LOUISIANA
WATERSHED
INITIATIVE

NATURE-BASED SOLUTIONS

FOR FLOOD RISK MANAGEMENT

AN INFORMATION GUIDE

APRIL 2022

Cover: Mollicy Farms floodplain restoration in Upper Ouachita National Wildlife Refuge.
Above: Green infrastructure at Maumus Center, St. Bernard Parish.

Image source by page:

i https://www.nature.org/en-us/about-us/where-we-work/united-states/louisiana/stories-in-louisiana/largest-floodplain-restoration-in-mississippi-river-basin/
ii https://www.danabrownassociates.com/maumus-center/
2 https://www.gulfspillrestoration.noaa.gov/2022/02/work-begins-texas-mcfaddin-beach-final-phase-salt-bayou-watershed-restoration
4 top images: https://www.epa.gov/sites/default/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf
6 https://coastal.la.gov/news/caminada-back-barrier-marsh-creation/
7 https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf
10 USDA *Louisiana Conservation Update* April, 2021.
14 https://www.gulfspillrestoration.noaa.gov/project?id=262
16 https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf
19 top images: https://www.crcl.org/habitat-restoration; right side images: https://www.louisiananativeseed.com/
22 https://www.biohabitats.com/wp-content/uploads/CypressCreekHouston-2.pdf
25 https://www.lmrcc.org/our-work/projects/restoring-americas-greatest-river-initiative/richard-k-yancey-blackhawk-scar-lakes-ecosystem-restoration-and-monitoring-project/
26 https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program

Table of Contents

Glossary of Terms

TERM	DEFINITION SPECIFIC TO THIS DOCUMENT
Carbon sequestration	The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape.
Cumulative effects	Changes to the environment caused by the combined effect (positive or negative) of past, present and future human activities and natural processes.
Flood attenuation	The reduction in peak discharge of a flood by temporary storage of water or the slowing of channel flows.
Surge and wave attenuation	The reduction in peak water levels and wave heights associated with the dissipation of energy by wetland vegetation or dunes.
Flood storage	The holding of floodwaters during a flood which are then gradually released into the drainage system.
Floodplain	Any land area susceptible to being inundated by floodwaters from any source.
Groundwater recharge	Downward movement of water from the surface to subsurface aquifers.
Habitat enhancement	Changing the physical, chemical or biological characteristics of a site with the goal of improving one or more aspects of its habitat function.
Habitat restoration	Changing the physical, chemical or biological characteristics of a site with the goal of returning the majority of natural functions to the lost or degraded native habitat.
Open space	Lands where there are no buildings, storage, fill, significant pavement or other encroachments to flood flows.
Pollution abatement	A reduction in pollution or its impact on the environment.
Riparian	The land area adjacent to the bank of a river or stream.
Stormwater management	Actions that reduce peak flows or total runoff from precipitation events.
Streamflow regulation	Modulation of fluctuations in river flow by temporary (managed or natural) storage.
Urban heat island	Urbanized areas that experience higher temperatures than outlying areas.
Water quality	The suitability of water for a particular use based on selected physical, chemical, and biological characteristics.
Watershed	An area of land that drains all streams and rainfall to a common outlet, such as the outflow of a reservoir, mouth of a river or any point along a stream channel.
Wetland	Areas where water covers the soil or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season.
Working lands	Lands used for farming, grazing or the production of forest.

Acronyms and Abbreviations

ADCIRC	ADvanced CIRCulation Model
AGWA	Automated Geospatial Watershed Assessment
BMP	Best Management Practice
BRIC	Building Resilient Infrastructure and Communities
CDBG	Community Development Block Grant
CLASIC	Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs
CPRA	Coastal Protection and Restoration Authority
DNR	Department of Natural Resources
ELOHA	Ecological Limits of Hydrologic Alteration
FEMA	Federal Emergency Management Agency
HEC	Hydrologic Engineering Center
HUD	Housing and Urban Development
INVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
LDAF	Louisiana Department of Agriculture and Forestry
LWI	Louisiana Watershed Initiative
NBS	Nature Based Solutions
NFWF	National Fish and Wildlife Foundation
NRCS	Natural Resources Conservation Service
STWAVE	STeady State Spectral WAVE
TNC	The Nature Conservancy
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VELMA	Visualizing Ecosystem Land Management Assessments

1 INTRODUCTION

The McFaddin Beach and Dune Restoration project restores beach and dune habitat in Jefferson and Chambers counties, Texas.

Why Use Nature-Based Solutions?

Wide-Ranging Benefits

Nature-based solutions, or NBS, are **sustainable planning, design, environmental management and engineering practices that weave natural features or processes into the built environment** to create more resilient communities.[1] NBS can be applied in rural and urban areas and can be compatible with many existing land uses to assist with flood risk management and achieve environmental benefits.

For example, floodplain and stream restoration reestablish the structure and function of ecosystems and floodplains, providing added benefits and services to surrounding communities by increasing floodwater storage and regulating stormwater runoff. Restoration of adversely impacted, flood-prone river systems is accomplished by restoring floodplains and associated wetlands through connectivity and storage—as well as by modifying the physical stability, hydrology, and biological functions of the impaired riverbanks to that of a natural, stable river with periodic overbank flow. Benefits go beyond flood risk management and environmental improvement and include aesthetics, educational opportunities, recreation and quality of life for surrounding communities.

Natural Systems Can Save Money While Supporting Resilience

The Louisiana Watershed Initiative (LWI) seeks to leverage the state's vast network of natural ecosystems to protect communities and enhance statewide resilience to floods and other hazards. And while NBS such as these can often be more cost effective than traditional approaches to mitigation, relatively few flood risk management programs specifically address the beneficial functions of natural environmental features and processes. There may be a variety of reasons for this, including mandates of federal programs, lack of awareness, and/or lack of experience among agency staff. FEMA's recent Building Resilient Infrastructure and Communities (BRIC) program encourages NBS, and this may signal a shift in federal program priorities. The LWI aims to increase awareness and prioritize NBS through state-funded and state-administered programs.

Nature-based solutions use existing and restored natural functions of the environment to mitigate flood risk as well as provide ecological and societal benefits such as water quality restoration and habitat enhancement.

1 https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf

NATURE-BASED SOLUTIONS FEATURED IN THIS GUIDE

NBS	DESCRIPTION
NBS for watershed and inland applications	
Floodplain Restoration and Preservation	Measures that reconnect floodplains and river channels, allowing overbank flow during floods, enhance the retention of floodwaters on floodplains and/or preserve existing floodplains to retain their flood storage function.
Natural Channel Design	Applies the principles of stream geomorphology to maintain a state of dynamic equilibrium among water, sediment and vegetation that creates a stable channel connected to a floodplain.
Wetland, Prairie, Forest Restoration and Enhancement	The rehabilitation of degraded natural lands including wetlands, prairies and forests or the reestablishment of land cover so that soils, hydrology, vegetative community and habitat are a close approximation of the original natural condition that existed prior to modification.
Detention Basins*	An area that has been excavated so that during storms, excess water can be held, helping prevent runoff. They are designed to dry out between flood events.
Retention Basins*	An artificial pond with vegetation around the perimeter and a permanent pool of water with additional capacity for use during floods. Sometimes called a wet pond, wet detention basin or stormwater management pond.
Infiltration Basins*	Similar to a retention basin, but designed to direct stormwater to groundwater through permeable soils.
Riparian Vegetation Restoration	Planting or enhancement of riparian vegetation to reduce erodibility of channel banks, stabilize channels and attenuate flood flows.
Green Infrastructure	A range of measures that use plant or soil systems; permeable pavement or other permeable surfaces or substrates; stormwater harvest and reuse; landscaping or rewilding to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters. Includes greenways, rain gardens, tree trenches, bioswales and green roofs.
Management of Working Lands	Adjustments in agriculture, forestry or other land management practices to improve infiltration and evapotranspiration, and/or hold water in the landscape. May include use of small stone/ earthen weirs in ephemeral channels or gullies to reduce runoff, planting native vegetation and maintaining riparian buffers.
Environmental Flows	Management of reservoir releases to maintain or enhance benefits to the ecosystem while supporting flood risk management.
NBS for coastal applications	
Wetland Restoration and Enhancement	Measures that contribute to the restoration and/or sustainability of coastal wetland landscapes including hydrologic restoration, marsh creation or river diversions.
Coastal Dune Restoration	Restoration of coastal sand dunes to provide a natural physical barrier that reduces inundation and wave impacts to the coast landward of the dune.

* Note that these basins can be specifically designed to be NBS but this may not always be appropriate.

Left: Detention and infiltration of stormwater within Elmwood Park in Omaha, Nebraska. Right: Cyclist riding the Indianapolis Cultural Trail alongside stormwater planters in Indianapolis, Indiana.

Using This Guide

The purpose of this guide is to provide a base level of information on NBS and its potential application in Louisiana to support flood risk management. It is designed to engage staff from LWI and other state agencies as well as regional stakeholders and those interested in the application of natural approaches to flood risk management. The information is high-level. More detailed site-specific information will be required to identify the most appropriate use and implementation of NBS on the ground.

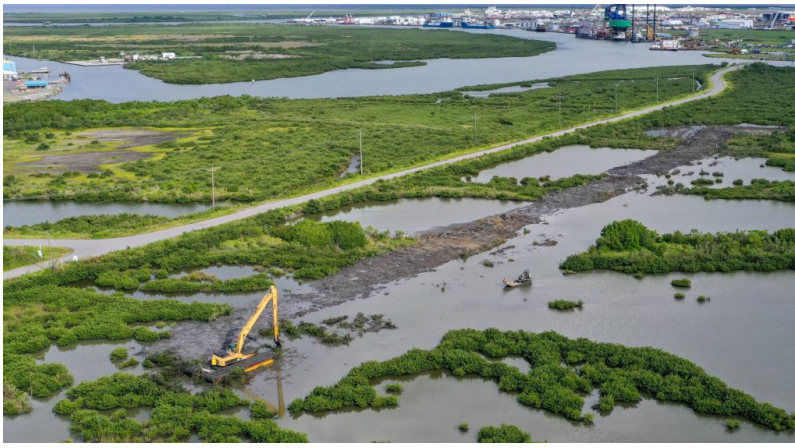
2. **Selecting an NBS** provides tables to help those interested in flood risk management and other additional environmental benefits identify NBS suitable for their needs.
3. **Implementing NBS** lists some of the advantages of different NBS relative to traditional flood risk management, outlines some of the challenges to NBS implementation, and addresses scalability for flood risk management.
4. **Synergies Between NBS** outlines some of the potential synergies across types of NBS showing how they can be used together in watersheds and across the coast.
5. **Tools and Resources** includes evaluation and design resources as well as sources for Louisiana native plants.
6. **Case Studies** includes links to case studies, many of them in Louisiana or adjacent states.
7. **Funding Nature Based Solutions** includes links to potential funding sources for NBS projects.
8. **Appendix** includes a summary sheet for each NBS that compiles the information provided elsewhere in the guide.

2 SELECTING NATURE-BASED SOLUTIONS

Selection Based on Flood Risk Management Considerations

When selecting an NBS for flood risk management, it is necessary to understand how it will influence flooding. For many NBS, there are primary ways in which they contribute to flood risk management strategies, while other effects may be secondary or require specific types of NBS design.

Use this table to detemine which NBS will contribute to the desired flood risk managment approach—and whether it is a **primary**, **secondary** or **additional effect**.



Restored intertidal marsh behind Caminada Headland in Lafourche Parish.

Primary effect

Secondary effect

Additional effect

Approaches to Flood Risk Management

Nature-Based Solution	FLOOD STORAGE	STORMWATER MANAGEMENT	GROUNDWATER RECHARGE	IMPROVED RIVER/ FLOODPLAIN CAPACITY AND STORAGE	FLOOD ATTENUATION	BARRIER TO FLOODWATERS	SURGE AND WAVE ATTENUATION
NBS for watershed and inland applications							
Floodplain Restoration and Preservation	Primary		Secondary				
Natural Channel Design				Secondary	Primary		
Wetland, Prairie, Forest Restoration and Enhancement	Primary		Secondary				
Detention Basins	Primary				Secondary		
Retention Basins	Primary				Secondary		
Infiltration Basins	Primary		Secondary				
Riparian Vegetation Restoration					Primary		
Green Infrastructure		Primary	Additional		Secondary		
Management of Working Lands			Secondary		Primary		
Environmental Flows	Primary				Secondary		
NBS for coastal applications							
Wetland Restoration and Enhancement							Primary
Coastal Dune Restoration						Primary	Secondary

Selection Based on Additional Beneficial Outcomes

Additional benefits, beyond flood risk management, to the environment and society (sometimes termed *ecosystem services)* are an important aspect of incorporating NBS into watershed and coastal flood risk management strategy and will vary according to the site and specific designs.

Use this table to detemine what additional beneficial outcomes are associated with each NBS—and whether it is a **primary**, **secondary** or **other additional benefit.**

Rain garden at City Hall in Bay Village, Ohio.

Primary benefit

Secondary benefit

Other additional benefit

Overarching Beneficial Outcomes

Nature Based Solution	HABITAT RESTORATION OR ENHANCEMENT	IMPROVED WATER QUALITY	CARBON SEQUESTRATION	RECREATION	OPEN SPACE	URBAN HEAT ISLAND + AIR QUALITY IMPROVEMENTS	STREAM FLOW REGULATION
NBS for watershed and inland applications							
Floodplain Restoration and Preservation	Primary	Secondary	Other	Other	Other		Other
Natural Channel Design	Primary	Secondary					
Wetland, Prairie, Forest Restoration and Enhancement	Primary	Secondary	Other	Other	Other		
Detention Basins	Secondary	Other	Other	Other	Primary		
Retention Basins	Secondary	Primary		Other			
Infiltration Basins	Secondary	Primary		Other			
Riparian Vegetation Restoration	Primary	Other	Secondary				
Green Infrastructure			Other	Other	Primary	Secondary	
Management of Working Lands	Primary	Secondary	Other				
Environmental Flows	Primary	Secondary					
NBS for coastal applications							
Wetland Restoration and Enhancement	Primary	Secondary	Other	Other			
Coastal Dune Restoration	Primary						

3 IMPLEMENTING NATURE-BASED SOLUTIONS

Implementation Tradeoffs

When selecting and implementing NBS for flood risk management, it is important to understand their varying advantages and challenges. For instance, while the provision of environmental benefits may be seen as the primary advantage of NBS versus traditional flood risk management approaches, there may also be other advantages such as the ability to incrementally implement and achieve benefits instead of waiting for the completion of an entire levee system to reduce flooding. There are also barriers to implementation, mostly associated with lack of experience or knowledge and questions about reliability. Further, while all NBS can contribute to flood risk management, whether benefits are achieved only locally or at a watershed scale depends on the ability of some NBS to be applied at large scale.

The table below outlines the potential advantages and limitations for each NBS.

NBS creating habitat for migratory shorebirds and waterfowl in Vermilion Parish.

ADVANTAGES VS. CHALLENGES

NBS	ADVANTAGES	BARRIERS + CHALLENGES	SCALABILITY
NBS for watershed and inland applications			
Floodplain Restoration and Preservation	• Low maintenance. • Passive operation.	• Restoring floodplain connectivity is necessary for flood risk reduction benefit. • Limited experience, capacity and expertise at the local level. • Habitat restoration as flood mitigation is not well understood or practiced. • Lack of state and local expertise, capacity and availability of technical resources. • Invasive species management. • Private lands may require acquisition or incentives.	Individual projects planned at scale can have watershed effects.
Natural Channel Design	• Low maintenance (once vegetation is established). • Passive operation.	• Incorporating the full array of ecosystem benefits into cost-effectiveness calculations can be difficult. • Societal expectations that natural channels must be altered by clearing, snagging, dredging or channelization to maximize their flood risk benefits are at odds with scientific understanding of rivers as dynamic, spatially heterogeneous, nonlinear ecosystems. • Lack of state and local expertise, capacity and availability of technical resources.	Cumulative effects require coordinated planning.
Wetland, Prairie, Forest Restoration and Enhancement	• Proven approach if hydrologic conditions are favorable and design is site appropriate.	• Invasive species management. • In some cases, original hydrologic factors that created the wetland's timing, duration, and depth of water no longer exist. • Enhancement of existing wetlands to provide specific functions, e.g., flood storage, depends on local conditions and adjacent land uses.	Cumulative effects require coordinated planning.

NBS	ADVANTAGES	BARRIERS + CHALLENGES	SCALABILITY
Detention, Retention and Infiltration Basins	• Proven approaches if hydrologic conditions are favorable and design is site appropriate.	• Large space requirement. • For detention and retention need to ensure drainage in areas with low slopes/high groundwater and ensure receiving channels can accommodate drainage flows without adverse consequences. • Potential for mosquitos in retention and infiltration basins.	Cumulative effects require coordinated planning.
Riparian Vegetation Restoration	• Low maintenance, once vegetation is established. • Passive operation.	• Contribution to flood risk reduction may be marginal unless revegetation is extensive. • Susceptible to disease, fire, and other hazards.	Small-scale application with potential for cumulative effects at watershed scale.
Green Infrastructure	• Can be applied incrementally, often at parcel scale. • Contributions can be made on public or private land. • Aesthetically pleasing.	• Knowledge and capacity of state and local professionals regarding the proper design and integration of green infrastructure concepts into traditional project scoping. • Lack of GI standards and limited technical resources. • Perception of higher costs. • Perception that performance is unknown. • Unfamiliarity with maintenance requirements and costs. • Conflicting codes and ordinances.	Small-scale application with potential for cumulative effects at watershed scale.
Management of Working Lands	• Can be applied incrementally. • Contributions can be made by private landowners and on state managed lands.	• Knowledge and capacity of state and local professionals regarding appropriate integration of flood/NBS-friendly landscape management practices. • Perception that performance is unknown. • Unfamiliarity with potential approaches and tradeoffs with existing land management goals.	Small-scale application with potential for cumulative effects at watershed scale.
Environmental Flows	• Additional ecosystem restoration and enhancement benefits *vs.* traditional reservoir operations.	• Balancing multiple uses of reservoir, especially during floods and droughts can be difficult. • Unfamiliarity of reservoir managers/operators with potential benefits. • Complex tradeoffs among water uses, e.g., M&I water supply, irrigation, ecosystem, and flood risk management. • Inability to predict the amount and timing of releases relative to multiple uses.	Individual projects planned at scale can have watershed effects.
NBS for coastal applications			
Wetland Restoration and Enhancement	• Low maintenance. • Passive operation. • Extensive Louisiana experience.	• Effectiveness for coastal storm risk reduction is highly dependent on location and extent of the wetlands and the character—intensity, track, speed of forward movement—of the storm.	Individual projects planned at scale can have watershed effects.
Coastal Dune Restoration	• Beaches and dunes together dissipate waves and prevent overtopping. • Ability to build vertically and recover from storm damage.	• Less robust than traditional measures such as seawalls; subject to damage during storms with potential loss of flood protection function. • Requires maintenance and availability of appropriate cost-effective sand sources.	Individual projects planned at scale can have watershed effects.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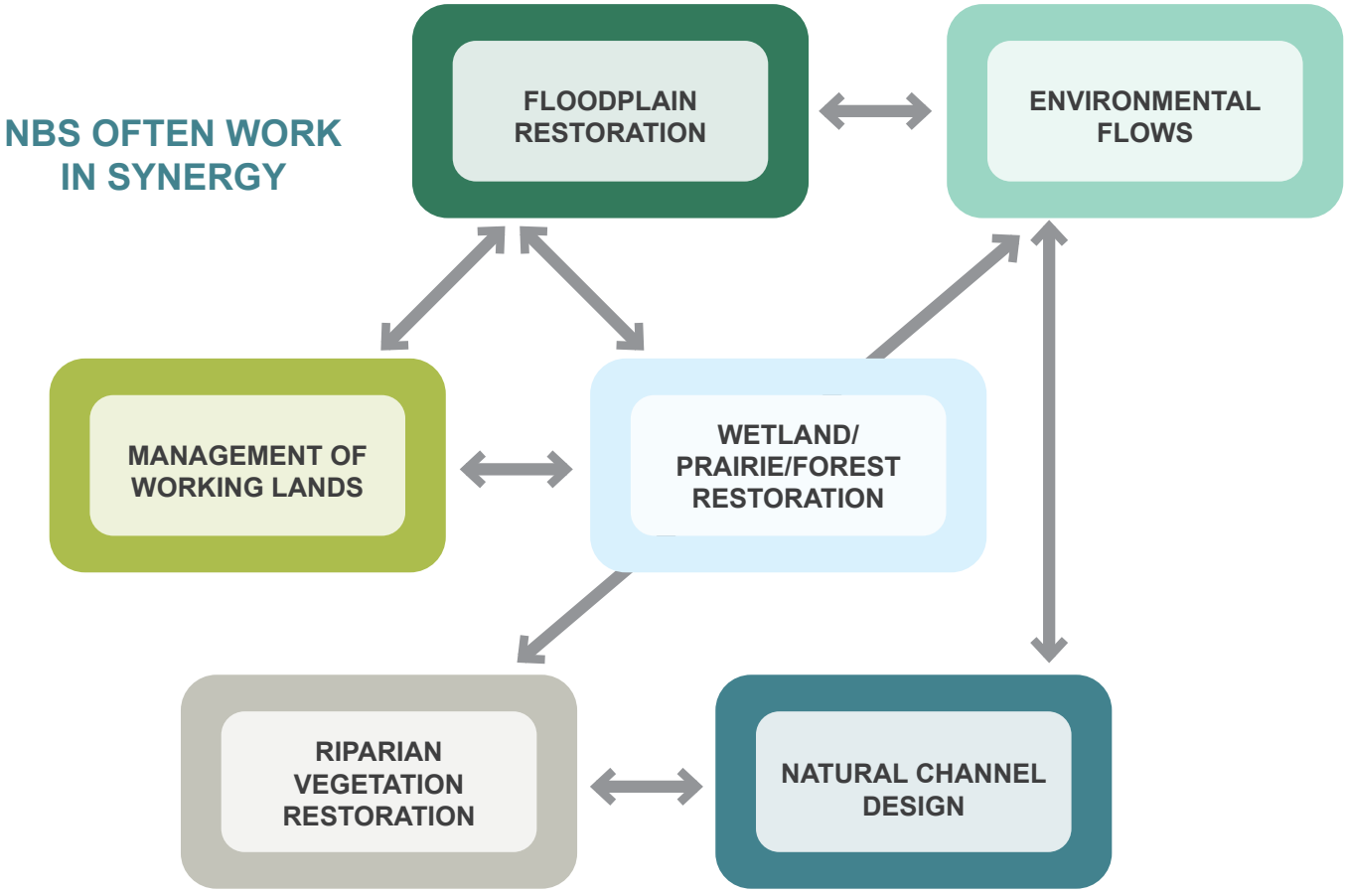
4 SYNERGIES BETWEEN NATURE-BASED SOLUTIONS

Using NBS Together

Thus far, this guide has considered each NBS as a separate approach, but there is great potential for synergy among many of them. Coastal areas, wetlands, beaches and dunes are often part of an integrated system. Similarly, natural environments in watersheds include floodplains and riparian vegetation—and in implementing a watershed approach to flood risk management these NBS can and should be used together, along with traditional flood management approaches, to generate benefits.

The diagram below identifies some potential synergies among NBS for watersheds.

Wetland and habitat restoration of the Mississippi River Bird's Foot Delta.



Note: Green Infrastructure is not included as it encompasses a suite of approaches for urban areas that can be designed synergistically to achieve multiple flood risk management and environmental benefits. Detention, retention and infiltration basins are also not included. These may be locally designed and implemented to include additional NBS elements. The potential for synergy is dependent on local conditions.

5 TOOLS AND RESOURCES

Managed dune restoration on Long Beach Island, New Jersey.

Increased attention to the role of NBS has led to the development of a variety of tools and resources that can be used to evaluate their effectiveness—both for flood risk management and in achieving other benefits—and support their design. In Louisiana, it is also important that NBS featuring vegetation use native plants and a number of resources are available to support these efforts across the state. **This section highlights some of these resources and provides links where more information can be found.**

Evaluation Tools

The high-level information provided in this guide on the potential benefits of NBS provides early guidance on what approaches might be useful. However, implementing projects requires detailed planning and tailoring the NBS to the site in question to ensure the benefits can be achieved.

LWI is developing several types of models that can be used to evaluate the role of different NBS approaches to flood risk management including the **watershed models** (which may require additional detail to capture attributes of NBS features) and the **TNC Watershed Explorer Tool.** In addition, a variety of established evaluation tools are available, and some are listed in the table on the next page.

Design Resources

Designing a project to achieve specific outcomes requires site-specific information as well as resources such as templates and guidance on specific attributes of NBS project features. This will involve the assessment of costs and benefits (see Evaluation Tools). A number of handbooks have been developed by federal agencies, states and professional societies to guide designers of NBS. Many of these are listed in the table on page 18. However, there are several web-based resources which are of wide application, two of the most user-friendly are:

- Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC)
- USACE Engineering with Nature

TOOLS TO EVALUATE NBS FUNCTION FOR FLOOD RISK + ADDITIONAL BENEFITS

NBS FUNCTION	EVALUATION TOOLS
Approach to flood risk management	
Floodplain Restoration and Preservation	• National Stormwater Calculator
Flood Storage	• National Stormwater Calculator
Stormwater Management — Green Infrastructure	• INVEST Urban Flood Risk Mitigation model • Green Values Stormwater Management Calculator • EPA's Green Infrastructure Wizard • i-Tree Hydro (Urban Forests)
Groundwater Recharge	• USGS Software and Models, Methods for Estimating Groundwater Recharge in Humid Regions
Improved River and Floodplain Capacity and Storage	• National Stormwater Calculator
Surge and Wave Attenuation	• ADvanced CIRCulation model (ADCIRC) • STeady State Spectral WAVE (STWAVE)
Flood Attenuation	• National Stormwater Calculator • HEC river models
Barrier to Floodwaters — Coastal Dunes	• ADvanced CIRCulation model (ADCIRC) • Beach-fx
Additional potential benefits	
Habitat Restoration and Enhancement	• USACE Ecosystem Restoration Model Library • INVEST Habitat Quality • Coastal Protection and Restoration Authority's Integrated Compartment Model • Open Source Conservation Planning Software
Improved Water Quality	• Automated Geospatial Watershed Assessment (AGWA) Tool • Visualizing Ecosystems for Land Management Assessment (VELMA) Model
Carbon Sequestration	• INVEST Carbon Storage and Sequestration • INVEST Coastal Blue Carbon
Recreation	• INVEST Recreation and Tourism
Open Space	• How to Map Open Space for Community Rating System Credit
Urban Heat Island and Air Quality Improvements	• INVEST Urban Cooling • i-Tree Eco • i-Tree Streets

DESIGN RESOURCES

NBS	TOOLS, MANUALS & OTHER RESOURCES
NBS for watershed and inland applications	
Floodplain Restoration and Preservation	• Iowa DNR River Restoration Toolbox • Management of Floodplain Forests • International Guidelines on Natural and Nature-Based Features for Flood Risk Management
Natural Channel Design	• Natural Channel Design Review Checklist • Natural Channel Design Protocol • Watershed Assessment of River Stability and Sediment Supply
Wetland, Prairie and Forest Restoration and Enhancement	• NRCS Engineering Field Handbook (Ch 13) • Management of Floodplain Forests
Detention Basins	• RECARGA model
Retention Basins	
Infiltration Basins	
Riparian Vegetation Restoration	• Iowa DNR River Restoration Toolbox • Riparian Restoration on Farms and Ranches in Texas
Green Infrastructure	• Green Infrastructure Municipal Handbook • Green Infrastructure Design and Implementation • Harris County Low Impact Development Design Criteria Manual • The Best Way to Deal with Stormwater • Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks
Management of Working Lands	• LDAF BMPs for Forest Management • National Forest Service: BMPs for Water Quality • NRCS Managing Forests for Fish and Wildlife • NRCS National Forestry Handbook
Environmental Flows	• A Practical Guide to Environmental Flows for Policy and Planning with Nine Case Studies in the United States • Environmental Flows Methods and Tools • Ecological Limits of Hydrologic Alteration (ELOHA)
NBS for coastal applications	
Wetland Restoration and Enhancement	• CPRA Marsh Creation Design Guidelines 1.0 • International Guidelines on Natural and Nature-Based Features for Flood Risk Management
Coastal Dune Restoration	• International Guidelines on Natural and Nature-Based Features for Flood Risk Management

Coalition to Restore Coastal Louisiana native plant program at work.

Louisiana Native Plants

The use of native plants for NBS further enhances their value to the ecosystem. The Louisiana Native Plant Society has established the **Louisiana Certified Habitat Program** (LCH). This program encourages property owners to increase and protect the ecological value and natural heritage of their land by recognizing efforts to utilize native plant species and best habitat gardening practices.

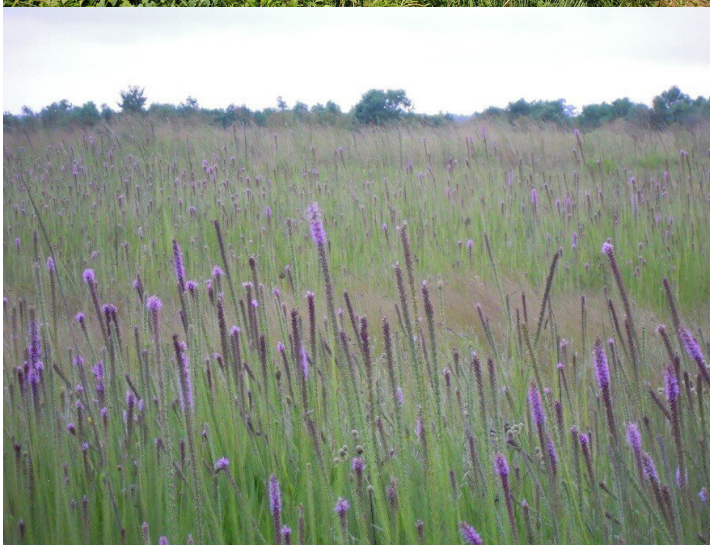
Habitat certification levels are determined by the number of native plant species or percentage of native plant species on a property.

- **Bronze:** 25 native species or 25% native plants
- **Silver:** 50 native species or 50% native plants
- **Gold:** 75 native species or 75% native plants

Resources for Obtaining Native Plants

Obtaining native plants for use in NBS should not be an obstacle. Contact the following statewide resources for information on the availability of plants and seeds.

Louisiana Native Plant Society
University of Louisiana Lafayette
Acadiana Native Plant Project
Louisiana Native Seed Co.
Native Plant Initiative of Greater New Orleans
Nicholls State Farm
Cajun Prairie Habitat Preservation Society



Native prairie and wildflowers for restoration and landscaping.

6 CASE STUDIES

Case Studies

Case studies provide practitioners with on-the-ground examples of NBS in action. These are useful to demonstrate to stakeholders and those new to NBS what might be achieved by including NBS as part of a watershed approach to flood risk management.

The table below includes examples from Louisiana as well as other states.

Integrated natural channel design and riparian restoration strategies at work for Cypress Creek in Houston, Texas.

NBS	CASE STUDY INFORMATION
NBS for watershed and inland applications	
Floodplain Restoration and Preservation	• Mollicy Farms • Richard K. Yancey Wildlife Management Area
Natural Channel Design	• Phillips Creek • Cypress Creek in Houston • Chattahoochee River - Crayfish Creek
Wetland, Prairie and Forest Restoration and Enhancement	• Eunice Prairie and Duralde Prairie restoration • Texas Prairie Wetlands Project
Detention Basins **Retention Basins** **Infiltration Basins**	• Coulee Mine East Detention Project * • Jones Creek Detention Project *
Riparian Vegetation Restoration	• Case Studies of Riparian and Watershed Restoration in the Southwestern United States—Principles, Challenges, and Successes
Green Infrastructure	• Green Light New Orleans • Louisiana Certified Habitat Program
Management of Working Lands	• Louisiana Certified Habitat Program • Pennsylvania initiative
Environmental Flows	• Big Cypress Bayou - Caddo Lake (Caddo Lake Institute) • Big Cypress Bayou – Caddo Lake (USACE) • USACE/TNC Sustainable Rivers Project
NBS for coastal applications	
Wetland Restoration and Enhancement	• Coastal Wetlands Planning Protection and Restoration Act projects • Coastal Protection and Restoration Authority projects
Coastal Dune Restoration	• Caminada Headland

* These projects are presently in planning and the extent of NBS is to be determined.

7 FUNDING NATURE-BASED SOLUTIONS

The multiple benefits of NBS, including flood risk reduction, mean that a number of funding sources are available to support NBS implementation. Some of these are focused on flood risk management and hazard mitigation, but include NBS as eligible activities. Others focus on environmental benefits and may be used to support projects that achieve these benefits and contribute to flood risk reduction. Examples of funding sources are provided here in both categories. Each has requirements and constraints, but still offer potential to support NBS and flood risk reduction in Louisiana.

Funding Related to Flood Risk Reduction

NBS are eligible activities in a number of federal and state funding sources that focus on flood risk reduction (see table below). The types of NBS supported by these programs and the information needed to support applications will vary. In addition, for coastal risk reduction projects the Gulf of Mexico Energy Security Act (GOMESA) provides federal revenues derived from offshore oil and gas production and shared with the Land and Water Conservation Fund, the four Gulf producing states, and their coastal political subdivisions. The State receives its GOMESA payment each spring based on revenues generated during the prior federal fiscal year. In Louisiana, funds have been constitutionally dedicated to the Coastal Protection Trust Fund and are used primarily to fund hurricane risk reduction projects.

Funding Related to Environmental Benefits

Many NBS that support flood risk reduction also provide water quality or habitat benefits. This means that a wide range of funding sources can be potentially applicable for a flood risk problem. Whether a water quality or habitat benefit NBS project contributes to flood risk reduction will depend on the specific application and site characteristics.

In addition to these federal programs, NRCS manages several streams of Farm Bill funding that support conservation activities on working lands, and LDWF manages Farm Bill and other funds under its Private Lands Program. Ducks Unlimited, Louisiana Department of Wildlife and Fisheries, USDA Natural Resources Conservation Service, and US Fish and Wildlife Service have joined forces and created the Louisiana Waterfowl Project South to develop wetland habitat on private lands. Technical assistance and incentives are available to landowners interested in improving the status of waterfowl and the quality of wetlands on their property. The Coastal Protection and Restoration Authority (CPRA) manages the Atchafalaya Basin Program, which places emphasis on projects that make a contribution to maintaining estuarine gradients in future decades (e.g., hydrological restoration), and those that provide risk reduction at the community or regional scale.

FUNDING FOR FLOOD RISK REDUCTION

The table lists the federal or state program name and indicates eligible applicants.

PROGRAM	STATE	TRIBES	LOCAL GOVERNMENT/ COMMUNITIES	PRIVATE	NON-PROFITS	INDIVIDUAL BUSINESS/ HOMEOWNER
FEMA Public Assistance	*	*	*		*	
FEMA Hazard Mitigation Assistance Grants	*	*	*		*	
HUD CDBG			*			
LA Statewide Flood Control Program			*			
USDA Emergency Watershed Protection	*	*	*	*	*	*

The Richard K. Yancey Blackhawk Scar Lakes Ecosystem Restoration and Monitoring Project, near Vidalia, Louisiana, will restore more natural floodplain hydrology to streams and lakes by repairing and replacing failing culverts and a weir.

FUNDING FOR ENVIRONMENTAL BENEFITS

The table below is adapted from a factsheet developed by Environmental and Energy Study Institute and includes federal programs that support different types of NBS through technical assistance or grants for projects.

FEDERAL PROGRAM	GREEN INFRASTRUCTURE	NATURAL INFRASTRUCTURE	URBAN FOCUS	HABITAT RESTORATION	FLOOD PREVENTION	WATER QUALITY	POLLUTION ABATEMENT
EPA Building Blocks for Sustainable Communities*	*		*		*	*	
EPA Clean Water Act Nonpoint Source Grant (Section 319)	*	*		*			*
EPA Clean Water State Revolving Fund	*	*		*			*
EPA Greening America's Communities Program*	*		*		*		
EPA Urban Waters Small Grants Program	*		*	*	*	*	*
NOAA Community-based Restoration Program		*		*			
USDA Urban and Community Forestry Program		*	*	*	*		
USDA Agricultural Conservation Easement Program		*		*	*	*	
USDA Watershed and Flood Prevention Operations		*		*	*	*	
USFWS Coastal Program	*	*		*	*	*	
USFWS North American Wetlands Conservation Act		*		*	*	*	
USFWS Coastal Impact Assistance Program		*		*		*	
USFWS National Coastal Wetlands Conservation Grant Program		*		*		*	

*These programs provide technical assistance from EPA only.

Several programs are available for funding projects along Louisiana's coast that are consistent with Louisiana's Comprehensive Master Plan for a Sustainable Coast:

- Coastal Wetlands Planning Protection and Restoration Act. These are federal funds used for the planning and implementation of projects that create, protect, restore and enhance wetlands in coastal Louisiana. Funds are derived through the Sport Fish Restoration and Boating Safety Trust Fund. The State provides a 15% match.
- Natural Resources Damage Assessment is a total of $5 billion in settlement funds used for Deepwater Horizon oil spill restoration activities. This funding stream is overseen by the Louisiana Trustee Implementation Group (LA TIG), which approves restoration and implementation plans that utilize these funds. These funds will be received annually over the 15-year period ending April 4, 2031.
- Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act). Four funding streams are managed by the RESTORE Council and the US Treasury, accounting for 80% of the Deepwater Horizon oil spill Clean Water Act civil penalties.

Another major source of funding for conservation and NBS is the National Fish and Wildlife Foundation (NFWF) which has supported a wide range of projects in Louisiana. Relevant NFWF programs include:

- Acres for America
- Bring Back the Native Fish
- Conservation Partners Program
- National Coastal Resilience Fund
- Five Star and Urban Waters Restoration Grant Program
- Lower Mississippi Alluvial Valley Restoration Fund
- Gulf Environmental Benefit Fund

The Five Star and Urban Waters Restoration Program focuses on the stewardship and restoration of coastal, wetland and riparian ecosystems.

8

APPENDIX: SUMMARY SHEETS

Floodplain Restoration + Preservation

Mollicy Farms, Upper Ouachita National Wildlife Refuge.[1]

Richard K. Yancey Blackhawk Scar Lakes Ecosystem Restoration and Monitoring Project.[2]

DESCRIPTION	Measures that reconnect floodplains and river channels, allow overbank flow during floods, enhance the retention of floodwaters on floodplains, and/or preserve existing floodplains to retain their flood storage function.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood storage:** The holding of floodwaters during a flood which are then gradually released into the drainage system. + **Groundwater recharge:** Downward movement of water from the surface to subsurface aquifers.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape. + **Recreation:** Providing recreational opportunities such as birdwatching and hiking. + **Streamflow regulation:** Modulation of fluctuations in river flow by temporary storage.
SCALABILITY	Individual projects planned at scale can have watershed effects.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Low maintenance. + Passive operation.	+ Restoring floodplain connectivity is necessary for flood risk reduction benefit. + Limited experience, capacity and expertise at the local level. + Habitat restoration as flood mitigation is not well understood or practiced. + Lack of state and local expertise, capacity and availability of technical resources. + Invasive species management. + Private lands may require acquisition or incentives.	+ Environmental Flows. + Riparian Vegetation Restoration. + Management of Working Lands.

Floodplain Restoration + Preservation

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USGS Software and Models, Methods for Estimating Groundwater Recharge in Humid Regions:** https://water.usgs.gov/ogw/gwrp/methods/software/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool	+ **Iowa DNR River Restoration Toolbox:** https://www.iowadnr.gov/Environmental-Protection/Water-Quality/River-Restoration/River-Restoration-Toolbox + **Management of Floodplain Forests:** https://naturalresources.extension.iastate.edu/encyclopedia/management-floodplain-forests + **International Guidelines on Natural and Nature-Based Features for Flood Risk Management:** https://ewn.erdc.dren.mil/?page_id=4351
CASE STUDIES	+ **Mollicy Farms:** https://www.nature.org/en-us/about-us/where-we-work/united-states/louisiana/stories-in-louisiana/largest-floodplain-restoration-in-mississippi-river-basin/ + **Richard K. Yancey WMA:** https://www.lmrcc.org/wp-content/uploads/2021/03/Yancey-WMA-Project-Profile_3.12.2021.pdf

1 https://www.nature.org/en-us/about-us/where-we-work/united-states/louisiana/stories-in-louisiana/largest-floodplain-restoration-in-mississippi-river-basin/

2 https://www.lmrcc.org/our-work/projects/restoring-americas-greatest-river-initiative/richard-k-yancey-blackhawk-scar-lakes-ecosystem-restoration-and-monitoring-project/

LOUISIANA WATERSHED INITIATIVE

Natural Channel Design



Log vane after a growing season; toe wood structures on stream bank; large woody debris-covered logs.[1]

DESCRIPTION	Applies the principles of stream geomorphology to maintain a state of dynamic equilibrium among water, sediment and vegetation that creates a stable channel connected to a floodplain.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood attenuation:** The reduction in peak discharge of a flood by temporary storage of water or the slowing of channel flows. + **Improved river/floodplain capacity and storage:** The holding of floodwaters during a flood which are then gradually released.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics.
SCALABILITY	Cumulative effects require coordinated planning.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Low maintenance once vegetation is established. + Passive operation.	+ Challenges of incorporating the full array of ecosystem benefits into cost-effectiveness calculations. + Societal expectations that natural channels must be altered by clearing, snagging, dredging or channelization to maximize their flood risk benefits are at odds with scientific understanding of rivers as dynamic, spatially heterogeneous, nonlinear ecosystems. + Lack of state and local expertise, capacity and availability of technical resources.	+ Riparian Vegetation Restoration. + Environmental Flows.

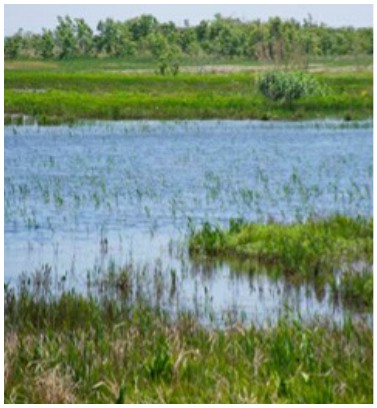
Natural Channel Design

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool	+ Harman, W., R. Starr. 2011. *Natural Channel Design Review Checklist.* US Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD and US. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division. Washington, D.C. EPA 843-B-12-005 + W. H. Harman, K.L. Tweedy, W.S. Hunt, J. Calmbacher, T. Norton, K. Van Stell, and C.H. Kaiser. 2012. *Natural Channel Design Protocol, v1.* San Antonio River Authority, San Antonio, TX
CASE STUDIES	+ **Phillips Creek:** https://www.deltaland-services.com/interactive-map/ + **Cypress Creek in Houston:** https://www.biohabitats.com/project/cypress-creek-restoration/

1 From: W. H. Harman, K.L. Tweedy, W.S. Hunt, J. Calmbacher, T. Norton, K. Van Stell, and C.H. Kaiser. 2012. *Natural Channel Design Protocol,* v1. San Antonio River Authority, San Antonio, TX

LOUISIANA WATERSHED INITIATIVE

Wetland / Prairie / Forest Restoration and Enhancement *1 of 2*



Conservation of agricultural lands, Vermilion Parish[1]; Cajun Prairie restoration, Eunice, Louisiana[2]; longleaf pine forest restoration, central Louisiana.[3]

DESCRIPTION	The rehabilitation of degraded natural lands including wetlands, prairies and forests, or the reestablishment of land cover so that soils, hydrology, vegetative community and habitat are a close approximation of the original natural condition that existed prior to modification.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood storage:** The holding of floodwaters during a flood which are then gradually released into the drainage system. + **Groundwater recharge:** Downward movement of water from the surface to subsurface aquifers.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape. + **Recreation:** Providing recreational opportunities such as birdwatching and hiking.
SCALABILITY	Cumulative effects require coordinated planning.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Proven approach if hydrologic conditions are favorable and design is site appropriate.	+ Invasive species management. + In some cases, the original hydrologic factors that created the wetland's timing, duration and depth of water no longer exist. + Enhancement of existing wetlands to provide specific functions, e.g., flood storage, depends on local conditions and adjacent land uses.	+ Management of Working Lands. + Floodplain Restoration/ Preservation.

Wetland / Prairie / Forest Restoration and Enhancement

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USGS Software and Models, Methods for Estimating Groundwater Recharge In Humid Regions:** https://water.usgs.gov/ogw/gwrp/methods/software/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool** - https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool	+ **NRCS Engineering Field Handbook (Ch 13):** https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=46277.wba + **Management of Floodplain Forests:** https://naturalresources.extension.iastate.edu/encyclopedia/management-floodplain-forests + **International Guidelines on Natural and Nature-Based Features for Flood Risk Management:** https://ewn.erdc.dren.mil/?page_id=4351
CASE STUDIES	+ **Eunice Prairie and Duralde Prairie Restoration:** https://www.cajunprairie.org/projects + **Texas Prairie Wetlands Project:** https://texanbynature.org/projects/texas-prairie-wetlands-project/

1 USDA *Louisiana Conservation Update* April 2021
2 https://www.cajunprairie.org/projects
3 https://www.nacdnet.org/2018/08/13/cattle-and-prescribed-burns-are-restoring-louisiana-longleaf-ecosystem/

LOUISIANA WATERSHED INITIATIVE

Detention / Retention / Infiltration Basins

Detention basin.[1]

Retention basin.[2]

DESCRIPTION	**Detention basins:** An area that has been excavated so that during storms excess water can be held helping prevent runoff. They are designed to dry out between flood events. **Retention basins:** An artificial pond with vegetation around the perimeter and a permanent pool of water with additional capacity for use during floods. Sometimes called a wet pond, wet detention basin or stormwater management pond. **Infiltration basins:** A retention basin designed to direct stormwater to groundwater through permeable soils.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood storage:** The holding of floodwaters during a flood which are then gradually released into the drainage system. + **Flood attenuation:** The reduction in peak discharge of a flood by temporary storage of water or the slowing of channel flows. + **Groundwater recharge (infiltration basins):** Downward movement of water from the surface to subsurface aquifers.
WHAT OTHER BENEFITS DOES IT PROVIDE?	***Note:*** *Basins are not necessarily nature-based solutions and the provision of other benefits is dependent on the design and local setting of the feature.* + **Habitat restoration/enhancement:** Changing the physical, chemical, or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical, and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape. + **Recreation:** Providing recreational opportunities such as birdwatching and hiking. + **Open space:** Lands where there are no buildings, storage, fill, significant pavement, or other encroachments to flood flows.
SCALABILITY	Cumulative effects require coordinated planning.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Proven approach if hydrologic conditions are favorable and design is site appropriate.	+ Large space requirement. + Potential for mosquitos—especially for retention and infiltration basins. + For detention and retention basins, must ensure drainage in areas with low slopes/high groundwater.	These basins may be locally designed and implemented to include additional NBS elements. The potential for synergy is dependent on local conditions.

Detention / Retention / Infiltration Basins

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USGS Software and Models, Methods for Estimating Groundwater Recharge In Humid Regions**: https://water.usgs.gov/ogw/gwrp/methods/software/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **INVEST Carbon Storage and Sequestration:** http://releases.naturalcapitalproject.org/invest-userguide/latest/carbonstorage.html + **INVEST Coastal Blue Carbon:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool:** https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **How to Map Open Space for Community Rating System Credit:** https://coast.noaa.gov/digitalcoast/training/crs.html	+ **RECARGA:** https://dnr.wisconsin.gov/topic/Stormwater/standards/recarga.html
CASE STUDIES	+ **Coulee Mine East Detention Project:** https://www.theadvocate.com/acadiana/news/article_02a3d842-bf06-11eb-86e3-034655841be4.html + **Jones Creek Detention Project:** https://www.wbrz.com/news/east-baton-rouge-parish-secures-funding-for-jones-creek-detention-project/

LOUISIANA WATERSHED INITIATIVE

1 https://www.manuelbuilders.com/blog/retention-pond-vs-detention-pond
2 https://connectorcomments.blogspot.com/2016/05/how-big-will-i-49-connector-retention.html

Riparian Vegetation Restoration

Buffalo Bayou in Houston, Texas.[1]

Nelson Creek in Walker County, Texas.[2]

DESCRIPTION	Planting or enhancement of riparian vegetation to reduce erodibility of channel banks, stabilize channels and attenuate flood flows.
HOW DOES IT MITIGATE FLOOD RISK?	**Flood attenuation:** Reduction in peak discharge of a flood by slowing of channel flows.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape.
SCALABILITY	Small-scale application with potential for cumulative effects at watershed scale.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Low maintenance, once vegetation is established. + Passive operation.	+ Contribution to flood risk reduction may be marginal unless revegetation is extensive. + Susceptible to disease, fire and other hazards.	+ Natural Channel Design. + Floodplain Restoration/ Preservation.

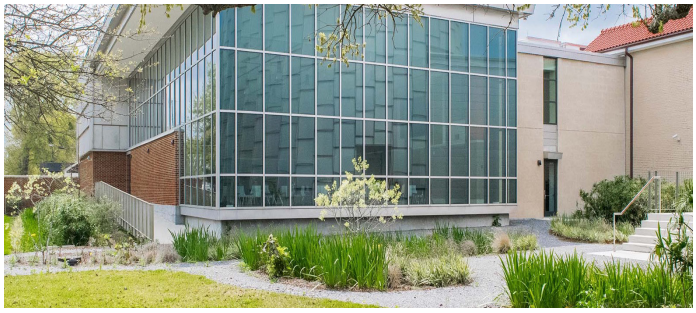
Riparian Vegetation Restoration

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **INVEST Carbon Storage and Sequestration:** http://releases.naturalcapitalproject.org/invest-userguide/latest/carbonstorage.html + **INVEST Coastal Blue Carbon:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html	+ **Iowa DNR River Restoration Toolbox:** https://www.iowadnr.gov/Environmental-Protection/Water-Quality/River-Restoration/River-Restoration-Toolbox + **Riparian Restoration on Farms and Ranches in TX:** http://bexar-tx.tamu.edu/files/2012/07/Riparian-Restoration-on-Farms.pdf
CASE STUDIES	**Case Studies of Riparian and Watershed Restoration in the Southwestern United States—Principles, Challenges, and Successes:** https://pubs.usgs.gov/of/2017/1091/ofr20171091.pdf

LOUISIANA WATERSHED INITIATIVE

1 http://www.savebuffalobayou.org/?cat=16
2 http://bexar-tx.tamu.edu/files/2012/07/Riparian-Restoration-on-Farms.pdf

Green Infrastructure



Maumus Center, St. Bernard Parish.[1]

Gene Green Beltway 8 Park in Houston, Texas.[2]

DESCRIPTION	Range of measures that use plant or soil systems; permeable pavement or other permeable surfaces or substrates; stormwater harvest and reuse; landscaping or rewilding to store, infiltrate or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters. Includes greenways, rain gardens, tree trenches, bioswales and green roofs.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Stormwater management:** Reduced peak flows or total runoff from precipitation events. + **Flood attenuation:** The reduction in peak discharge of a flood by temporary storage of water or the slowing of channel flows. + **Groundwater recharge:** Downward movement of water from the surface to subsurface aquifers.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical, or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape. + **Recreation:** Providing recreational opportunities such as birdwatching and hiking. + **Open space:** Lands where there are no buildings, storage, fill, significant pavement or other encroachments to flood flows. + **Urban heat island and air quality improvements:** Mitigating temperatures in urbanized areas that experience higher temperatures due to extensive development and local improvements to air quality through reduced particulates and absorption of gaseous pollutants.
SCALABILITY	Small-scale application with potential for cumulative effects at watershed scale.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Can be applied incrementally, often at parcel scale. + Contributions can be made on public and private land.	+ Lack of knowledge and capacity of state and local professionals regarding the proper design and integration of green infrastructure concepts into traditional project scoping. + Lack of green infrastructure standards and limited technical resources. + Perception of higher costs and unknown performance. + Unfamiliarity with maintenance requirements and costs. + Conflicting codes and ordinances.	Green infrastructure encompasses a suite of approaches for urban areas which can be designed synergistically to achieve multiple flood risk management and environmental benefits.

Green Infrastructure

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USGS Software and Models, Methods for Estimating Groundwater Recharge In Humid Regions:** https://water.usgs.gov/ogw/gwrp/methods/software/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Visualizing Ecosystems for Land Management Assessment (VELMA) Model:** https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20 + **INVEST Carbon Storage and Sequestration:** http://releases.naturalcapitalproject.org/invest-userguide/latest/carbonstorage.html + **INVEST Coastal Blue Carbon:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **INVEST Urban Cooling:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_cooling_model.html + **i-Tree Eco:** https://www.itreetools.org/tools/i-tree-eco + **i-Tree Streets:** https://www.itreetools.org/tools/i-tree-streets	+ **Green Infrastructure Municipal Handbook:** https://www.epa.gov/green-infrastructure/green-infrastructure-municipal-handbook + **Green Infrastructure Design and Implementation:** https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation + **Harris County Low Impact Development Design Criteria Manual:** https://www.hcfcd.org/Resources/Technical-Manuals/Harris-County-Low-Impact-Development-Design-Criteria-Manual?folderId=16300&view=gridview&pageSize=10 + **Homeowners:** https://www.thisoldhouse.com/driveways/21018862/best-drainage-systems-to-deal-with-storm-water + **Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks:** https://floodresilience.net/resources/item/resource-guide-for-planning-designing-and-implementing-green-infrastructure-in-parks/
CASE STUDIES	+ **Green Light New Orleans:** https://www.greenlightneworleans.org/rainbarrels.html + **Louisiana Certified Habitat Program:** https://www.lnps.org/louisiana-certified-habitat

LOUISIANA WATERSHED INITIATIVE

1 https://www.danabrownassociates.com/maumus-center/
2 https://www.epa.gov/sites/default/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf

Management of Working Lands

Cover crops.[1]

Saturated buffer strips.[2]

DESCRIPTION	Adjustments in agriculture, forestry or other land management practices to improve infiltration and evapotranspiration, and/or hold water in the landscape. May include use of small stone/earthen weirs in ephemeral channels or gullies to reduce runoff, planting native vegetation and maintaining riparian buffers.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood storage:** The holding of floodwaters during a flood which are then gradually released into the drainage system. + **Groundwater recharge:** Downward movement of water from the surface to subsurface aquifers.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics.
SCALABILITY	Small-scale application with potential for cumulative effects at watershed scale.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Can be applied incrementally. + Contributions can be made by private landowners as well as on state managed lands.	+ Lack of knowledge and capacity of state and local professionals regarding appropriate integration of flood/NBS friendly landscape management practices. + Perception that performance is unknown. + Unfamiliarity with potential approaches and tradeoffs with existing land management goals.	+ Floodplain Restoration/ Preservation. + Wetland/Prairie/ Forest Restoration and Enhancement.

Management of Working Lands

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **USGS Software and Models, Methods for Estimating Groundwater Recharge In Humid Regions**: https://water.usgs.gov/ogw/gwrp/methods/software/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment (AGWA) Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **Visualizing Ecosystems for Land Management Assessment (VELMA) Model:** https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20	+ **LDAF BMPs for Forest Management:** http://www.ldaf.state.la.us/wp-content/uploads/2014/04/BMP.pdf + **National Forest Service:** https://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf + **NRCS Managing Forests for Fish and Wildlife:** https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_010130.pdf + **NRCS National Forestry Handbook:** https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=37005.wba
CASE STUDIES	+ **Louisiana Certified Habitat Program:** https://www.lnps.org/louisiana-certified-habitat + **Pennsylvania Lawn Conservation Initiative:** https://www.bayjournal.com/news/pollution/pa-initiative-to-convert-10-000-acres-of-lawns-into-meadows-forests/article_b07ea216-79d0-11ea-8198-571a9d2fbaff.html

1 https://www.nwf.org/~/media/PDFs/Water/2015/Drought-and-Flood-Report-Final.pdf
2 http://www.saturatedbufferstrips.com/

LOUISIANA WATERSHED INITIATIVE

Environmental Flows

Caddo Lake and Lake o' the Pines Dam above Caddo Lake, Texas.[1]

DESCRIPTION	Management of reservoir releases to maintain or enhance benefits to the ecosystem while supporting flood risk management.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Flood storage:** The holding of floodwaters during a flood which are then gradually released into the drainage system. + **Flood attenuation:** The reduction in peak discharge of a flood by temporary storage of water or the slowing of channel flows.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Streamflow regulation:** Modulation of fluctuations in river flow by temporary storage.
SCALABILITY	Individual projects planned at scale can have watershed effects.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
Additional ecosystem restoration/enhancement benefits versus traditional reservoir operations.	+ Challenge of balancing multiple uses of reservoir, especially during floods and droughts. + Unfamiliarity of reservoir managers/operators with potential benefits. + Complex tradeoffs among water uses, e.g., municipal and industrial water supply, irrigation, ecosystem and flood risk management. + Inability to predict the amount and timing of releases relative to multiple uses.	+ Floodplain Restoration/ Preservation. + Natural Channel Design. + Riparian Vegetation Restoration.

Environmental Flows

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **National Stormwater Calculator:** https://www.epa.gov/water-research/national-stormwater-calculator + **HEC river models:** https://www.hec.usace.army.mil/ + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Automated Geospatial Watershed Assessment Tool**: https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **Open Source Conservation Planning Software:** https://www.landscapepartnership.org/maps-data/gis-planning/conservation-planning/conservation-planning-software	+ **A Practical Guide to Environmental Flows for Policy and Planning:** https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Documents/Practical%20Guide%20Eflows%20for%20Policy-low%20res.pdf + **Environmental Flows Methods and Tools:** https://www.conservationgateway.org/conservationpractices/freshwater/environmentalflows/methodsandtools/Pages/environmental-flows-metho.aspx + **Ecological Limits of Hydrologic Alteration:** https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Pages/ecological-limits-hydrolo.aspx
CASE STUDIES	**Big Cypress Bayou – Caddo Lake:** https://caddolakeinstitute.org/flows-project/ and https://www.iwr.usace.army.mil/sustainablerivers/sites/bigcypress/

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1 https://www.hec.usace.army.mil/sustainablerivers/sites/bigcypress/

Coastal Wetlands

Oyster Bayou marsh creation.[1]

DESCRIPTION	Measures that contribute to the restoration and/or sustainability of coastal wetland landscapes including hydrologic restoration, marsh creation and river diversions.
HOW DOES IT MITIGATE FLOOD RISK?	**Surge and wave attenuation:** The reduction in peak water levels and wave heights associated with the dissipation of energy by wetland vegetation.
WHAT OTHER BENEFITS DOES IT PROVIDE?	+ **Habitat restoration/enhancement:** Changing the physical, chemical, or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat. + **Improved water quality:** Increasing suitability of water for a particular use based on selected physical, chemical and biological characteristics. + **Carbon sequestration:** The process by which carbon dioxide is removed from the atmosphere and held in solid form in the landscape. + **Recreation:** Providing recreational opportunities such as birdwatching and hiking.
SCALABILITY	Individual projects planned at scale can have watershed effects.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Low maintenance. + Passive operation. + Extensive experience in Louisiana.	Effectiveness for coastal storm risk reduction is highly dependent on location and extent of the wetlands and the character—intensity, track and speed of forward movement—of the storm.	+ Coastal Dune Restoration.

Coastal Wetlands

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **ADvanced CIRCulation model (ADCIRC):** https://adcirc.org/ + **STeady State Spectral WAVE (STWAVE):** https://csdms.colorado.edu/wiki/Model:STWAVE + **Integrated Compartment Model (ICM):** https://github.com/CPRA-MP + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Open Source Conservation Planning Software:** https://www.landscapepartnership.org/maps-data/gis-planning/conservation-planning/conservation-planning-software + **Automated Geospatial Watershed Assessment (AGWA) Tool:** https://www.epa.gov/water-research/automated-geospatial-watershed-assessment-agwa-tool + **INVEST Carbon Storage and Sequestration:** http://releases.naturalcapitalproject.org/invest-userguide/latest/carbonstorage.html + **INVEST Coastal Blue Carbon:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html	+ **CPRA Marsh Creation Design Guidelines 1.0:** https://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx?Root=0&Folder=0# + **International Guidelines on Natural and Nature-Based Features for Flood Risk Management:** https://ewn.erdc.dren.mil/?page_id=4351
CASE STUDIES	+ https://lacoast.gov/new/Projects/Default.aspx + https://cims.coastal.louisiana.gov/outreach/projects/OPL_Full_page.html

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1 https://cims.coastal.louisiana.gov/outreach/projects/ProjectView?projID=CS-0059

Coastal Dune Restoration

Coastal dune restoration in Louisiana.[1]

DESCRIPTION	Restoration of coastal sand dunes to provide a natural physical barrier that reduces inundation and wave attack on the coast landward of the dune.
HOW DOES IT MITIGATE FLOOD RISK?	+ **Barrier to floodwaters:** The deflection of flooding from an area. + **Surge and wave attenuation:** The reduction in peak water levels and wave heights associated with the dissipation of energy by dunes.
WHAT OTHER BENEFITS DOES IT PROVIDE?	**Habitat restoration/enhancement:** Changing the physical, chemical or biological characteristics of a site with the goal of returning or improving the natural functions to the lost or degraded native habitat.
SCALABILITY	Individual projects planned at scale can have watershed effects.

Advantages Relative to Traditional Flood Management	Potential Barriers or Issues Relative to Traditional Flood Management	Potential Synergies with other NBS
+ Beaches and dunes together dissipate waves and prevent overtopping. + Ability to build vertically and recover from storm damage.	+ Less robust than traditional measures such as seawalls, i.e., subject to damage during storms with potential loss of flood protection function. + Requires maintenance and availability of appropriate cost-effective sand sources.	+ Coastal Wetland Restoration.

Coastal Dune Restoration

RESOURCES	
EVALUATION TOOLS	**DESIGN SUPPORT**
+ **ADvanced CIRCulation model (ADCIRC):** https://adcirc.org/ + **STeady State Spectral WAVE (STWAVE):** https://csdms.colorado.edu/wiki/Model:STWAVE + **USACE Ecosystem Restoration Model Library:** https://cw-environment.erdc.dren.mil/model-library.cfm?CoP=Restore&Option=Search&Type=Restore&Id=ALL + **INVEST Habitat Quality:** http://releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html + **Open Source Conservation Planning Software:** https://www.landscapepartnership.org/maps-data/gis-planning/conservation-planning/conservation-planning-software	**International Guidelines on Natural and Nature-Based Features for Flood Risk Management:** https://ewn.erdc.dren.mil/?page_id=4351
CASE STUDIES	+ **Caminada Headland:** https://coastal.la.gov/project/caminada-headland-beach-and-dune-restoration/

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1 https://cims.coastal.louisiana.gov/outreach/projects/OPL_Full_page.html

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