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UNDERSTANDING FLOOD SCENARIOS: A ROADMAP TO RESILIENCE GOOSE CREEK, SC

PROJECT REPORT 2025-003

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This report was prepared by the Project IN-CORE Team as part of the Geos Institute's Climate Ready America Southeast Navigator Network with funding from the Walmart Foundation to analyze future flood hazard scenarios and implement risk reduction and resilience planning strategies.

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Credits and Acknowledgements

Project IN-CORE Team

Project IN-CORE is a fiscally sponsored project of Community Initiatives, a non-profit dedicated to helping communities thrive. Project IN-CORE's objective is to apply IN-CORE capabilities to provide technical assistance and scenario-based modeling to develop resilience strategies for future flood hazards.

Project IN-CORE Goose Creek Report Authorship

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Geos Institute's Navigator

The Geos Institute's Navigator program supports communities in building climate resilience by providing access to funding, capacity-building resources, and technical assistance. Through its Southeast Navigator Network, the program fosters collaboration across Florida, South Carolina, North Carolina, and Georgia, focusing on Community Disaster Resilience Zones.

A special thank you to *Navigator* Adelaide Bates, from the Shi Institute for Sustainable Communities at Furman University.

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The mapped flood depths used in these analyses have been developed from climate projections generated by Argonne National Laboratories in collaboration with the AT&T Foundation and provided to Project IN-CORE by the AT&T Foundation for the development of use cases of the climate data available on the Climate Risk and Resilience Portal (ClimRR). A version of this data will be available on the ClimRR portal.

Funding Acknowledgements

This report was prepared by the Project IN-CORE Team as part of the Geos Institute's Climate Ready America Southeast Navigator Network with funding from the Walmart Foundation to analyze future flood hazard scenarios and implement risk reduction and resilience planning strategies. The findings, conclusions, and recommendations presented in this report are those of the authors alone and do not necessarily reflect the opinions of the Walmart Foundation.

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1. Purpose and Objective

This study presents a comprehensive flood resilience analysis for Goose Creek, South Carolina, to inform policy decisions and guide resilience planning strategies. The analysis evaluates future flood hazard scenarios, identifying areas within the community vulnerable to current and mid-century flooding. Considering the increasing frequency and intensity of precipitation, the study highlights evolving risks to help policymakers and stakeholders plan effectively for climate impacts. The overarching goal of this report is to support the City's capacity to navigate urban growth and flood risk uncertainties, fostering a resilient and adaptive community.

This study also analyzes flood vulnerabilities within Goose Creek's Community Disaster Resilience Zone (CDRZ) since it represents opportunities for integrating resilience planning into broader community development efforts. Addressing flood risks within CDRZ ensures that areas remain viable for growth and investment while aligning with state and federal priorities for resilience funding.

The analysis was conducted using the IN-CORE platform (www.in-core.org), incorporating its Flood Damage Analysis and Population Dislocation Models. To account for mid-century climate conditions, flood data from the Climate Risk and Resilience Portal (ClimRR) was integrated, providing a comprehensive assessment of climate projections and future risks.

2. Background

Goose Creek, South Carolina, is a rapidly growing city in Berkeley County, just north of Charleston. With approximately 50,000 residents (Census, 2023), it is part of the Charleston metropolitan area. It benefits from its proximity to major employment centers, including the Naval Weapons Station Charleston and regional industrial hubs. Originally a rural community, Goose Creek experienced significant suburban expansion after the 1950s, a trend that has continued to the present day. Driven by economic growth and an influx of new residents, it is one of the fastest-growing areas in the Charleston metro region. The city is characterized by a mix of residential neighborhoods, commercial developments, and natural landscapes, including wetlands and waterways that contribute to both its scenic beauty and vulnerability to flooding. Over the past 15 years, the region has been impacted by several presidentially declared disasters, primarily due to severe weather events, as stated below:

- **October 2015:** Historic flooding affected large portions of South Carolina.
- **October 2016:** Hurricane Matthew caused widespread damage along the southeastern U.S. coast, including South Carolina.
- **September 2019:** Hurricane Dorian impacted the southeastern U.S., including South Carolina.
- **August 2024:** Tropical Storm Debby caused extensive flooding and damage in South Carolina, resulting in a major disaster declaration.

- **September 2024:** Hurricane Helene, one of the most destructive storms in U.S. history, devastated parts of the southeastern U.S., including South Carolina, leading to a major disaster declaration.

These repeated events underscore Goose Creek's vulnerability to natural hazards, particularly flooding, due to its location near tidal rivers and low-lying areas. The city has one Community Disaster Resilience Zone (CDRZ) within the city boundaries, as shown in (Figure 1). These zones were established under the Community Disaster Resilience Zones Act of 2022, which amended the Stafford Act to enhance the Federal Emergency Management Agency's (FEMA) ability to identify and support areas most at risk from natural disasters. Signed into law on December 20, 2022, the act empowers FEMA to designate CDRZs based on comprehensive assessments of disaster risk and community vulnerability. By designating these zones, the legislation ensures that resources, funding, and technical assistance are strategically directed to areas where they are most needed, enabling communities to better prepare for, respond to, and recover from disasters. The areas in Figure 1 labeled as 1, correspond to the census tract 45015020718. This area includes part of Goose Creek and a portion of the surrounding unincorporated land the city intends to annex according to its comprehensive plan.

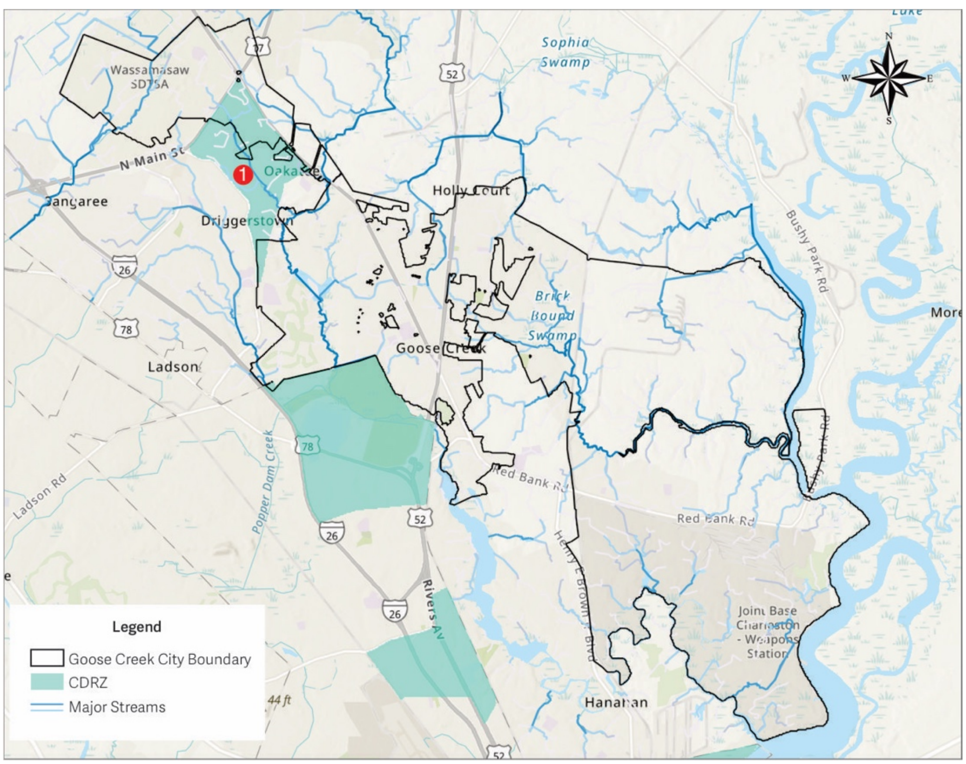

Figure 1. Goose Creek, South Carolina
Source: Source: FEMA, Esri | Charleston County GIS

3. Future Flood Hazard Scenarios and Impacts

This section was developed using the Interdependent Networked Community Resilience Modeling Environment (IN-CORE) and ClimRR flood hazard data. IN-CORE is a powerful computational tool designed to help communities model natural hazards, assess risks, and develop strategies to enhance resilience and recovery. ClimRR (Climate Risk and Resilience Portal) is an online platform that provides detailed climate data and future flood projections to help communities prepare for climate-related risks. It was developed by Argonne National Laboratories and shared by Project IN-CORE's collaboration with the AT&T Foundation.

To run IN-CORE, we used building data inventory from the National Structures Inventory (NSI). The details of the methodology are provided in Appendix A. The flood scenarios in this report are based on mid-century climate projections (2045–2054) from ClimRR. These scenarios include a 100-year coastal flood, which accounts for rising sea levels and storm surges from hurricanes and tropical storms, and a 50-year inland flooding event caused by heavy rainfall (pluvial flood). This approach helps capture the increasing intensity of future storms and rainfall patterns.

The information in the current report is useful for understanding potential future flooding conditions. However, they do not include river flooding or municipal stormwater systems information. For river flooding, FEMA flood maps are still a reliable source. For urban flooding, a more detailed analysis of stormwater systems may be needed. The results presented should be interpreted considering these limitations.

3.1. Flood Hazard Zones

Flood hazard zones are designated areas that reflect varying levels of flood risk, helping communities plan for and mitigate potential flood impacts. These zones are established by FEMA through Flood Insurance Rate Maps (FIRM), which assess flood probability based on historical data, topography, and hydrological modeling. In Goose Creek, a combined total of approximately 31%[1] of the city's total land area falls within the FEMA-established Hazard Zones, as shown in Figure 2, and detailed below:

- **500-year floodplain:** This area has a 0.2% annual chance of flooding in any given year, representing 6% of the city's total land area. While considered a moderate flood risk, flooding can still occur, particularly during extreme weather events. Properties in this zone are not required to have flood insurance under the National Flood Insurance Program (NFIP), but they remain vulnerable to significant flooding.
- **100-year floodplain:** Also known as the base floodplain, this area has a 1% annual chance of flooding in any given year, presenting a high risk for properties. It

[1] Goose Creek Resilience Chapter (2022)

represents 23% of the city's total land area. Mandatory flood insurance is required for properties with federally backed mortgages. New construction and substantial improvements within this zone must comply with FEMA regulations, including elevating structures above the Base Flood Elevation (BFE) to reduce flood damage risk.

- **Regulatory Floodway:** The floodway consists of the main river channel or watercourse and adjacent land that must remain unobstructed to allow floodwaters to flow without significantly increasing water levels. It represents 2% of the city's total land area. This area is extremely high-risk, and construction is heavily restricted or prohibited. Regulatory floodways help protect natural floodplains and ensure that floodwaters can move efficiently through rivers and streams, minimizing upstream and downstream impacts.

3.2. Flood Damage Analysis

The building damage analysis estimates damage levels by considering building categories and simulated flood scenarios across the region, as detailed in the methodology in Appendix A. In this analysis, the term Damage State (DS) is used to represent different levels of damage, which are explained below:

- **DS 0 (No Damage or Slight Damage)**: The building experiences no visible damage from flooding. All structural and non-structural elements remain intact, with no repair required. It can have minor impacts from flooding, such as superficial water staining, damp walls, or minimal seepage into basements or ground floors. Repairs are light and typically involve cleaning or cosmetic fixes.
- **DS 1 (Moderate Damage):** Floodwaters cause more significant damage, such as partial inundation of ground floors, damage to finishes like flooring and drywall, and minor effects on electrical or plumbing systems. Repairs are required, but the structural integrity remains intact.
- **DS 2 (Severe Damage):** Substantial flooding leads to significant structural impacts, such as prolonged submersion of key components, damage to load-bearing walls, or failure of essential systems (e.g., electrical, HVAC). The building may be uninhabitable until extensive repairs are completed.
- **DS 3 (Complete Damage):** The building is fully inundated or structurally compromised, resulting in total loss. Repairs are not feasible, and the structure may need to be demolished and rebuilt.

Table 1 summarizes the results of the building damage analysis, highlighting that while low-level damage (Damage State 1) is expected for approximately 4.61% of buildings, only two buildings are likely to experience moderate to severe damage (Damage States 2). The results highlight only buildings with a probability greater than 50% of being damaged within each category. Figure 2 shows the areas in which buildings vulnerable to DS1 are concentrated. The flood depths used in our modeling represent realistic events that the local community is likely to encounter and should be prepared to repeatedly withstand in the coming years rather than a worst-case scenario. Appendix A provides more details on the methodology.

Table 1: Summary of the building damage analysis – Goose Creek

Damage State	Building Count	% of Buildings
Damage State 0 (No Damage or Slight Damage)	47911	95.38%
Damage State 1(Moderate Damage)	2317	4.61%
Damage State 2 (Severe Damage)	2	0%
Damage State 3(Complete Damage)	-	-

Source: IN-CORE

While DS 1 represents moderate damage, global climate models indicate that the flooding events described in this report will likely become more frequent as the century progresses. With repeated flood events, structures currently in DS 1 become a concern, as ongoing exposure could gradually compromise the functionality and structural integrity of a larger portion of the building stock over time (Figure 2).

A particularly concerning finding is that many of these at-risk areas fall outside FEMA-designated flood hazard zones, leaving them unaccounted for in current flood risk assessments and regulations. The most affected flooding areas within Goose Creek city limits are projected to occur in the Wood Hill neighborhood along Highway 52. Cane Bay is expected to experience the largest flood impact beyond the city's boundaries. Minor flooding is anticipated in smaller pockets within the Okatie, Sedgefield, and Harbour Lake neighborhoods, as well as isolated damage along the northern boundary of Wannamaker County Park.

In these areas, proactive flood management strategies are recommended. These include avoiding utility installations in flood-prone crawlspaces, installing sump pumps in areas where low-level flooding is projected to be more common, and landscaping to divert heavy precipitation away from building foundations. Additionally, nature-based solutions, such as enhancing infiltration and preventing erosion along rivers, streams, and coastlines, can play a critical role.

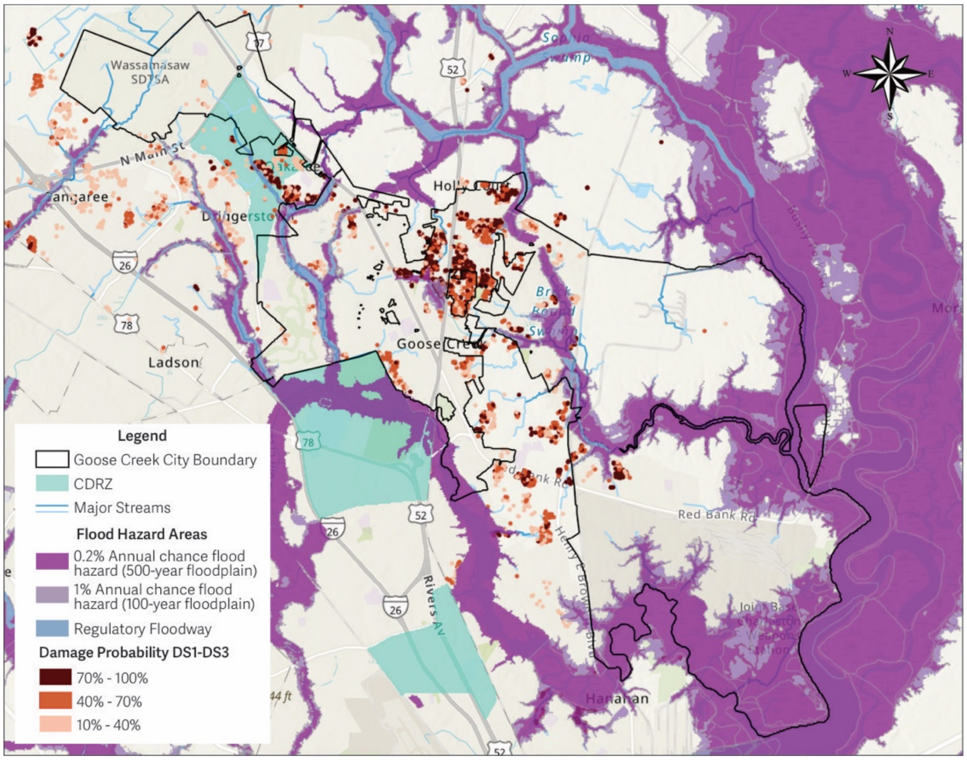

Figure 2. Areas with the probability of experiencing Damage State 1 (moderate flood damage)

3.3. Population Dislocation

Population dislocation refers to the displacement or temporary relocation of individuals due to disasters (Oliver-Smith, 2018). While people are the cornerstone of community resilience planning, existing models prioritize buildings and infrastructure over human-centered considerations. This repository addresses this gap by integrating people into community resilience models and linking population dynamics with building data.

The dislocation model relies on data about both people and structures. A specialized Python package, **Pyncoda**, developed under the Center of Excellence for Risk-Based Community Resilience Planning, is utilized to allocate population data to housing units. This tool synthetically assigns households to housing units, enabling a more comprehensive understanding of community resilience. A detailed explanation of the methodology is provided in Appendix B. The demographic characteristics of the synthetic population match the characteristics at the Census block group level. This work is described as follows by Pyncoda's README file on GitHub authored by Nathanael Rosenheim (2021).

Once a housing unit allocation has been generated, then the damage result for each building can be combined with the social data for each household, such as tenure status, race, and household income, to determine whether a household is likely to temporarily relocate due to a hazard event, in this case, flood. The results of a population dislocation analysis can be analyzed further to understand the equity impacts of such hazards. Figure 3 shows dislocated households in Goose Creek after a simulated hazard event. Details of this procedure can be found in the population dislocation methodology section (Appendix B). Minimizing damaged areas will also minimize population dislocation.

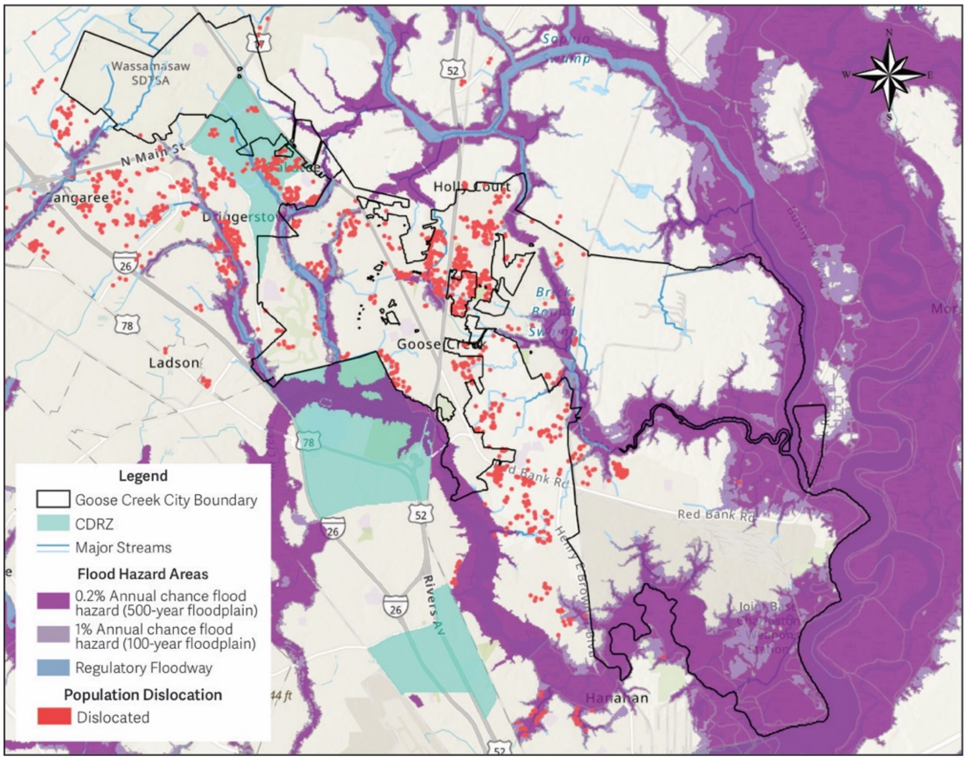

Figure 3. Population Dislocation

4. Current Planning Initiatives for Flood Resilience

Goose Creek is actively advancing flood resilience through planning initiatives. In alignment with the Disaster Relief and Resilience Act of 2020, the city has incorporated a resilience chapter into its comprehensive plan to identify flood hazards and implement mitigation strategies. Additionally, Goose Creek collaborates with the South Carolina Office of Resilience, integrating measures from the Strategic Statewide Resilience and Risk Reduction Plan, which outlines key flood risks and provides adaptive strategies for local governments. The city also participates in the Berkeley County Hazard Mitigation Plan, strengthening efforts to reduce flood vulnerabilities and enhance community preparedness and mitigation. This section examines key plans and ordinances related to flood resilience, assessing the city's efforts, identifying potential gaps, and highlighting any discrepancies hindering progress toward flood resilience, taking into consideration flood scenarios based on mid-century climate projections.

2023 South Carolina Strategic Statewide Resilience and Risk Reduction Plan

The Strategic Statewide Resilience and Risk Reduction Plan aims to enhance South Carolina's resilience to disasters by mitigating flood risks and improving long-term disaster preparedness. Developed by the South Carolina Office of Resilience (SCOR), the plan is a guiding framework for state investment in flood mitigation projects, regulatory updates, and policy initiatives. It identifies key environmental threats, such as extreme weather events, rising sea levels, and changing precipitation patterns contributing to increased flood vulnerability. Findings indicate that rapid population growth, particularly in coastal areas, has heightened flood exposure and that FEMA flood maps do not fully capture flood risk. The plan also highlights the necessity of updating infrastructure design standards, improving data collection for flood forecasting, and incorporating climate projections into planning decisions.

To enhance flood resilience, the plan recommends a range of strategies, including adopting stricter building codes, increasing weather station density for better climate modeling, and developing a comprehensive flood hazard conservation map. It emphasizes the need for watershed-based resilience planning, promoting nature-based flood mitigation solutions, and implementing a voluntary pre-disaster buyout program for high-risk properties. Additionally, SCOR suggests establishing a Resilience Grant/Loan Program to fund mitigation projects and increase public education on flood risks through hazard disclosure programs and signage initiatives. The plan calls for integrating resilience into housing recovery efforts, ensuring new developments in flood-prone areas adhere to stricter elevation standards, and strengthening infrastructure maintenance policies.

Goose Creek Comprehensive Plan

The Goose Creek Comprehensive Plan, adopted in 2021 and amended in 2024, serves as a long-term strategic framework for guiding the city's growth and development while addressing critical issues such as flood resilience, land use, infrastructure, and environmental sustainability. The plan's primary goal is to balance urban expansion with preserving natural resources, ensuring the city's resilience against flooding and other climate-related hazards. Key findings indicate that Goose Creek faces increased flood risks due to rapid urbanization, aging infrastructure, and reliance on outdated floodplain mapping. The city's low-lying areas and proximity to water bodies exacerbate vulnerability to stormwater surges and extreme weather events. Additionally, public input reveals concerns regarding flood management policies, drainage system inefficiencies, and the need for updated zoning regulations to mitigate risks.

To enhance flood resilience, the comprehensive plan recommends adopting stricter stormwater management regulations and incorporating green infrastructure solutions such as bioswales, permeable pavements, and rain gardens, to reduce runoff. The city is encouraged to update floodplain maps, restrict development in high-risk areas, and integrate climate projections into zoning codes. Another key recommendation is the implementation of nature-based solutions, including wetland conservation and stream buffer zones, to improve flood absorption capacity.

The plan also proposes infrastructure investments, such as upgrading drainage systems and expanding flood retention basins, to enhance the city's capacity to withstand extreme weather events. Furthermore, it advocates for community engagement programs to educate residents on flood risks and preparedness strategies, ensuring a comprehensive and proactive approach to resilience planning.

Our study confirms the comprehensive plan claim about increasing flood risk and the need to update the flood mapping since it identifies numerous areas vulnerable to moderate flood damage that lie outside the FEMA-designated flood hazard zone, as illustrated in Figure 2 (pg. 8). These areas are likely to experience partial inundation of ground floors, damage to interior finishes such as flooring and drywall, and minor impacts on electrical and plumbing systems. By comparing zoning designations with areas predicted to experience moderate flood damage (Figure 4), we identify areas affected in the following zones:

- **Residential Single-Family District (RSF):** This area provides accommodation primarily to single-family detached dwellings at moderate densities. They have an impervious surface ratio maximum of 45%.
- **Residential Mixed District (RM):** This area accommodates a walkable, moderate-density mix of residential development that allows single-family, two-family, townhouse, scaled multi-family dwellings, parks/ recreation, and limited convenience uses.
- **General Commercial District (GC):** This area accommodates a wide range of non-residential uses, primarily retail, office, and service establishments. Development is primarily auto-oriented, serving isolated commercial areas outside the activity centers.
- **Planned Development District (PD):** This area encourages integrated and well-planned mixed-use development in locations throughout the City. A range of residential and nonresidential uses are allowed, with the intent of providing various housing options and mutually supportive nonresidential uses that serve the residents and the surrounding neighborhood. Substantial flexibility is provided, with an expectation that development quality will surpass what is otherwise achievable through the base zoning district.

Several areas around Okatie are susceptible to moderate flood damage, particularly within the designated CDRZ zone (Figure 4). This zone aligns with the area the city plans to incorporate, as outlined in the comprehensive plan (Figure 5). Given this overlap, it is crucial that, once incorporated and zoned, the city proactively addresses flood vulnerability by implementing targeted mitigation measures.

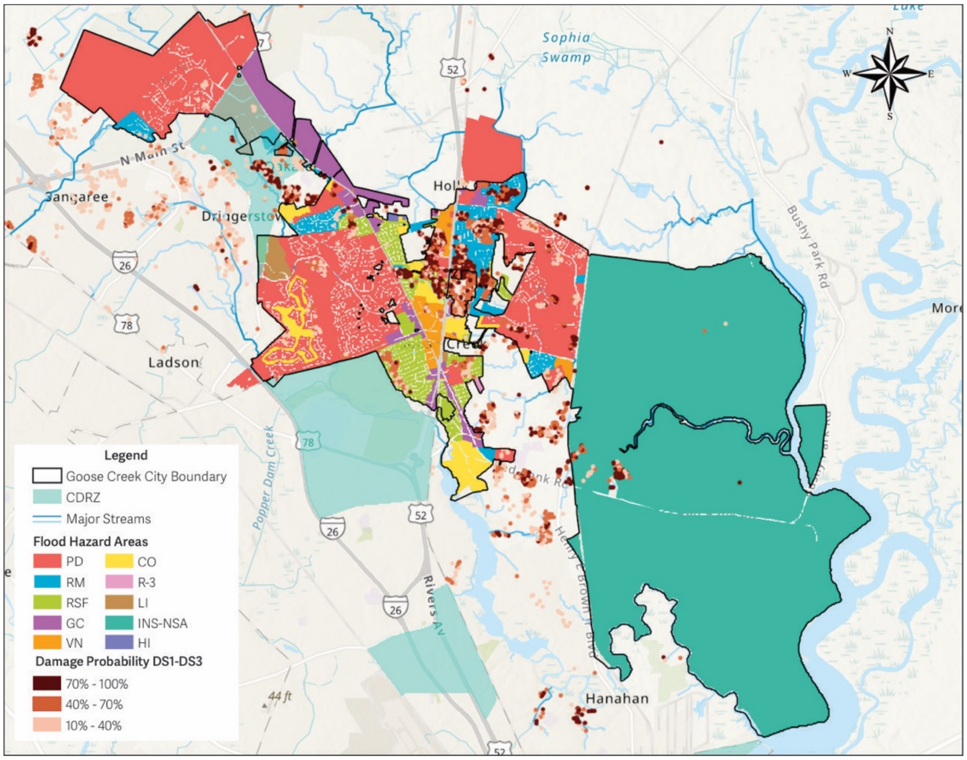

Figure 4. Goose Creek zoning vs. areas with probability of experiencing moderate flood damage (DS1)

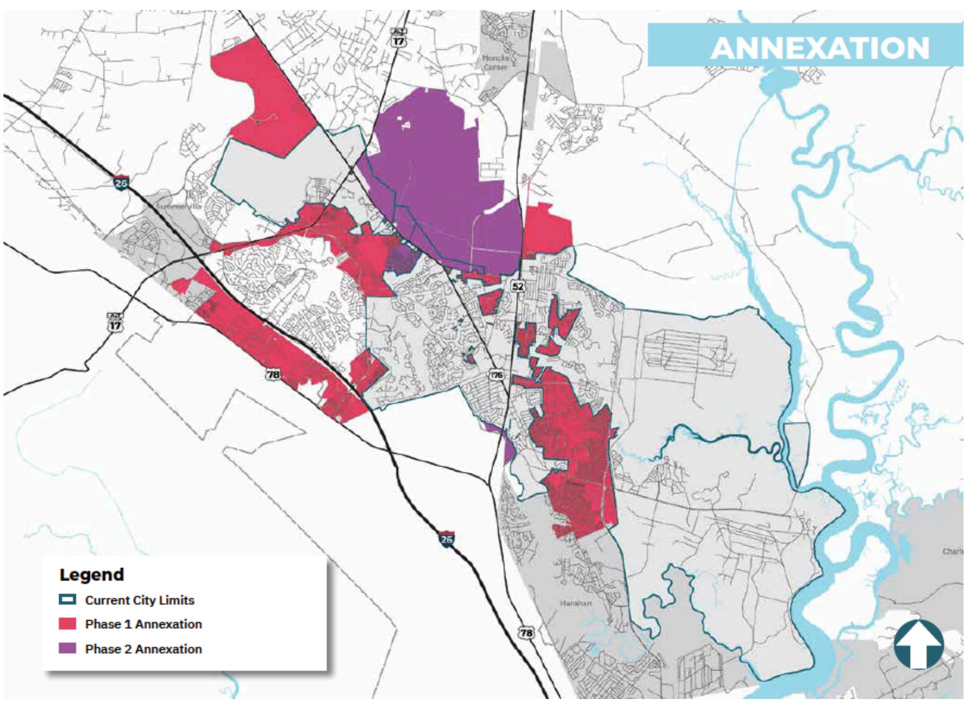

Figure 5. Goose Creek Annexation Plan
Source: Goose Creek Comprehensive Plan

Goose Creek Resilience Chapter

The South Carolina Resilience Revolving Fund Act (RRFA), also known as the Disaster Relief and Resilience Act, was passed by the South Carolina legislature on September 29, 2020, to support communities in addressing flood risks and disaster resilience. In response to this legislation, the Resiliency Chapter has been developed as an addendum to the City of Goose Creek's Comprehensive Plan, and it was formally adopted by ordinance in 2022. While this chapter provides preliminary planning-level recommendations, it is not intended to serve as a local hazard mitigation plan. Instead, it lays a strategic foundation for further data refinement, studies, and policy development, ensuring that future resilience efforts are both comprehensive and data-driven.

Building upon this foundation, the Goose Creek Resiliency Plan takes a targeted approach to flood risk assessment and mitigation. It identifies the city's key vulnerabilities to natural hazards and outlines strategies to reduce risks. The plan highlights extreme weather events, sea-level rise, and urban development patterns that intensify stormwater runoff as primary drivers of flood risks. Currently, approximately 25% of Goose Creek's land area falls within FEMA-designated Special Flood Hazard Areas (SFHAs), with over 1,300 built structures located within or near flood-prone zones. Furthermore, the city's wetlands and floodplains, which play a crucial role in absorbing excess stormwater and reducing flood impacts, are increasingly threatened by urban expansion. Flood mapping projections indicate that climate change will increase both the frequency and severity of flood events, reinforcing the need for proactive and adaptive resilience measures.

The resilience chapter identifies approximately 444 properties as being at major to extreme flood risk and 165 properties at moderate risk. However, our analysis presents 2,317 properties at moderate risk and only two at severe or higher risk. These discrepancies happen due to differences in flood risk assessment methodologies and data sources.

First, our report, although it provides valuable insights into potential future flooding conditions, does not account for river flooding, which can significantly impact flood exposure. Additionally, differences in flood prediction models contribute to the variation in results. Our report utilizes ClimRR, which is based on downscaled CMIP6 climate models and focuses on future precipitation trends, extreme weather patterns, and climate-driven flood risks at a regional and community scale. In contrast, the resilience report integrates historical flood occurrences, NOAA (National Oceanic and Atmospheric Administration) and NWS (National Weather Service) projections, and Flood Factor data, which rely on past events, hydrological models, and FEMA-designated floodplain maps to estimate current and future flood risks at the property and city level. Given these differences, the city should not rely on a single data source but rather incorporate insights from both reports to develop comprehensive and resilient flood mitigation policies.

To strengthen flood resilience, the resilience chapter report recommends adopting stricter floodplain management policies, including enhanced building codes that require higher elevation standards, floodproofing measures for critical infrastructure, and stronger stormwater management regulations to reduce runoff. The report also emphasizes nature-based solutions, such as wetland conservation, riparian buffers, and green infrastructure, to absorb floodwaters and enhance water quality. A key recommendation is the expansion of voluntary property buyout programs in high-risk areas, supported by state and federal funding sources. The plan further advises updating local land-use policies to prevent new developments in high-risk zones, improving public awareness through flood risk education campaigns, and integrating climate data into long-term city planning efforts.

Berkeley County Hazard Mitigation Plan, 2020

The goal of the Hazard Mitigation Plan is to enhance the community's ability to withstand, adapt to, and recover from hazards, including flood and sea level rise. The report identifies key contributing factors, including increased urban development, stormwater runoff issues, and the projected impacts of climate change, which are expected to intensify future flooding risks. The following key recommendations have been outlined to enhance flood resilience in Goose Creek:

Table 2: Action Plan for the City of Goose Creek, SC

Activity	Goal	Lead Agency	Funding Source
Continue working with Berkeley County to implement stormwater management plan	Project addresses preventative activity goals of providing public information about hazards and potential hazards and mitigation activities.	Public Works Department	General Fund Stormwater Management Fee
Provide hazard specific checklists to residents and business owners	Public information advisories and awareness about hazards can minimize future damages.	Public Information Office Planning Department	General Fund
Develop and Maintain Stormwater and Floodplain Mapping using GPS and GIS Technology	Preventative activities are intended to reduce vulnerability to hazards	Public Works Department Planning Department	General Fund Stormwater Management Fees
Construct disaster resistant records storage facility	Preventative activities are intended to reduce vulnerability to hazards	Administration Department	General Fund Bond Funding
Retrofit all municipal facilities to withstand impacts of a disaster	Property protection activities protect existing structures to withstand a hazard event.	All Departments	General Fund Enterprise Fund Bond Funding
Construct interconnected stormwater and flood control detention/retention pond system	Structural mitigation activities reduce the impacts of a hazard event by modifying the physical environment to withstand the particular hazard	City Council Administration Department Planning	Grant Funding Stormwater Management Fees Bond Funding

Source: Berkeley County Hazard Mitigation Plan, 2020

Flood Hazard Control Ordinance

The Goose Creek Flood Hazard Control Ordinance is identified as § 155 – Flood Hazard Controls. This ordinance was enacted on March 14, 2017, with subsequent amendments, including Ord. 18-028, passed on November 27, 2018. It establishes development regulations, floodproofing standards, and elevation requirements to mitigate flood risks and protect structures from flood damage. The ordinance aligns with FEMA's NFIP and applies to all areas of special flood hazard within Goose Creek, as identified in FEMA's Flood Insurance Study.

Our study identified several areas at risk of moderate flood (DS1) despite being outside wetlands, floodplains, and FEMA-designated flood zones. While these areas may not currently fall within traditional high-risk flood classifications and are only exposed to moderate floods, the increase in frequency and intensity of extreme weather events poses a growing concern. These events can impact buildings repeatedly and gradually compromise their functionality and structural integrity over time.

To mitigate these risks, we recommend that the city establish an overlay district in areas identified by our study as at risk of DS1 (moderate flood damage). This district would facilitate a thorough review and analysis of the need for targeted flood resilience strategies, proactively addressing vulnerabilities before they escalate. This district would incorporate enhanced building standards, improved stormwater management systems, and resilient infrastructure requirements, helping to reduce long-term flood damage, protect property values, and enhance overall community resilience.

5. Recommended Actions

The IN-CORE analysis provides valuable insights into identifying areas at risk and assessing the severity of impacts, enabling more effective protection strategies. Preventing development in high-risk areas is often more cost-effective than implementing mitigation measures. Therefore, integrating risk assessments into planning processes is crucial. Since most of the findings in this report pertain to moderate flood damage, we recommend implementing proactive mitigation measures through an overlay zoning district that complements existing zoning regulations. This approach would ensure that at-risk areas receive targeted flood resilience strategies without disrupting current land use patterns. Below are the specific recommendations for each zoning district:

- **Residential Single-Family District (RSF):** This area provides accommodation primarily to single-family detached dwellings at moderate densities. They have an impervious surface ratio maximum of 45%. To make these areas more resilient, we recommend the following:
    - Encourage permeable pavers, bioswales, and rain gardens to enhance infiltration and reduce runoff, improving stormwater management and flood resilience.

- Implement detention basins and swales to slow runoff and reduce localized flooding, enhancing stormwater management and mitigating flood risks in vulnerable areas.
- Encourage residents to obtain NFIP flood insurance even if not required.

- **Residential Mixed District (RM):** This area accommodates a walkable, moderate-density mix of residential development that allows single-family, two-family, townhouse, scaled multi-family dwellings, parks/ recreation, and limited convenience uses. To make these areas more resilient, we recommend the following:
  - Use flood-resistant materials: Ground-floor construction should use materials like concrete, pressure-treated wood, ceramic tile, and closed-cell insulation that can withstand temporary flooding. Drywall, carpet, and wood paneling below flood levels should be avoided to reduce damage.
  - Floodproofing for mixed-use or multi-family structures: For scaled multi-family buildings, consider dry floodproofing (sealing exterior walls, flood barriers, and backflow preventers). Townhouses and two-family dwellings should incorporate breakaway walls for garages and non-livable ground-floor spaces.
  - Flood-resistant utilities and infrastructure: Elevate electrical panels, water heaters, and HVAC systems above the expected flood level. Use sealed, elevated electrical outlets and switches to prevent water damage.
  - Encourage residents and businesses to obtain NFIP flood insurance even if not required.
- **General Commercial District (GC):** This area accommodates a wide range of non-residential uses, primarily retail, office, and service establishments. Development is primarily auto-oriented, serving isolated commercial areas outside the activity centers. To make these areas more resilient, we recommend the following:
  - Elevate commercial structures and critical equipment: Place electrical panels, mechanical rooms, and HVAC systems on upper floors or platforms.
  - Floodproofing for commercial buildings: Dry floodproofing (use sealed exterior walls, watertight doors, and backflow preventers to keep floodwaters out of buildings) or wet floodproofing (if dry floodproofing is not feasible, design ground floors to allow controlled flooding using flood vents and water-resistant materials).
  - Use flood-resistant materials: Install concrete, tile, metal, and other water-resistant flooring and wall materials on the ground floor. Avoid using drywall, wood paneling, or carpet in flood-prone areas.

   - Design for temporary closure and rapid recovery: Provide flood barriers or removable flood panels at entry points for retail and service businesses. Develop emergency flood plans for businesses, including storing critical documents and inventory above flood levels.
   - Encourage businesses to obtain NFIP flood insurance even if not required.
- **Planned Development District (PD):** This area encourages integrated and well-planned mixed-use development in locations throughout the City. A range of residential and nonresidential uses are allowed, with the intent of providing a variety of housing options and mutually supportive nonresidential uses that serve the residents and the surrounding neighborhood. Substantial flexibility is provided, with an expectation that development quality will surpass what is otherwise achievable through the base zoning district. To make these areas more resilient, we recommend the following:
   - Mixed-use buildings should have commercial spaces on ground floors with floodproofing, while residential units should be elevated.
   - Floodproofing for mixed-use and multi-story buildings: Dry floodproofing (sealing ground-level commercial and office spaces with waterproof materials, watertight doors, and flood barriers) or wet floodproofing (using flood vents and breakaway walls for ground-floor garages and storage areas in residential structures)
   - Install water-resistant materials (concrete, tile, treated wood, metal studs, and closed-cell insulation) for ground floors.
   - Elevate electrical panels, water heaters, HVAC units, and fuel tanks above expected flood levels.
   - Encourage green roofs, elevated terraces, and rooftop water collection to enhance stormwater management.
   - Implement rainwater harvesting systems for irrigation and gray water use.
   - Incorporate bioswales, rain gardens, permeable pavement, and detention ponds throughout the district.
   - Use permeable streets and sidewalks to improve stormwater absorption and reduce runoff.
   - Design parks, plazas, and open spaces as temporary flood retention areas that can absorb excess water during storms.
   - Concentrate higher-density housing and essential services on higher ground or flood-resistant structures.

- Design roadways with proper grading and drainage to prevent flooding of major access routes. Ensure that transit stops, bike paths, and pedestrian zones are designed with flood-resistant materials and raised infrastructure.
- Encourage residents and businesses to obtain NFIP flood insurance even if not required.

It is important to mention that some of the recommended strategies are within the CDRZ, which offer significant advantages when pursuing grants and external funding. Designated CDRZ areas are prioritized for resilience-building activities as they highlight communities with heightened vulnerability to natural hazards and the greatest need for mitigation and adaptation efforts. These areas often align with the funding priorities of federal programs such as FEMA's BRIC and FMA, HUD's CDBG-MIT, and state-level resilience initiatives. Projects in CDRZs address critical vulnerabilities and strengthen grant applications by demonstrating alignment with federal and state resilience goals, ensuring that investments target the most impactful solutions. Table 3 also presents some recommended actions, and below is a list of potential funding sources available at various levels.

Federal Level

- **HMGP – FEMA Hazard Mitigation Grant Program:** This program provides funding for projects that reduce risks from natural disasters, including retrofitting high-risk structures:
- **FMA—FEMA Flood Mitigation Assistance:** This program offers grants for flood mitigation activities, including elevation, acquisition, and floodproofing of buildings.
- **BRIC – Building Resilient Infrastructure and Communities:** This program offers Funds to proactive community resilience projects, including retrofitting vulnerable properties.
- **USDA Rural Development Water and Environmental Programs:** This program provides funding for stormwater-related projects in rural and unincorporated areas that could complement building retrofits.
- **NOAA Coastal Resilience Grants:** This program supports flood mitigation projects in coastal areas
- **EPA Water Infrastructure Finance and Innovation Act (WIFIA):** Provides low-interest loans for water infrastructure projects, including retention ponds and stormwater systems.
- **USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP):** Funds conservation practices, including nature-based flood mitigation solutions.
- **Department of Housing and Urban Development (HUD) Grants**:

- *Community Development Block Grant Disaster Recovery (CDBG-DR)* – Provides flexible funding for rebuilding efforts in disaster-affected areas.
- *Community Development Block Grant Mitigation (CDBG-MIT)* – Supports strategic flood mitigation projects to reduce future risks.

- **New Federal Funding Programs**:
  - *Bipartisan Infrastructure Law (IIJA)* – Includes $50 billion for climate resilience, flood protection, and environmental justice programs.
  - *Inflation Reduction Act (IRA)* – Funds nature-based resilience solutions and provides grants for community resilience projects.

Key state funds include:

- **Disaster Relief and Resilience Reserve Fund** – Supports the development and implementation of the Statewide Resilience Plan, provides disaster relief assistance, and funds hazard mitigation and infrastructure improvements.
- **South Carolina Resilience Revolving Fund** – Offers low-interest loans to buy out properties with repetitive flood losses and restore floodplains.
- **Safe Home Program** – Administered by the South Carolina Department of Insurance, providing grants to retrofit homes against hurricanes and high winds.
- **Rural Infrastructure Authority (RIA) Grants** – Helps develop reliable infrastructure and increase capacity for economic growth.

Table 3. Recommended Strategies

Action	Description	Potential Funding Source	Priority	Timeframe
Use this current study to establish base flood elevation standards in building codes and floodplain damage prevention ordinance	Actively using the results of the current study to establish and enforce base flood elevation data for new construction, considering the impacts of climate change. By taking this approach, cities can directly address flood risks, promote safer building practices, and enhance resilience in flood-prone areas.	General funds	High	Short-term
Discourage Development in High-Risk Areas	The flood depth in certain areas of Goose Creek ranges from 3 to 15 feet. Flood depths of **6 feet or more** are generally considered extremely hazardous for construction, as they pose significant risks to life safety, structural integrity, and emergency access. Therefore, the city should strongly discourage development in regions where flood depths exceed 6 feet.	General funds	High	Short-term
Provide hazard specific checklists to residents and business owners	Use the current report to disclose public information regarding flood depth as well as areas and buildings that are at risk of moderate flood damage. Awareness about hazards can minimize future damages	General Fund	High	Short-term
Establish and Implement Flood Resilience Overlay Using ClimaRR Data and Risk Mapping	Utilize ClimaRR flood depth data and identified at-risk buildings from this report to inform targeted flood mitigation strategies and enhance resilience planning.	General Fund	High	Short-term
Retrofit all municipal facilities to withstand impacts of a disaster	Utilize ClimaRR flood depth data and identified at-risk buildings from this report to prioritize municipal facilities for retrofitting and implement targeted mitigation strategies.	General Fund Enterprise Fund Bond Funding	Medium	Medium-term
Construct interconnected stormwater and flood control detention/retention pond system	Invest in structural mitigation activities to reduce the impacts of flooding in areas vulnerable to moderate flood damage	Grant Funding Stormwater Management Fees Bond Funding	Medium	Medium-term

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Appendices

Appendix A. IN-CORE Methodology

In order to run an IN-CORE building damage analysis, information about the local building stock is required. To build this dataset, the publicly available data from the National Structures Inventory (NSI) is typically utilized. This data has information on the structure type and size, foundation type and height, and number of stories. This data is used to determine the most appropriate building flood archetype for each structure. Some uncertainty arises at this stage as the NSI makes necessary assumptions to populate missing records. The quality of this dataset at the local level should always be considered. The flood archetype assignment process bins all buildings into one of 15 possible building archetypes (Table 4), which are assumed to behave similarly under hazard loading. In the case of flood, these archetypes were developed in order to effectively predict the structural and non-structural damage caused by a given flood depth on different types of buildings. The full list of building archetypes and their defining characteristics was put forth in the work of Omar Nofal and John W. van de Lindt in the peer-reviewed paper Minimal Building Flood Fragility and Loss Function Portfolio for Resilience Analysis at the Community Level (2020) and has been referenced in several subsequent publications.

Table 4. A reproduction of the tabulated archetypes

Building Archetype	Building Description
F1	One-story single-family residential building on a crawlspace foundation
F2	One-story multi-family residential building on a slab-on-grade foundation
F3	Two-story single-family residential building on a crawlspace foundation
F4	Two-story multi-family residential building on a slab-on-grade foundation
F5	Small grocery store/Gas station with a convenience store
F6	Multi-unit retail building (strip mall)
F7	Small multi-unit commercial building
F8	Super retail center
F9	Industrial building
F10	One-story school
F11	Two-story school
F12	Hospital/Clinic
F13	Community center (place of worship)
F14	Office building
F15	Warehouse (small/large box)

Source: Nofal and van de Lindt (2020)

With buildings sorted into the most appropriate archetype category and archetypical building damage determined by flood depth, a flooding scenario in the form of mapped flood depths is the final element required to run a building damage analysis with IN-CORE. The mapped flood depths used in these analyses have been developed from mid-century climate projections generated by Argonne National Laboratories, purchased by AT&T, and provided to Project IN-CORE by AT&T for the development of use cases of the climate data available on the Climate Risk and Resilience Portal (ClimRR). A version of this data will be available in short order on the ClimRR portal. The flood depths shown for this analysis represent a 100-year flood depth along the coastline and a 50-year pluvial flooding event inland in the mid-century decade of 2045-2054. The coastal flood dataset captures the increase in storm surge under sea-level rise scenarios compounded by hurricane and tropical storm events. Meanwhile, the inland pluvial flooding dataset captures the non-stationarity of intense rainfall events across the United States.

ClimRR provides peer-reviewed climate datasets in a nontechnical format and puts high-resolution, forward-looking climate data into the hands of those who need them most. Community leaders and public safety officials can now understand how changing climate risks will affect the populations they serve. Access to this information will assist leaders as they strategically invest in infrastructure and response capabilities to protect communities for future generations. ClimRR has been made publicly available at no cost by Argonne, AT&T, and FEMA to enable greater climate resilience among local communities.

These datasets are immensely helpful in understanding possible future flooding conditions; however, they do not reflect riverine flooding, nor do they capture municipal stormwater systems. For fluvial (riverine) flooding information, FEMA flood maps remain a good source of information. Meanwhile, for urban flooding, engaging in a more in-depth stormwater analysis may be necessary. The results below are provided to support this understanding of the bounds of the analysis.

Building the Damage Analysis: Running the Model and Obtaining Results

As described above, the building damage analysis is run by taking a set of buildings, binning them into 15 archetypical building categories, simulating a flood across the region of interest, and then determining the predicted damage level in accordance with these input factors. Upon running this analysis, you will note the term Damage State (DS) is used to denote varying levels of damage. In the latest version of IN-CORE, damage states are defined as DS0, DS1, DS2, and DS3. This is not in direct alignment with previously mentioned work and the figures shown below. This is because the most up-to-date version of IN-CORE has simplified the damage state prediction by grouping the slight damage category of "DS1" with the insignificant damage category of "DS0." Thus, in Figure 6, the original table of anticipated functionality from Nofal and van de Lindt (2020) has been annotated to show the new damage states and how they map to the original ones.

	DS Level	Functionality	Damage Scale	Loss Ratio
DS0	DS0	Operational	Insignificant	0.00–0.03
	DS1	Limited Occupancy	Slight	0.03–0.15
DS1	DS2	Restricted Occupancy	Moderate	0.15–0.50
DS2	DS3	Restricted Use	Extensive	0.50–0.70
DS3	DS4	Restricted Entry	Complete	0.70–1.00

Figure 6. Anticipated functionality by damage state according to Nofal and van de Lindt (2020) and augmented to align with the outputs of up-to-date IN-CORE models

Building Functionality Analysis: Defining Damage Probabilities

If the community experiences this event only once, our primary concern would be structures with a probability exceeding 50% of reaching Damage State 2 or 3. This would represent an impactful result for those structures with only a single occurrence of the modeled hazard event. However, global climate models suggest that the flooding event shown in this report will occur with greater frequency as we progress through this century. Thus, there becomes a greater level of concern with not only buildings in the DS2 and DS3 levels but also buildings in the DS1 level that will see a wearing down of their functionality as similar events become more common. As such, we have highlighted two scenarios. The first is the scenario where this event happens a single time, and the second is where this event happens frequently enough to degrade a larger portion of the building stock through repeated exposure. We have chosen to provide both of these scenarios because the flood depths we used for modeling do not represent a worse-case scenario for the local community but rather an event that the community should be very much expected to experience and successfully withstand in the coming years and possibly on multiple occasions. These two thresholds are superimposed onto Archetype 1's set of fragility curves in Figure 11 below. Thus, the following damage probability values do not represent damage probabilities due to separate events but rather serve to explore the possibility of how the flooding event described above would have varied impact if it occurred habitually versus a single time. The reality will likely be somewhere between these two scenarios.

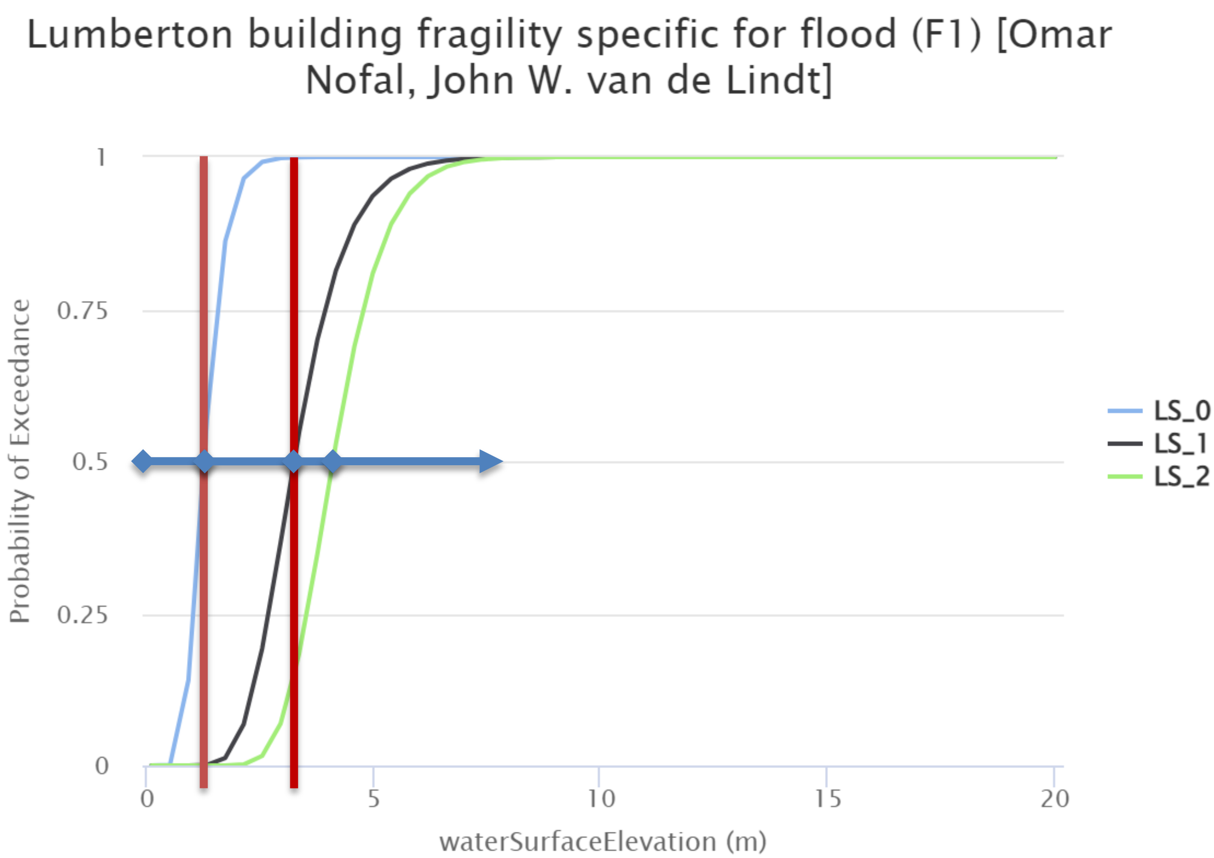

Figure 7. An example set of fragility curves to demonstrate the failure thresholds defined for this analysis
Source: Nofal and van de Lindt (2020)

Appendix B. Sourcing the Necessary Data to Run an IN-CORE Population Dislocation Analysis

The dislocation model requires data on people as well as on structures. To generate the housing unit population allocation, a separate python package called Pyncoda developed as part of the Center of Excellence for Risk-Based Community Resilience Planning, is used to synthetically allocate households to housing units. The demographic characteristics of the synthetic population matches the characteristics at the Census block group level. This work is described as follows by Pyncoda's README file on GitHub authored by Nathanael Rosenheim:

People are the most important part of community resilience planning. However, models for community resilience planning tend to focus on buildings and infrastructure. This repository provides a solution that connects people to buildings for community resilience models. The housing unit inventory method transforms aggregated population data into disaggregated housing unit data that includes occupied and vacant housing unit characteristics. Detailed household characteristics include size, race, ethnicity, income, group quarters type, vacancy type, and census block. Applications use the housing unit allocation method to assign the housing unit inventory to structures within each census block through a reproducible and randomized process. The benefits of the housing unit inventory include community resilience statistics that intersect detailed population characteristics with hazard impacts on infrastructure, uncertainty propagation, and a means to identify gaps in infrastructure data such as limited building data. This repository includes all of the Python code files. Python is an open-source programming language, and the code files provide future users with the tools to generate a 2010 housing unit inventory for any county in the United States. Applications of the method are reproducible in IN-CORE (Interdependent Networked Community Resilience Modeling Environment).

Population Dislocation Analysis: Running the Model and Obtaining Results

Once a housing unit allocation has been generated, then the damage result for each building can be combined with the social data for each household, such as tenure status, race, and household income, to determine whether a household is likely to temporarily relocate due to a hazard event, in this case a flood. The results of a population dislocation analysis can be analyzed further to understand the equity impacts of such hazards.