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Subtask 2.7: Existing Inventory of Toolkit Flood Resilience Strategies

North Carolina Flood Resiliency Blueprint

Prepared for the North Carolina Department of Environmental Quality by AECOM

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Definitions

A comprehensive list of definitions applicable to multiple Flood Resiliency Blueprint documents is provided in a separate document.

- https://ncfloodblueprint.com/documents/DraftBlueprint_DefinitionsGlossary.pdf (PDF)

Common Acronyms

BFE	Base Flood Elevation
CCAP	Community Cost Assistance Program
CMSWS	Charlotte-Mecklenburg Stormwater Services
CRS	Community Rating System
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
HMP	Hazard Mitigation Plan
HUD	US Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air Conditioning
MID	Most Impacted and Distressed
NBS	Nature-Based Solution
NC	North Carolina
NCORR	North Carolina Office of Resilience and Recovery
NCDEQ	North Carolina Department of Environmental Quality
NFIP	National Flood Insurance Program
SCM	Stormwater Control Measure
SMPP	Stormwater Management Program Plan
STIP	State Transportation Improvement Program
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation Act
WPP	Wetland Program Plan

1 Introduction

This report provides inventory and evaluation of existing flood resilience and mitigation strategies for developing the North Carolina (NC) Flood Resiliency Blueprint (Blueprint). The following strategies were considered (Table 1):

- Infrastructure-Based Solutions
- Nature-Based Solutions
- Planning and Policy
- Programmatic Best Management Practices

For each flood resilience and/or mitigation strategy under the *Gray Infrastructure Solutions* and *Nature-Based Solutions* sections, the following items are discussed:

- Flood hazards targeted (source/frequency) and limiting factors such as geographic constraints, implementation and maintenance costs, technical difficulty, availability of funding sources, whether funding is tied to the disaster declaration, and environmental or community impact on other functions.
- The pros and cons of each strategy and in what situations the strategy is best deployed versus under what conditions the strategy is less effective.
- The level of technical planning and modeling required to be awarded funding from sponsors and how the Blueprint can close the technical resource gaps.

The dichotomy between grey and green infrastructure solutions is a common point of discussion in flood resiliency. Grey infrastructure, characterized by conventional artificial structures like dams and levees, contrasts with green infrastructure, which involves natural elements such as wetlands and permeable surfaces. However, the most effective flood resiliency projects often embrace a nuanced, mixed approach that integrates grey and green strategies. This hybrid model recognizes the strengths of each solution—grey infrastructure's robustness and predictability and green infrastructure's ecological benefits—and leverages them to achieve the greatest possible benefits. By combining both advantages, these projects create a comprehensive and resilient flood management system that protects against flooding and fosters multiple benefits and environmental sustainability. This holistic approach underscores the importance of adapting strategies to the unique characteristics of each location, promoting a more flexible and adaptive response to the complex challenges posed by flood management.

Large-scale mitigation processes were considered for the Neuse Basin and documented in *Subtask2_13_NatureBasedSolutionsGapAnalysis*. Processes that reduce the volume of water in a system should be discussed moving forward in the Blueprint process.

The North Carolina Flood Resiliency Blueprint is an ongoing process in which the Blueprint Team and its partners learn as we move through the state and work with each basin. Some documents may be revisited as experience is gained, more information is gathered, and better data, methodologies, and new technologies become known.

Table 1-1 Existing Flood Resiliency and Mitigation Strategies Summary

<table>
<tr><th>Solution</th><th>Project Type</th><th>Project Focus</th></tr>
<tr><td rowspan="4">Infrastructure-Based</td><td>Stormwater</td><td>Improve Stormwater Drainage System Capacity</td></tr>
<tr><td>Structure/Debris Removal</td><td>Property Buyouts to Remove Existing Structures from Flood Hazard Areas</td></tr>
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<tr><td rowspan="5">Planning & Policy</td><td colspan="2">Flood Hazard Included in Community Comprehensive Plan</td></tr>
<tr><td colspan="2">Local Hazard Mitigation Plan Approved by FEMA and NC Emergency Management Agency</td></tr>
<tr><td colspan="2">Form Partnerships to Support Floodplain Management</td></tr>
<tr><td colspan="2">Planning Across Disciplines</td></tr>
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<tr><td colspan="2">Join or Improve Compliance with the National Flood Insurance Program (NFIP)</td></tr>
<tr><td colspan="2">Manage the Floodplain Beyond Minimum Requirements</td></tr>
<tr><td colspan="2">Participate in the Community Rating System (CRS)</td></tr>
<tr><td colspan="2">Establish Local Funding Mechanisms for Flood Mitigation</td></tr>
<tr><td colspan="2">Increase Awareness of Flood Risk and Safety</td></tr>
<tr><td colspan="2">Educate Property Owners about Flood Mitigation Techniques</td></tr>
<tr><td rowspan="4">Land Use Strategies</td><td>Planning and regulatory floodplains</td></tr>
<tr><td>Use built-out floodplain for regulation</td></tr>
<tr><td>Land use limitations</td></tr>
<tr><td>Provide incentives for staying out of the floodplain</td></tr>
</table>

	Strategies to Reduce Damage Due to Flooding	Implement a comprehensive floodproofing program
		Enhanced first flood elevation requirements
		Maximize floodplain flow capacity
		Develop a flooding mitigation plan
	Strategies to Preserve and Restore Open Space Features	Extension of floodplain management to smaller streams
		Flood prone property and land acquisition
		New construction floodplain dedication
		Innovative density trading away from flood prone areas
	Strategies to Use Technology for Better Information Management Support	Downstream impact assessment
		Aggressive map maintenance
		On-line GIS models
		Make floodplain maps accessible

2 Infrastructure-Based Solutions

Gray infrastructure solutions refer to traditional, human-engineered stormwater and flood control approaches. These solutions typically include infrastructure for moving and storing flood water, such as gutters and pipes, and traditional stormwater control measures (SCMs) like wet ponds and dry detention basins. This document does not include a comprehensive list of typical SCMs. Still, more information on traditional SCMs can be found in the North Carolina Department of Environmental Quality's (NCDEQ) Stormwater Design Manual (https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/stormwater/stormwater-program/stormwater-design-manual).

Flood protection barriers such as levees or floodwalls may also be classified as gray infrastructure and are discussed further below. This section also considers broader infrastructure-based solutions, including programmatic and/or operational strategies, such as property buyouts and flood-proofing.

2.1 Improve Stormwater Drainage System Capacity

Improving stormwater drainage system capacity is an essential strategy to get more value and higher function from existing systems. Improving stormwater drainage system capacity includes increasing the conveyance capacity of culverts and pipes and adding stormwater runoff storage capacity within a drainage area to increase the average amount of time the water remains (the hydraulic residence time) and reduce flooding. Note that stormwater drainage system capacity improvements may often contain nature-based solutions, which will be discussed in the next section. Regularly maintaining stormwater management facilities ensures the system functions as designed, and whether infrastructure- or nature-based, flood resilience and mitigation strategies can have overlapping components. *Subtask 2.13 - Nature-Based Solutions Gap Analysis* discusses options for nature-based stormwater solutions. Topics included in that document are Agricultural Land Stormwater Retention, Park Stormwater Retention, and Green Stormwater Infrastructure.

2.1.1 Flood Hazards Targeted

The flood hazards targeted by generally improving stormwater drainage would be a reduction of peak flows and recurrent urban flooding from precipitation events. Like wetlands' benefits, bioretention and detention stormwater basins may reduce peak flows during storms and support groundwater recharge and local water connectivity. Improving stormwater drainage system capacity is a strategy that can also support broader hydrologic connectivity within a watershed. Increasing the capacity of undersized culverts and stormwater pipes can reduce localized flooding caused by inadequate capacity and heavy rainfall events.

2.1.2 Pros and Cons

Table 2-1 Pros and Cons Improved Stormwater Drainage

Stormwater Drainage Improvement Pros	Stormwater Drainage Improvement Cons

Simple maintenance may provide value	Improvements in flooding impacts are limited to the existing system location
Potential for strategic localized project scopes	Easement or land acquisition challenges
	Utility conflicts can arise, increasing the cost

Compared to large-scale flood mitigation projects, increasing the conveyance and storage capacity of existing stormwater systems can be a relatively lower-cost solution (https://www.deq.nc.gov/energy-mineral-and-land-resources/stormwater/bmp-manual/e-3-retrofits/download) that can significantly impact the frequency and severity of flooding events. Targeted stormwater system upgrades can eliminate the need for other building-level flood mitigation/protection methods mentioned in this chapter (raising elevation, wet proofing /dry proofing, floodwalls, levees, etc.) for each structure in the flood prone areas.

Stormwater system maintenance and capacity improvements have limitations, however. The larger, more intense precipitation events experienced in recent years and anticipated in the future often exceed current stormwater systems capacity, which may have been built using outdated design standards. Communities should consider increasing the design storms used for system sizing to account for increased rainfall depths and intensities that are currently experienced and are expected to increase. In coastal areas, stormwater system upgrades should consider increasing the height of detention outlets to ensure the device can handle the increase in stormwater and increase structure elevations in consideration of future compound flooding increases, including sea level rise.

2.1.3 Technical Planning

A significant amount of planning is required to determine where stormwater system improvements are needed in a community. This planning begins with data gathering to map the current stormwater system, conveyance properties (including pipe and ditch sizes, pipe condition, inverts, and materials), Geographic Information System (GIS) analysis and retrieval, watershed delineation, and current and future project parcels or other data within the project watershed. While data gathering and mapping are critical to technical planning, it is worth acknowledging that GIS data coverage and availability are continued challenges in many municipalities, particularly in rural and/or under-served communities. Understanding the historical development of the watershed and the potential for future development is crucial to designing and/or adequately planning feasible system improvements. Then, a condition assessment analysis should be conducted to determine the extent of deterioration and/or inadequacies of the system. A targeted and standardized asset management program is vital in maintaining and preventing unnecessary degradation and malfunctioning of the stormwater drainage system.

Major municipalities in North Carolina have programs developed for planning and executing stormwater improvement projects and improving capacities. Municipal stormwater improvement projects are typically funded through Stormwater Utility Fees. Established in the early 1990s, Charlotte-Mecklenburg Storm Water Services (https://charlottenc.gov/StormWater/Pages/default.aspx) is the most prominent example of such a program. It is a joint municipal/county stormwater utility that includes the City of Charlotte and the surrounding towns of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, Pineville, and Mecklenburg County. The Storm Water Services fee is based on a property's impervious surface area, such as rooftops and concrete driveways. Properties with the least impervious surface area pay the lowest Storm Water Services fee. Each property in the tier is billed the same amount. Other programs, such as the City of Raleigh Stormwater Program fees, also utilize a tiered fee approach based on Impervious Area. Some of these municipal programs in North Carolina and their project links are below:

- Charlotte-Mecklenburg Stormwater Services Storm Drainage Improvement Projects – https://charlottenc.gov/StormWater/Projects/Pages/StormDrainageImprovements.aspx
- City of Raleigh Stormwater Projects - https://raleighnc.gov/stormwater/stormwater-projects
- Greensboro Stormwater Programs and Projects- https://www.greensboro-nc.gov/departments/water-resources/stormwater-program/programs-and-projects
- City of Durham Stormwater Capital Improvement Projects - https://www.durhamnc.gov/509/Construction-Design-Projects-Active
- City of Winston Salem Stormwater Capital Improvement Projects - https://www.cityofws.org/2371/Capital-Improvement-Projects
- City of Fayetteville Stormwater Improvement Projects- https://www.fayettevillenc.gov/city-services/public-services/resources/projects
- Town of Cary Stormwater Projects- https://www.carync.gov/projects-initiatives/project-updates/stormwater-projects
- City of Wilmington Stormwater Projects- https://www.wilmingtonnc.gov/departments/public-services/stormwater/projects
  City of High Point Stormwater Improvement- https://www.highpointnc.gov/741/Stormwater-Improvement

North Carolina Department of Transportation Stormwater Improvement projects are funded through the State Transportation Improvement Program (STIP). The STIP is a multi-year capital improvement document that denotes the scheduling and funding of construction projects across the state over a minimum 4-year period, as Federal law requires. North Carolina's STIP covers ten years, with the first six years (2020-2025 in this version) referred to as the delivery STIP and the latter four years (2026-2029) as the developmental STIP.

- https://connect.ncdot.gov/projects/planning/STIPDocuments1/NCDOT%20Current%20STIP.pdf

The type of flood hazard targeted by improved stormwater drainage system capacity depends on the kind of infrastructure being improved. For example, improving a closed pipe system could help mitigate flood hazards from a 10-year storm. Similarly, improving the drainage capacity of culverts or major thoroughfares would target hazards generated from a 25- to 50-year storm. Additionally, designers must account for downstream impacts. Relieving flooding in one area may increase flooding downstream.

This is discussed in more detail in the North Carolina municipality Stormwater Design Manuals, some of which are below:

- Charlotte-Mecklenburg Stormwater Design Manual- (https://charlottenc.gov/StormWater/Regulations/Pages/StormWaterDesignManual.aspx)
- City of Raleigh Stormwater Management Design Manual- (https://cityofraleigh0drupal.blob.core.usgovcloudapi.net/drupal-prod/COR16/StormwaterDesignManual.pdf)
- City of Greensboro Stormwater Management Manual- https://www.greensboro-nc.gov/home/showpublisheddocument/3623/636510647144300000
- Stormwater design criteria for North Carolina Department of Transportation roadways are found in their "Drainage Studies Guidelines" — https://connect.ncdot.gov/resources/hydro/Pages/DrainageStudiesGuidelines.aspx—for guidance in the methods, procedures, policies, and criteria for Drainage Studies and Hydraulic Design.

2.2 Property Buyouts to Remove Existing Structures from Flood Hazard Areas

This strategy involves "buyouts," in which property owners sell their flood-prone properties to the state or local government and relocate to areas with lower flood risk. These buyout programs are voluntary, and the flood prone areas can often be converted back to natural open space, which provides an added benefit of flood mitigation and habitat conservation.

2.2.1 Flood Hazards Targeted

Property buyout programs target flood hazards, including coastal and riverine flooding, and eliminate future impacts on residents and property owners by removing structures and people from the flood prone areas.

2.2.2 Pros and Cons

Table 2-2 Pros and Cons Property Buyouts

Property Buyout Pros	Property Buyout Cons
Eliminates flood risk to property and contents	Federal funding requirements are cumbersome for state and local governments to implement
Eliminates need for flood insurance or reduces premiums for homeowners relocating to lower flood risk areas	Limited availability of affordable housing options for residents who are displaced, and fair market value of the home may not be sufficient to acquire equivalent housing elsewhere
Reduces the likelihood of physical, financial, and emotional strain associated with flooding	Participation is voluntary, and property owners may have other compelling reasons not to participate

Natural open spaces function as flood mitigation features	Federal resources are often tied to individual disasters, making long-term implementation and maintenance difficult
Reduction of spending on disaster and emergency funds and rescues	Communities and people have varied and complex views of buyout programs. They can displace people and break up communities. They may disproportionately be utilized in under-resourced communities, fixed-income senior citizens, and communities of color. ANOTHER CON They may increase maintenance responsibilities for communities or risk becoming unkept eyesores.
Potential access to well-funded programs such as FEMA's Building Resilient Infrastructure and Communities and Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act	Communities without pre-disaster planning are often not able to organize effectively to participate in buyout programs, and post-buyout maintenance funding is non-existent
	The reality of the loss of tax base/revenue and the community's inability to track where participants go to keep people out of the floodplain

2.2.3 Technical Planning

The North Carolina Office of Recovery and Resiliency (NCORR) program serves as an example of a strategic buyout program for select NC counties that were most impacted by Hurricanes Florence and Matthew[1].

The state's $182 million strategic buyout program is fully funded by the U.S. Department of Housing and Urban Development (HUD). Figure 2-1 below depicts counties that fall into HUD's Most Impacted and Distressed (MID) category, a threshold for allotting recovery assistance after a natural disaster. HUD determines its target areas by selecting the MID and Unmet Recovery Needs categories. 23 counties in the state are buyout eligible. The strategic buyout program is voluntary and buys out homes at the current fair market value, creating an undeveloped property. Additional incentives are provided to some homeowners for relocation to safer areas within the county or state. It is recognized that many cannot move to a place with less flood risk and often end up with the same or greater flood risk.

[1] https://www.rebuild.nc.gov/homeowners-and-landlords/strategic-buyout-program

Applicant and property eligibility requirements must be met, such as owning the property and being able to sell it. Those in other buyout programs, such as the Hazard Mitigation Grant Program under the Federal Emergency Management Agency (FEMA), are not eligible. An owner can withdraw from other programs to regain eligibility.

The map from the ReBuild website below shows the counties with buyout areas currently included in the MID location that were affected by Hurricanes Florence and Matthew.

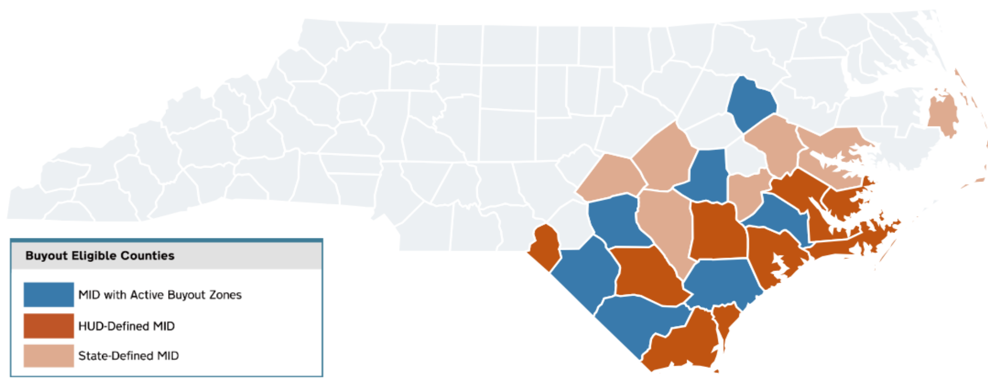

Figure 2-1 NCORR Strategic Buyout Counties with Most Impacted and Distressed (MID) Categories[1]

Local governments can also develop buyout programs. For example, Charlotte-Mecklenburg Stormwater Services (CMSWS) has implemented a local Floodplain Buyout (Acquisition) Program. CMSWS estimates that buyouts have avoided more than $45.5 million in losses since its inception in 1999. Each of the 5,000 individual properties in Charlotte-Mecklenburg's regulated floodplain has been analyzed using CMSWS' Risk Analyze Risk Reduction Tool.

2.3 Retrofits for Floodproofing of Residential and Non-Residential Structures

FEMA defines floodproofing as "any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures, and their contents." Floodproofing is a strategy aimed at prevention, and its benefits are discussed more below.

2.3.1 Flood Hazards Targeted

Solutions that can help mitigate and/or avoid damage to structures and contents include structure elevation, wet and dry-floodproofing, construction of levees, floodwalls, or other landscaping/site topography alterations designed to protect structures and infrastructure.

2.3.2 Pros and Cons

Table 2-3 Pros and Cons Retrofits

Retrofits for Floodproofing Pros	Retrofits for Floodproofing Cons
Potential for minimal costs relative to value-added	Wet floodproofing requires adequate warning time and human intervention
A flood insurance policy may cover costs	Extensive cleanup post-flooding may be necessary
Reduces the likelihood of physical, financial, and emotional strain associated with flooding	Houses should be evacuated during flooding and for a time afterward
Additional land is not required	Pumping flood waters may result in structural damage
	It does not minimize potential damage from high-velocity floods or wave action
	Floodproofing does not decrease the overall risk of flooding; it only reduces the extent of damage
	NFIP regulations prohibit DRY floodproofing of residential structures.
	DRY floodproofing requires adequate warning to install temporary barriers, etc.
	WET floodproofing allows water to enter and exit the building without damage because at-risk elements (HVAC, water heaters, and other fixtures) are elevated above the potential flood height. However, it still requires clean-up after the event.

2.3.3 Technical Planning

- Wet floodproofing in a basement may be preferable to keeping water out entirely because it allows controlled flooding to balance exterior and interior wall forces and discourages structural collapse. NFIP regulations do not permit basements (subgrade spaces on all four sides) in the special flood hazard area. Pre-Flood Insurance Rate Map (FIRM) buildings with basements should consider abandoning and filling subgrade spaces.
- For areas below the base flood elevation, consider wet floodproofing.
- Using flood damage-resistant materials allows easy cleanup after floodwater exposure in accessory structures or a garage area below an elevated residential structure.

Conditions to Be Avoided When Wet Floodproofing:

After flood waters recede from the area around a house with a wet flood-proofed basement, the homeowner will want to pump out the water that filled the basement during the flood. However, if the soil surrounding the basement walls and below the basement floor is still saturated with water, removing the water in the basement too quickly can be dangerous. As the water level in the basement drops, the outside pressure on the basement walls and floor becomes greater than the inside pressure (see figure below). As a result, the walls can collapse, and the floor can be pushed up or cracked. Basement and crawl-space areas below the base flood elevation should be constructed with flood-resistant materials and used only for temporary parking, storage, or building access.

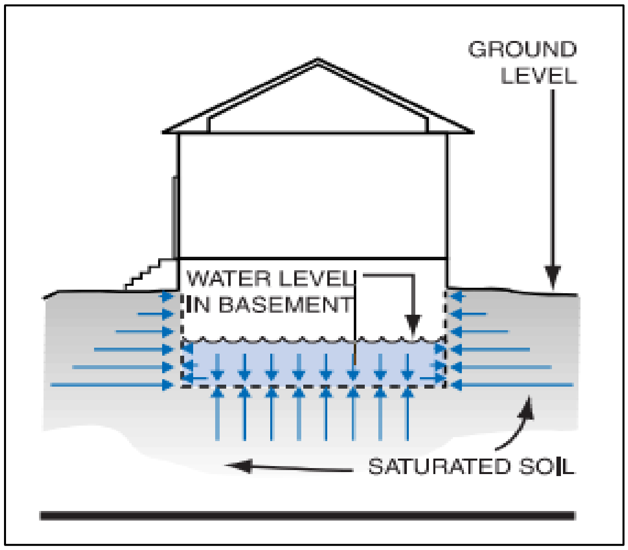

Figure 2-2 Pressure Differential[3]

Table 2-4 Cost of Wet Floodproofing[3]

CONSTRUCTION TYPE	HEIGHT OF WET FLOODPROOFING (in feet above basement floor or LAG[1])	EXISTING FOUNDATION	COST (per square foot of house footprint)
FRAME OR MASONRY	2	Basement[2]	$1.70
		Crawlspace	$1.30
	4	Basement[2]	$3.50
		Crawlspace	$3.25
	8	Basement[2]	$10.00
		Crawlspace	NA[3]

[1] House with basement: feet above basement floor; house with crawlspace: feet above LAG
[2] Unfinished
[3] A house would almost never have a crawlspace 8 feet high, which is nearly the height of a full story.

Conditions to Be Avoided When Dry Floodproofing:

Even concrete block and brick walls should only be dry floodproofed above a height of three feet if an engineering analysis shows that they can withstand the expected hydrostatic and hydrodynamic loads and debris impact forces. The effects of buoyancy on slab floors must also be considered. In alignment with FEMA's NFIP Technical Bulletin 3 (2021), which states, "the NFIP regulations do not permit the use of dry floodproofing for residential buildings in Zone A, and dry floodproofing is not permitted for any buildings in Special Flood Hazard Areas that are subject to high-velocity wave action, called coastal high-hazard areas and identified on FIRMs as Zone V (V, VE, V1-30, and VO," dry floodproofing should be applied ONLY to non-residential (commercial and other non-residential uses) and mixed-use (both residential and commercial or other non-residential uses) structures[2].

Table 2-5 Cost of Dry Floodproofing[3]

COMPONENT	COST	PER
Sprayed-on Cement (above grade)[1]	$3.30	Square Foot of Wall Area Covered
Asphalt (two coats on foundation below grade)[1, 2]	$1.10	Square Foot of Wall Area Covered
Waterproof Membrane (above grade)[1]	$1.10	Square Foot of Wall Area Covered
Drainage Line Around Perimeter of House	$31	Linear Foot
Plumbing Check Valve	$620	Lump Sum
Sump and Sump Pump (with backup battery)	$1,000	Lump Sum
Metal Flood Shield	$73	Square Foot of Shield Surface
Wood Flood Shield	$23	Square Foot of Shield Surface

[1]Cement, asphalt, and membrane are alternative sealant methods.
[2]Does not include the cost of excavation

2.4 Construct Flood Protection Barriers

Levees and floodwalls are types of flood protection barriers. A levee is typically a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both. When these barriers are built to protect a house, they are generally referred to as "residential," "individual," or "on-site" levees and floodwalls. The practical heights of these levees and floodwalls are usually limited to six feet and four feet, respectively.

- Using minor structural projects that are smaller and more localized (e.g., floodwalls or small berms) in areas that cannot be mitigated through non-structural activities or where structural activities are not feasible due to low densities.
- Using revetments (hardened materials placed atop existing riverbanks or slopes) to protect against floods.

[2] https://www.fema.gov/sites/default/files/documents/fema_technical-bulletin-3_1-2021.pdf#:~:text=The%20NFIP%20regulations%20do%20not%20permit%20the%20use,as%20Zone%20V%20%28V%2C%20VE%2C%20V1-30%2C%20and%20VO%29.

- Using bioengineered bank stabilization techniques.

2.4.1 Flood Hazards Targeted

Flood protection barriers reduce the likelihood and extent of flooding on a local-to-watershed scale.

2.4.2 Pros and Cons

Table 2-6 Pros and Cons of Flood Protection Barriers

Construct Flood Protection Barriers Pros	Construct Flood Protection Barriers Cons
Protection from inundation	Cost may be prohibitive for large projects
Minimal to no disruption to the property itself	Periodic maintenance is required
Reduces the likelihood of physical, financial, and emotional strain associated with flooding	May not bring property into compliance with floodplain management ordinance or law
It may cost less than a rebuild option	Needs to be coupled with other protective measures to prevent a single point of failure
	Human intervention and adequate warning time are required
	It may alter local drainage by displacing water, causing flooding in other areas, and impacting ecosystems and neighboring properties.
	Property should be evacuated during flood
	May restrict access to property

2.4.3 Technical Planning

In most cases, Levees and Floodwalls are highly discouraged when this measure is used to protect more than one home, as the many disadvantages stated above are magnified when a community of homes is protected against floods. Earthen levees require a 1:7 height/width ratio and have an optimum slope based on those heights and widths. The amount of land use and floodplains removed should be considered. Maintenance for these structures should also be appraised as water accumulated through rainfall or flooding behind the structures will have to be pumped out, and the structures will have to be periodically inspected for leaks.

Table 2-6 Cost of Levees and Floodwalls[3]

COMPONENT	COST (per linear foot)
Levee – 2 feet above ground	$37
Levee – 4 feet above ground	$69
Levee – 6 feet above ground	$115
Floodwall – 2 feet above ground	$85
Floodwall – 4 feet above ground	$124

Table 2-7 Cost of additional Leve and Floodwall Components[3]

COMPONENT	COST	PER
Levee Riprap	$31	Cubic Yard
Interior Drainage System	$4,200	Lump Sum
Closure (each)	$73	Square Foot of Closure Area
Seeding of disturbed areas	$0.05	Square foot of Ground Area

The costs for levee construction can vary greatly depending on the distance between the construction site and the source of the fill dirt used to build the levee. The greater the distance that fill dirt must be hauled, the greater the cost.

The storm frequency for retrofit measures would be the 100-year storm frequency or more extreme events. While the 100-year floodplain serves as the footprint for the NFIP mandatory insurance purchase requirements and regulatory floodplain management requirements, the relative frequency of any given flood (2-year vs. 10-year) can also be helpful when choosing between retrofitting options. In addition, the appropriate freeboard will need to be considered. FEMA's floodplain studies may be valuable when evaluating flood mitigation and protection measures, but it is worth acknowledging that they are not the only resource. FEMA flood studies are based on the watershed conditions that existed when the analyses were performed. For any flood protection or mitigation measures, always consider full build-out of the watershed per land use within the watershed and future climatic conditions. The level of modeling required would be determined by utilizing the flood mapping and current flood models (revised for full build-out and other considerations for evaluating flood mitigation measures) across the state.

Comprehensively modeling flood elevations, depths, durations, and velocities can be challenging because the model does not include streams and stormwater infrastructure that are not FEMA-regulated. This is commonly seen in municipalities with small stormwater and stream systems. Often, small municipalities may need access to funding for additional flood modeling, but herein lies another area where Blueprint provides value. Blueprint could close the technical resource gaps by gathering information on model limitations for small storm and/or stream systems. The data gaps could be mapped and incorporated as objectives or deliverables in other projects. Higher priority would be placed on under-resourced and underserved populations, including populations protected by Title VI of the Civil Rights Act.

Constructing flood protection barriers should be weighed against upsizing the storm drainage systems, mentioned in Section 2.2, or evaluating a combination of these two strategies.

3 Transitional Solutions

"Transitional" solutions are a non-formal category used in this toolkit to describe flood reduction strategies that use elements of infrastructure- and nature-based solutions. If infrastructure- and nature-based solutions exist as endpoints on an idealized spectrum (see conceptual diagram below), then transitional solutions would sit in the middle. Green roofs, for example, are included in this transitional category because they broadly mimic nature by capturing rainwater where it falls while seated on a traditional roof structure.

3.1 Elevate or Retrofit Structures and Utilities

Depending on what method will work best for each house, there are a few different methods for retrofitting a structure to protect it from flooding. FEMA's overview[3] of retrofitting methods lists and describes the six methods below.

- Elevation
- Wet Floodproofing
- Relocation
- Dry Floodproofing
- Levees and Floodwalls
- Demolition

3.1.1 Flood Hazards Targeted

Elevating or retrofitting structures and utilities can prevent damage associated with inundation.

3.1.2 Pros and Cons

Table 3-1 Pros and Cons of Elevate or Retrofit

Elevate or Retrofit Structures and Utilities Pros	Elevate or Retrofit Structures and Utilities Cons
May bring property into compliance with floodplain management ordinance or law	Cost may be prohibitive

[3] https://www.fema.gov/pdf/rebuild/mat/sec3.pdf

Reduces the flood risk to the house and its contents	Appearance of the house may be adversely affected
Except where a lower floor is used for storage, elevation eliminates the need to move vulnerable contents to areas above the water level during flooding	Accessibility to the house may be adversely affected for seniors or people with mobility challenges
Reduces flood insurance premiums	Property should be evacuated during flood
Techniques are well-known, and qualified contractors are often readily available.	Unless special measures are taken, elevation is not appropriate in areas with high-velocity flows, waves, fast-moving ice or debris flow, or erosion
Does not require the additional land needed to construct floodwalls or levees.	Additional costs are likely if the house must be brought into compliance with current code requirements for plumbing, electrical, and energy systems
Reduces the physical, financial, and emotional strain that accompanies floods	Potential wind and earthquake loads must be considered
	It may require Environmental and Historic Preservation reviews and consideration

3.1.3 Technical Planning

Retrofitting may be the best means of protection for the dwelling owner whose house is in an area where a large flood control project, such as a dam, levee, or major waterway improvement, is not feasible, warranted, or appropriate. However, most retrofitting measures cannot be simply installed and forgotten. There will need to be periodic inspections and maintenance to ensure these measures will continue to work overtime, especially if they require human intervention. Even though retrofitting will help protect the structure from flooding, occupants should never remain in the retrofitted structure during flooding. The occupants should stay informed about flooding conditions by monitoring local radio and television stations and must be prepared to evacuate when necessary. Some examples of elevating and/or retrofitting include:

- Elevating structures so that the lowest floor, including the basement, is raised above the applicable floodplain management regulations
- Raising utilities or other mechanical devices above expected flood levels.
- Relocating utilities and water heaters above base flood elevation and using tankless water heaters in limited spaces.

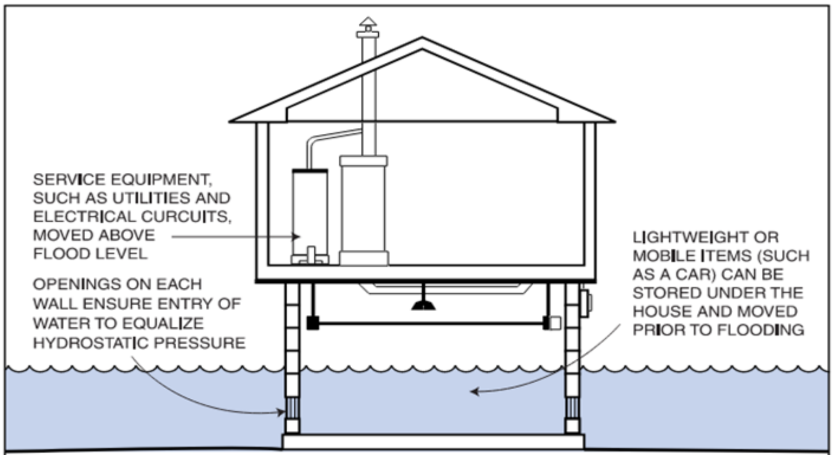

Figure 3-1 Elevating Structures and Utilities[3]

The design frequency storm for this measure should be the 1% (100-year storm) or more extreme events. In addition, the appropriate freeboard will need to be considered. The designer should not fully rely on FEMA's floodplain studies to evaluate flood mitigation or protection measures. FEMA flood studies are based on the watershed conditions (e.g., the amount of impervious area in the watershed) that exist when the studies are performed, and they may be outdated and inaccurate. For any flood protection or mitigation measures, always consider the full build-out of the watershed per the zoned land used within the watershed. The level of modeling required for a project of this type would be determined based on the availability of accurate flood mapping and current flood models (revised for full build-out and other considerations for use in evaluating flood mitigation measures).

The National Flood Insurance Program (NFIP) does not map all flood risks. Generally, the NFIP only maps streams with a drainage area of one square mile or greater. There is a significant number of tributaries, pipes, ditches, etc., upstream of the mapped floodplains that can contribute to flood risk to surrounding properties. The municipalities typically manage these systems. The project designer should coordinate with the municipality to gather this local information (if available) for input to elevating or retrofitting structures. In these smaller systems, this mitigation option should be weighed against upsizing the storm drainage systems mentioned in Section 2.2 or evaluating a combination of these two strategies. In smaller municipalities with streams that are not FEMA-regulated, this information most likely does not exist. This is where the Blueprint could close the technical resource gaps by gathering information on these models for these minor storm systems/streams that exist or modeling and mapping the information that does not exist for use as input for these types of projects. Higher priority should be placed on under-resourced and underserved populations, including populations protected by Title VI of the Civil Rights Act.

3.2 Green Roofs

Green roofs are structures that commonly overlay a traditional roof. Green roofs consist of a protective membrane, growing media, and typically low-growing vegetation. Note that green roofs are sometimes a component of stormwater management and drainage capacity improvements. Green roofs exemplify the fluidity between infrastructure- and nature-based solutions, depending on the project goals and objectives.

3.2.1 Flood Hazards Targeted

A green roof reduces runoff by capturing rainfall. This process reduces flooding in urban areas by decreasing the overall volume of runoff generated by a storm and is considered a stormwater control measure (SCM). In North Carolina, a peak attenuation and volume reduction credit is available.

- https://www.deq.nc.gov/water-quality/surface-water-protection/spu/spu-bmp-manual-documents/bmpman-ch19-20070928-dwq-spu/download

3.2.2 Pros and Cons

Table 3-2 Pros and Cons of Green Roofs

Green Roof Pros	Green Roof Cons
Secondary benefits such as air quality improvements	Cost may be prohibitive depending on roof type, roof structure, and building location
Reduction in energy costs during warm seasons and reduces heat-island effect	Regular maintenance required
Retrofitting a roof is possible with the necessary structural support	Increases weight load on a roof and supports
Added aesthetic value	Water detention may cause a roof to leak
Insulates sound	
Conserves space	

3.2.3 Technical Planning

Technical planning includes a site-specific investigation. Property specifications and weight load capacities should be considered to ensure that green roof installation is feasible and appropriate for the property. Weight is one of the driving factors controlling the feasibility and cost of green roofs. Because of the regular maintenance, safety measures and procedures are needed to prevent falls during maintenance. This strategy may be best suited for a property where stormwater management is needed, but the overall property size is too small for other SCMs.

NCDEQ's Stormwater Design Manual and Minimum Design Criteria

- https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Stormwater/BMP%20Manual/C-8%20%20Green%20Roof.pdf

3.3 Permeable Pavement

Permeable pavement intercepts stormwater and filters it through an underlying media reservoir. Permeable pavements allow more rainfall to soak into the ground; these devices detain runoff but may also facilitate infiltration. Common types include pervious concrete, porous asphalt, and interlocking pavers. Permeable pavements are mainly used for parking lots, roadway shoulders, and new developments with limited space and high costs. NCDEQ's Stormwater Design manual lists the following types of permeable pavement: permeable interlocking concrete pavers, pervious concrete, porous asphalt, concrete grid pavers, and plastic turf reinforcing grids. Note that the Community Cost Assistance Program by the NC Department of Agriculture does not allow permeable pavement in western regions of the state.

3.3.1 Flood Hazards Targeted

Permeable pavement reduces runoff by capturing and infiltrating rainfall. This process reduces flooding in developed areas by decreasing the overall volume of runoff generated by a storm. In addition to runoff volume capture, permeable pavements may also support peak attenuation and pollutant removal, such as total suspended solids.

3.3.2 Pros and Cons

Table 3-3 Pros and Cons of Permeable Pavement

Permeable Pavement Pros	Permeable Pavement Cons
Replaces built-upon-area with a treatment device	Regular maintenance is required, which can also be influenced by soil type
Prevents standing water in trafficked areas	Susceptibility to clogging, reducing its effectiveness if not maintained
Reduces pollutants, rate, and runoff volume	Initial installation costs may be prohibitive

3.3.3 Technical Planning

Technical planning includes a site-specific investigation. Elements like soil characteristics and hydraulics, slope, and elevation of the seasonal high-water table should be considered. To that end, the site-specific elements of a permeable pavement technical planning investigation can be reviewed in Section C-5 of the NCDEQ Stormwater Design Manual.

- https://www.deq.nc.gov/energy-mineral-and-land-resources/stormwater/bmp-manual/c-5-permeable-pavement-11-20-2020/download

3.4 Rainwater Harvesting

Rainwater harvesting is a collection of components that collect, store, and reuse rainwater. They reduce runoff volume by capture and can reduce the demand for potable water. Generally, a rainwater harvesting system is comprised of a collection mechanism (e.g., gutters on roofs or pipes from pavement), a pre-treatment device (e.g., filters or screens) to prevent sediment and debris from entering storage devices, storage, overflow, and a distribution mechanism to drain or pump water to its point of use. The storage component may be rain barrels that store tens of gallons or rainwater cisterns that store hundreds to thousands of gallons. A rain garden is a shallow, vegetated basin that collects and absorbs runoff from rooftops, sidewalks, and streets. Rain gardens can be added around homes and businesses to reduce and treat stormwater runoff.

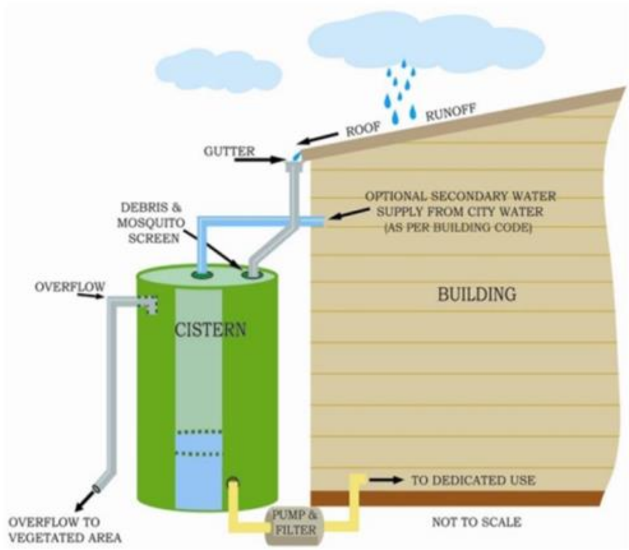

Figure 3-2 Rainwater Harvesting System Example (NCDEQ Stormwater Design Manual)

3.4.1 Flood Hazards Targeted

Rainwater harvesting reduces runoff by capturing rainfall. This process can reduce flooding in developed areas by decreasing the overall volume of runoff generated by a storm. Additionally, rainwater harvesting supports peak attenuation and pollutant removal, such as total suspended solids, nitrogen, and phosphorus.

3.4.2 Pros and Cons

Table 3-4 Pros and Cons of Rainwater Harvesting

Rainwater Harvesting Pros	Rainwater Harvesting Cons
Provides a variety of uses for rainwater	Requires the owner to ensure water is emptied to make way for the next storm
Reduces water utility cost	Risk of rainwater contamination
Reduces energy expenditure	The benefit is tied to the amount of storage available or attainable
Reduces flood volume	

3.4.3 Technical Planning

Like other flood reduction strategies, a site-specific investigation should be conducted. The feasibility study should address soil type(s), slope, proximity to sensitive or regulated areas such as water supply wells or riparian buffers, operation and maintenance accessibility, and total costs. For this mitigation option to be successful, the captured water must be effectively utilized. A few examples of rainwater use include irrigation, toilet flushing, laundry, and animal systems. NCDEQ and North Carolina State University's Biological and Agricultural Engineering Department developed a design manual for rainwater harvesting that includes major design elements and considerations, construction components, necessary inspections, and O&M procedures.

- https://www.deq.nc.gov/energy-mineral-and-land-resources/stormwater/bmp-manual/ch-25-rwh-final-draft/download

4 Nature-Based Solutions

Nature-based solutions are the "sustainable planning, design, environmental management, and engineering practices that weave natural features or processes into the built environment (i.e., areas with impervious surfaces) to promote adaptation and resilience. These solutions use natural features and processes to combat climate change, reduce flood risks, improve water quality, protect coastal property, restore and protect wetlands, stabilize shorelines, reduce urban heat, add recreational space, and more."[4] This section is not an exhaustive list of Nature-Based Solutions (NBS) but is meant to provide a few NBS strategies for implementation at a smaller scale. For a more thorough data gap analysis on NBS solutions and a review of larger-scale, basin-wide solutions, refer to the *Nature-Based Solutions Gap Analysis* and *Nature-Based Solutions Existing Opportunities Gap Analysis in the Neuse River Basin* documents.

4.1 Protect and Restore Natural Flood Mitigation Features

Natural floodplains provide economic, social, and environmental benefits while reducing flood risk through flow rate and erosion reduction, storing excess floodwater, and slowing runoff. Protecting, restoring, and enhancing these landforms that serve as natural flood mitigation features is a broad category with many diverse strategies and is an important flood resilience strategy that should be considered. Some of the solutions below fall under this category of *protecting and restoring natural flood mitigation features* and were given more specific analyses in the sections below.

4.1.1 Flood Hazards Targeted

Natural flood mitigation features target peak flow attenuation, flood volume capture, and storage. This strategy reduces erosion by stabilizing stream banks, provides floodwater storage, and repairs and restores riparian ecosystem habitats to pre-development states.

4.1.2 Pros and Cons

Table 4-1 Pros and Cons of Natural Flood Mitigation Features

Natural Flood Mitigation Features Pros	Natural Flood Mitigation Features Cons
Reduces and prevents erosion	Costs may be prohibitive depending on size and location but can be offset by lower maintenance costs over the life of the project

[4] https://www.fema.gov/emergency-managers/risk-management/nature-based-solutions#:~:text=Nature%2Dbased%20solutions%20are%20sustainable,Reduce%20flood%20risk

Supports watershed hydrologic connectivity	Requires expert design and installation/construction
Restores and protects riparian habitats	May require easements, land use contracts, or land/property buyout
Reduces flood volume	Requires monitoring and maintenance
Provides storage and groundwater recharge potential	Often require federal, state, and local permits
Removes contaminants and pollutants	
Potential recreation, beautification, and economic development benefits	

4.1.3 Technical Planning

Protecting and restoring natural flood mitigation features involves site-specific investigation to determine project feasibility. This strategy is generally ideal in areas with existing natural features, like streams or floodplains.

One way communities restore natural mitigation features is by removing impervious surface areas (e.g., de-paving). Removing impervious areas or "de-paving" is most associated with improving water quality or combating climate-related extreme heat. However, in some situations, removing pavement and other impervious areas may reduce flooding immediately downstream. The benefits of the de-paving can be further expanded if the land is graded and runoff from adjoining properties is routed through the property, where the peak runoff can be reduced. At the same time, the volume is treated for pollutant removal using natural vegetation.

The targeted removal of impervious areas, especially in older developments that pre-date impervious surface restrictions on parcels, can lead to multiple benefits beyond flood risk reduction and water quality, including a measurable reduction in heat islands. Heat islands are pockets of extraordinarily high temperatures that form because impervious surfaces absorb and re-emit the sun's heat. While the previously discussed benefits of removing impervious surfaces make the practice an important strategy to consider, communities should also weigh the risks and potential barriers to implementation.

In certain circumstances, de-paving and placing restrictions on impervious surface cover on future developments can reduce a community's tax base. Some businesses and potential new residents may choose to relocate to an area with fewer restrictions. The process of de-paving is also expensive, depending on the use of the property, and limited in its application. The flood mitigating benefits of removing impervious surfaces from one road, sidewalk, and/or parking lot may not equal that of another due to factors such as grade/slope, material, surrounding land uses, proximity to bodies of water, etc. For communities to effectively identify and implement this strategy, a detailed analysis is required to identify sites with the greatest potential impact on mitigating the impacts of flooding.

4.2 Wetland Restoration

Specific soils, hydrologic processes, and vegetation characterize wetlands. Wetland restoration and protection is an important component of watershed and ecosystem health. For content related to wetland restoration research at a basin-wide scale, refer to *Nature-Based Solutions Existing Opportunities Gap Analysis in the Neuse River Basin* (Subtask 2.13).

4.2.1 Flood Hazards Targeted

Not only do wetlands recycle key nutrients, but they also reduce peak flows and expand the capacity for water storage. In urban areas, wetlands may be a mitigation tool for runoff generated by impervious surfaces. During a storm, the wetland captures runoff, which reduces peak flow. Wetlands can also store the flow generated from a storm and release it slowly over time, supporting hydrologic connectivity and groundwater recharge. Hydrologic connectivity is the "water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle" (Pringle, 2001).

The efficacy of flood abatement by wetlands varies due to several factors (e.g., slope, soil condition, total area). A wetland covering one acre can store up to one million gallons (or three acre-feet). It is generally understood that restoring a floodplain's "natural" hydrology can reduce flooding damage and associated costs. For example, a study conducted by the Watershed Initiative in the Upper Mississippi River Basin found that restoring the 100-year flood zone may have prevented the Great Flood of 1993, which resulted in billions of dollars in damage. Creating and/or restoring wetlands is a nature-based solution that directly reduces flood potential on a local to drainage basin scale and provides additional ecological system benefits.

4.2.2 Pros and Cons

Table 4-2 Pros and Cons of Wetland Restoration

Wetland Restoration Pros	Wetland Restoration Cons
Nutrient recycling	Land acquisition or easement requirements
Groundwater recharge	Requires groundwater flow
Broad ecological benefits	Susceptible to invasive species
Remove contaminants	Maintenance requirements

4.2.3 Technical Planning

Because wetland programs in North Carolina are diverse and data-rich, much of the required technical planning and modeling already exists. The NC Wetland Program is housed within the Division of Water Resources within the NCDEQ. In June 2023, an overall program update (https://www.ncwetlands.org/wp-content/uploads/NC-DWR-Wetland-Science-Team-Work-Website-Intro-2023-for-website.pdf) was published detailing the methodology and key findings from 30 projects over the last two decades. The NC Wetland Program Plan (WPP) (https://www.ncwetlands.org/wp-content/uploads/NC-Wetland-Program-Plan-2021-to-2025-web.pdf) was updated in 2021 by the Division with the support of the Environmental Protection

Agency (EPA) under the Enhancing State and Tribal Programs Initiative. Seven projects were initiated after the initial adoption of the NC Wetland Program Plan in 2015. The Division of Mitigation Services, within NCDEQ, has restored over 30,000 acres of wetlands. The North Carolina Coastal Federation (https://www.nccoast.org/project/north-river-wetlands-preserve/) has overseen the restoration of some 6,000 acres of wetland in Carteret County since 1999 with the support of multiple agencies and civilian volunteers. At the federal level, the United States Department of Agriculture's Wetlands Reserve Program (WRP) (https://www.ncwildlife.org/CURE/Wetlands-Reserve-Program#:~:text=The%20U.S.%20Department%20of%20Agriculture's,eligible%20land%20from%20agricultural%20production.) provides technical and financial assistance to restore wetlands in exchange for retiring private- or Tribal-owned agricultural land. This is a voluntary program with 1.9 million acres currently enrolled.

4.3 Living Shorelines

Living shorelines are a cost-effective approach to help reduce shore erosion by combining natural structures such as rock or oyster bed material with living components like native plants. Living shorelines are the preferred strategy to reduce erosion while protecting waterfront or coastal property. Salt marshes are a major component of living shorelines in the Gulf and the Atlantic. Waterfront parks in coastal areas can be intentionally designed to flood during extreme events, reducing flooding elsewhere. Waterfront parks can also absorb the impact of tidal or storm flooding and improve water quality.

4.3.1 Flood Hazard Targeted

Living shorelines help minimize erosion caused by rising sea levels, boat wave action, and increased storm intensity. They target flooding hazards indirectly by mitigating the effects of flooding events.

4.3.2 Pros and Cons

Table 4-3 Pros and Cons of Living Shorelines

Living Shorelines Pros	Living Shorelines Cons
Attenuate wave action	Site selection may be challenging
Restore and/or protect nursery habitats	It may not be aesthetically pleasing to some
Trap sediment	Short-term costs may be prohibitive
Support food and shellfish production	Newer, less known strategy that may influence resources or stakeholder buy-in
Long-term cost-effectiveness	

4.3.3 Technical Planning

North Carolina has some 12,000 miles of estuarine shoreline, and various governmental and research entities working in cooperation have already developed much technical planning guidance. Weighing Your Options (https://files.nc.gov/ncdeq/Coastal%20Management/coastal-reserve/research/publications/Weighing-your-Options-Final-5x7-11-18-15.pdf) is a planning tool produced by National Oceanic and Atmospheric Agency, NC Division of Coastal Management, and NC Coastal Reserve & National Estuarine Research Reserve, targeted to estuarine property owners and shoreline stabilization strategies. The North Carolina Coastal Federation has overseen the design, construction, and monitoring of living shoreline projects, another valuable resource for this strategy.

Site-specific investigations should be conducted to determine best practices for building and what materials to use. The location and the way the site is situated can affect the effectiveness of a living shoreline, so utilizing the existing research and guidance is required for the desired results.

4.4 Bioretention

A bioretention is a depression or excavated area (i.e., basin) with water-tolerant plants and specialized soils that temporarily capture and treat stormwater runoff and promote infiltration. These are sometimes referred to as rainwater gardens on smaller scales. Stormwater pollution is removed via adsorption, filtration, ion exchange, and biological decomposition. Bioretention basins allow sediment in the runoff to settle, removing particulate matter from the runoff. This stormwater control measure provides many benefits, including peak flow attenuation, water infiltration, and groundwater recharge.

4.4.1 Flood Hazard Targeted

Bioretention basins reduce runoff by capturing rainfall and reducing peak flows during precipitation. They target flood hazards directly.

4.4.2 Pros and Cons

Table 4-4 Pros and Cons of Bioretention

Bioretention Pros	Bioretention Cons
Removes pollutants and contaminants	Relatively frequent trash removal in high-traffic areas
Supports groundwater recharge	Soil layer may clog over time, but can be restored
Reduces flood volume and peak flow	Recurring plant and mulch maintenance
Efficient strategy for small areas	May need more than one bioretention for large drainage areas
Provides landscape benefits	

4.4.3 Technical Planning

Like other flood reduction strategies, a site-specific investigation should be conducted. This strategy's major considerations include physical site constraints and runoff volume. For larger sites with more runoff to treat, multiple, decentralized bioretention units dispersed across the site work best. Bioretention basins require regular maintenance, so technical planning should incorporate the feasibility of standard maintenance procedures (e.g., plant pruning and watering and monitoring erosion control).

NCDEQ's Stormwater Design Manual and Minimum Design Criteria

- https://www.deq.nc.gov/water-quality/surface-water-protection/spu/spu-bmp-manual-documents/bmpman-ch12-bioretention-20090724-dwq-spu/download

5 Planning & Policy

In addition to the physical solutions discussed above (i.e., infrastructure- and nature-based), operational solutions, those derived from planning and policy initiatives, contribute to a comprehensive strategy for flood resiliency. This section introduces potential pathways to integrate structural and operational flood mitigation strategies into existing planning and policy initiatives. Instead of providing an in-depth discussion of select plans and policies, an abridged list of flood mitigation strategy components that should be considered and/or incorporated is provided. Effective planning is the first step in addressing flood hazards and should be coordinated across planning efforts, planning teams, and organizations with geographic or topic consistencies.

5.1 Flood Hazard Included in Community Comprehensive Plan

A Comprehensive Plan is a long-term document approved by a city council or similar entity to drive the overall vision and direction of the municipality. Ensuring the Comprehensive Plan is comprehensive in flood hazard considerations and cross-references the Hazard Mitigation Plan is important. During development, the involvement of local government personnel, such as emergency response, the floodplain manager, and the Department of Public Works, is key to a comprehensive and actionable plan moving forward. A floodplain management plan, updated regularly, that avoids, discourages, or disallows building in or near the floodplain is a cost-effective way to comprehensively increase community flood resiliency. Lastly, flood hazard mitigation strategies should be identified during development planning. If construction is to occur in flood- or erosion-prone areas, identify, for example, what risks extending a road or utilities might present during a flood.

5.2 Local Hazard Mitigation Plan Approved by FEMA and NC Emergency Management Agency

- Cross-reference Hazard Mitigation Plans with Community Comprehensive Plan
- Local government (planning/zoning) involvement in developing /updating a comprehensive plan
- Involvement in Hazard Mitigation Plan from local businesses, schools, hospitals/medical facilities, agricultural landowners, and others who could be affected by floods
- Involvement from other local governments within the same watershed for coordination of responses and strategies
- Non-structural pre-disaster mitigation measures emphasized, such as acquiring flood-prone lands and adopting No Adverse Impact floodplain regulations
- Encouragement of green infrastructure techniques into the plan to help prevent flooding
- Identification of projects that could be included in pre-disaster grant applications and expediting the application process for post-disaster Hazard Mitigation Grant Program projects

5.3 Form Partnerships to Support Floodplain Management

- Developing a stormwater committee that meets regularly to discuss issues and recommend projects
- Forming a regional watershed council to help bring together resources for comprehensive analysis, planning, decision-making, and cooperation
- Establishing watershed-based planning initiatives to address the flood hazard with neighboring jurisdictions
- Forming a citizen plan implementation steering committee to monitor progress on local mitigation actions. Include a mix of representatives from neighborhoods, local businesses, and local government

5.4 Planning Across Disciplines

Hazard Mitigation Planning – Community hazard mitigation activities are typically guided by a Hazard Mitigation Plan (HMP), updated on a five-year cycle. The HMP identifies specific risk reduction projects as mitigation actions. Each action is linked to a plan that describes how and when the project will be completed. A Steering Committee typically leads the development of the HMP. The committee often includes planners, emergency managers, and other local officials.

Transportation Planning - The Transportation Element of the local Comprehensive Plan, the regional Long-Range Transportation Plan, and the Transportation Improvement Program typically guide transportation planning. These plans set goals for a community's transportation system over the next 20 to 30 years. They also identify strategies and projects to support these goals. The plans provide the basis for local codes related to transportation and for local investments in transportation infrastructure.

Open Space Planning - Open Space and Recreation Element of a community's Comprehensive Plan typically guides open space planning. This element establishes a policy framework and action program. These are used for maintaining, improving, and expanding the community's open spaces and recreational facilities.

Stormwater Master Planning - There are many sources for Stormwater Master Planning. One such reference is the Draft "Community Solutions for Stormwater Management" by the EPA that outlines concepts guiding smart infrastructure investments and components of a long-term stormwater plan to use as a guide for laying out a path forward to cost-effective, sustainable, and comprehensive solutions to managing and mitigating flooding issues as well as addressing water quality goals. An important component of a Stormwater Master Plan is incorporating opportunities for Green Infrastructure and flooding protection through nature-based systems.

Wetland Protection - Wetlands provide many functions, including flood mitigation. Regulatory protection results from federal, state, tribal, or local laws and regulations and limits and mitigates impacts to existing wetlands. In some states, wetlands are not protected by federal regulations but rely on a community's voluntary protection, while other communities and states have regulations that provide protection and mitigation. Both play a vital role in maintaining existing wetlands and their functions, including flood mitigation.

5.5 Land Development Regulations

Land development regulations are operational solutions that aim to reduce flood hazards by limiting the extent and location of development. These regulations also focus on flood mitigation via stormwater and drainage control methods and standards. This section briefly introduces regulations, standards, and policies utilized by various communities to limit their flood hazard risk and costs to mitigate increases in impervious surfaces.

Development near Floodplain Areas:

- Prohibiting or limiting floodplain development through regulatory and/or incentive-based measures.
- Limiting the density of developments in the floodplain.
- Requiring that floodplains be kept as open space.
- Limiting the percentage of allowable impervious surfaces within developed parcels.
- Developing a stream buffer ordinance to protect water resources and limit flood impacts.
- Prohibiting any fill-in floodplain areas or establishing regulated floodways.

Adopt and Enforce Building Codes and Development Standards:

- Adopting the International Building Code and International Residential Code.
- Adopting ASCE 24-05 Flood-Resistant Design and Construction. ASCE 24 is a standard referenced in the International Building Code that specifies minimum requirements and expected performance for the design and construction of buildings and structures in flood hazard areas to make them more resistant to flood loads and damage.
- Adding or increasing “freeboard” requirements (feet above base flood elevation) in the flood damage ordinance.
- Prohibiting all first-floor enclosures below base flood elevation for all structures in flood hazard areas.
- Considering new development orientation during design (e.g., subdivisions, buildings, infrastructure, etc.).
- Setting the design flood elevation at or above the historical high-water mark if it is above the mapped base flood elevation.
- Subdivision design standards are used to require elevation data collection during platting and to have buildable space on lots above the base flood elevation included in the plat.
- Requiring standard tie-downs of propane tanks.

Adopt Policies to Reduce Stormwater Runoff:

- Designing a “natural runoff”/ “zero discharge” policy for stormwater in subdivision design.
- Requiring more trees be preserved and planted in landscape designs to reduce the amount of stormwater runoff.

- Requiring developers to plan for on-site sediment retention.
- Encouraging porous pavement, vegetative buffers, and islands in large parking areas.
- Conforming pavement to land contours to not provide more accessible avenues for stormwater.
- Encouraging permeable driveways and surfaces to reduce runoff and increase groundwater recharge.
- Adopting erosion and sedimentation control regulations for construction and farming.

Stormwater Management Regulations for Land Development Projects:

- Regulating development in upland areas to reduce stormwater run-off through a stormwater ordinance.
- Developing engineering guidelines for drainage from new development.
- Requiring a drainage study with new development.
- Encouraging Low Impact Development techniques (see also Natural Systems Protection, Land-Use Planning).
- Requiring developers to construct on-site retention/detention basins for excessive stormwater and as a firefighting water source.
- Require effective stormwater quantity management - Ensure that upstream developments, remote from the floodplain or adjacent to it, mitigate the stormwater runoff impacts of their development downstream to the point that the impacts are insignificant.
- Incorporate Nature-Based Solutions into Land Development Stormwater Management practices (See Natural Systems Protection section).

Federal Flood Risk Management Standard:

- Note that the Federal Flood Risk Management Standard requires agencies to select one of three approaches for establishing the flood elevation and corresponding flood hazard area for constructing federally funded buildings and projects. The three approaches are the Climate Informed Science Approach, Freeboard Value Approach, or 500-year floodplain.

6 Programmatic Best Management Practices

Like planning and policy, programmatic best management practices are operational solutions. This section discusses specific practices and strategies that may be incorporated into broader planning and policy initiatives.

6.1 Land Use Strategies

- **Planning and regulatory floodplains** - Communities can adopt two floodplain definitions. The full built-out floodplain is used for the location and elevation of new construction, while the current condition FEMA maps are used for the Federal flood insurance program.
- **Use built-out floodplains for regulation—**Regulate new development based on full built-out floodplains based on a master plan, even if FEMA's regulatory maps have recently been updated.
- **Land use limitations** – Limit the types of land uses allowable in the floodplain to those necessary uses that are functionally dependent on being close to the water and those that would not be substantially damaged by flooding. Use the master plan and GIS capability to influence rezoning decisions before approval.
- **Provide incentives for staying out of the floodplain** – Develop the ability to make the dedication of floodplain areas attractive to developers through transferable development rights, tax credits for conservation designs, partnering with developers to establish greenways along streams, or other approaches.

6.2 Strategies to Reduce Damage Due to Flooding

- **Implement a comprehensive floodproofing program** – As stated in section 2.3 of this document, floodproofing can effectively reduce damages. However, limitations related to the NFIP restriction of dry floodproofing to non-residential/mixed-use structures and the fact that while wet floodproofing reduces damages from a flood, the strategy does not reduce flood risk. To this effect, in alignment with the stated purpose of the Blueprint, which is to…
    - Reduce the likelihood and extent of flooding
    - Reduce the vulnerability and impact of flooding
    - Increase community ability to maintain and quickly resume pre-storm activities,

  it is recommended that the Blueprint seek to reduce the damage to local nonresidential structures located in the present floodplain through a combined capital improvement program, floodproofing, voluntary and attractive property acquisition, and education and warning (as appropriate). Further, a cost-shared floodproofing program should be developed for nonresidential structures that experience only shallow flooding, and an elevation program should be developed for residential structures.
- **Enhanced first-floor elevation requirements –** Implement a requirement to raise the lowest floor of all structures in a floodplain one foot (or more) above the full built-out 100-year flood elevation.

- **Maximize floodplain flow capacity**—Prioritize minimizing floodplain infill and enhancing and maintaining the conveyance of streams in flood prone areas.
- **Develop a flooding mitigation plan** – Develop a during- and post-flood mitigation and assistance plan that protects citizens from the risk of driving or falling into floodwaters (e.g., traffic barricades in place well ahead of deep-water conditions). The plan should seek to eliminate repetitive loss properties and floodproof those damaged by flooding. This planning process could be included with existing planning efforts. Several options, such as hazard mitigation plans, Municipal planning endeavors, and regional plans, are already required.

6.3 Strategies to Preserve and Restore Open Space and Natural Features

- **Extension of floodplain management to smaller streams** - Extend the floodplain program to feeder streams and areas above the study limit of mapped areas and consider downstream flood elevations on all streams not mapped.
- **Flood prone property and land acquisition** – Acquire flood prone properties, perhaps as part of a community open space or greenway program, and construct open space parks in their place.
- **New construction floodplain dedication**—Incentivize developers to dedicate floodplains and buffers for flood protection, pollution reduction, and multi-objective riparian corridor recreation.
- **Innovative density trading away from flood prone areas** – Provide the ability and incentive to dedicate floodplain areas while retaining the ability to construct the same number of homes on a tract of land without dedication. This is often integrated with a community greenway program or other riparian buffer requirements.

6.4 Strategies to Use Technology for Better Information Management Support

- **Downstream impact assessment** – Implement a mandatory requirement to assess and mitigate the impacts of proposed new developments downstream to a point where the impact is negligible. Mitigation can include the purchase of a flood easement, on-site controls, system improvements, etc. This might also include developing watershed master plans to solve floodplain problems and avoid exacerbating problems. An upstream assessment may be necessary and considered as well.
- **Comprehensive FEMA map maintenance** – Mandate the property owner get formal approval from FEMA if the floodplain is altered in any manner by development (FEMA Letter of Map Change), or a mandatory requirement for modeling the impacts from the cumulative loss of floodplain storage due to current and proposed developments along all streams. Other requirements could be mapping the estimated full built-out floodplain and/or no flood elevation increase (No Rise/No Impact Certification) of all developments in and around the floodplain.
- **Online GIS and models** – Implement the use of GIS and online models in assessing new developments as they are proposed and before re-zoning request approvals. The city or county

would work with the developer to produce an alternative that reduces impacts and preserves floodplain areas while maintaining economic viability.
- **Make floodplain maps accessible** – The community's most current floodplain boundaries are available online. Identify persons in the floodplain and notify them of the availability and advisability of flood insurance.

6.5 Improve Stormwater Management Planning

Stormwater management programs typically aim to reduce water pollution, preserve aquatic ecosystems, and protect the public from stormwater flooding. Many must also comply with federal and state stormwater management regulations. These regulations reduce pollutant discharges from Municipal Separate Storm Sewer Systems and Combined Sewer Overflow. Communities with Municipal Separate Storm Sewer Systems typically base their program on a Stormwater Management Program Plan. Those with Combined Sewer Overflows typically use a local Long-Term Control Plan. Various local programs, ordinances, and development procedures carry out these plans. Best management practices for improving stormwater management planning include:

- Completing a stormwater drainage study for known problem areas.
- Preparing and adopting a stormwater drainage plan and ordinance.
- Preparing and adopting a community-wide stormwater management master plan.
- Linking flood hazard mitigation objectives with EPA Stormwater Phase II initiatives.
- Incorporate Nature-Based Solutions into Stormwater Management practices (See Natural Systems Protection section).

6.6 Improve Flood Risk Assessment

The following are complimentary or an expansion of some of the strategies discussed in 5.4 above.

- Incorporating the procedures for tracking high water marks following a flood into emergency response plans.
- Conducting cumulative impact analyses for multiple development projects within the same watershed.
- Conducting a verification study of FEMA's repetitive loss inventory and developing an associated tracking database.
- Regularly calculating and documenting the amount of flood-prone property preserved as open space.
- Requiring a thorough watershed analysis for all proposed dam or reservoir projects
- Developing a dam failure study and emergency action plan.
- Using GIS to map areas that are at risk of flooding,
- Obtaining depth grid data and using it to illustrate flood risk to citizens.
- Incorporating digital floodplain and topographic data into GIS systems in conjunction with hazards to assess risk.
- Developing and maintaining a database to track community exposure to flood risk.

- Revising and updating regulatory floodplain maps.

6.7 Join or Improve Compliance with the National Flood Insurance Program (NFIP)

- Participating in NFIP.
- Conducting NFIP community workshops to provide information and incentives for property owners to acquire flood insurance.
- Designating a local floodplain manager and/or CRS coordinator who achieves Certified Floodplain Manager certification.
- Completing and maintaining FEMA elevation certificates for pre- and/or post-FIRM buildings.
- Requiring and maintaining FEMA elevation certificates for all new and improved buildings located in floodplains.

6.8 Manage the Floodplain Beyond Minimum Requirements

- Incorporating the Association of State Floodplain Manager's "No Adverse Impact" policy into local floodplain management programs.
- Revising the floodplain ordinance to incorporate cumulative substantial damage requirements.
- Adopting a "no-rise" in base flood elevation clause for the flood damage prevention ordinance.
- Extending the freeboard requirement past the mapped floodplain to include an equivalent land elevation.
- Including requirements in the local floodplain ordinance for homeowners to sign non-conversion agreements for areas below base flood elevation.
- Establishing and publicizing a user-friendly, publicly accessible repository for inquirers to obtain Flood Insurance Rate Maps.
- Developing an educational flyer for NFIP policyholders on the increased cost of compliance during post-flood damage assessments.
- Annually notifying the owners of repetitive loss properties of Flood Mitigation Assistance funding.
- Offering incentives for building above the required freeboard minimum (code plus).

6.9 Participate in the Community Rating System (CRS)

Potential activities that are eligible to receive credit include:

- Advising the public about the local flood hazard, flood insurance, and flood protection measures.
- Enacting and enforcing regulations that exceed NFIP minimum standards so that more flood protection is provided for new development.
- Implementing damage reduction measures for existing buildings such as acquisition, relocation, retrofitting, and maintenance of drainageways and retention basins.
- Taking action to minimize the effects of flooding on people, property, and building contents through flood warnings, emergency response, and evacuation planning.

6.10 Establish Local Funding Mechanisms for Flood Mitigation

- Using taxes to support a regulatory system.
- Using impact fees to help fund public projects to mitigate impacts of land development (e.g., increased runoff).
- Levying taxes to finance maintenance of drainage systems and capital improvements.
- Establishing or expanding a stormwater utility fee based on impervious area, a combination of gross area and density of development, or some other methodology that links the fee with the contribution to the problem.
- General obligation, revenue, or other bond funding strategies to fund mitigation projects.

6.11 Increase Awareness of Flood Risk and Safety

- Encouraging homeowners to purchase flood insurance.
- Annually distributing flood protection safety pamphlets or brochures to flood-prone property owners.
- Educating citizens about safety during flood conditions, including the dangers of driving on flooded roads.
- Using outreach programs to advise homeowners of life, health, and safety risks.
- Offering GIS hazard mapping online for residents and design professionals.
- Establishing a Program for Public Information with a committee (as suggested by Activity 332 of the CRS Coordinator's Manual).

6.12 Educate Property Owners about Flood Mitigation Techniques

- Using outreach activities to facilitate technical assistance programs that address measures citizens can take or facilitate funding for mitigation measures.
- Encouraging homeowners to install backflow valves to prevent reverse-flow flood damages.
- Encouraging residents in flood-prone areas to elevate homes.
- Educating the public about securing debris, propane tanks, yard items, or stored objects that may otherwise be swept away, damaged, or hazardous if picked up and washed away by floodwaters.
- Asking residents to help keep storm drains clear of debris during storms (not to rely solely on Public Works).