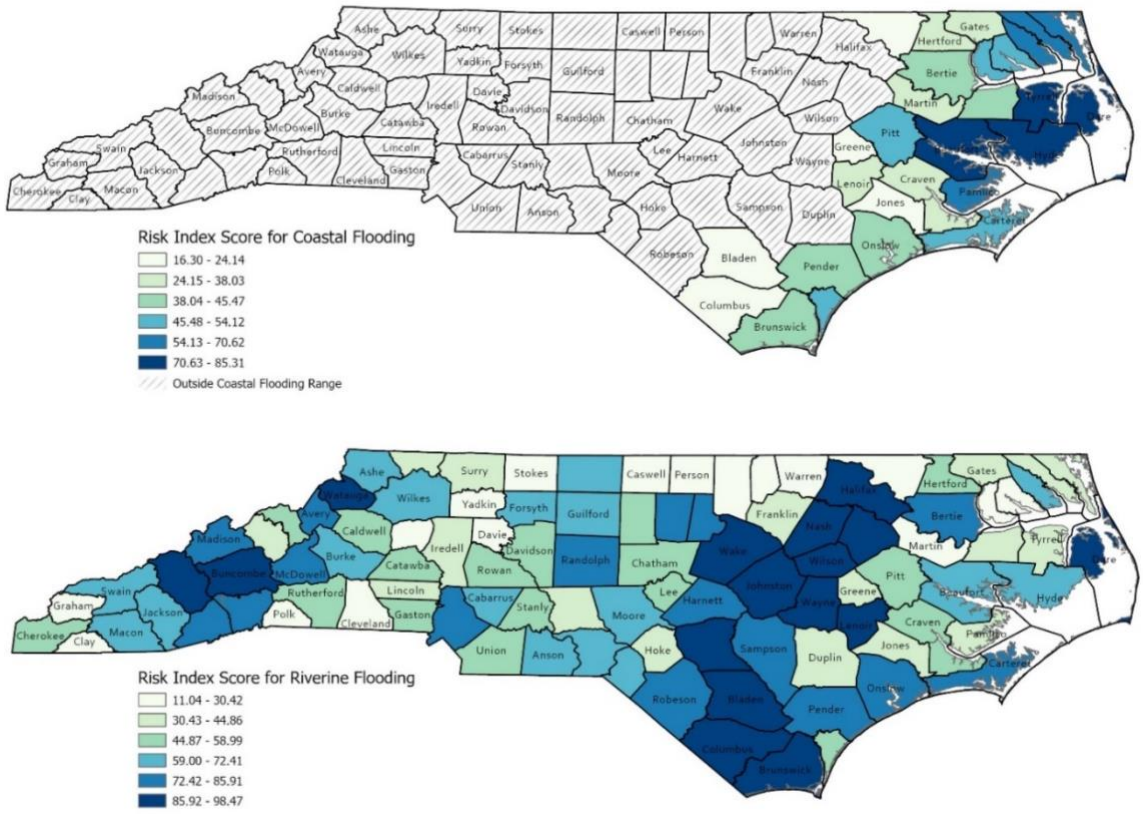


*Figure 10. Risk Index Score of Coastal and Riverine Flooding*

**Expected Annual Loss**

To understand how the state is investing in counties with economic impacts due to flood hazards, I utilized the National Risk Index's calculations of Expected Annual Loss (EAL) by county. EAL for each county is the average economic loss in dollars resulting from flood hazards each year[23]. To conduct this analysis, I used a multivariate symbology to depict the overlap between the Flood Resilience Funding total and the Expected Annual Loss total per county. The map at the top of Figure 11 depicts the EAL for the Coastal Flooding hazard compared to funding for each county and the map at the bottom of Figure 11 depicts the EAL for the Riverine Flooding hazard compared to funding for each county. The darkest red counties indicate alignment between a high EAL amount and high flood

[22] The Risk Index Score incorporates data about the expected annual losses to individual natural hazards, social vulnerability and community resilience. See methodology for more information.

[23] EAL only quantifies loss for relevant consequence types (i.e., buildings, population, or agriculture). While the Riverine Flooding EAL includes agriculture, the Coastal Flood EAL only includes buildings and population.

resilience funding amount. The overlap of the top 10 funded counties and the counties with the highest EAL for Coastal Flooding includes only New Hanover County (10% overlap). The overlap of the top 10 funded counties and the counties with the highest EAL for Riverine Flooding includes Johnston, Harnett, Brunswick, Randolph, and Cabarrus (50% overlap).

Pamlico, Tyrrell, Currituck, Camden, Wilson, Moore, Orange, Durham, and Mecklenburg counties fell into the high-EAL, low-funding group, suggesting that these counties may be important targets for increased resource allocation to address risks associated flooding.

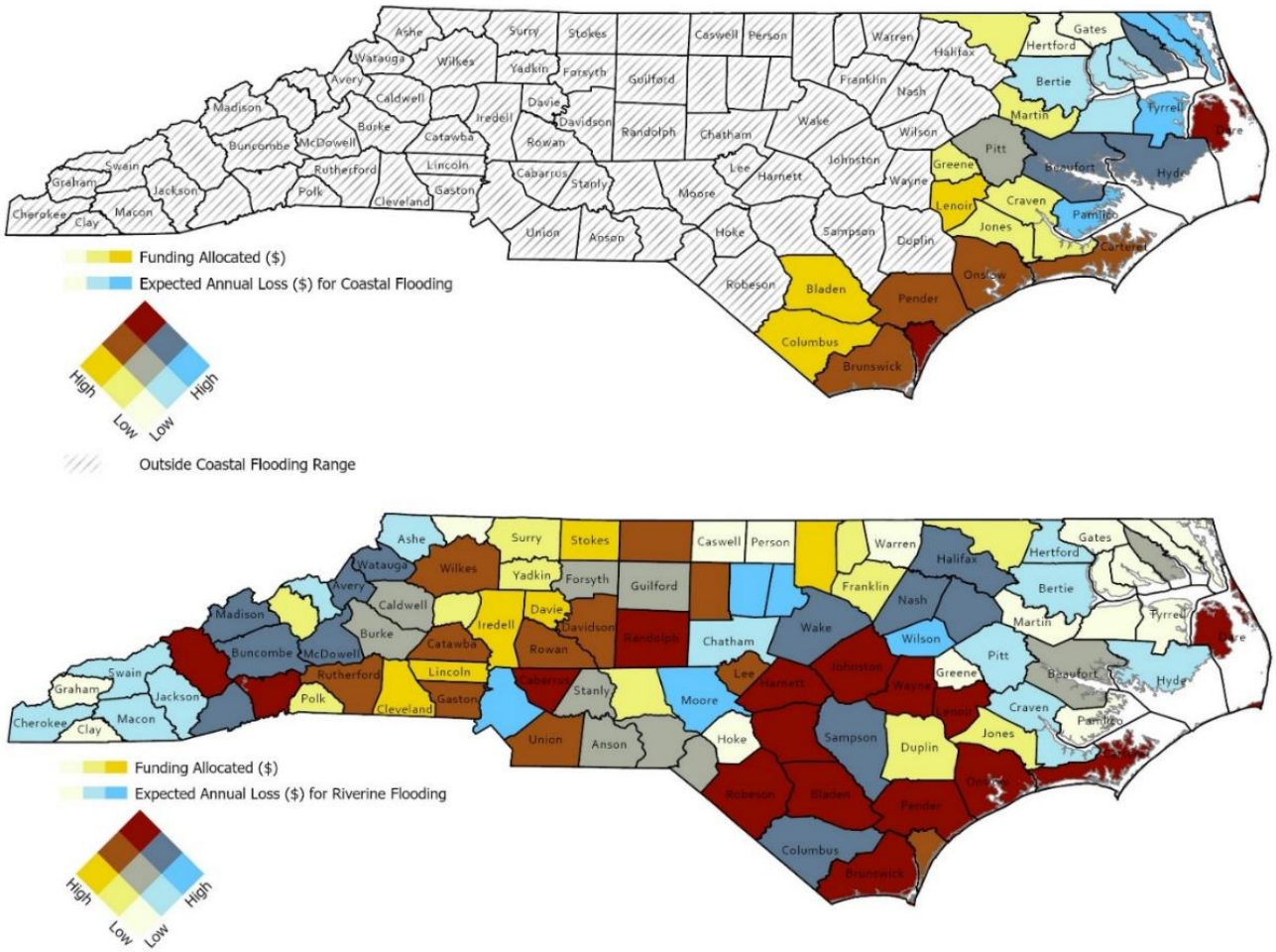


*Figure 11. Expected Annual Loss for Coastal and Riverine Flooding*

**Risk Index Value**

To understand how EAL overlaps with the amount of funding allocated to counties for flood resilience, I used a multivariate symbology. The map at the top of Figure 12 depicts the RIV for the Coastal Flooding hazard compared to funding for each county and the map at the bottom of Figure 12 depicts the RIV for the Riverine Flooding hazard compared to funding for each county. The darkest blue counties indicate alignment between a high RIV and high flood resilience funding amount. The overlap of the top 10 funded counties and the counties with the highest EAL for Coastal Flooding includes no counties (0% overlap). The overlap of the top 10 funded counties and the counties with the highest EAL for Riverine Flooding includes Johnston, Harnett, Brunswick, and Randolph (40% overlap).

Pamlico, Tyrrell, Currituck, Camden, Chowan, Bertie, Wilson, Orange, Durham, and Mecklenburg counties fell into the high-RIV, low-funding group, suggesting that these counties may be important targets for increased resource allocation to address risks associated flooding.

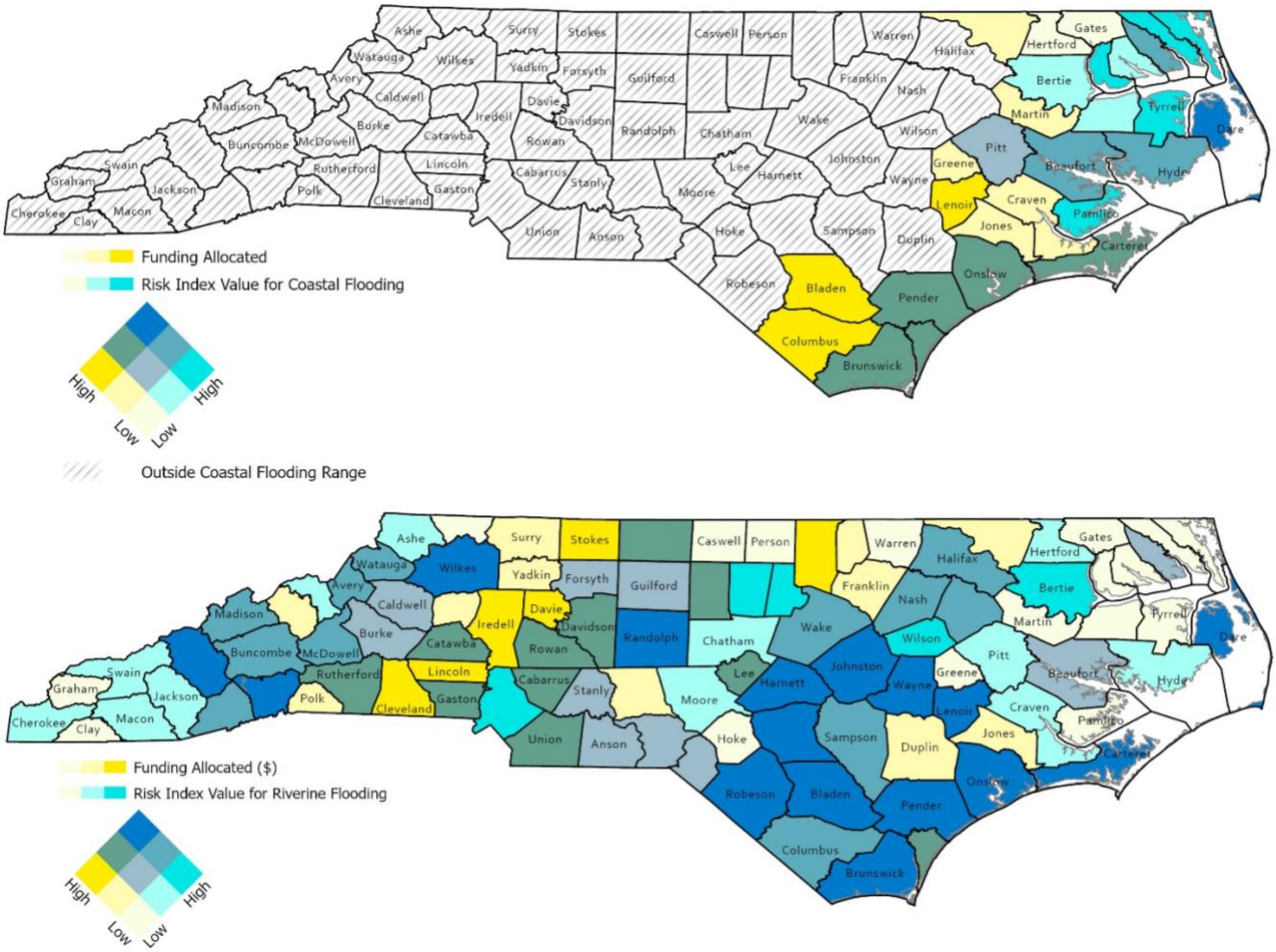


*Figure 12. Risk Index Value (RIV) by County for Coastal and Riverine Flooding*

**Community Risk Factor and Rural Capacity**

To analyze the counties with the most social vulnerability and least amount of community resilience and rural capacity, I utilized the National Risk Index's Community Risk Factor (CRF) and Headwaters Economics' Rural Capacity Index (RCI) Map. Figure 13 depicts the overlap between Community Risk Factor and funding for flood resilience for each county. Figure 14 depicts the overlap between rural capacity and funding for flood resilience for each county.

When examining the overlap between CRF and funding for flood resilience, the deep brown counties indicate alignment between a high CRF and high flood resilience funding amount. The overlap of the top 10 funded counties and the counties with the highest CRF includes Lee, Harnett, and Rockingham (30% overlap).

Swain, Alleghany, Caswell, Hoke, Wilson, Greene, Warren, Hertford, Bertie, Martin, Washington, and Tyrrell counties fell into the high-CRF, low-funding group, suggesting that these counties may be important targets for increased resource allocation related to community risk factors impacting flood resilience.

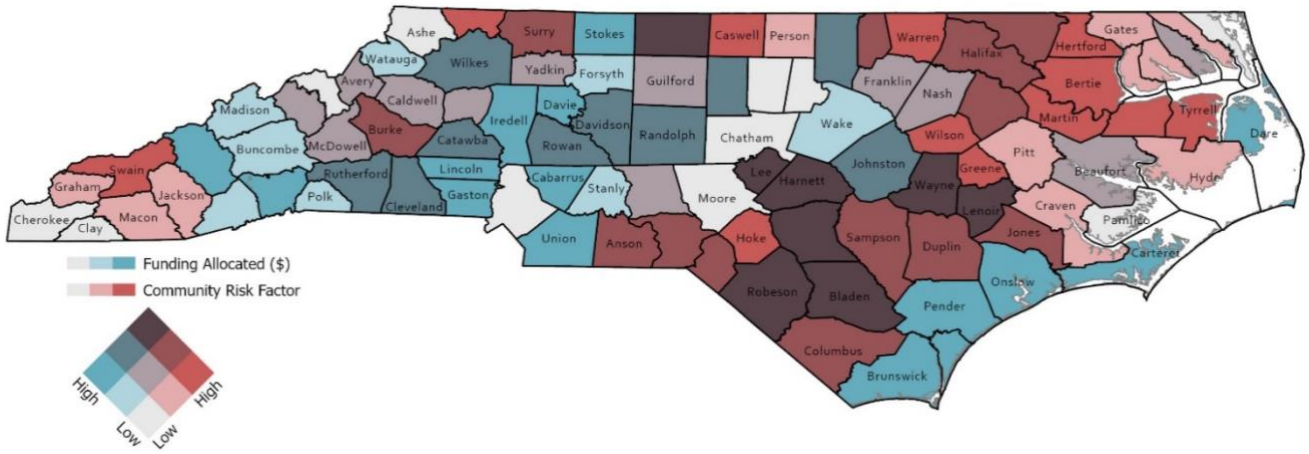


*Figure 13. Overlap between Flood Resilience Funding and CRF by County*

When examining the overlap between RCI and funding for flood resilience, the bright green counties indicate alignment between low RCI and high flood resilience funding amount. The overlap of the top 10 funded counties and the counties with the lowest RCI includes only Stokes County (10% overlap).

Cherokee, Clay, Macon, Graham, Swain, Mitchell, Ashe, Alleghany, Caswell, Hoke, Warren, Greene, Martin, Bertie, Hertford, Gates, Chowan, Perquimans, Washington, Tyrrell, and Hyde counties fell into the low-RCI, low-funding group, suggesting that these counties may be important targets for increased resource allocation related to rural capacity impacting flood resilience.

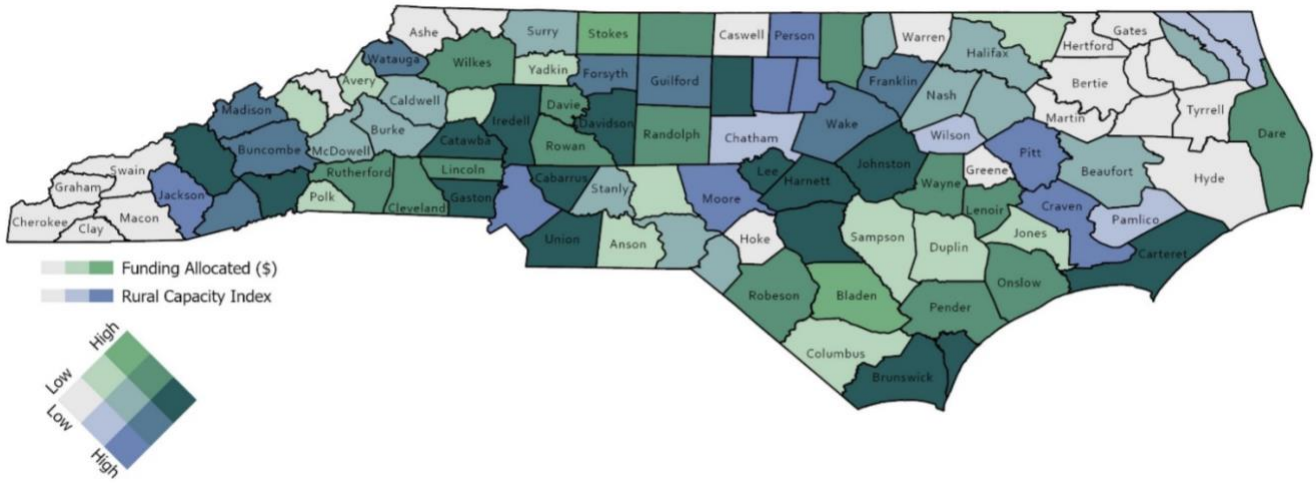


*Figure 14. Overlap between Flood Resilience Funding and Rural Capacity by County*

# Discussion

*Patterns within Flood Resilience Funding Data and Equity Considerations*

To address the guiding questions of this report regarding North Carolina's investments in flood resilience and how the communities align with the most physical and social vulnerability to flooding, this report started with a flood extent comparison. The map of the Top Funded Counties for Flood Resilience was compared to the map of the Flood Extent of Hurricane Matthew and Hurricane Florence. The data showed that there was little to no overlap (0-20%) with the counties who received the most funding. To expand the picture of flood risk at the county level, data from the National Risk Index (NRI) was incorporated into this report, providing a breakdown of coastal and riverine flooding. In an exploration of how funding for flood resilience matched the communities who scored the highest for flood risk, this report used the National Risk Index's Risk Index Score (RIS), Risk Index Value (RIV), and Expected Annual Loss (EAL). Of the top 10 funded counties, 7 counties, Johnston, Harnett, Brunswick, Randolph, and Cabarrus, Lee and Rockingham, showed overlap on the NRI's flood risk measures included in our analysis. However, 20% of the top 10 funded counties showed overlap on all 3 flood risk maps, Johnston and Brunswick counties. As another layer of analysis into the vulnerability of North Carolina counties, this report included maps utilizing Community Risk Factor and Rural Capacity Index data to identify the counties with the most social vulnerability and least amount of community resilience and rural capacity. Of the top 10 funded counties, 4 counties, Harnett, Lee, Rockingham, and Stokes showed overlap on the social vulnerability and rural measures included in our analysis. However, none of the top 10 funded counties showed overlap across all of the risk and vulnerability maps, indicating a misalignment of the counties receiving the most flood resilience funding and those in most need of it. This misalignment may be indicative of the need for improved practices and normative principles to assure equitable distribution of resources (Driessen et al, 2018).

These analyses revealed a pattern of under-resourcing for several counties in the Northeast, North Central, and Western regions of the state. 33 counties, Pamlico, Tyrrell, Currituck, Camden, Moore, Chowan, Bertie, Wilson, Orange, Durham, Mecklenburg, Swain, Alleghany, Caswell, Hoke, Greene, Warren, Hertford, Bertie, Martin, Washington, Cherokee, Clay, Macon, Graham, Swain, Mitchell, Ashe, Alleghany, Caswell, Gates, Perquimans, and Hyde, received little funding for flood resilience but scored high for RIV and EAL, high for community risk factor, or low for rural capacity for flood resilience. Further examination the counties with low funding and high risk and high vulnerability revealed that Wilson, Chowan, and Bertie counties are likely targets for increased resource allocation in order to improve their flood resilience capacity and underlying vulnerabilities. With a third of North Carolina's counties showing signs of under-resourcing despite flood risks and high vulnerabilities, this may call for a deeper exploration of the integration social equity in the decision making for flood resilience investments. As suggested in the literature, conventional flood adaptation paradigms are not adequate in their consideration of inequities beyond income-based, which could cause further harm to vulnerable communities (Peck et al, 2022; Wing et al, 2022; Araos et al, 2021).

Through analysis of the types of flood resilience projects that received state funding, there are some promising patterns revealed through Peck et al (2022)'s characterization of flood adaptation hierarchy tiers, depicted in Figure 15. Their framework, along with the literature (Plastrik et al, 2020; Peck et al, 20222; Young et al, 2021), indicates that flood resilience strategies are often dominated by Tiers 4-6, which have shorter time frames and greater inequities (Peck et al, 2022). The comparison across budget years revealed that North Carolina has increased its investments in Tiers 1-3 and reduced its investments in Tiers 4-6. While 2018 and 2019 had proportionally greater funded projects within Tiers 4-6, application of the framework criteria for the 2021 and 2022 budgets found that most investments were within Tier 3. However, there is a notable lack of investment in Tiers 1

and 2, with a downward trend in 2021 and 2022 compared to 2018 and 2019[24]. Notably, the primary project type is water and sewer infrastructure (WIS) projects. While it is recommended for states to enable local capacity for public infrastructure projects (Plastrik et al, 2020; Environmental Finance Center, 2021), there is a large proportional amount that is lacking for non-WIS projects. According to the literature, North Carolina needs to diversify the resilience projects they fund and accelerate investment in nature-based flood resilience strategies, especially those with several direct and indirect co-benefits (Plastrik et al, 2020; Peck et al, 20222; Young et al, 2021).

### *Challenges in Tracking Flood Resilience Investments*

Despite recommendations in the literature for states to comprehensively track flood resilience investments, North Carolina does not currently have a tracking system (Young et al, 2021; Schroeder et al, 2018). Therefore, the primary data source for this report was the state budgets for 2018-2022. The budget review conducted in this report revealed several factors that complicate the ability to build a full picture of flood resilience investments. Across the budgets, the funded projects exhibited a confusing lack of continuity. Many projects lacked thorough descriptions, requiring outside research to determine their intention and connection to flood resilience strategies. This outside research was often limited to newspaper articles with short and sometimes contradictory project descriptions that may not be reflective of the final project details. Committee reports related to the budgets were included in my budget review, but the reports revealed discrepancies in the amount or funding source for some funded projects and often only included financial information rather than robust project descriptions. Furthermore, while this information may be stored within departments, there is a notable lack of transparency around decision-making processes that went into determining the amount of funds allocated to communities.

Additional gaps revealed through my analysis of NC's Flood Resilience Investment is the need for greater emphasis on communities with compounding social and physical vulnerabilities. The misalignment between community risk factor, rural capacity, and funding indicates that communities with compounding vulnerabilities are not being centered in investment processes. Additionally, many of the funded projects are impacting individual communities, rather than regional or watershed scales. If one community within a watershed plans for resilience but others do not, the resilience of all the communities will be compromised (Plastrik et al, 2020).

### *Limitations*

I have identified several limitations that may have resulted in gaps in my research and analysis. First, my research relies explicitly on quantitative data analysis. However, several of the questions that I raise around project goals and determination processes may be more comprehensively answered through qualitative data collection with the departments coordinating and administering the funding[25]. Without interviewing the departmental funding managers, it is difficult to know if funding projects are truly intending to address and build flood resilience (such as for water and sewer infrastructure projects). Qualitative data would also have allowed for more accurate analysis of the funded projects using Peck et al (2022)'s framework for equity considerations. While I did have initial discussions with North Carolina Office of Recovery staff members about what to include as flood resilience projects, I ultimately utilized a relatively liberal definition, including nearly all projects that can be considered as contributing to or allowing for flood resilience, with the caveat that a county or municipality was associated with the project[26]. For example, there were some dam repair projects that were allocated to organizations but listed specific communities in their descriptions. Therefore, I excluded these projects because of my criteria that a community needed to be identified as the

[24] 2020 budgetary documents only included one project for flood resilience, therefore it is hardly mentioned in this discussion.

[25] See Figure 3 for the departments coordinating and administering funding.

[26] See Appendix X for my exclusion and inclusion justifications.

recipient of the funding. As a result, project exclusion criteria may be skewing my findings. Another potential limitation of my research is the inability to filter the impact of the infusion of significant ARPA funds into the 2021 budget, since their use was not identified in the 2021 or 2022 budget documents. This may be causing anomalies in my data, since the 2021 flood resilience funding amount was so large compared to the other years. Finally, many of my data sources were aggregated to the county level, including the funding and flood extent data. This may be blurring the layers of inequity occurring at the city or census tract level without further analysis. Additionally, I did not utilize the National Risk Index's Hurricane Hazard, which may also be skewing the risk values and scores.

### *Next Steps*

I would like to note several next steps for this research, if it were to be pursued for a future project. The information compiled about funded projects could be enhanced by exploring, quantitatively and qualitatively, the current state of what is happening with these funded projects. Some of this information can be found through the Office of State Budget Management. In my initial look at the funded projects for the 2021 budget, I identified that a lot of funding has been caught up in administrative processes. It would be interesting to build a layer of data based on how much funding has actually been expended, while also gauging how the slowness of administrative processes may be compromising the resilience of communities allocated but yet to receive funding for flood resilience projects.

This report could also be enhanced by delving deeper into the vulnerability data, especially for the counties identified as under-resourced. While Orange, Durham, and Mecklenburg counties were identified as under-resourced, this is likely due to only exploring two measures of vulnerability and capacity. The under-resourced counties warrant a further exploration of the vulnerability and capacity barriers unique to each county through a case study type of report.

Plastrik et al (2020) emphasizes the need to build a state resilience financial system, inclusive of state budget allocations but not limited to them. Therefore, the report from Plastrik et al (2020) could be utilized to identify the robustness of state resilience financial system by adding funding for non-governmental entities, well as pulling in state investment funding outside of budget documents. Additionally, while this project was limited to individual communities receiving funding, it would be interesting to look at projects aiming to impact at the watershed level, considering the recommendations in the literature focus on watershed-level flood resilience projects to have more of an expansive impact (Plastrik et al, 2020). Finally, it would be interesting to explore the differences in investments for coastal and riverine flooding, as well as adding in the hurricane hazard from the National Risk Index.

## Conclusion

This report included an analysis of the flood resilience projects funded through North Carolina's 2018-2022 state budgets. The analysis focused on identifying patterns and gaps between the communities funded and those at risk of experiencing coastal and riverine flooding. Another layer of analysis was understanding how communities with the most vulnerability and least capacity for flood resilience compared to the top funded communities. My findings indicated a mismatch in the counties receiving the most flood resilience funding and those with the great need for financial support, according to their flood risk, vulnerability, and rural capacity. This exploration of state investments in flood resilience identified several communities were more resources and support are needed to enhance flood resilience and ensure that North Carolina communities are prepared and proactive in the wake of increasingly severe and expansive flooding. This report has also identified several directions to continue this research and build a more comprehensive picture of North Carolina's investment in flood resilience.

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# Appendices

## Appendix 1. Agency Acronyms

North Carolina State Acronyms (OSBM):
Commerce= Department of Commerce
DACS= Department of Agriculture and Consumer Services
DEQ= Department of Environmental Quality
DHHS= Department of Health and Human Services
DMVA= Department of Military and Veterans Affairs
DNCR= Department of Natural and Cultural Resources
DOA= Department of Administration
DOL=Department of Labor
DOT= Department of Transportation
DPI= Department of Public Instruction
DPS= Department of Public Safety
NCAOC= NC Administrative Office of the Courts
NCPRO= NC Pandemic Recovery Office
OSBM= Office of State Budget and Management
OSBM-DR= Office of State Budget and Management Disaster Recovery Office

Federal Acronyms:
FEMA: Federal Emergency Management Agency
NCEI: National Centers for Environmental Information
HVRI: Hazards Vulnerability & Resilience Institute

## Appendix 2. Search Terms used in Step 1 of Methodology

| | | |
|---|---|---|
| "flood" | "Dykes" | "greening" |
| "resilience" | "floodwalls" | "rain gardens" |
| "Coastal" | "quay walls" | "permeable paving" |
| "fluvial" | "Reservoirs" | "green roofs" |
| "flood-prone" | "dam repair" | "Shoreline" |
| "flood-proof" | "Nature-based infrastructure" | "Building codes" |
| "town" | "flooding reduction" | "evacuation plans" |
| "city" | "rainfall detention | "waterproofing" |
| "county" | "rainfall retention" | "removable stop logs" |
| "Avoidance" | "green buffers" | "water-retaining walls" |
| "prevention" | "mangroves" | "mobile barriers" |
| "Defense" | "dunes" | "footings" |
| "Mitigation" | "marshes" | "Road networks optimization" |
| "Preparation" | "wetlands" | "Safe havens creation" |
| "Recovery" | "lakes" | "recovery" |
| "Floodplain" | "blue-green corridors" | "critical infrastructure" |
| "land acquisition" | "waterways" | "Building reconstruction" |
| "relocation" | "culvert" | "reinforcement" |
| "Watershed management" | "drainage" | |
| "engineering" | | |

Adapted from Meng et al (2020)

## Appendix 3. Project Research and Tier Justification

| Project Name | Justification |
|---|---|
| "§ 143-215.73B. Water resources development grants administration. | In the 2021 budget, the Water Resources Development Projects fund became the Water Resources Development Grants Special Fund. |
| Princeville funding report | The 2016 authorized plan includes extending a portion of the existing levee to the east to improve the level of flood risk reduction provided to the main historic area of Princeville; raising local roadways, installing culvert flap gates, and construction of a shoulder levee along U.S. Highway 64 interchange.<br>While this is both Tier 6 and Tier 3, assume most money is going to Tier 6 levees |
| Categorized Brunswick Town/Ft. Anderson Cape Fear Stream Restoration (Phase 2) as shoreline protection | According to a case study on this project, construction for Phase 2 (240') was completed in early August 2018, prior to Hurricane Florence battering the project area. The structure was not damaged after several storm-related high tide storm surges. The shoreline in these areas has stabilized, and a new shoreline is being formed as the Atlantic Reefmaker disrupts wave energy and allows for flushing which enables accretion. |
| Mateo | According to the plan, the goal is oyster reef restoration, therefore Tier 5 |
| Lillington for "flood resiliency projects" | According to the Harnett County Resilient Redevelopment Plan, deeming it Tier 3 |
| Flooding abatement project on Chockoyotte Creek – | According to the Harnett County Resilient Redevelopment Plan, deeming it Tier 3 because culverts |
| Scotland neck project in Halifax County | According to the ReBuild Halifax County Plan, the culverts at Highway 301, Bridges Road, Ringwood Road, and Route 481 are all roads leading to the Town of Enfield and Route 258 to Scotland Neck tends to flood in major thunderstorms and heavy rain events. The culverts are not large enough to handle floods and there are issues with obstructions of trash and sediment clogging the culverts. The project is to construct bigger culverts at those locations and fund a regular ditch maintenance program. |
| Littleton | According to the ReBuild Halifax County Plan, top priorities are drainage, so deemed Tier 3 |
| Flood resilience project on the French Broad River at Pleasant Grove | Determined it is floodplain restoration, therefore Tier 1 for restoring an existing degraded floodplain |
| Mattamuskeet Restoration Drainage project | Water quality restoration will be achieved by using alternative water management strategies designed to achieve volume reduction and by other management strategies, such as land acquisition and enrollment in conservation easement programs that have beneficial effects on reducing overall direct discharge volumes.<br>Deemed this Tier 1 |
| Martin County | According to the ReBuild Martin County Plan, the top priorities are drainage, debris, housing rehab – deemed Tier 4 |
| Bogue Sound Shoreline | The project to restore more than a half-acre of salt marsh on waterfront property purchased earlier this year by the federation and county is expected to reduce erosion, improve water quality and create more fish habitat, according to the federation. |