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New Jersey Nature-Based Solutions:

Planning, Implementation, and Monitoring Reference Guide

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Executive Summary

Nature-based solutions (NBS) can help mitigate certain natural hazards in New Jersey while also offering direct benefits to people and nature. NBS can be used in a range of environments from urban to rural, from inland to along the coast, and from small spaces that take up a patch of sidewalk to large spaces spanning acres. Whether on their own or paired with more traditional grey infrastructure, NBS can help mitigate flooding, extreme heat, erosion, and more over time.

This document compiles research, resources, and best practices from public and private entities, academics, and on the ground subject matter experts regarding the planning, implementation, and monitoring of NBS in New Jersey. The document can be used by anyone seeking funding for an NBS, anyone who is managing a NBS project, or anyone overseeing the hiring of contractors to carry out a NBS project. This document is designed for those who are completely new to the world of NBS as well as individuals who may have experience. The document is intended to guide readers through the opportunities and challenges associated with NBS planning, implementation, and monitoring.

Readers of this document will walk away with: a better understanding of the fundamental factors involved with planning for NBS; a basic knowledge of benefit-cost analyses used in funding proposals for NBS; the ability to identify specific NBS types, what environment makes each NBS type the most successful, and the benefits each NBS type can provide; and a robust toolbox of relevant literature, resources, case studies, data, and expertise that can be used to advance current and future NBS projects.

The information presented in this document – including references to Federal, State and local government programs, laws, regulations, and policies – were last updated in January 2025.

Table of Contents

SECTION 1

Setting the Stage

Nature-based solutions (NBS) are "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" (IUCN 2024). There are different definitions that exist, both more broad and more limited in scope, but for the purpose of this document we are using the above. Nature-based solutions are not new, and many are derived from Indigenous Peoples ways of life (Reed et al., 2022; Arkema et al., 2024).

1.1 WHAT THIS DOCUMENT IS ABOUT AND WHO IS IT FOR

This guidance is intended, but is not limited to, people, organizations, governments, and anyone else who is interested in implementing a nature-based solution. The information presented in this document is centered around the different environments found in New Jersey and can most commonly apply to the surrounding region that contains similar environments and ecosystems (Massachusetts to Virginia).

If you do not fall into one of the categories above, you may still find this guidance useful if you are interested in better understanding planning for nature-based solutions, benefit-cost analysis (economics related project justification), and want to gather more information before making the leap to applying for funding.

The purpose of the **New Jersey Nature-Based Solutions Reference Document** is to provide an overview of existing knowledge relating to nature-based solutions, specifically:

1. Planning for NBS.
2. Basics of understanding the benefit-cost analysis process.
3. Best practices and considerations for implementing certain NBS types.

There is a plethora of existing information on nature-based solutions, including academic literature, online toolkits, and other guidance and technical documents. This guidance acknowledges and references these existing sources throughout the document and within the appendix. Our goal is to provide NBS planning and best practices guidance to inform and empower readers to implement and seek funding for NBS.

The nature-based solution types covered within this document are limited to the most relevant for environments in New Jersey. They were selected due to the following qualities: the variation in physical size; representation of different environment types; covering at least one of the primary hazards impacting the state as identified in the 2024 State Hazard Mitigation Plan; and the availability of extensive literature and data to support their efficacy.

1.2 How to Use This Document

This document is broadly divided into two sections. The first portion, Setting the Stage, outlines general information that is valuable for all readers who plan to apply for funding and/or construct an NBS. The second half is dedicated to NBS profiles to provide in-depth information on specific solutions. There is an abundance of information, including resources, case studies, a list of potential funding sources and more in the appendix. The document should further assist with walking through the necessary steps to identify the most well-suited NBS for a particular issue; if the necessary pre-planning and information is completed; and what to consider when applying for funding. To aid in this we've created Table 1 (Appendix 4.2) that outlines the co-benefits and hazards addressed by each NBS type and a checklist (Appendix 4.1) that ask planning and process questions covered within the content of this document.

1.3 Hybrid Approach

Nature-based solutions fall under the umbrella of natural or green infrastructure. Traditional infrastructure projects that are manmade (bulkheads, seawalls, levees, storm drains, pump stations) are referred to as "built" or "gray" infrastructure. Combining green (natural) and gray (built) infrastructure yields a hybrid approach. Hybrid approaches allow for more flexible planning and design since both methods can be utilized to different extents depending on the proposed site and purpose of the structure (Sutton-Grier et al., 2015). Although this document focuses on nature-based solutions, the hybrid approach is used for a variety of reasons:

1. Combining green and gray infrastructure can reduce the amount of stormwater the gray infrastructure system needs to manage.
2. Gray infrastructure has an easier time passing BCA requirements and can "carry" some green infrastructure with it.
3. Projects can be constructed to address multiple hazards at once.
4. Public perception may trust the combination of methods more than strictly using one over the other.
5. The selected project site is not suitable for an NBS (limitations in physical space, environmental conditions inappropriate, wave energy too high, etc.) but can still incorporate portions of green infrastructure.
6. Gray infrastructure "effectiveness declines over time and does not have the capacity to adapt to changing coastal conditions" (Sutton-Grier et al., 2015) but NBS do have this ability to adapt to changing environments. Combining both can potentially prevent complete failure of systems.

The consideration of utilizing hybrid approaches should not be dismissed and can still provide benefits to the environment and community in similar ways to nature-based approaches. However, in this guidance document, we will focus more on green approaches rather than gray.

For more information related to hybrid approaches, please refer to the following sources for further reading:

- *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*, USACE
- *Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems*, Sutton-Grier et al., 2015
- Ecoshorelines on Developed Coasts Guidance and Best Practices, Miller et al., 2022
- Case Study – Hoboken's ResilienCity Park (formerly Northwest Resiliency Park)

SECTION 2

Planning for Nature-Based Solutions

Courtesy of The Nature Conservancy

SECTION 2

Planning for Nature-Based Solutions

NBS have a much stronger chance of succeeding in the long term when properly planned for. This means integrating and aligning nature-based solutions with existing plans and allowing for enough time before project implementation to ensure proper resource allocation, site suitability, permitting completion, and community buy-in. Proper pre-project planning can lead to smoother project implementation and more equitable outcomes.

2.1 SELECTING A PLANNING HORIZON

As one would develop plans for buildings and bridges to last for a certain number of years, the same needs to be done for NBS. Projects not only need to account for current conditions, but also for future conditions. To ensure an NBS has longevity, it's important to think about the 'planning horizon', or how far into the future one should be making decisions for. There are numerous resources being invested into the development, implementation, and maintenance of NBS (as further outlined in the subsequent sections of this guide). It's crucial to properly plan far enough into the future so the project has enough monetary and physical resources to last over the full project lifespan.

When determining how many years out to adequately plan for, consider external conditions and factors that could impact the proposed project. This includes the suitability of the site itself and surrounding area and how a changing climate will affect the proposed location over time.

Questions to ask before beginning a project

- When do you want/need to implement the action?
- By when do you expect to see benefit from the action?
- Do you have the resources required to implement the action?
- What partners do you need to involve in the planning process?
- What hazard(s) are you trying to address?

Land Use Change

Land use and patterns of development change over time and should be considered when planning for NBS. The growth or decline of population and infrastructure over 10, 20, 30 years or more can alter the efficacy of an NBS project.

For example, if a wetland is being considered for construction in an underdeveloped area of town to serve as additional water storage for the town's stormwater runoff, the original plans might only consider the existing population size and existing impervious surface cover. As more people move into the town over time, increasing development and impervious surface cover, there will be an increase in stormwater runoff that the wetland then must hold. If the original plans did not account for the increased runoff, the wetland may eventually fail to succeed in its original goal of preventing increased stormwater flooding in the community and lead to additional flooding in the newly developed surrounding area.

Depending on the NBS type, the scale of the project can differ greatly, requiring anywhere from a city block to hundreds of acres of land (this is further addressed in the NBS Profiles section of this document). Consideration of land use, zoning, and development over time can help determine the most suitable site for an NBS to ensure its longevity. Alignment with local planning documents will be further discussed in *Section 2.2 Land Use and Other Plans*.

- What permits for other projects and infrastructure in or around the NBS project site have already been issued?
- What is the area that will impact the NBS project site zoned for?
- How much physical space does the NBS need?

Future Climate Conditions

The climate conditions of today are not the climate conditions of the future. In New Jersey, precipitation will increase over time leading to additional inland and riverine flooding. The continual sea-level rise will increase the frequency of coastal flooding and further shift permanent standing water inland (Kopp et al., 2019). Average temperatures will also change, with more extreme heat days and longer heat waves (Wamsher et al., 2024). Infrastructure projects in general, but especially NBS, should be planned for the conditions of 50+ years out to properly account for the changing climate. Climate data and tools that can be used for planning purposes can be found in the Appendix.

The average measurements for precipitation, sea-level rise, temperature, and additional environmental values are used for technical planning. Engineers use these values to properly select materials, determine dimensions, use in mathematical equations for hydraulics and soils calculations, and more. Using values that most accurately reflect future conditions means that the NBS project can be constructed to stand the test of time.

Coastal

- How will my NBS project site be impacted by sea-level rise?
- What are the projected sea-level rise values for 2050, 2070, and 2100?
- Will the NBS project type be able to withstand or adapt to these water levels?

Inland

- How will my NBS project site be impacted by increased precipitation and runoff?
- What are the projected increases in precipitation? and population?
- Will the NBS project type be able to withstand the increased precipitation and any potential riverine flooding?

2.2 LAND USE AND OTHER PLANS

As mentioned in the previous section, the site suitability and therefore efficacy of an NBS is influenced by the land use in and around the proposed project site. In addition to considering land use, NBS should align, when possible, with:

1. County and municipal comprehensive plans.
2. Hazard mitigation plans.
3. Open space and recreation plans.
4. Sustainability and resilience plans.
5. Utilities plans.
6. Transportation plans.

Engage in the planning process and communicate with planning staff as far in advance as possible. This is useful for discussing how NBS can align with existing

plans and goals, connecting with future stakeholders, aligning potential funding and budget allocations, and conducting education and outreach around NBS. Also consider engaging with:

1. Emergency and floodplain management.
2. Parks and recreation.
3. Public works.
4. Local public health office.
5. Local environmental commissions.
6. Utilities boards.
7. Local schools and universities.
8. Community members.
9. Other local departments that would overlap with an NBS project.

Resources for aligning NBS with planning include FEMA 2021 and Pathak et al., 2022.

- Consider zoning – can an NBS be built on your proposed site? What types of NBS are allowed?
- Are there multiple options for an NBS project and how can those different project options best align with the planning and hazard mitigation goals of the community?

Comprehensive Plan

A comprehensive plan (or master plan) is required to be re-examined every 10 years for every municipality in New Jersey and includes considerations of the growth and development of a community. In New Jersey, a Climate Change Related Hazard Vulnerability Assessment (CCRHVA) is now required as part of updating a comprehensive plan (P.L.1975, c.291, New Jersey Municipal Land Use Law). NBS should ideally align with the hazards identified in the CCRHVA to provide risk reduction to communities. Additionally, comprehensive plans can help determine where potential project sites for an NBS could be within a jurisdiction based on growth and development maps.

Hazard Mitigation Plan

A hazard mitigation plan (HMP) is required by FEMA for every state and county in the country in order to access certain pre- and post-disaster dollars (Hazard Mitigation Assistance Grants). HMPs identify current and future hazards of concern in the jurisdiction, the level of risk they pose to people and property, and include a list of mitigation actions the community can complete to reduce risk. NBS can be incorporated into the proposed mitigation action list. FEMA (along with other federal and state programs) offer funding for mitigation actions included in or aligned with FEMA-approved HMPs. Engaging with a jurisdiction before or during their HMP update is useful to suggest NBS projects that could be included in the upcoming plan.

As of September 2024, FEMA's Federal Flood Risk Management Standard (FFRMS) rule is in effect. The rule increases flood risk minimization requirements for federally funded projects and requires that applicants consider NBS as part of their alternatives analyses for projects that may affect a floodplain or wetland (44 CFR Part 9; FEMA FFRMS).

- To align an NBS project with the local HMP, consider the hazards identified within the plan.
- Which of the identified hazards will the NBS mitigate (and for how many years in the future)?
- Are there any proposed mitigation actions that are already NBS or could be part of one?

2.3 LOGISTIC CHALLENGES

There are several logistical hurdles one must overcome to both plan and implement an NBS. The section below outlines three broad categories: timing and permitting, coordination, and funding and financing. All three should ideally be addressed in the pre-planning phase before a project funding application is submitted to ensure projects can be constructed and completed in an adequate amount of time.

Timing and Permitting

There can be difficulty in achieving the perfect timing for funding to be distributed, permits approved, and construction started all at once. There are some things that are less controllable, such as when funding becomes available, application deadlines, and the funding distribution cut-off period. However, there is some pre-project scoping and planning that can be done in advance to move certain processes along more smoothly.

Most, if not all, projects require state or federal permitting due to construction that will impact the surrounding environment. To obtain a permit, certain data and documentation must be provided to the agency authorizing permits. Required permits can vary depending on the kind of project being constructed, the location and who owns the land, if the location itself is under special protections or restrictions, if there are species or environments under special protection status, and any other special ordinances. It is recommended to reach out to agencies before submitting an application, that way the regulatory body itself can give preliminary feedback and guidance on the proposed project plan. Permitting requirements can change over time as new regulations and rules are approved. As of the time of publication of this document, there is the proposed REAL Rule from the New Jersey Department of Environmental Protection that would directly impact permitting requirements for NBS (NJ REAL 2024). While this document is not intended to list all active permitting rules and regulations, a list of relevant permitting agencies can be found in the Appendix.

Follow all state and federal permitting requirements and instructions, but ensure that permitting applications include the:

- Existing conditions of the site.
- Ecological & resilience goals.
- Structural and physical goals.
- Success criteria.
- Alternative analyses.
- How potential impacts will be minimized.
- The impacts vs. benefit trade-offs.
- Construction methodology.
- Monitoring criteria to track 'success' of the project.
- Adaptive management plans for pre- and post-construction.

Coordination

Multiple stakeholders are involved throughout the NBS project process from the pre-planning phase, to application submittal, to implementation and maintenance and monitoring. It is key to establish contact in advance, especially when a goal of an NBS project is to engage and involve the community (discussed more in *Section 2.4 Community Engagement*). People and entities to consider can include but are not limited to (Brill et al., 2022):

1. Landowners.
2. State and federal agencies.
3. Community members and local organizations.
4. Consultants, contractors and engineers.
5. Relevant municipal and county staff.
6. Academic institutions.
7. Non-governmental organizations (NGOs).

It is recommended to keep a list of people that might need to be involved over the course of the project. Consider partnering with or hiring experts to supplement any lack of technical expertise, project construction, public outreach, etc. In addition to consultants and engineering firms, local universities, watershed organizations, and NGOs should also be considered, especially when it comes to planning and design, public outreach, and monitoring. Partnerships can also improve the likelihood of success of a project by involving people with multiple viewpoints and diverse resources and skills.

From the beginning of a project, it is critical to determine both who owns the land that the project is planned to be constructed on and who manages the project land so contact with them can be established as soon as possible. Ownership of the land can impact permitting (discussed previously), authorizations, and more. If land is privately owned, there may be additional requirements by the landowner. If land has delegated management, permission and support from both the managing entity and owner may be required.

Funding and Financing

NBS projects cannot be completed without proper funding and financing. There are both public and private funding sources for NBS. Public investments make up a large source of funding and financing for NBS projects. This includes federal grants, state grants, and loans from local government. There are also private investments that include environmental impact bonds and disaster insurance. Public and private and local and external resources should be combined as often as possible (Pathak et al. 2022; FEMA 2021). For resources on funding and financing coastal related NBS, visit NOAA Funding and Financing Coastal Resilience. For resources on hazard mitigation funding, visit FEMA Hazard Mitigation

Assistance Grants. Another resource for funding and financing is the U.S. Department of Agriculture – Rural Development, visit USDA Programs in New Jersey.

Funding mechanisms include grants and donations provided by federal, state, and philanthropic sources (see *Appendix 4.6 Funding Opportunities for NBS*) to provide money that is not repaid by the recipient. Funders may require matching funds or cost-sharing to ensure buy-in from the applicant (Pathak et al., 2022).

Financing mechanisms such as loans (e.g., Clean Water State Revolving Funds and Safeguarding Tomorrow Revolving Loan Funds) and bonds (e.g., Environmental Impact Bonds) can provide supplementary funds but these are required to be repaid with interest. (Pathak et al., 2022). In New Jersey, the Infrastructure Bank offers loans for NBS projects through both their New Jersey Water Bank and the Community Hazard Assistance Mitigation Program. Additionally, the New Jersey Water Bank often combines low-interest rate loans with principal forgiveness (similar to grants) for eligible projects that include NBS.

When determining the estimated total costs of an NBS, the full project lifespan needs to be accounted for. This includes upfront costs before construction even begins, the construction phase, then maintenance and monitoring costs. Upfront and maintenance/monitoring costs should be incorporated into any project budget so funds needed are not underestimated. Upfront costs can include a preliminary site assessment, legal fees, grant writing services, environmental planning, engineering design, initial stakeholder engagement, and any permitting fees. There are alternative funding sources that can be utilized for pre-project planning, that may not require rigorous economic justification (*Section 2.7 Benefit-Cost Analysis*). Different funding sources can be used for different portions of the NBS project. This can be a strategic decision to leverage multiple available funding options, apply for funding programs with less "complex" applications, or target funders who provide technical assistance and support.

2.4 COMMUNITY ENGAGEMENT

Like any infrastructure project, NBS construction directly impacts the people and communities around it. As mentioned throughout the previous sections of this document, it's important to engage the community both before an NBS project and throughout the duration of it to best incorporate the community's input and values. It's worth noting that "communities" of people are often not a monolith, and that there are distinct groups of people within jurisdictionally defined communities (this is discussed further in *Section 2.5 Equity and Environmental Justice*). The most equitable and successful scenarios are when "communities drive or at least actively support an NBS project." Community leaders "provide valuable knowledge exchange throughout the community through its various phases, find local capacity to build the project, and provide the leadership to maintain and sustain the project to meet its goals after implementation. They can also be an important aspect of establishing and maintaining trust." (Reilly-Moman et al., 2023).

Engaging the community in advance can help manage expectations, prevent misunderstandings and long-term reputational damage around NBS. If a project is not successful, or brings more perceived negative impacts than positive, people can swear off funding or approving all similar projects in the future (Sefton et al., 2023). While NBS can provide a wide breadth of benefits and mitigate certain natural hazards risks, there are still limitations as to what NBS can do and what problems they can solve. It is necessary to communicate what NBS can and cannot do so expectations are reasonably set.

Engagement can include outreach efforts related to educating the public about NBS and their benefits, asking what their needs are and identifying hazards of concern, and even identifying physical sites best suited for future projects. An engagement plan can be developed to accomplish these goals. There are multiple resources that provide information on developing an engagement plan amongst other best practices for community work, including The University of Sheffield Guide for Community Engagement, the Pacific Institute and UN's Stakeholder Engagement Guide for Nature-Based Solutions, and the USACE International Guidelines NNBF 2021 (p.66 & p.70).

There are populations who are not familiar with nature-based solutions so it's important to explain what they are, where people might have seen them before (providing any relevant examples), and the wide breadth of co-benefits NBS could supply. When discussing the co-benefits the proposed NBS could provide, explain how interconnected the benefits can be and how much of an impact they would have on the community (Schuster and Doerr, 2016). In addition to the benefits, risks and potential negative impacts should also be discussed. Explicitly outlining when both positive and negative impacts can occur throughout the project lifetime (during construction, after construction, and long-term) is needed to properly inform community members (Sefton et al., 2023).

Unsure what kinds of questions to ask to engage community members and stakeholders?

- What are the biggest challenges facing your community?
- How important do you think water quality [or insert another category] is to the residents of your municipality?

Explore more in Schuster and Doerr, 2016.

If a particular type of NBS project has not been chosen or there are multiple options for project types, engage in conversation with the community to determine what their desires and needs are. The start of a project and its initial planning stages are a key time for building in community involvement and granting people a seat at the table. Working together early on can help ensure the people most impacted by the NBS are having a say in the project direction itself. Overall, community buy-in is useful to ensure the long-term success of the project (Zhang et al., 2020). It can help with the initial application for funding, and by demonstrating there is community-buy in and support, there is a greater chance of the project getting funded. More equitable projects are created when the community members and other stakeholders are brought in during the project inception phase.

2.5 EQUITY AND ENVIRONMENTAL JUSTICE

Environmental justice can be thought of as "actions taken to prevent future or current harm, increase or rebuild the relational value of residents to both the environment and the city, and repair the processes that have led to environmental injustices" (Hoover et al., 2021). Equity means ensuring that people have fair opportunities to participate in society and relates to issues of the distribution of benefits, costs, or risks (Seigerman et al., 2022). Within the broad definition of "equity", there are three interrelated dimensions (Seigerman et al., 2022; Arkema et al., 2024):

Recognitional Equity – recognition of different experiences and ethics.

Ex: How are the community's cultural and social values being taken into account when developing an NBS, especially when determining the perceived benefits of an NBS?

Ensure that the community's knowledge and values are not only being considered, but directly incorporated into the development of an NBS.

Procedural Equity – access to decision-making processes.

Ex: Who is actively involved in the development of the NBS and has authority to make project decisions?

Consider how and when throughout the project planning process stakeholders and different community members are engaged and compensated for their participation.

Distributional Equity – the distribution of benefits and harms.

Ex: How are some groups of people within a community more positively/negatively impacted by a proposed NBS?

Identify the different groups within the whole community and how they may be impacted by the proposed NBS and what can be done to minimize/eliminate harm.

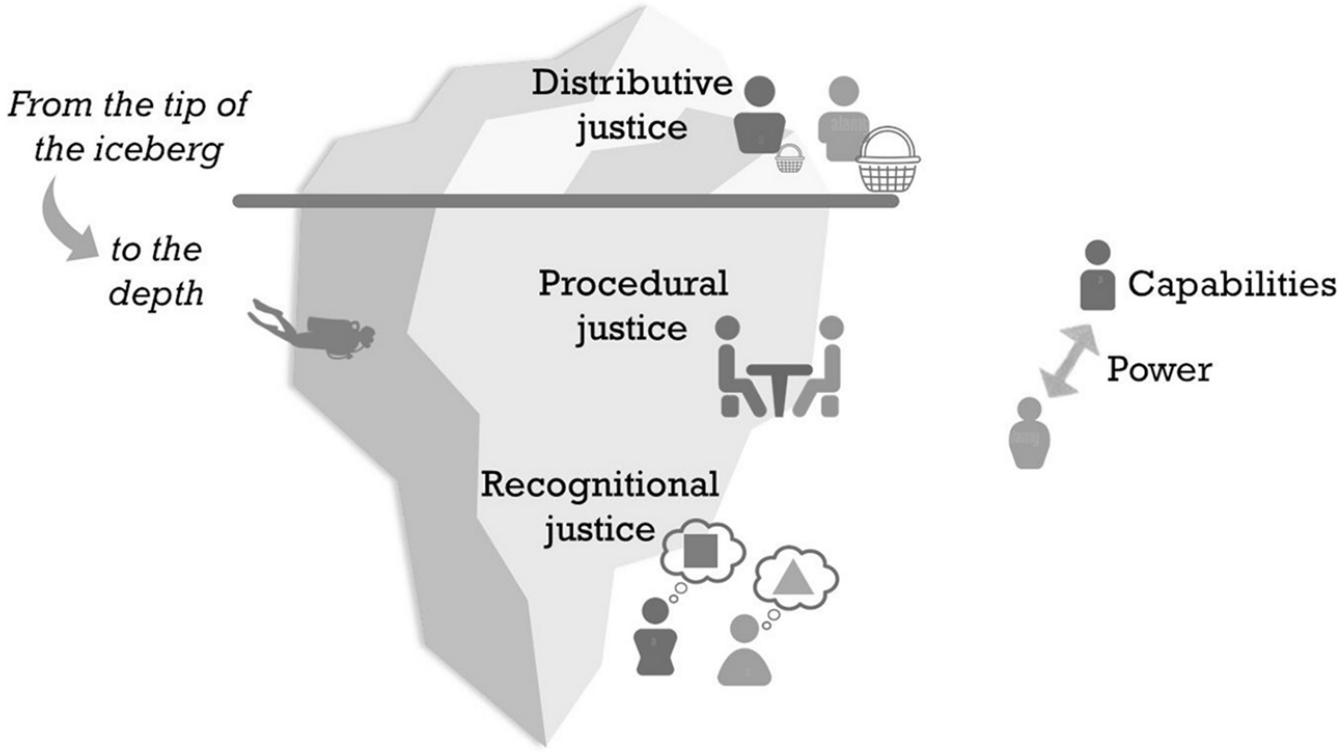


Figure 1. The justice dimensions intersecting with ecosystem services assessments and management displayed as an iceberg. Figure and description from "*An environmental justice perspective on ecosystem services*" Loos et al., 2022.

Historic inequities and systemic racism cannot be ignored when analyzing the current landscape for NBS development. "For example, studies have shown that the effects of racial covenants, redlining (a policy of discriminatory home loan financing), and other forms of housing segregation are still reflected in green space and ecosystems (Locke et al., 2020; Schell et al., 2020)." This is crucial to consider because the development of NBS are often viewed as "desirable" and will impact the property values and development in a surrounding area. Urban and built environments in particular face the possibility of "green gentrification" (Gould and Lewis, 2016) where the development of an NBS can displace existing residents and create further geographic inequity within a community (Hoover et al., 2021). Despite this concern, NBS should still be considered and implemented (with emphasis on community engagement and participation) since they provide numerous benefits to the surrounding people and environment.

NBS can provide certain benefits that can help address existing social and health inequities. There is the public health benefit of having increased access to green space that can improve air quality, decrease urban heat island effects, increase exercise and activity levels, increase mental health and well-being, decrease certain chronic diseases, and serve as a social and cultural gathering space (Pathak et al., 2022). Accessibility to NBS should not only be considered by car-based drive time, but by how easy it is to access the space by public transit, walking, or biking. Depending on the NBS type, it can also directly mitigate natural hazard impacts and reduce damage costs to residents. For more specific details on the benefits of NBS, see the individual NBS Profiles in Part 2 of this guide.

It is important to raise the issue of jurisdictions' access to resources and capacity. Counties and municipalities all have varying degrees of budget, staff, and general resources. This greatly impacts the ability of certain places to apply for NBS funding. Applications can often be long and arduous, taking up a lot of time for a non-guaranteed payoff. Additional upfront costs (while sometimes necessary) serve as another barrier. Wealthier communities have the resources to produce more funding applications because they are often more well-staffed and/or hire technical experts to assist with this work. A state or county could be receiving a large amount

of funding, but it is not necessarily distributed equitably amongst communities. There are many jurisdictions that have a strong desire (and great need) for NBS, but these barriers prevent them from accessing funds.

Many NBS are directly derived from indigenous methods and ways of life. Indigenous ways of knowing needs to be considered and utilized just as much as "western" scientific knowledge in the development of NBS. There is a need for "two-eyed" seeing, which involves "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all" (Bartlett et al., 2012; Arkema et al., 2024).

In *Section 2.7 Benefit-Cost Analysis* of this document, BCAs equity issues are further discussed.

2.6 FRAMING FUNDING APPLICATIONS AND ADAPTIVE MANAGEMENT

Applying for NBS funding is no small task between meeting application requirements and proposing a project in a way that makes it stand out amongst the crowd. This section will break down two main topics related to NBS applications: tips for framing and the inclusion of an adaptive management plan.

What should I highlight in my funding applications?

- How the funder's and project's goals align.
- How the project is supported by existing plans and initiatives.
- How the community was involved in project development and supports the project.
- How the proposed project will protect existing infrastructure and save costs.

Framing Applications

Prior to beginning an application, it's important to identify which funding organization or agency would be the best fit for a proposal. This is done by aligning relevant NBS projects with funders who have similar goals. For example, the federal agency FEMA focuses on funding projects that "protect life and property" related to hazards. If one were to submit a proposal for an NBS project that does not mitigate natural hazards impacting people, property, or infrastructure, (e.g. habitat restoration) the subapplication may be considered ineligible. This does not indicate that the project itself is a poor idea, but that it would be better suited to receiving funds from an organization such as the National Fish and Wildlife Foundation who prioritizes "habitat protection and conservation". Choosing a funder that aligns with the broad goals of the proposed project helps to draw stronger justification within the application narrative.

Proposed NBS projects that are supported by municipal, county, and state plans and initiatives can have stronger incentives to fund. This demonstrates that the existing government, agency, or public plan to prioritize similar projects. For example, if extreme heat is identified as a hazard of concern in a county HMP and one of the proposed mitigation actions is to increase canopy cover, this can be cited and used to help justify funding a native tree planting project.

Community support and buy-in should be made clear wherever possible within an application. This would mean highlighting how the community wants or needs the NBS project, what engagement has been done thus far to gather support, and how the project relates to the values of the community. Places to directly highlight this can include the mission statement and goals of the project. To take this a step further, the project and community goals and values should connect back to the goals and priorities of the funder whenever possible.

Where relevant, it should be noted how the proposed NBS project would protect existing infrastructure. For example, how a restored coastal wetland would serve as a buffer from intense wave action and based on modeling results, would likely prevent damage to 20 nearby homes during a 100-year storm event. This is an important point to make because it indicates how money would be saved from potential spending on infrastructure repairs and resources in the future.

Adaptive Management

NBS can at times be unpredictable due to environmental systems having multiple factors at play that are out of human control, such as increased storm severity and

frequency. The "unpredictable" aspect of climate change is yet another added layer. To account for this level of inherent unpredictability, adaptive management should be used in project planning.

Adaptive management is an "...iterative process for adjusting management measures to changing circumstances or new information about the effectiveness of NBS projects or the system being managed." Adaptive management "reduces uncertainties regarding project performance by developing and using new information, gathered by monitoring, and evaluating key uncertainties. This can facilitate the ability to make adjustments to the project during its life cycle to meet or improve expected outcomes and benefits at either project or system scales and to inform future projects" (USACE International Guidelines 2021, p. 274; modified from Craig and Ruhl 2014). Adaptive management is not exclusively used for NBS and green infrastructure projects, but also in the maintenance of traditional grey infrastructure (Williams et al., 2009).

It is useful to have multiple design versions and alternative options that can aid in pivoting the project soon after installation or over time as conditions change. Overall, adaptive management provides flexibility to tweak projects and maximize the benefits and performance. It can reduce unexpected costs or complete project failure because adjustments were already factored into the planning and implementation process. It can also allow for adjustments to other resources, including the environment. If a project is found to contribute to unforeseen environmental impacts, such as unintentionally capturing sediment, appropriate adaptive measure can reduce negative outcomes. Demonstrating cost effective measures and well-thought-out alternative scenarios to the funder indicates the commitment to an NBS project. For more information on developing an adaptive management plan, refer to the *USACE International Guidelines on NNBF* pg.280.

Benefits of Investing in Adaptive Management

Reducing Life-Cycle Project Costs

- Reduces up-front costs by allowing management of unknowns over time.
- Saves cost by not overdesigning up front, while providing the ability to adapt the design over time, as needed, sustaining project life span and benefits.
- Optimizes operations and maintenance costs over time.

Reducing Risk and Improving Outcomes

- Improves outcomes and robustness by using adaptive actions over time.
- Allows phasing of projects, instead of needing to minimize uncertainties up front.
- Provides flexibility to change direction or adapt overall strategy.
- Allows acceptance of risk to innovate with confidence where uncertainty and risk are addressed over time.
- Facilitates environmental permitting, acknowledging uncertainties regarding impacts.
- Enhances ability to meet multiple objectives and benefits over time.
- Improves design life via asset resilience.

Adapting to Improve Knowledge

- Improves future work through lessons learned from ongoing projects.
- Enhances knowledge about performance of features through monitoring and evaluation.
- Quickly builds knowledge of system functionality and performance by accepting risks early during planning and design phases.
- Leads to more innovative design by evaluating new technologies in the field.

A key part of adaptive management and NBS projects is monitoring. Monitoring is factored into projects for multiple reasons (Yepsen et al., 2016):

1. To assess project performance (it helps determine if a project is "successful" in that it meets the initial goals).
2. Inform adaptive management (can help inform when a project is operating differently than expected and allow for adjustments or modifications to components of a project).
3. Fulfill monitoring requirements (native plant die off rate, biodiversity values, etc.).
4. Aid in data collection that can be used to improve upon existing and future projects.
5. Provide more information as to when a project starts to provide a return on investment and help pinpoint when benefits start to outweigh costs.

There needs to be a clear set of goals, standard indicators/metrics (for across-the-board comparison), and defined methodology (including tools, equipment, and schedule). The goals and objectives of a project determine the metrics and methodology to be used for monitoring the NBS (Pathak et al. 2022; USACE International Guidelines for NNBF 2021 p.170) in addition to any state and federal requirements. For additional information on monitoring best practices, see the NBS profiles in Part 2 of this document, which highlight resources like *Developing monitoring Plans for Living shoreline projects in DE: A Goal-based framework and A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey*.

SECTION 2.7 BENEFIT-COST ANALYSIS

The following section describes benefit-cost analysis, benefit transfer methodology, and their use in the evaluation of proposed nature-based solutions. It should be noted that these methodologies are complex and require a substantial understanding of concepts and practices in economics and/or environmental science. As such, the information provided here is intended to familiarize readers with the approaches and techniques used in these analyses. It is not intended as a step-by-step guide to their implementation. Some agencies and foundations provide detailed guidance, values, and platforms that guide funding applicants through the completion of benefit-cost analyses required for the assessment of their applications. Others are more open-ended in their application processes and might simply require that the applicant complete a benefit-cost analysis. In either case, consulting the expertise of trained economic and/or environmental analysts is essential to the production of credible, high-quality analyses to support project financing applications.

Avoiding a Benefit-Cost Analysis

While this document focuses primarily on funding sources that may require a benefit-cost analysis (BCA) to be completed, there are funding opportunities available that do not require one to be performed. These funding opportunities are often much smaller amounts of money in comparison to BCA-required programs but can still be useful for smaller-scale projects and pre-project planning activities. Examples of activities include but are not limited to leveraging funds for:

- Community engagement and outreach.
- Relationship building.
- Scoping for site suitability.
- Establishing project partners.
- Developing conceptual designs.
- Permit planning.

What is Benefit-Cost Analysis (BCA)?

Benefit-cost analysis (BCA) is a systematic process used to evaluate the economic viability of a project or policy. Conducting a BCA involves identifying, quantifying, and assigning a monetary value to a particular project's total benefits and costs (Boardman et al., 2011). More broadly, BCA is a decision-making tool that objectively compares the standardized value of different projects—including nature-based solution (NBS) projects—to ensure resources are allocated efficiently and effectively.

Governments and other organizations use BCAs to make informed decisions about allocating budget resources, primarily by evaluating and comparing the value of different projects, investments, or other actions. Additionally, many grant programs available to governments or other entities require a BCA for eligibility.

Looking specifically at NBS projects, BCAs may not be useful for highlighting the broader environmental, social, and economic benefits that often do not have a clear monetary value. Traditional financial analyses may often overlook the benefits of NBS projects, such as flood control and resilience, carbon sequestration, water purification, species protection, recreation value, etc. BCA endeavors to express all these benefits – both the direct and the less tangible - in dollar terms, allowing a more accurate and full evaluation of the project's overall benefits. However, economists sometimes struggle to find ways to express non-quantitative values. Doing so often requires rights holder outreach and narrative description.

Additionally, NBS and other climate-resilience projects typically have high, upfront capital costs (i.e., for initial construction and operation) but a stream of benefits that persists across future years. To effectively compare the value of different projects, all benefits accrued, and costs incurred over the active lifetime of the project must be considered. Especially for NBS, with benefits accruing across many years after project implementation, BCAs provide a method to standardize those benefits to present an objective evaluation of a project's overall lifetime value.

Equity in BCAs

Economic models for calculating benefit-cost analyses (BCA) of NBS don't always provide alternative approaches or adjustments for equity issues that arise when:

- Property values are used to estimate damages avoided.
- Willingness to pay studies do not adjust results based on income.
- Pricing of land and benefits.
- Cultural benefits are not incorporated.
- Health of people amongst other factors.

To learn more about equity and the BCA process, explore the following resources:

1. *Operationalizing equity for integrated water resources management*, Seigerman et al., 2022
2. *Beneficiaries, Equity, and Trade-Offs in Estuarine and Coastal Ecosystem Services*, Arkema et al., 2024
3. *Equitable Investments in Resilience*, The Urban Institute, Junod et al., 2021
4. *Improving benefit-cost analyses for rural areas*, Headwaters Economics 2021
5. *Ecosystem accounting and the need to recognise Indigenous perspectives*, Normyle et al., 2022

Key Concepts to Understand About Benefit-Cost Analysis

Understanding the fundamental concepts of BCA is crucial for local officials seeking to assemble high-quality proposals and applications for funding of NBS projects. Provided below is a brief description of several key terms and concepts integral to BCA. Definitions of these and other terms can be found in the Glossary in the Appendix of this document.

Costs, Benefits, Net Benefits, and Net Present Value

Net benefits represent the difference between the total benefits and the total costs of a project. Generally, a project is considered economically viable if its net benefits are positive, meaning its benefits outweigh its costs. When calculating net benefits, it is important to consider not just direct, financial consequences, but also total costs and benefits to society, including direct, indirect, future cost avoidance/reduction, and even intangible impacts. For example, the benefits associated with a flood resilience project would directly include avoided flood damages, but may also include other indirect ecosystem services, such as water purification and erosion control, and intangible values, such as any additional recreation or aesthetic value associated with the project. Labor, capital, and planning expenses are often initial costs for a project, followed by ongoing maintenance and operational costs over the project's lifetime.

Net present value (NPV) is the present value of a project's net benefits expressed after accounting for the time value of money, a common economic assumption that people prefer consumption today more than consumption tomorrow. Both benefits and costs must be adjusted, or discounted, into present values to provide a standardized comparison of net benefits occurring over many years. A positive NPV indicates that a project is expected to generate more value over time than it costs, making it economically favorable. It is important to note that these costs and benefits may be delayed (i.e., occur in future years after project implementation), or may not occur in a linear pattern (i.e., benefits may not be distributed proportionately across a project's lifetime).

Time Horizon, Discounting, and Benefit-Cost Ratio

The **time horizon** is the period of time that the costs and benefits of a particular project are evaluated. Choosing a longer time horizon for a project will ensure benefits and costs occurring later in the future are included

compared to a shorter time horizon. For example, evaluating a project over a 50-year horizon compared to a 20-year time horizon includes an additional 30 years of costs and benefits, and as such has the potential to alter overall net benefits of a project, depending on the magnitude of benefits and costs occurring across those future years.

Discounting is the process of adjusting benefits and costs that occur across different periods into comparable, present-value terms. Discounting reflects the time value of money - the concept that it is preferable to receive a dollar today than to receive one in the future. In calculating the net present value of benefits and costs, the value of benefits enjoyed in future years is thus discounted to reflect that preference. Discounting therefore reflects how much future benefits and costs are worth today (EPA, 2016).

The ***discount rate*** is effectively the inverse of an interest rate; it is an estimate of how rapidly the value of money changes over a particular period. This is different from the inflation rate, which refers to the rate at which the price of broad goods and services increases over time, leading to a reduction in purchasing power (McKinsey and Company, 2024). Choosing an appropriate discount rate is extremely important for any BCA, particularly those considering NBS projects, as many of the benefits occur later over future years after upfront project costs. Accordingly, choosing a high discount rate will often diminish the overall benefits of a project. Current guidance issued by the federal Office of Management and Budget (OMB) for analysis of federal regulatory actions suggests an annual discount rate of 2% per year (OMB, 2023). An important consideration to make is that, even with a low discount rate, future values become extremely minimal over the moderate-to-long-term. For example, assuming a 2% annual discount rate, the NPV of $100 50 years from the current year is only $37. Assuming a 5% annual discount rate, this value decreases to only $9. As such, choosing an appropriate discount rate is extremely important and can be consequential to the overall economic feasibility of a particular project. BCAs conducted for grant proposals typically require usage of a particular discount rate.

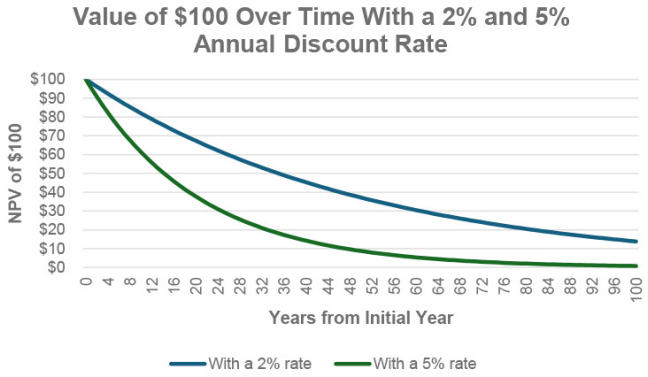


Figure 2. Future values of $100 USD using a 2% ADR versus 5% ADR.

The ***Benefit-cost ratio (BCR)*** expresses the relationship between the present value of benefits and the present value of costs, specifically a BCR equals the present value of benefits divided by the present value of costs. A BCR greater than 1 simply means that the benefits of the project exceed the costs, while a BCR less than 1 suggests the opposite. This ratio is used to gauge the overall cost-effectiveness of a project, with BCRs greater than 1 often being a threshold for project support or funding. For example, FEMA (2024) requires applicants to demonstrate the cost-effectiveness of projects by showing a BCR of greater than 1 before granting project funding.

Please note that there are other methods used to understand the economic effectiveness of a project. One of these is a net benefits test. A net benefits test is an alternative method to gauge the effectiveness of a project, where the singular project with the greatest NPV is selected (Boardman et al., 2011). A net benefits test is usually used when comparing different alternative projects, while the BCR test is more of a project hurdle pass-fail.

Key BCA Terms for Nature-Based Solutions

Ecosystem services play a critical role in benefit-cost analysis of nature-based solutions (NBS). **Ecosystem services** are services provided by the Earth's ecological systems and resources to support both human life and the health and wellbeing of the greater planet. These values can include more intentional benefits of NBSs, such as reduced flood risk, or less direct benefits like

water purification…, "enhanced fisheries, carbon sequestration, and improved tourism and recreation opportunities" (NOAA, 2021). NBS co-benefits also may not directly support human life but instead support the greater ecosystem, such as increased biodiversity or improved habitats for native species. The value of all ecosystem service benefits and the co-benefits of NBS should be included in a BCA to accurately and comprehensively reflect the project's benefits. Quantified and monetized values of ecosystem service benefits (where available) can be found in the NBS Profiles of Part 2 in this document.

Benefit transfer is "used to estimate the values of ecosystem benefits (goods and services) in a location or context, when values are not available from an original study, by applying data and values from studies in different but similar locations or contexts" (NOAA, 2021). For example, if an organization is interested in restoring a wetland in New Jersey, the organization could use studies about similar wetlands in New York in their New Jersey BCA. When properly and appropriately implemented, benefit transfer can be a less expensive method of evaluating ecosystem service benefits than primarily data collection.

The ***policy site in a benefit transfer*** is the site of the proposed project, or the site where the cost-effectiveness of the project is being evaluated. The ***study site*** is a comparable site in which a similar project has already been implemented and the costs and benefits of that project have been quantified and monetized.

Nature-Based Solutions and Benefit-Cost Analyses

The information in this section is intended for educational purposes to help readers understand the basics of BCAs and tips for doing them well, but this section should not replace or supersede the specific requirements of a funding agency or program. Many agencies that require a BCA for grant funding provide toolkits with pre-existing values and methodologies to use in the applicant's analysis, such as FEMA's BCA Toolkit, or other existing guidelines that should be adhered to when available.

When conducting a BCA, appropriately utilizing benefit transfer can provide benefit estimates at a significantly lower time and cost burden than other valuation methods. Benefit transfer relies on pre-existing values already calculated from similarly focused but different studies, and does not require primary data collection, which is often expensive and time-consuming (NOAA, 2021). Accordingly, "[benefit] transfers offer a feasible means to provide information on economic values to support decision-making when time, funding, and other practical constraints impede the use of original valuation studies" (Johnston et al., 2021).

However, benefit transfer "has a higher level of error than a primary study" and requires appropriate judgment to ensure the applicability of the other studies and their values transferred (NOAA, 2021). As such, ensuring the transferred value is associated with a truly comparable ecosystem is crucial, and consultation with experts in justifying a benefit transfer is recommended.

There are two types of benefit transfers: unit value transfers and function transfers. Unit value transfers "include the transfer of a single value, for example an average value across multiple studies (e.g., average consumer surplus per bird-watching trip). Benefit function transfers, in contrast, calculate values using an estimated function from empirical research that allows multiple factors (e.g., socio-demographic variables) to be used to adjust the study site value to the policy site" (Wainger et al.). Function transfer is more sophisticated and generally outperforms value transfer in terms of accuracy, however, value transfer is less complicated and expensive to conduct, and "can perform satisfactorily if the study and policy contexts (e.g., social factors, geographic and time scales, degree of resource scarcity) are very similar" (Wainger et al.). The focus of this section will be on unit value transfer.

Basics of Benefit Transfer

When conducting benefit transfer (unit value transfer), the practitioner first seeks out one or more values from prior studies of the same type of ecosystem (e.g., wetlands, riparian buffers, etc.). The relevance and applicability of these prior values to the policy site

are then evaluated before inclusion in the BCA. Values should be expressed on a per-unit per-year basis. This allows for scalability and discounting over the life of the project. For example, if a prior study estimates wetland restoration benefits at $500 per hectare per year in one region, and the policy site has similar ecological and economic conditions and is of comparable magnitude, the total annual value would be calculated by scaling the $500 per acre unit value to the size of the policy site, then discounting that total annual value back for each year that the ecosystem service is provided.

An adjustment that should be made during benefit transfer is the transferred values should be converted into present-day dollar values. For instance, if the $500 per hectare per year value were expressed in 2006 dollars, in 2024 it would need to be adjusted into 2024 dollars (or the dollar value associated with the current year). The net present value of benefits and costs is then calculated by discounting prospective streams of benefits and costs in terms of these real, inflation-adjusted 2024 dollars. That is, unless called for by agency guidance, future values are not inflated to reflect annual changes in the purchasing power of the dollar. (Real dollars describe dollar values in present-day terms by accounting for annual inflation.) Past values can be adjusted into current-year dollars by using the GDP deflator, which "measures inflation for all of the final goods and services produced in the United States" (Congressional Research Service, 2022).

Conducting a Benefit Transfer BCA

The procedures for conducting benefit transfer in a BCA can be summarized in the following steps (adapted from Johnston et al., 2021): "identification of potentially relevant studies, evaluation and screening of studies for transfer suitability, identification and coding of relevant study-site data, and supplementation of study-site data with information from external sources." Using this framework, the guidance can be categorized into four primary steps:

1. Identify similar study sites to the policy site.
2. Identify the full spectrum of benefits for a project.
3. Identify the full spectrum of costs for a project.
4. Apply estimates to the policy site.

Each of these four steps are discussed in detail below.

1. Identify Similar Study Sites to the Policy Site

The first step in benefit transfer involves identifying study sites that closely resemble the proposed policy site. There are three key parameters across which sites should be compared:

- ***Socioeconomic and demographic parameters.*** The socioeconomic and demographic makeup from the study site should be similar to that of the policy site. This includes the number of people in the area affected or the population density, the number of affected properties and property values, percentage of homes elevated, average income, etc.

- ***Ecosystem features.*** The study site ecosystem (e.g., habitat, geographic location) should be similar to that of the policy site. For example, using a mangrove ecosystem service value as a proxy for a wetland ecosystem service value would not be appropriate.

- ***Size.*** The physical extent of the project at the study site should be similar to that of the policy site. The size of a project can impact project costs as well as ecosystem services generated. For example, the effective wave attenuation of a 20-foot living shoreline for a 100-year storm will be much different than that of a ½ mile living shoreline.

Note that there are no specific metrics according to which to determine whether the similarity of a study site to the policy site is sufficient. This is why it is important to consult subject matter experts in making these determinations.

Robust data sources, which separate ecosystem service values into distinct categories should be utilized, such as in Costanza's "*The Value of New Jersey's Ecosystem Services and Natural Capital*" (2006). Data sources provided in the Profiles section of this document represent the most relevant data available at the time of publication, but the methods used to develop the ecosystem service values in the Profiles should be

considered before using said values in a BCA. Below are considerations for extracting relevant data from robust data sources:

- ***Type of Data:*** It is essential to recognize that some values may not be additive (i.e., a project's recreation service value may already contain the benefits from proved water quality) or may be presented as ranges rather than singular figures (i.e., a BCA may report a project's flood reduction benefits as a minimum-to-maximum range instead of a singular estimate), and acknowledge the advantages and disadvantages of how the study presents the data.

- ***Source of Data:*** FEMA provides pre-existing ecosystem service values within its BCA toolkit and explains the origins and methodology behind these values in the "Ecosystem Service Value Updates" (2022) report. Understanding the source of the ecosystem service estimates is critical, as it provides context on a data source's strengths, limitations, and how applicable they are to a particular policy site or situation.

Careful consideration and contextual awareness in these assessments will enhance the relevance and effectiveness of the benefit transfer and the greater BCA.

2. Identify the Full Spectrum of Benefits

After identifying comparable study sites, the collective costs and benefits associated with the project must be calculated. Refer to the NBS profiles in Part 2 within this guide, which detail the potential co-benefits associated with each different NBS project type.
Benefits of NBS projects broadly include:

- ***Avoided damages*** (e.g., reduced flood risk and associated response costs, reduced damages for nearby properties, reduced heat risk for residents).
- ***Provisioning services for humans*** (e.g., food, water, raw materials, genetic resources, medicinal resources, ornamental resources, physical health benefits).
- ***Regulating services*** (e.g., air quality, climate regulation, disturbance mitigation, infrastructure protection, regulation of water flows, waste treatment, erosion prevention, nutrient cycling, pollination, biological control).
- ***Habitat services*** (e.g., nursery service, gene pool protection, biodiversity, shelter for animals).
- ***Cultural services*** (e.g., aesthetic value, recreation, inspiration, spiritual experience, cognitive development, social well-being, mental-health benefits) (Morizet-Davis et al., 2023).

Once the relevant benefits have been identified, the next step is to find values from study sites that are applicable to the policy site.

Values for avoided damages taken from a study site may require substantial adjustment prior to application to the policy site, as these values may have been estimated in economic contexts different than those of the policy site. For example, the value of wetlands serving as a coastal buffer at a study site with a more expensive coastal housing stock than at the policy site might require adjustment to reflect the lower aggregate value of property at risk. "The Value of New Jersey's Ecosystem Services and Natural Capital" (Costanza et al., 2006) and FEMA's "Ecosystem Service Value Updates" (2022) report both categorize different recreational and nutrient benefits, as well as estimates for avoided damages, for a series of NBS types.

When completing a list of co-benefits for a particular policy site, it is helpful to categorize both use and non-use values separately. Use values include both the direct and indirect benefits of a particular policy site. For example, …Non-use value is the value individuals have for a particular service or good without directly using the service or good, such as ***existence value*** (i.e., the WTP an individual has for a good that they would never use) (Zerbe & Dively, 1994). For example, an individual may value a public beach simply for existing, even if they do not plan on ever visiting or utilizing the beach. Similarly, ***option value*** describes the value individuals associate with maintaining the ability to potentially utilize something in the future. For instance, an individual may have some WTP to maintain the ability to visit a public beach in the future, even if they have bever previously visited the beach and are not certainly they will visit moving forward.

Additionally, be mindful of whether chosen values are additive, or aggregated with other values. Certain benefits may be recorded distinctly, while others may be aggregated for economic (e.g., WTP values often may

aggregate different benefits into one value) or ecological reasons (e.g., improved water quality in a stream can lead to indirect co-benefits such as enhanced fish habitat and increased recreational opportunities). For example, a flood resilience NBS may generate co-benefits like recreation and cultural services, improved water quality, improved fishing stock, and existence value, but one BCA may group all those individual benefits as a single recreational value, while another study may record them separately. As such, it is important to evaluate whether the transferred value accurately represents the identified benefit in order to avoid double counting or under-representing the co-benefits for the policy site.

3. Identify Full Spectrum of Costs for a Project

Costs for NBS projects are similar to the costs for other types of resiliency projects and primarily include:

- ***Capital expenditures*** (e.g., design, planning, and construction costs).
- ***Operating and monitoring costs*** (e.g., maintenance and operation costs over the life of the project, and cost to monitor the ecological, biological, and socioeconomic benefits of a project for the years following the project, if applicable).
- ***Transaction costs*** (e.g., expenditures associated with achieving successful project investment, such as technical assistance or stakeholder engagement).
- ***Opportunity costs*** (i.e., the forgone value of using the policy site or required resources for the next best alternative use).
- ***Disservices caused by the NBS*** (i.e., any negative impacts on human or environmental welfare due to the implementation of the NBS)

In general, a majority of project costs are often upfront capital costs, and most of the project benefits occur as a continuous stream following the project's completion.

As noted earlier, the selected benefits and costs should align with the ***socioeconomic and demographic parameters***, ***ecosystem features***, and ***size*** of the relevant NBS and policy site. The values should then be organized into a table, clearly defining the values, and explaining specifically what benefit or cost category each value represents.

Additionally, while utilizing studies with references for ecosystem service valuations, it is important to obtain data and value estimates that most accurately reflect ***the timing of quantifiable ecosystem service benefits.*** When implementing NBSs, the benefits of that project may not be realized for a certain period following project implementation. For example, the restoration of wetlands with the primary purpose of reducing storm surge risk may not begin to generate benefits from avoided damages until five years after restoration efforts. This potential delay in benefits must be incorporated into the ecosystem service benefit evaluations. Similarly, the value of a NBS can increase over time if either environmental or demographic conditions change. For instance, "changes in exposed assets or population composition through time" or "changing environmental conditions such as sea-level rise and other climate change factors" could potentially augment the future benefits of a NBS (Zanten et al., 2023). Thus, the potential for conditions to change or worsen and the effect this may have on a project's future benefits must additionally be considered in the value estimates.

4. Apply Estimates to the Policy Site

Once the comparability of the study sites to the policy site has been established and the range of benefit values from the study sites has been determined, the values are then adjusted where necessary to reflect the parameters of the policy site and used to calculate the streams of various benefits over the lifespan of the project. If there are multiple study sites with value estimates for the same types of benefits, a common approach is to use the average value for each benefit type across the various study sites. In these cases, the relevant parameters for each study site should be identified and described.

Sensitivity analysis provides a useful means to reflect the uncertainty surrounding the applicability of benefit transfer estimates by measuring how sensitive the net benefits of a project are to a change in a given benefit value (Zerbe & Dively, 1994). This approach seeks to account for potential differences in expected benefits between the study and policy site. For example, if the recreation benefits of a policy site are expected to be less accessible than those of a study site, the value estimate from the study site might be adjusted downward by 50% to evaluate how the net benefits of

the project would change based on this one adjustment. Similar tests can be used for other benefit types and combinations thereof to assess the sensitivity of the net benefit estimate to possible over- or underestimates of ecosystem service values.

In cases where multiple study sites present a wide range of benefit values, a common practice is to identify the average, maximum and minimum values of each type of benefit across the various study sites and apply these in varying combinations to determine a range of estimates for aggregate benefits at the policy site.

The lifespan of NBS projects vary and there is no definitive duration for provision of ecosystem services or other co-benefits. The lifespan of a NBS depends primarily on the three key factors described below. It is reasonable to assume that any NBS project would perform for several decades (~50 years), but that would depend on good maintenance and incorporating long-term planning considerations into the NBS design process:

- **Maintenance** – Nature-based solutions will last longer if properly maintained (e.g., invasive species removed from wetland restoration projects or afforested landscapes, living shorelines reseeded with shellfish in subsequent years, no-till practices utilized annually on agricultural lands).
- **Changing environmental conditions** – NBS that are implemented in 2024 will experience new weather norms in the decades to come (e.g., higher temperatures, higher sea-level). These changing conditions may gradually degrade the performance of an NBS.
- **The prevalence of extreme environmental conditions** – Climate change will bring more frequent and intense precipitation events and storms that could overwhelm, damage, or destroy an NBS.

Best Practices for Benefit Transfer

1) Include only similar study sites when selecting values from prior studies. Sites should be comparable across the three key categories noted above: socioeconomic and demographic characteristics, ecosystem features (including geomorphology), and project size. For example, sites should have similar income levels, population densities, and levels of development, and should fall within similar or the same ecoregions, which are areas with similar types, quantities, and qualities of environmental resources (EPA, 2024).

Additionally, sites should have comparable levels of storm frequency, flood risk, or extreme heat risk when estimating the damage reduction potential—or benefits—of a particular NBS at a policy site. Certain maps and flood projections may be outdated, so verifying that the information utilized is accurate and current is crucial. NJADAPT is a suite of tools developed by Rutgers University that are designed to assist planners, community leaders, businesses, and residents to understand and adapt to the impacts of climate change on people, assets, and communities in New Jersey. The NJ HazAdapt tool located within the NJADAPT suite provides a good starting point for these hazard analyses (additional tools available in the Appendix).

Identifying similar study sites is a subjective process. There is no specific geographical threshold for the proximity of study sites to policy sites. Nor are there set rules regarding the number of study sites necessary to use in a benefits transfer. Those conducting NBS will need to use their best judgment and utilize the relevant guidelines above when applicable.

2) Use average values and perform sensitivity analysis where possible. Considerable uncertainty often surrounds the value estimates used in benefit transfer. This is because value estimates are often not single values but are instead statistically derived point estimates surrounded by a probability distribution. To mitigate this uncertainty, it is advisable to take the average value estimate from multiple comparable sites when possible.

3) Address equity considerations, quantitatively where possible. When attempting to monetize all impacts of a particular disaster, project, or intervention in a standardized way, there are equity concerns to consider. Many studies may derive certain impact values using methods that do not account for income disparities. For instance, a common approach to assessing the value

of a non-market good involves surveying respondents about their willingness to pay (WTP) for a particular outcome. WTP represents the amount an individual is prepared to pay or requires to be indifferent between the status quo and the proposed policy outcome with the payment (Boardman et al., 2011). In other words, WTP is the monetary amount an individual or society values a particular intervention or outcome compared to the current situation. While WTP is a valid method of estimating project benefits, the amount someone is willing to pay "tends to be higher the greater the wealth that she or he has available" (Boardman et al., 2011) Additionally, studies estimating benefits by looking at damage avoided from a particular intervention often rely on property values, which similarly can lead to the prioritization of wealthier neighborhoods and higher income areas. While flood risk damages are typically estimated in terms of property or other types of material damages, flooding and other disasters also threaten lives. As such, including values that estimate the reduced risk to life and injury should also be included in a BCA.

Additionally, benefits may be different for particular subgroups of an overall population. For example, the health benefits derived from a particular project may be different for lower-income or disadvantaged communities compared to wealthier communities. Similarly, a particular subgroup may either bear a more significant percentage of the project costs or may have a disproportionately higher disaster risk than other subgroups. When possible, evaluate and discuss the distributional effects of a project (i.e., how the benefits and costs of a particular project are disseminated across different populations). Where it is not feasible to incorporate equity concerns numerically in the BCA, include narratives whenever possible about the potential distributional effects of an event or project. Refer to the Urban Institutes' "Equitable Investments in Resilience" (Junod et al., 2021) report and "Beneficiaries, Equity, and Trade-Offs in Estuarine and Coastal Ecosystem Services" (Arkema et al., 2024) for further insight on addressing equity concerns in BCAs.

Awareness of these issues is crucial and should not only be covered in distributional analysis. To address these concerns, select studies that adjust for these shortcomings or make modifications where possible. For more insight on equity concerns in data collection and potential solutions, refer to Urban Institute's "Elevate Data for Equity" project (Gaddy & Scott, 2020).

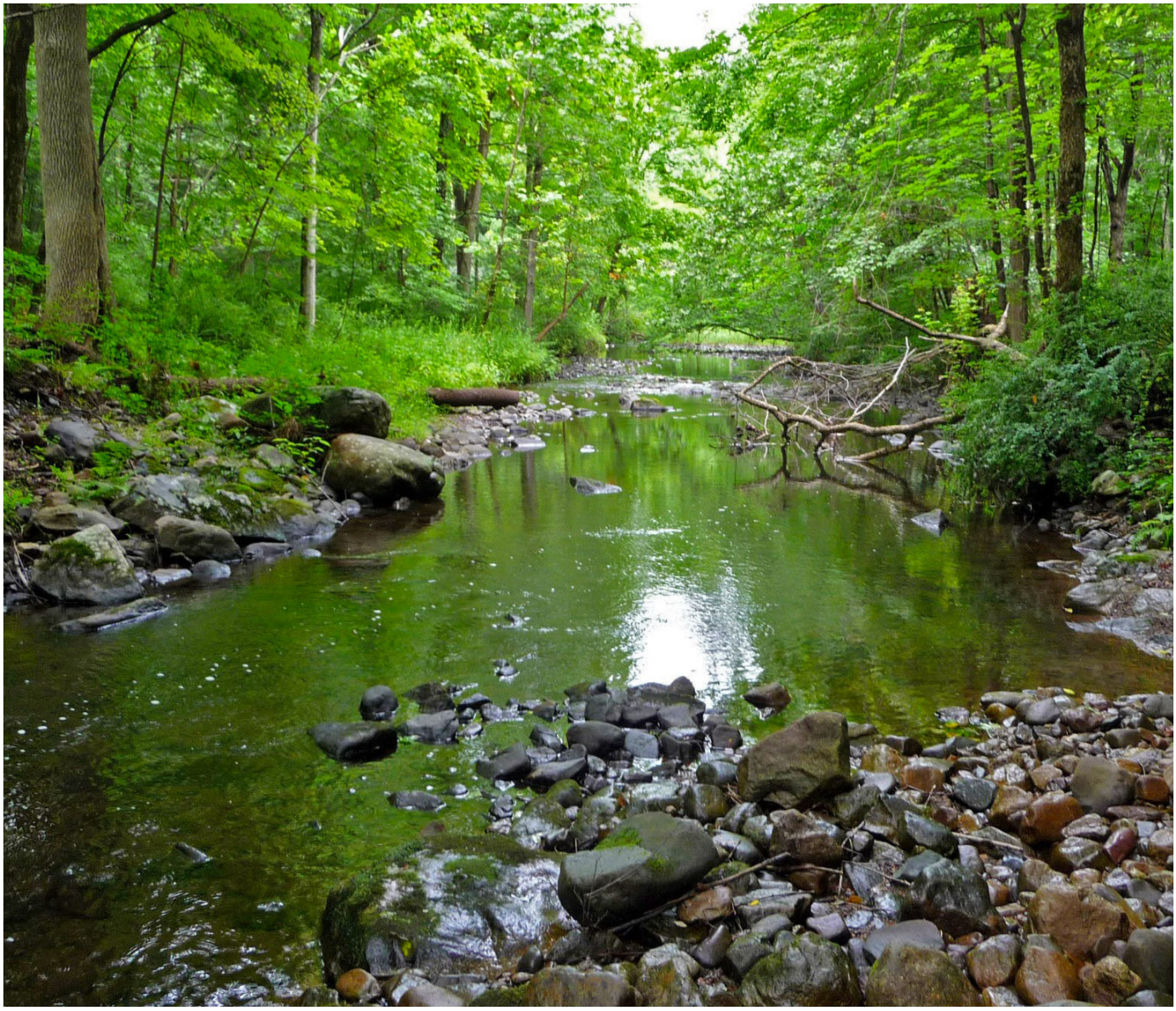
Future Considerations

Changing value of ecosystem services in the face of climate change – As the frequency and severity of extreme weather events rises, the risks to human life and property will increase commensurately. Whether the future benefits ascribed to adaptive nature-based solutions should reflect this increasing risk in the form of higher service values is an open question, but it is worth considering how a changing climate might positively or negatively impact the services provided by an NBS or estimates of its value – another benefit of monitoring.

Potential for changing technologies – It is possible that future resiliency technologies and approaches may prove more cost-effective and generate more overall benefits than those available today. Decisions about the deployment of NBS should consider whether resources to be invested today might be used more efficiently and/or effectively in the future as climate mitigation technologies evolve.

SECTION 3

Nature-Based Solutions Profiles



Courtesy of The Nature Conservancy

SECTION 3

NBS Profiles

New Jersey is experiencing an "increase in temperature, shifts in precipitation, and sea-level rise among other climate change-related impacts [that] threaten air quality, water quality, and the state's natural and built environments," (NJDEP 2021). The cost of these natural hazards across the United States are high but mitigation actions today can save money in the long-run (NIBS 2020, USCC 2024). The NBS in this reference document represent the breadth of NBS that can help mitigate the various hazards the State is experiencing. These hazards include inland flooding and stormwater issues, coastal flooding, storm surge, wildfire, drought, extreme heat, and other hazards (NJDEP 2020, NJDEP 2024).

The NBS Profiles section of this report highlights information regarding five NBS categories: Bioretention Systems, Coastal Habitats, Regenerative Land Management, Stream Restoration, and Urban Forestry. Several NBS types are highlighted within each category such that this document contains eleven NBS Profiles.

3.1 Bioretention System
- 3.1.1 Rain Garden Profile
- 3.1.2 Bioswale Profile

3.2 Coastal Habitat
- 3.2.1 Living Shoreline Profile
- 3.2.2 Salt Marsh Profile

3.3. Regenerative Land Management
- 3.3.1 Working Lands Profile (including agroforestry, conservation agriculture, avoided forest conversion, riparian forest buffers, and windbreaks)
- 3.3.2 Natural Lands Profile (including open and green space, fire management, native tree management, and wildlife lawns)

3.4 Stream Restoration
- 3.4.1 Dam Removal Profile
- 3.4.2 Culvert Removal and Upgrades Profile
- 3.4.3 Vegetated Riparian Buffer Zone Profile
- 3.4.4. Freshwater Wetland Profile

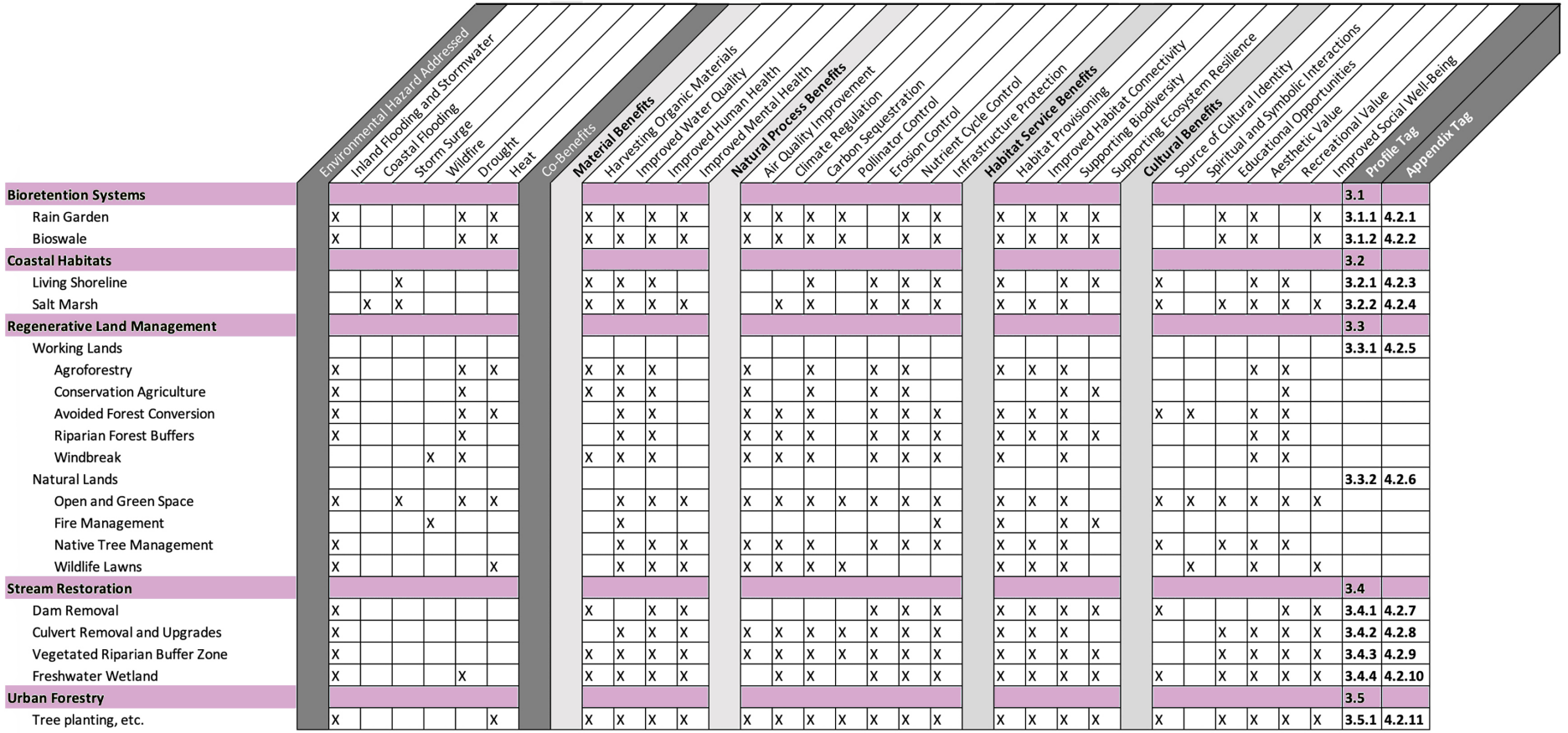
3.5 Urban Forestry
- 3.5.1 Urban Forestry Profile (including stormwater planters, tree filter boxes, and other methods of tree planting)

The following topics are highlighted within each NBS Profile: an introduction to the NBS; the hazard type addressed by the NBS; the suitable environment for the NBS; co-benefits of the NBS; common challenges associated with the planning, implementation, and monitoring phase of the NBS development; monitoring techniques; case studies; funding opportunities; and key resources. The co-benefits section of each NBS Profile is organized by four co-benefit themes which are broadly used in published literature (Morizet-Davis et al., 2023). These co-benefit themes are:

1. Material Benefits - including harvesting organic materials, improved water quality, human health, and mental health.
2. Natural Process Benefits – including air quality improvement, climate regulation, carbon sequestration, pollinator services, erosion control, nutrient cycle control, and infrastructure protection.
3. Habitat Service Benefits – including habitat provisioning (e.g., provisioning habitat with food, shelter, and nesting materials); improved habitat connectivity; supporting biodiversity (i.e., supporting biodiversity of flora and fauna); and supporting resilience of ecosystem.
4. Cultural Benefits - including source of cultural identity, spiritual and symbolic interactions, education, aesthetic value, recreational value, and social well-being

Content within each profile may overlap with similar NBS profiles. When this occurs, readers will be directed to other NBS profiles to avoid repetition.

Table 1 on the next page provides an overview of the hazards addressed by each NBS, the associated co-benefits, as well as each profile's page number. Table 1 should not be considered an authoritative list of co-benefits provided by the NBS: instead it should be considered a foundation of possible co-benefits for each NBS type. Co-benefits for any NBS project will vary based on site specific conditions and may include the same, fewer, or more co-benefits than those included in Table 1.



	Environmental Hazard Addressed						Co-Benefits	Material Benefits				Natural Process Benefits								Habitat Service Benefits				Cultural Benefits						Profile Tag	Appendix Tag
	Inland Flooding and Stormwater	Coastal Flooding	Storm Surge	Wildfire	Drought	Heat		Harvesting Organic Materials	Improved Water Quality	Improved Human Health	Improved Mental Health	Air Quality Improvement	Climate Regulation	Carbon Sequestration	Pollinator Control	Erosion Control	Nutrient Cycle Control	Infrastructure Protection	Habitat Provisioning	Improved Habitat Connectivity	Supporting Biodiversity	Supporting Ecosystem Resilience	Source of Cultural Identity	Spiritual and Symbolic Interactions	Educational Opportunities	Aesthetic Value	Recreational Value	Improved Social Well-Being		
Bioretention Systems																												**3.1**	
Rain Garden	X				X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X			X	X		X	**3.1.1**	**4.2.1**
Bioswale	X				X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X			X	X		X	**3.1.2**	**4.2.2**
Coastal Habitats																												**3.2**	
Living Shoreline			X					X	X	X				X		X	X	X	X		X	X	X			X	X		**3.2.1**	**4.2.3**
Salt Marsh		X	X					X	X	X	X		X	X		X	X	X	X	X	X		X		X	X	X	X	**3.2.2**	**4.2.4**
Regenerative Land Management																												**3.3**	
Working Lands																												**3.3.1**	**4.2.5**
Agroforestry	X				X	X		X	X	X		X		X		X	X		X	X	X					X	X			
Conservation Agriculture	X				X			X	X	X		X		X		X	X				X	X					X			
Avoided Forest Conversion	X				X	X			X	X		X	X	X		X	X	X	X	X	X		X	X		X	X			
Riparian Forest Buffers	X				X				X	X		X	X	X		X	X	X	X	X	X	X				X	X			
Windbreak				X	X			X	X	X		X	X	X		X	X	X	X		X					X	X			
Natural Lands																												**3.3.2**	**4.2.6**
Open and Green Space	X		X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		
Fire Management				X					X								X		X		X	X								
Native Tree Management	X								X	X	X		X	X	X		X	X	X	X	X		X		X	X	X			
Wildlife Lawns	X					X			X	X	X	X					X	X	X					X		X		X		
Stream Restoration																												**3.4**	
Dam Removal	X							X		X	X				X	X	X	X	X	X	X		X				X	X	**3.4.1**	**4.2.7**
Culvert Removal and Upgrades	X								X	X	X	X	X	X	X	X	X	X	X						X	X	X	X	**3.4.2**	**4.2.8**
Vegetated Riparian Buffer Zone	X							X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	**3.4.3**	**4.2.9**
Freshwater Wetland	X				X			X	X	X	X		X	X	X	X	X	X	X	X	X		X		X	X	X	X	**3.4.4**	**4.2.10**
Urban Forestry																												**3.5**	
Tree planting, etc.	X					X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	**3.5.1**	**4.2.11**

Table 1. Overview of the environmental hazards addressed and co-benefits provided by each of the eleven NBS highlighted in this document denoted by an "X." To learn more about each NBS refer to the Profile Tag on the right side of the table, searching for the Profile Tag number will bring you to the proper subsection of this reference document. The Appendix Tag number refers to the corresponding subsection of Appendix 4 which contains additional information for each NBS not covered in detail in each profile.

3.1 Bioretention Systems

What profiles are in this NBS category?

Rain Garden

Crown Hill Foundation

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwater
- ✓Drought

Suitable Environments

- ✓Low slope area on soil with good drainage

Key Takeaways

1. Bioretention systems are generally less costly than traditional grey infrastructure.
2. Individuals/organizations responsible for longterm rain garden maintenance should be identified early in the planning process.
3. Rain gardens are not large enough to mitigate intense rain-driven flooding.

Bioswale

The Klausing Group

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwater
- ✓Drought

Suitable Environments

- ✓Low slope area on soil with good drainage

Key Takeaways

1. Bioretention systems are generally less costly than traditional grey infrastructure.
2. Bioswales capture larger volumes of runoff that travels at higher speeds than a rain garden can handle.
3. Vegetation in bioswale can be vulnerable to damage if exposed to high velocity runoff too soon after planting.

Information about bioswales, beyond what is covered in this profile, can be found in Appendix 4.2.2.

Introduction to Bioretention Systems

Stormwater can cause runoff which contributes to flooding and poor water quality conditions across New Jersey including along the coast (NOAA 2024) and inland (NJDEP 2024). The pollution that is carried by stormwater runoff to water bodies is called nonpoint source pollution (Obropta et al., 2023). Stormwater runoff increases in urban areas when impervious surfaces (like roadways, parking lots, and rooftops) block water from seeping into the soil during precipitation events (Wilson et al., 2020, Figure 3). Stormwater runoff increases in more rural environments when a lot of rain falls quickly because the rainwater cannot saturate into the ground fast enough (RCEWRP 2015). Stormwater management practices that capture, filter, absorb, and/or reuse stormwater can help to mitigate flooding and water pollution. Bioretention systems use high-performance landscapes, sometimes complemented with grey infrastructure, to mitigate flooding and water pollution

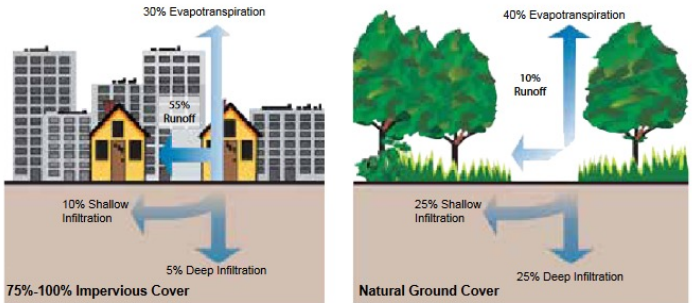


Figure 3. Comparison of stormwater in an urban (left) and natural (right) environment. (Modified from EPA 2003).

caused by stormwater. Bioretention systems are a form of "green infrastructure" or "green stormwater infrastructure." Best Management Practices (BMPs) outlined by NJDEP's stormwater rules consist of strategies to manage stormwater in the State and include bioretention systems, manufactured treatment devices, wet ponds and more (NJAC 7:8 Stormwater Management). For information on additional stormwater management BMPs visit the EPA's National Menu of Best Management Practices for Stormwater-Post-Construction (2024) and EPA's Bioretention Design Handbook (2023). For the purposes of this document, not all BMPs are considered NBS.

Two NBS profiles are highlighted within this NBS category: bioswales and rain gardens. Below are a couple key takeaways from experts regarding these NBS:

1. **Small Scale, Effective Projects that Need Maintenance –** These NBS are generally small-scale, are relatively simple to install, and effective if properly maintained. Experts have reflected one of the biggest reasons these NBS fail is because of poor long-term maintenance. on the lack of maintenance do not require an extensive amount of land to construct. Refer to the "Maintenance" subsection below for recommended actions to keeping these NBS at their optimal performance.
2. **Native Plants are Important –** These NBS are relatively popular and have been built throughout the State. Due to the ubiquitous nature of these NBS they provide a great opportunity to integrate more native plants into New Jersey (Jersey-Friendly Yards 2025). Prioritizing native plants in the planning stage of any bioretention system project will help ensure these plants are used.

3.1.1 RAIN GARDEN PROFILE

Introduction

Under the new Municipal Stormwater regulations (NJFuture 2023), NJDEP is requiring municipalities to map stormwater facilities as part of Stormwater Pollution Prevention Plans (SPPP) (SPPP templates available here). Stormwater facilities include green infrastructure which includes rain gardens. A rain garden is a landscaped, shallow depression that captures, filters, and infiltrates stormwater runoff (Obropta and Bergstrom 2024). Rain gardens are low-cost, small-scale solutions to treat stormwater runoff generated from buildings, roadways, parking lots, and sidewalks. Rain gardens are estimated to cost $5 to $16 per square foot to build and between $0.31 and $0.41 per square foot to maintain annually (NOAA 2020, Jack et al., 2014). Rain gardens in New Jersey are generally designed to hold 1.25 inches of rain over two hours (this amount of rain is known as "New Jersey's Water Quality Design Storm" or WQDS (NJDEP 2023). Common features of a rain garden include an inlet where water enters the rain garden, a depression to collect water (this depression will normally be twice as long as it is wide to maximize stormwater infiltration), and an outlet where extra stormwater the rain garden cannot handle will exit the rain garden system. Rain gardens can be made entirely of natural materials while some may have piping underneath to (1) distribute the infiltrated water over a larger surface area or to (2) transport excess stormwater offsite (*e.g.,* a nearby catch basin) (Obropta and Bergstrom 2024).

What hazards do this NBS address?

Rain gardens are designed to hold the volume of water from a heavy precipitation event per state requirements (i.e., 1.25 inches over two hours) to mitigate localized and site specific flooding from storm events (Sharp 2020). Rain gardens can also be designed to handle a two-year design storm (i.e., 3.2 – 3.5 inches of rainfall over 24-hours) which is a slightly larger

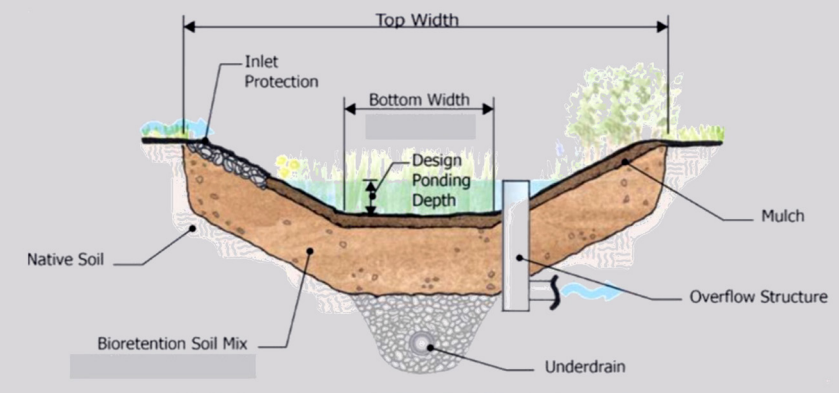


Figure 4. Schematic of a rain garden (Obropta and DiMuro 2023)

rain garden that can withstand more intense storms (RCEWRP 2015). Rain gardens also mitigate water pollution by capturing runoff from storm events. The most polluted runoff occurs at the beginning of a storm when runoff picks up and carries pollutants away leaving clean surfaces behind. Rain gardens thus reduce drought conditions by recharging groundwater stores. Rain gardens also mitigate urban heat island effects through evapotranspiration and shading (Wang et al. 2024).

Where should this NBS type go?

A rain garden functions best when (Obropta and Bergstrom 2024):

- ✓ Located near an impervious surface that will generate runoff
- ✓ On land with less than a 12% slope
- ✓ With soil that has good drainage

The key steps to identifying the suitable habitat for a rain garden are highlighted below (modified from RCEWRP 2015) and detailed in Appendix 4.2.1.

1. Assess Existing Stormwater Issues
2. Identify Site Opportunities
3. Evaluate Rain Garden or Bioswale Feasibility
4. Design According to Precipitation and Environmental Conditions

What are the co-benefits of this NBS?

Rain gardens mitigate flooding, improve water quality, sequester carbon, and mitigate heat islands, among other meaningful co-benefits (Wilson et al., 2020). Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.1.

MATERIAL BENEFITS

Harvesting Organic Materials	🖩
Improved Water Quality	💵 🖩
Human Health	🧠
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	🧠
Improved Habitat Connectivity	🧠
Supporting Biodiversity of Flora and Fauna	💵 🖩
Supporting Resilience of Ecosystem	🧠

NATURAL PROCESSES BENEFITS

Air Quality Improvement	💵
Climate Regulation	💵 🖩
Carbon Sequestration	🧠
Pollinator Services	💵
Erosion Control	
Nutrient Cycle Control	🖩 🧠
Infrastructure Protection	🖩

CULTURAL BENEFITS

Sources of Cultural Identity	👥
Spiritual and Symbolic Interactions	👥
Education	🧠
Aesthetic Value	🖩
Recreational Value	👥
Social Well-Being	🧠

💵 = Monetized Values
🖩 = Quantified Values
🧠 = Qualitative
👥 = Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a rain garden.

Permitting

Under the new stormwater regulations (NJFuture 2023), NJDEP is requiring municipalities to map stormwater facilities as part of Stormwater Pollution Prevention Plans (SPPP) (SPPP templates at NJDEP 2024a). Stormwater facilities include green infrastructure which includes rain gardens. Every town and public complex in New Jersey has a Stormwater Program Coordinator with training to navigate the complexities of rain garden permitting and who is responsible for ensuring maintenance plans for rain gardens are being followed on public and private land (SPC Training 2024). The Stormwater Program Coordinator should be contacted to ensure proper permitting requirements for a rain garden project are being met.

Additional permitting may be required for soil testing in regulated areas, such as areas regulated under the Flood Hazard Area Control Act Rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Coastal Zone Management Rules (N.J.A.C. 7:7), and the Highlands Water Protection and Planning Rules (N.J.A.C. 7:38) (NJDEP 2021).

Maintenance

Perhaps the greatest challenge associated with rain gardens is long-term management of the site. While management is inexpensive, rain gardens can fall into disrepair if no one remembers who is responsible for maintaining those rain gardens. Communication of rain garden management best practices and identifying individuals who are responsible for said management is key. Maintenance plans for rain gardens are required through various regulations including the New Jersey Pollutant Discharge Elimination System (NJPDES) rules which are discussed in Chapter 8 of New Jersey Stormwater Best Management Practices Manual with additional guidance available in the Green Infrastructure BMP, Chapter 9.7 on Small-Scale Bioretention Systems. Rain garden best management practices include the following and are explored in greater detail at Rutgers' Inspection and Maintenance – Maintaining Your Rain Garden. For detailed tips, refer to New York's Rain Garden Stewardship Program Maintenance Manual (2019).

- During years 1 and 2 of the project, the plants will need to be: weeded on a monthly basis to prevent the weeds from overtaking the plants and watered depending on the plants selected (most plants require one inch of water per week during their first growing season) (Obropta et al., 2023).
- From year 3 onward, the site will need pruning in the spring, possible replanting of select plants, and sediment removal to ensure inlet and outlet are functioning properly (Obropta et al., 2023).
- Overflow devices and outlet controls should be inspected after storms exceeding one inch in rainfall and at least four times annually for clogging that may prevent water from leaving the system. The NJDEP recommends bi-weekly inspections during vegetation establishment and a minimum of one inspection during the growing season and one during the non-growing season for established vegetation (Wilson et al., 2020).

Logistics

Calculating Rain Garden Size

Experts have created resources to help individuals create rain gardens that are most appropriate for a space (*e.g.,* Obropta and Bergstrom 2024). The authoritative resource for calculating the size of a rain garden is the Green Infrastructure BMP, Chapter 9.7 on Small-Scale Bioretention Systems.

Native Plant Suppliers

Native plants generally perform better in a rain garden than non-natives, but it can be challenging to find native plant suppliers. The Watershed Institute's Stormwater and Green Infrastructure Basic Resource Guide for Homeowners provides a list of native plant suppliers and nurseries where plants can be bought wholesale by landscape companies (available here).

Community Engagement

The public may be hesitant to install rain gardens because of concerns over standing water, mosquitos, and overgrown plant material. These qualities are only seen in improperly maintained rain gardens. Mosquitos reach their adult stage after 72 hours in or around water and rain gardens are designed to drain in less than 24 hours which precludes properly functioning rain gardens as a source of mosquitos. Regarding rain gardens looking overgrown, community members should be engaged early and often in the rain garden design process. This will help to set expectations for the public on what the rain garden will look like through various stages of development (*e.g.,* construction, post-construction growing season, winter). Rain gardens can be designed to look more natural (*e.g.,* with grasses to look like a meadow) or more formal (*e.g.,* a traditional garden with flowering plants and shrubs), but proper trimming and care will allow the desired aesthetic to be maintained (Wilson et al., 2020).

How can I monitor this NBS?

The type of monitoring conducted for a rain garden may be mandated by various State programs, permits, and/or detailed by the funding source or agency. In the event a rain garden funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a rain garden installation.

The following are templates and resources to consider when planning a monitoring strategy for rain gardens.

1. **Rain Garden Measurement and Evaluation Guide** (2017)
2. **Hey and Associates of Chicago Case Study** (2012)

Case Study of an Exemplary Project

Case studies of rain gardens can be found in numerous locations including New Jersey's Green Infrastructure Champions Program, those installed with Rutgers Water Resources Program, as well as those found in Appendix 4.4. Below is an example of a small- and large-scale rain garden projects in New Jersey.

Union County Vocational Technical School Rain Garden

Scale of Project: Small
Cost: $915.47
Project Timeline: Two days of labor (the time spent on planning/permitting could not be found for this project).
Funding Source: US Department of Agriculture Cooperative State Research Education and Extension Service National Integrated Water Quality Program

Figure 5. Construction of the UCVTS rain garden (NJWRRI 2008).

This 360 square foot rain garden was built in March 2008 to manage stormwater from the Union County Vocational Technical School's (UCVTS) parking lot. The planning for the rain garden included landscapers, the Business Administrator for the school, the horticulture teacher for the school, the maintenance department for the school, and the Union County Department of Public Works. Plants included arrowwood viburnum, iris, inkberry holly, red chokeberry, soft rush, sweet pepperbush, and winterberry holly. The rain garden is maintained by the UCVTS horticulture students and the Union County Future Farmers of America (FFA) organization. Costs ranged from $4.25 per quart of perennials, to $299.97 for sand. The total cost of $915.47 does not include the cost of labor and equipment rental which consisted of one county backhoe operator (6 hours) and 142 hours of volunteer labor (34 people). Additional details for this project can be found on Rutgers' New Jersey Demonstration Rain Gardens website and detailed cost estimates for the project are available in this presentation. This project was selected for its detailed account of costs.

Jonathan Dayton High School Rain Garden

Scale of Project: Large
Cost: Unknown
Project Timeline: Unknown
Funding Source: Unknown

Figure 6. Completed Jonathan Dayton High School rain garden (Hartman and Robison 2017).

A 3,000 square foot rain garden was built in collaboration with Springfield, NJ's Department of Public Works and Board of Education Facilities personnel to manage runoff from the roof of the school and other ground source areas near the site (Hartman and Robinson 2017). The garden has been monitored since it's installation (report available at Hartman and Robinson 2017) and is reported to support biodiversity in an urbanized environment (e.g., birds, butterflies, and small mammals have been seen on site).

This case study is being highlighted because of its educational value and creativity. The rain garden was designed to represent New Jersey's four physiographic regions (i.e., ridge and valley, highlands, piedmont, and coastal plain) (NJAES 2022) and sustains a vegetable garden (Rubino 2017). Building this rain garden in front of the high school provides an easily accessible educational opportunity to teach students core science concepts directly (e.g., stormwater and the water cycle) and indirectly (e.g., the embedded narrative of the physiographic regions). Specifically the design goals for this project were create a rain garden that: highlights NJ's geology and how it is connected to water and plants, demonstrates the relationship between paved (imperviousness) and unpaved areas, and create interest in real landscapes by referencing and mimicry in the garden (NJAES 2022). This project is also tied to long-term planning by Springfield, NJ as evidenced by the Jonathan Dayton High School's inclusion in the town's Impervious Cover Reduction Action Plan (2015b).

Where can I find funding for this NBS?

There are several local programs in place to aid interested individuals in funding and implementing rain gardens. Some examples are highlighted below. For related Federal funding possibilities, refer to the Bioswale profile.

1. North Jersey Resource Conservation and Development Rebate Program
2. Pinelands Preservation Alliance Rebate Program
3. Hudson Raritan Estuary Urban Rain Garden Grant

Top Resources

1. NJDEP Municipal Stormwater Regulation Program
2. Rain Garden Manual of New Jersey (2023)
3. Green Infrastructure Guidance Manual for New Jersey (2015)
4. Center for Neighborhood Technology Green Values Stormwater Management Calculator (2020)

3.1.2 BIOSWALE PROFILE

Introduction

Figure 7. Bioswale in Parsippany, NJ (RCEWRP 2015).

A bioswale is a vegetated ditch, similar to a rain garden, but designed to capture larger volumes of runoff traveling at higher speed. Specifically, bioswales are best where water needs space to move, slow down, then infiltrate into the groundwater. A bioswale conveys runoff from one location to another while removing pollutants and allowing water to infiltrate. Bioswales are not vegetative filter strips: vegetative filter strips are designed to capture sheet flow (overland flow that happens in a continuous sheet) while bioswales are designed to capture a more concentrated flow like runoff from a swale or pipe. Much like rain garden systems, bioswales can also be designed with an underdrain pipe that allows excess water to drain to the nearest catch basin or existing stormwater system (RCEWRP 2015, Wilson et al., 2020). Bioswales are expected to cost as much as $5.05 to $24 per square foot to install, and $0.31 to $0.61 per square foot to maintain annually with annual maintenance consisting of pruning, weeding, and soil management at least twice per year and after major storm events (NOAA 2020, Jack et al., 2014).

What hazards do this NBS address?

Bioswales, like rain gardens, mitigate floods and water pollution by capturing runoff from storm events. While bioswales are designed to collect stormwater runoff traveling at a higher velocity than a rain garden could handle, bioswales do not have unlimited storage capacity for runoff. Each bioswale is built to collect water from a specific design storm including the WQDS (guidance for building a WQDS bioswale for a small area is available at NJDEP 2021, and for a large area is available at NJDEP 2021b), a 2 year storm (guidance for building available at RCEWRP 2015), or a larger storm. Multiple NBS bioretention systems could be used to treat large volumes of stormwater on one site pending the topography of the site allowed stormwater to drain equitably to each bioretention system. Bioswales thus reduce drought conditions by recharging groundwater stores. Bioswales also mitigate urban heat island effects through evapotranspiration and shading (Wang et al. 2024).

Where should this NBS type go?

A bioswale functions best when (NJFuture 2020):

- ✓ Located near an impervious surface that will generate runoff
- ✓ On land with between a 2-10% slope
- ✓ With soil that has good drainage

Additional details can be found in Appendix 4.2.2.

Key steps to identifying the suitable habitat for a bioswale are nearly identical for those identified above for rain gardens, with one exception. Bioswales require additional calculations to ensure that the peak flow during a storm event can travel through the bioswale without causing erosion or scouring. This is because high velocity water could exceed the allowable erosive velocity for the soil texture and plant material in the bioswale. The maximum velocity calculated should be a 10-year frequency storm, unless communities prefer to design the bioswale to handle a larger storm event for reasons of safety and compatibility with other stormwater management measures (RCEWRP 2015).

What are the co-benefits of this NBS?

The co-benefits of a bioswale align with the co-benefits of a rain garden. Refer to the Rain Garden Profile (Section 3.1.1) for a list of relevant co-benefits.

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a bioswale.

Permitting

Under the new stormwater regulations (NJFuture 2023), NJDEP is requiring municipalities to map stormwater facilities as part of Stormwater Pollution Prevention Plans (SPPP) (SPPP templates available here). Stormwater facilities include green infrastructure which includes bioswales. Every town and public complex in New Jersey has a Stormwater Program Coordinator with training to navigate the complexities of bioswale permitting and who is responsible for ensuring maintenance plans for bioswales are being followed on public and private land (SPC Training 2024). The Stormwater Program Coordinator should be contacted to ensure proper permitting requirements for a bioswale project are being met.

Additional permitting may be required for soil testing in regulated areas, such as areas regulated under the Flood Hazard Area Control Act Rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Coastal Zone Management Rules (N.J.A.C. 7:7), and the Highlands Water Protection and Planning Rules (N.J.A.C. 7:38) (NJDEP 2021).

Logistics

Calculating Bioswale Size

The authoritative resource for calculating the size of a bioswale is the Green Infrastructure BMP, Chapter 9.7 on Small-Scale Bioretention Systems.

Plant Survival

Bioswales are vegetated ditches that are designed to withstand stormwater traveling at fast speeds. The difficulty in constructing a bioswale is to ensure the vegetation is well-established to prevent erosion within the bioswale. In some cases, stormwater runoff is diverted around a newly established bioswale to allow plants to become fully established (NJFuture 2020).

Maintenance

Proper, long-term maintenance of a bioswale is key to ensuring the longevity of the system. Maintenance plans are required through various regulations including the New Jersey Pollutant Discharge Elimination System (NJPDES) rules which are discussed in Chapter 8 of New Jersey Stormwater Best Management Practices Manual. The following general maintenance practices are recommended: inspect vegetation bi-weekly when establishing the vegetation; inspect established bioretention structures at least four times annually as well as after every storm exceeding 1 inch of rainfall; maintain 85% vegetative cover and replant damaged vegetation; inspect bed at least twice annually to ensure permeability has not decreased; do not use bioretention structures for stockpiling plowed snow, ice, compost, or any other material; and more. (Guidance for small- and large-scale bioswales respectively at NJDEP 2021 and NJDEP 2021b).

How can I monitor this NBS?

The type of monitoring conducted for a bioswale may be mandated by various State programs, permits, and/or detailed by the funding source or agency. In the event a bioswale funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a bioswale installation. For templates and resources to consider when planning a monitoring strategy for bioswales, refer to the Rain Garden profile above.

Case Study of an Exemplary Project

Below is an exemplary bioswale project. Additional case studies can be found on the Earth Economics webpage, as well as in Appendix 4.4.

Parsippany Department of Public Works (DPW) Bioswale

Scale of Project: Small
Cost: $6,900
Project Timeline: Two days of labor (time spent on planning/permitting could not be found for this project)
Funding Source: 319(h) funding via NJDEP

Figure 8. Completed DPW bioswale (Rector 2016).

In 2011, a 2,000-square-foot bioswale was installed in Parsipanny, NJ that treats 1.6 acres of parking lot during the 10-year storm (5.23 inches for Morris County) as well as some rooftop runoff and washwater from vehicle washing (Rutgers 2024). This site was identified for several stormwater control measures as the adjacent Troy Brook had been impaired for biological life and the Troy Brook Regional Stormwater Management Plan identified the DPW facility as an area that contributes poor water quality and localized flooding issues in the stream (NJAES 2022). The project used check dams made of rocks in wire cages (also known as gabions) to reduce water velocity, jute matting to prevent erosion and support growth of young plants, a berm to maintain linear flow of runoff within the channel, and used grasses and sedges in the bioswale which can bend but not break during high flow conditions (NJAES 2022). Additional details for this project can be found in a Rutgers pamphlet on the project and on this website.

This project was selected for the diversity of projects on site to address stormwater runoff including sediment chambers, cisterns, and turf stone and because of the stakeholder engagement used to develop the Troy Brook Stormwater Plan that laid the foundation for this bioswale project. More details on these points are available in a 2016 presentation on the project (available here).

Funding

There are many programs in place to aid interested individuals in funding and implementing bioswales. Key federal programs are highlighted below (GCC 2024). For related local funding possibilities, refer to the Rain Garden profile.

1. 319 Nonpoint Source Program, U.S. Environmental Protection Agency (EPA)
2. Community Development Block Grant, U.S. Housing and Urban Development (CDBG, HUD)
3. Hazard Mitigation Assistance Programs, including Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA), Building Resilient Infrastructure and Communities (BRIC), and Local Pre-Disaster Mitigation (LPDM), Federal Emergency Management Agency (FEMA)
4. Transportation Alternatives Program, U.S. Department of Transportation (DOT)

Top Resources

1. NJDEP Green Infrastructure BMP, Chapter 9.7 on Small-Scale Bioretention Systems
2. Green Infrastructure Guidance Manual for New Jersey (2015)
3. U.S. Army Corp of Engineers, Engineering with Nature Resources

3.2 Coastal Habitats

What profiles are in this NBS category?

Living Shorelines

Mark Baranoski

Hazards Addressed

- ✓Coastal Erosion
- ✓Storm Surge

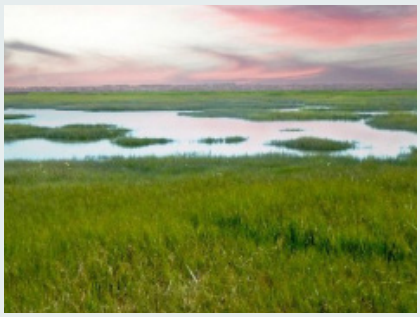
Suitable Environments

- ✓Low to moderate wave energy environments

Key Takeaways

1. A successful living shoreline requires both engineering and ecological principles are considered during the planning process.
2. There are several types of living shorelines, all of which provide a diversity of co-benefits.

Salt Marshes



The Nature Conservancy

Hazards Addressed

- ✓Coastal Erosion
- ✓Storm Surge
- ✓Coastal Flooding

Suitable Environments

- ✓Low to moderate wave energy environments

Key Takeaways

1. Salt marsh protection, enhancement, and restoration is restricted by available open space on land for salt marsh retreat.
2. Sediment placement for salt marsh enhancement and restoration requires adaptive management to ensure project goals are being met.

Information about salt marshes, beyond what is covered in this profile, can be found in Appendix 4.2.4.

Introduction to Coastal Habitats

New Jersey has 1,792 miles of tidal coastline spanning Raritan Bay, Atlantic oceanfront, the Delaware Bay, and the Delaware River. New Jersey's coastal zone is diverse in terms of natural habitats and built environments. As the state's Coastal Resilience Plan states, "The coastal zone is home to nearly 7 million year-round residents (80% of the state's population), the largest container port on the east coast, the Hudson River Waterfront Walkway, internationally known cultural attractions, multiple military facilities, [as well as] tidal wetlands, an expansive barrier island beach and dune system, tidal flats, and coastal forest and shrublands," (Angarone et al., 2021). These coastal habitats provide food, shelter, and nursery grounds for wildlife including fish, horseshoe crabs, birds and other marine life which, in turn, supports a booming recreation industry (*e.g.,* kayaking, hiking, fishing, tourism) and a commercial fishing industry (*e.g.,* finfish, shellfish, crustaceans) (Angarone et al., 2021). The coastal zone also contains homes, businesses, marinas, ports and terminals, and critical infrastructure of significant socioeconomic value.

New Jersey's coastal ecosystems and infrastructure are vulnerable to flooding as a result of climate change driven sea-level rise (SLR) and storm intensity (Kopp et al., 2019). Flooding may occur during and after coastal storms driven by storm surges and precipitation into the coastal zone. Flooding may also occur independent of storm events in the form of tidal nuisance flooding (sometimes called "sunny day flooding") where coastal areas become inundated with tidal flooding twice each day during high tide (Angarone et al., 2021). SLR and storms can also cause increased erosion and inundation in coastal habitats.

Two NBS profiles are highlighted within this NBS category: living shorelines (to mitigate coastal erosion) and coastal marshes (to mitigate SLR and storm surge). Below are several key takeaways from experts regarding NBS in the coastal zone:

1. **Nature-based solutions in coastal habitats are generally better suited for low-energy environments.** Living shorelines and salt marsh creation, restoration, and enhancement provide protection against flooding and coastal erosion, but these NBS do not thrive in high-energy coastal ecosystems and are more common in protected coastlines like the back bays of New Jersey. Where more armored techniques are applicable, it is important to investigate opportunities to add ecological components to stack protection and ecosystem service gains.
2. **Balance short term and long-term benefits.** NBS along New Jersey's coastlines will experience sea level rise and there are not sufficient resources to protect and enhance every coastline. Therefore, resource managers need to prioritize protection, enhancement, and restoration in important areas but accept that some coastlines will not be resilient to climate change (*e.g.,* marshes may be converted to mudflats, tidal freshwater marshes to salt marshes, shorelines to open water). Projects should be planned to not only protect today's coastline and communities, but the coastlines and communities 50, 100, and more years into the future.

3.2.1 LIVING SHORELINE PROFILE

Introduction

Living shorelines are a NBS to reduce shoreline erosion and was a term first coined in the 1980s in Maryland (Whalen et al., 2011). For the purposes of this document, living shorelines include natural living shorelines and hybrid living shorelines (TNC 2019). Natural living shorelines include using all natural materials (*e.g.,* native vegetation, clean sediment, rocks, and biodegradable materials like coconut fiber logs) to mitigate erosion in low energy coastal environments. Hybrid living shorelines incorporate manmade materials (*e.g.,* concrete breakwaters like oyster castles and reef balls) with natural materials (*e.g.,* oyster castles will be colonized by oysters) that can mitigate erosion in low to moderate energy coastal environments. Living shorelines have garnered widespread support as a coastal resilience strategy across the country (NWF 2020).

This profile will focus on four categories of living shoreline types described below:

1. *Living Breakwaters*- Breakwaters are manmade structures constructed parallel to the shore that reduce wave energy by "breaking waves." This can allow for the accretion of sediment between the breakwater and shoreline which, in turn, could help create a beach or marsh habitat. (Miller et al., 2022) Living breakwaters occur when the breakwater is enhanced with organic materials, either naturally or through direct deployment, to mimic natural ecology (*e.g.,* rock habitat to provide substrate for oysters to settle and to provide fish habitat) (DOI 2023; NYS 2024).

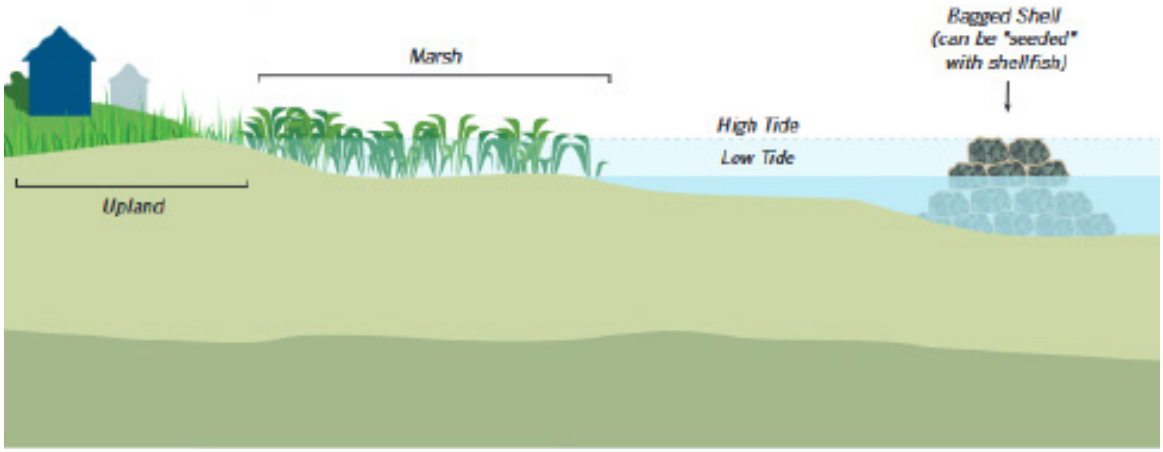


Figure 9. Schematic of a living breakwater (TNC 2019).

2. *Marsh Sill* - Sills are low-elevation, manmade structures constructed parallel to a shoreline. These shorelines typically have marshes or wetlands (*i.e.,* fringe marshes or wetlands) in need of protection from erosion. The sills allow waves to break on the structure rather than the more fragile fringe habitat and, over time, this protection can increase the amount of sediment stored behind the sill and/or cause the marsh to grow out to the sill (Miller et al., 2022).

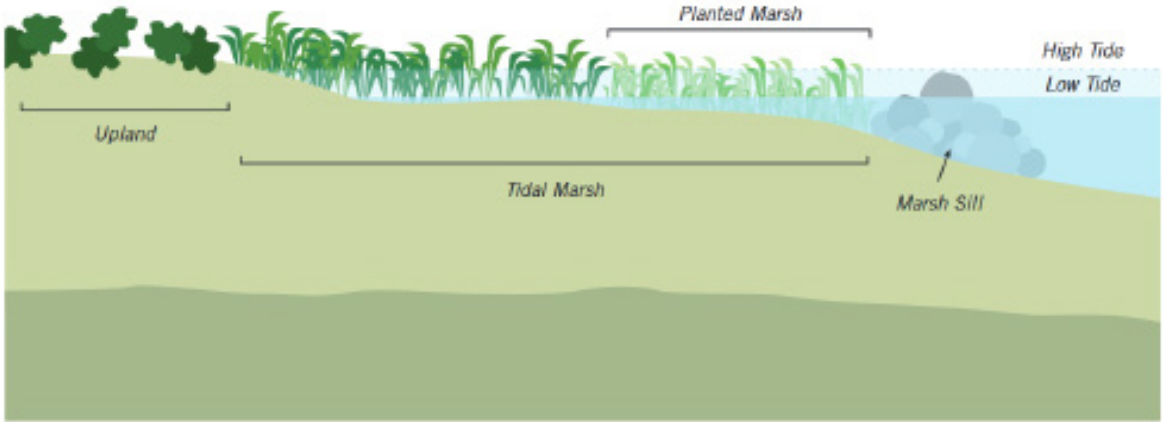


Figure 10. Schematic of a marsh sill (TNC 2019).

3. *Oyster Living Shorelines* - Oyster living shorelines are constructed oyster reefs (Petrolia et al. 2022). The process begins with the deployment of an engineered structure (*e.g.,* oyster castles, bagged shells, eco-friendly concrete, reef balls) or natural material (*i.e.,* oyster, clam, or whelk shells) to create a reef base of varying size (*i.e.,* height, length, and width) and distance from the shoreline (*e.g.,* depth, intertidal vs. subtidal) (Morris et al., 2019). The reef base is important as this is the structure oysters will colonize and grow on to creating a structure that is adaptive to environmental change. Oysters grow on top of one another so, as new generations settle on the living shoreline, the living shoreline footprint will expand both vertically and horizontally and can recover if oysters are lost during storm events. Oyster living shorelines built in the nearshore could be considered a type of marsh sill, while oyster living shorelines built in deeper water could be considered a type of living breakwater.

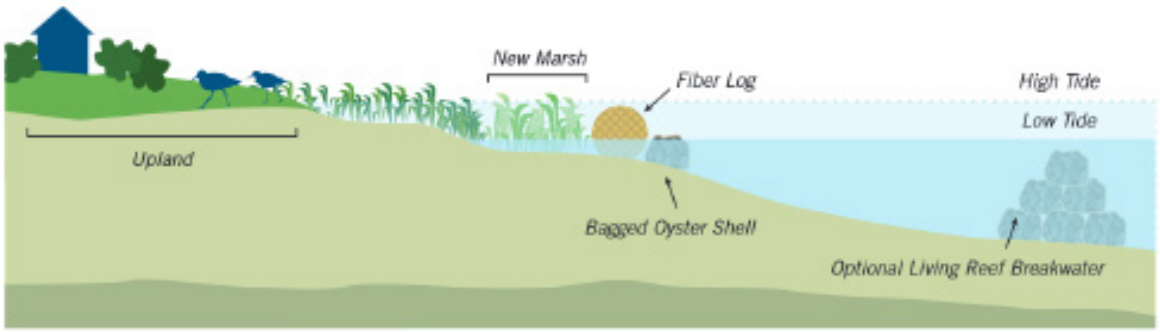


Figure 11. Schematic of an oyster living shoreline (TNC 2019).

4. *Mussel Living Shorelines* - Ribbed mussels are common in New Jersey tidal marshes and are most abundant along the intertidal edge of a marsh that is most prone to erosion (PDE 2013). These shellfish bind to each other and to marsh vegetation which creates a natural "superglue" to protect the coast from erosion (PDE 2013). A mussel living shoreline consists of adding bio-logs (or coir-logs), coir mats, and/or bags of oyster shell to mitigate coastal erosion, recruit mussels, and reestablish other marsh plant species to the site. Mussel populations on these structures must naturally colonize as there are no commercially available mussel seed

(experts agree natural recruitment can be challenging for mussel living shorelines and may take 3-5 years (Moody et al., 2020; Bilkovic et al., 2021). For best practices in establishing mussel living shorelines refer to this Best Practices Report from the Delaware Estuary, the Enhancement of Ribbed Mussel Populations in Mid-Atlantic Salt Marshes and Living Shorelines for Water Quality Ecosystem Services (Moody et al., 2019), the Practitioner's Guide to Shellfish-Based Living Shorelines for Salt Marsh Erosion Control and Environmental Enhancement in the Mid-Atlantic (Whalen et al., 2011), and this presentation on mussels mitigating salt marsh erosion.

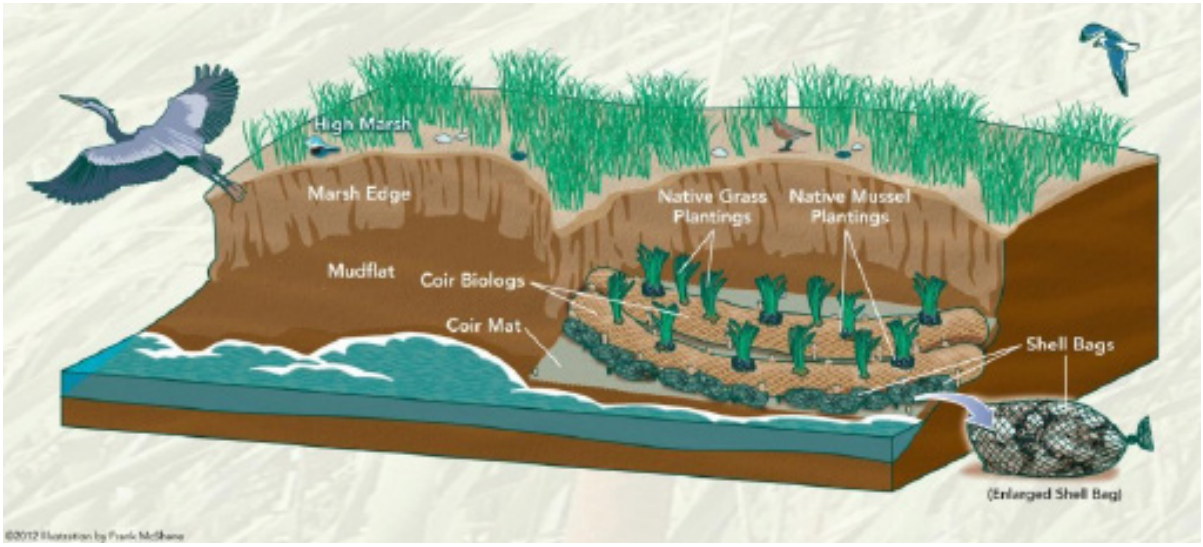


Figure 12. Schematic of a mussel living shoreline (modified from PDE 2013).

What hazards does this NBS address?

Living shorelines address coastal erosion, not coastal flooding. As Miller et al., 2022 notes, "the primary function of a living shoreline is the stabilization of the shoreline edge and developing or maintaining habitat; while flood mitigation is needed in many coastal and riverine areas, a living shoreline is often not the most appropriate tool for addressing flooding issues." Living shorelines can also mitigate storm surge (O'Donnell 2017) by protecting coastal habitats and reducing erosion to preserve the natural ecosystems that aid in flood protection. To be clear, living shorelines themselves do not protect against coastal flooding, instead living shorelines protect the coastal habitats that do mitigate coastal flooding (like salt marshes). However, a living shoreline expert has noted most current living shorelines in New Jersey are either, "too submerged or too narrow to have a large impact on storm conditions/reduce flooding."

Where should this NBS type go?

Living shorelines function best in estuaries, bays, tributaries, and other sheltered shorelines (NOAA 2024). High wave energy environments, like beaches and the open ocean, are not suitable for living shorelines. A living shoreline functions best when (Miller et al., 2022, DOI 2023):

- ✓ Located in low to moderate wave energy environments
- ✓ Located in a low slope environment
- ✓ Placed properly in the tidal prism
- ✓ Built on top of soil with high bearing capacity
- ✓ The presence of winter ice is integrated into living shoreline materials
- ✓ Erosion rates are considered

Additional information regarding suitable habitats for each living shoreline type is available at Appendix 4.2.3. For a more in-depth assessment of suitable habitat, refer to the following detailed resources:

1. NJ Restoration Tool Organization Suite, Living Shorelines Explorer
2. Stevens Institute of Technology's Living Shorelines Engineering Guidelines
3. Stevens Institute of Technology's Ecoshorelines on Developed Coasts Guidance and Best Practices

What are the co-benefits of this NBS?

Properly designed living shorelines can have many benefits to the local environment, economy, and quality of life. Living shorelines can preserve the ability of the shoreline to provide shelter and food for a wide variety of organisms, and reduce the amounts of nutrients, sediments, and other pollutants carried by runoff and groundwater from uplands to rivers and coastal environments. Living shorelines can supply sand for other nearby beaches, buffer low-lying lands from erosion, provide recreational and commercial opportunities, and serve as visually pleasing features for everyone in the coastal zone (VIMS 2024).

Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.3. These valuations should only be used when conducting site-specific valuations is not economically feasible as published valuations are estimates that (1) do not follow a unified or standard methodology for monetizing benefits and (2) are not based on long-term data which would greatly improve the accuracy of these valuations (Miller et al., 2022). For information regarding the process for using ecosystem service valuation as a tool to support coastal restoration projects, visit TNC's guide here. Additionally, a NOAA produced repository of the ecosystem service values for shellfish enhancement project may help supplement all co-benefit estimates (Northern Economics 2012). The details of a benefit cost analysis for a small scale living shoreline in Mississippi is outlined in a report by Sicangco et al., (2021).

MATERIAL BENEFITS

Harvesting Organic Materials	🖩
Improved Water Quality	💵 🖩
Human Health	🗣
Mental Health	🗣

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	🗣
Improved Habitat Connectivity	🗣
Supporting Biodiversity of Flora and Fauna	💵 🖩
Supporting Resilience of Ecosystem	🗣

NATURAL PROCESSES BENEFITS

Air Quality Improvement	💵
Climate Regulation	💵 🖩
Carbon Sequestration	🗣
Pollinator Services	💵
Erosion Control	
Nutrient Cycle Control	🗣 🖩
Infrastructure Protection	🖩

CULTURAL BENEFITS

Sources of Cultural Identity	👥
Spiritual and Symbolic Interactions	👥
Education	🗣
Aesthetic Value	🖩
Recreational Value	👥
Social Well-Being	🗣

💵 = Monetized Values
🖩 = Quantified Values
🗣 = Qualitative
👥 = Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a living shoreline.

Planning

General Considerations

Properly designed living shorelines require that both engineering and ecological principles are applied such that persistent and functioning living shorelines are constructed (Morris et al., 2019). If shellfish are an element of the living shoreline design, it is essential to consult shellfish experts when developing a living shoreline to enhance the likelihood of good shellfish recruitment and survival on a living shoreline project. Other general considerations that can affect the success of the project include wave energy, salinity, turbidity, placement within the tidal prism, soil bearing capacity, presence of ice, and surrounding land use. Below is a list of resources to help individuals identify, plan, and implement successful living shorelines in New Jersey (additional information can be found in Appendix 4.2.3):

1. The Living Shorelines in the Delaware Estuary Best Practices document (2013)
2. The Community Resource Guide for Planning Living Shorelines Projects New Jersey (2019)
3. The Living Shorelines Engineering Guidelines (2022)

Long-term Changes to the Environment

Sea level rise and future coastal flooding could alter future erosion of the coastline and hinder the ability of a living shoreline to prevent erosion (Fanning et al. 2023). Considering future SLR and coastal flooding (intensity and frequency) is imperative for ensuring the long-term success of a living shoreline.

Environmental Justice Considerations

There are restrictions in place in New Jersey that require additional permitting and monitoring to create living shorelines in urban areas, areas near CSOs, or areas with underserved communities. This is because of shellfish contamination and consumption rules designed to protect individuals from illnesses derived from eating contaminated shellfish (Barr et al., 2023).

Communication with Locals

Living shoreline projects can take several years after construction for the full suite of ecological benefits to materialize, including reduced coastal erosion. Clear communication with locals, especially regarding expected outcomes and estimated timelines for those outcomes, will be essential in long-term support for living shoreline projects. See the Community Engagement section below for helpful resources.

Timing of project

Be sure to note all fixed dates for funding applications and consult with State and Federal wildlife management agencies about the best time of year to start a project to avoid disrupting fish and migrating and nesting birds. There may also be timing restrictions as determined by the permitting and regulatory agencies.

Permitting

The coastal zone covers 3,218 square miles and comprises 239 municipalities consistent with the requirements of the U.S. Coastal Zone Management Act (CZMA) of 1972. The CZMA defined the “coastal zone” as the coastal waters and adjacent shorelands strongly influenced by each other and includes, but is not limited to, islands, intertidal areas, salt marshes, wetlands, and beaches (NJDEP 2024a, NJDEP 2024b, 16 U.S.C. § 1453). The coastal zone is primarily managed by the New Jersey Coastal Management Program (NJCMP) which is part of the National Coastal Zone Management Program administered by the National Atmospheric and Oceanic Administration (NOAA) (Parker 2024, NJDEP 2024a).

These, and other regulations, make permitting living shorelines a challenging process. Furthermore, different permit requirements exist for projects on private and public land: private landowners wishing to obtain a permit for a living shoreline may need sponsorship from a government or academic partner for a project to begin (TNC 2019).

In general, it is important to engage permitting agencies early and often in project development to ensure alignment with proper permitting protocols. Specifically, experts recommend engaging State and Federal partners at the project inception phase to allow for design changes prior to designs being developed. The US Army Corps of Engineers (USACE) is responsible for project compliance with Federal permitting requirements and the NJDEP is responsible for project compliance with State permitting requirements. For Federal permits, either a Nationwide Permit 54 (Living Shorelines) or Nationwide Permit 27 (Aquatic Habitat Restoration, Enhancement, and Establishment Activities) is likely the permitting mechanism. For state permits, a General Permit 24 (Habitat creation, restoration, enhancement and living shoreline activities) will likely be the permitting mechanism (projects outside the coastal area may also require a Freshwater Wetlands General permit (FWW GP26) or a Flood Hazard General permit (FHA GP4)). To help individuals navigate the permitting process, NJDEP is developing permit application guidance documents (expected publication early 2025). More information on NJDEP coastal permitting and a list of all coastal permits can be found here (*i.e.,* https://dep.nj.gov/wlm/lrp/coastal-zone/). To help identify if the project is in the coastal zone, or in another protected area, navigate through the Land Resource Web Application. An explanation of permitting requirements and mechanisms can be found in the NJDEP's Science Advisory Board's Final Report on the Status and Future of Tidal Marshes in New Jersey Faced with Sea Level Rise, starting on page 45 (Weis et al., 2020).

Logistics

Financial Costs

The financial costs and time dedicated to a living shoreline project will vary based on the size, location, and complexity of the project. Factors like the shipping and staging of materials, the accessibility of the project site, and monitoring/maintenance requirements can increase the cost of a project. The following resources may be helpful in living shoreline planning efforts:

1. The Community Resource Guide for Planning Living Shorelines Projects New Jersey (2019)
2. The Restore America's Estuaries' 2018 report (available here) and the Virginia Institute of Marine Science's Summer 2014 newsletter (available here) – provides a snapshot of living shoreline project costs.

Quality and Suitability of Materials

To ensure that the project enhances the ecosystem as much as possible, careful attention should be placed on the nature and quality of materials used to construct the project (TNC 2019). Loose substrate (e.g., oyster shell) have not performed well when exposed to wave action. Loose oyster shell substrate tends to degrade over time because of scatter and abrasion, which is why oyster shell in bags is a necessary component living shorelines if oyster shell is the desired substrate.

Community Engagement

Several best practices are highlighted below to foster meaningful community engagement in a living shoreline project:

- Define the goals of community engagement (*e.g.,* community engagement in defining the problem, evaluating alternatives to the project design, maintenance and evaluation planning) using Section 3 of the International Guidelines on Natural and Nature-Based Features for Flood Risk Management as a guide.
- Engaging local conservation groups, landowners, permitting officials early in the planning process which can help identify project partners (TNC 2019)
- Facilitating a community workshop to engage individual community members, partner organizations, and regulatory agencies to identify hurdles that may impair the completion of a project (PDE 2013)

See the *Community Engagement* of the Salt Marsh Profile (Section 3.2.2) for additional discussion on community engagement.

Unintended Consequences

Limited Shoreline Access

Habitats created by living shorelines are vulnerable to heavy foot traffic. It is possible these areas may be closed for public recreation as the living shoreline takes hold in the ecosystem. Nearby residents may not be pleased with the short-term limited coastal access but will benefit long term erosion protection and shoreline protection (NOAA 2015). Experts recommend communicating the shore-term limited access to nearby residents early in the process.

Impacts to the Surrounding Ecosystem

A living shoreline can change on-the-ground conditions that may result in shifts in wave energy and bottom scour that can cause unforeseen negative consequences to adjacent shorelines. This change in wave energy is not unique to living shorelines with grey infrastructure (*e.g.,* bulkheads) shifting wave energy that can have negative consequences (*e.g.,* can exacerbate coastal erosion on nearby unhardened or unprotected adjacent shorelines). When examining possible locations for a living shoreline, impacts to adjacent locations should be thoroughly examined by engineers and ecologists to avoid these negative impacts (NJRCI 2019).

How can I monitor this NBS?

Monitoring before, during, and after a living shoreline is constructed is important, and sometimes required by the State and funding agency, for ensuring the living shoreline is achieving the intended project goals. Ultimately, the project objectives will help define the core set of metrics that will be used to help evaluate the success of a project, while the project budget and technical capabilities of the group responsible for the monitoring will drive the type and frequency of the measurements used to evaluate the metrics (Miller et al., 2022). Experts have emphasized the importance of monitoring wave dissipation (metrics include, but are not limited to, incident and transmitted significant wave height, wave period, water levels) and consistent monitoring metrics (Bredes et al., 2024). The following is a brief list of monitoring considerations highlighted in the Steven's Institute of Technology's Living Shorelines Engineering Guidelines (2022).

- Critical aspects include the incorporation of before and after surveys and the inclusion of a control site so that valid comparisons can be made.
- Consideration should be given to short term variations (e.g., diurnal or seasonal) as well as anthropogenic factors that may influence the results.
- Recent studies have indicated that living shorelines projects typically don't begin to thrive until several years after construction. Based on this observation, monitoring is suggested through at least the first several growing seasons.

Below are several resources that outline more specific best practices for monitoring a living shoreline:

1. *A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey (*2016)
2. A 20-Year Systematic Review of Wave Dissipation by Soft and Hybrid NBS (2024)
3. *Cost and Effectiveness Analysis of Select New Jersey Living Shoreline Projects (*2020)
4. Oyster Habitat Restoration Monitoring and Assessment Handbook (2014)
5. *Measuring Success: Monitoring Natural and Nature-Based Shoreline Features in New York State* (2020)

Case Study of an Exemplary Project

There are various existing repositories of coastal resilience projects including the New Jersey Coastal Ecological Restoration and Adaptation Planning (CERAP) Explorer (available here) and the list of mitigation actions in the 2024 State of New Jersey Hazard Mitigation Plan (available here). Below is one such coastal resilience project. To find more case studies, please refer to Appendix 4.4.

Living Shoreline at Rutgers Aquaculture Innovation Center in North Cape May, NJ

Scale of Project: Small
Cost: $97,000 (excluding design and permitting phase). Detailed in Appendix 4.2.3
Project Timeline:

- Fall 2020- enhanced erosion tracking and living shoreline initial planning
- June 2021 – Permits approved
- Oct - Nov 2021 – Construction
- May 2022 – vegetation planting

Funding Source: Rutgers University, Institutional Planning and Operations

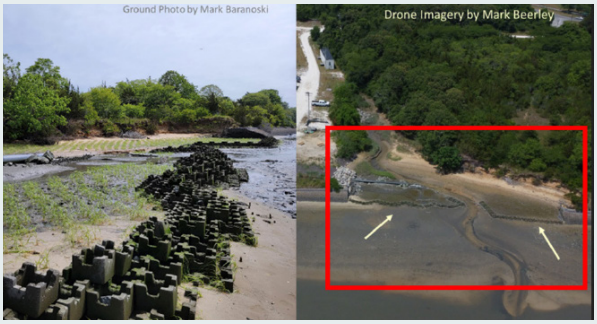


Figure 13. Completed AIC living shoreline (image credit: Mark Baranoski, left; Mark Beerley, right).

A 200-yard section of shoreline near the Rutgers University Aquaculture Innovation Center (AIC) experienced severe erosion due to heavy wake energy, flood tides, and seawater outflow from the AIC (Sovereign Consulting 2024a). The living shoreline involved the placement of Oyster Castles ® shell bags, and marsh grasses to attenuate wave energy and increase the sediment elevation. The project was challenging due to the intensive labor and time constraints to install the materials during low tide. An individual working on the project noted, "From the time we arrived on site until we finished, we were constantly moving materials and getting ready for constructing the next section of oyster castle reef. What I've come to learn is that it's always a race against the tide. The whole day and schedule are based on the low tide or when we'll reach low tide," (Sovereign Consulting 2024b). To learn more about what it was like to assemble this living shoreline and the co-benefits that are starting to appear, watch this video summarizing the project, refer to Sovereign Consulting's press release on the project which follows an employee through the three day construction process (Sovereign Consulting 2024b), and review the firm's presentation on the planning and construction process (Janiec 2023).

This case study was chosen because the community was engaged in the construction of the living shoreline and because it is a public education site. This project engaged community members by (1) engaging local fourth and fifth grade students in building the hundreds of oyster shell bags used to protect the base of oyster castles and edges from scouring and (2) engaging with Camden, NJ high school student volunteers to plant the vegetation in May 2022 (Alexander 2022). This project is also easily accessible and therefore continues to be used as a demonstration site to educate visiting students, scientist and community members about living shorelines. The project is also visible by recreational and commercial boats using the Intracoastal Waterway (Sovereign Consulting 2024b).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing living shorelines. Key programs are highlighted below, additional information about these programs is available in Appendix 4.2.3.

1. National Coastal Resilience Fund, The National Fish and Wildlife Foundation (NCRF, NFWF)
2. Readiness and Environmental Protection Integration Program (REPI)
3. National League of Cities (NLC)

Top Resources

1. New Jersey Coastal Resilience Collaborative (NJCRC)
2. NJ Restoration Tool Organization Suite's (NJResTOrS) Living Shoreline Explorer
3. A Community Resource Guide for Planning Living Shoreline Projects New Jersey (2019)
4. Living Shorelines Engineering Guideline, Stevens Institute of Technology (2022)

3.2.2 SALT MARSH PROFILE

Introduction

A wetland is a low-lying land area that is saturated with water, either permanently or seasonally, and contains hydric soils and aquatic vegetation. A salt marsh is a coastal wetland that is dominated by herbaceous plants (NPS 2024) that is regularly flooded by the tides. Salt marshes are valuable coastal ecosystems that provide habitats for wildlife, protect coastlines from storm surges and waves, reduce flooding, sequester pollutants, and remove nutrients (Weis et al., 2021). Salt marshes can increase their elevation over time by (1) trapping sediment that is brought into the marsh during high tides and from upstream sources and (2) the accumulation of root material. Unfortunately, salt marshes in New Jersey are being lost because they cannot keep pace with sea-level rise and because of damage from anthropogenic disturbance (*e.g.,* boat wakes, damaging storms, coastal development, drainage ditches, eutrophication) (Whalen et al. 2011; Weis et al., 2021; TNC-NJ 2022; Ensign et al., 2023).

This profile focuses on several NBS salt marsh protection, enhancement, and restoration methods, listed below, that promote a salt marsh's ability to withstand sea-level rise and other anthropogenic stressors. For additional detail on each NBS type, see Appendix 4.2.4.

1. *Living Shorelines* - Living shorelines reduce shoreline erosion and develop or maintain habitat, including salt marsh erosion. Living shorelines usually attend to horizontal protection of coastlines while the remainder of this profile focuses on maintaining the vertical integrity of a salt marsh. See the Living Shorelines profile for more information.

2. *Sediment Manipulation – A* healthy marsh is able to maintain vegetation, support fauna, and accrete sediment and plant matter to gain elevation over time (TNC and NJDEP 2021). An unhealthy marsh may have areas of shallow standing water that continuously expands and causes a decline in marsh biodiversity. Creating runnels (*i.e.,* small channels that are dug along the surface of a marsh to shallow, puddled water during low tide (Besterman 2021) and elevating the marsh surface (*i.e.,* placing large amounts of sediment on a marsh surface followed by planting marsh vegetation) are two sediment manipulation techniques that improve marsh health.

3. *Phragmites Management - Phragmites australis*, known as the Common Reed, is an invasive species of grass that spreads quickly, can grow up to 20 feet tall, and grows in dense formations in wetlands across New Jersey which alter the marsh elevation and tidal reach within the marsh (Princeton Hydro 2020). Phragmites can change the ecosystem of a marsh when their fast growth eliminates the intertidal channels and pool habitats used by wildlife (Princeton Hydro 2020), but Phragmites have been shown to build marsh resilience to sea-level rise as this invasive grass can enable marshes to increase their elevation more quickly than native species (NJDEP 2020).

Phragmites can be managed by mechanical removal, applying herbicides, mowing, grazing, flooding area, and prescribed burns to preclude Phragmites colonization (Smith-Fiola and Ayeni 1998, Hazelton et al., 2014).

4. *Wetlands Pathway Protection* - Protecting open space landward of a marsh provides space for wetlands to migrate as sea-levels continue to rise. Wetlands may experience the "coastal squeeze" problem where roads, buildings, and other development have depleted the stock of natural land marshes can gradually migrate into (NJDEP 2020; Figure 14). Wetland pathway protection requires working with local governments to develop a comprehensive wetland migration strategy (considerations for which are summarized in the Georgetown Climate Center's Managed Retreat Toolkit for Wetlands Migration).

What hazards does this NBS address?

Sediment manipulation, phragmites management, and wetlands pathway protection are all means to promote the longevity and health of marsh ecosystems. Healthy salt marsh ecosystems have been found to mitigate coastal erosion and coastal flooding events: salt marshes in New Jersey can attenuate flooding and provide protection from storm surges and waves by reducing wave energy and dampening the flow of water inland on a site-specific basis (Weis et al., 2021, Shepard et al., 2011, Narayan et al., 2016a, Narayan et al., 2016b, Möller et al., 2014, Narayan et al., 2017, Sheng et al., 2021, Sheng et al., 2022). Marshes have been shown to prevent erosion better than some hard infrastructure under storm conditions (Gittman et al. 2014). Indeed, using an extensive database of property exposure, the regional study shows that wetlands avoided $625 Million in direct flood damages during Hurricane Sandy (Narayan et al., 2016b; Narayan et al., 2017). The local study combines these models with a database of synthetic storms in Ocean County and estimates a 16% average reduction in annual flood losses by salt marshes with higher reductions at lower elevations Narayan et al., 2016b; Narayan et al., 2017).

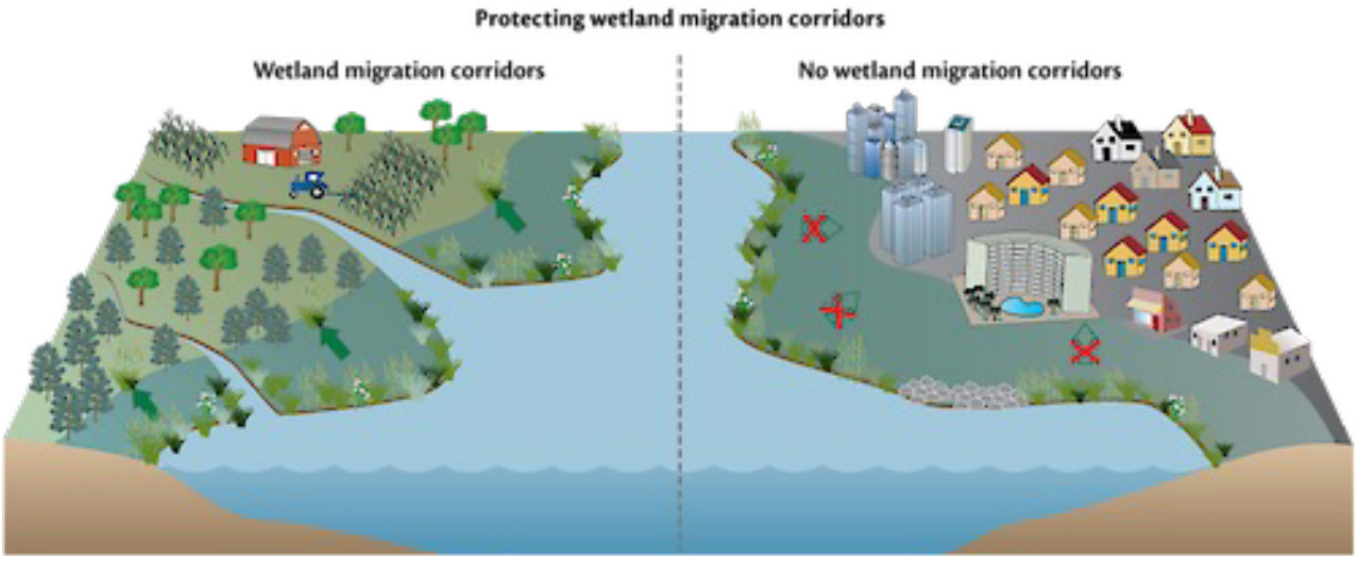


Figure 14. Schematic of coastal squeeze. (Modified from UMCES 2008).

Where should this NBS type go?

Salt marshes occur in low-lying coastal areas along wave-protected shorelines "where fine sediments accumulate along shoreline [in low-energy environments] protected from the open ocean," (DOI 2023).

Locations where salt marshes need protection, enhancement, or restoration can be identified using the NJ Restoration Tool Organization Suite (NJResTOrS) Marsh Explorer Tool. The tool evaluates coastal locations across New Jersey the need for and location of appropriate intervention strategies based on eight issues of concern including: coastal ecosystem degradation and habitat loss, shoreline erosion, coastal flood damage, nuisance flooding, costal storm damage, water quality degradation, loss of CO_2 sequestration, and the presence of overburdened communities (NJDEP 2024). The EPA's Principles of Wetland Restoration offer a list of restoration guiding principles that can also help individuals identify priority sites for salt marsh projects.

What are the co-benefits of this NBS?

Coastal marshes filter water, protect coastal communities from floods, provide opportunities for recreation and aesthetic appreciation, provide habitat for fish and other wildlife, among many other co-benefits. These co-benefits can be naturally present in the case of salt marsh protection projects, but the co-benefits are only present in properly planned/designed salt marsh enhancement and restoration projects (O'Donnell et al. 2017; Bridges et al. 2021). The total monetary value of all the ecosystem services provided by coastal wetlands is $12,163 per hectare per year in 2007 international dollars (de Groot et al., 2012). Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.4.

MATERIAL BENEFITS

Harvesting Organic Materials	💵
Improved Water Quality	💵
Human Health	🧠
Mental Health	🧠

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	💵 🧠
Improved Habitat Connectivity	🧠
Supporting Biodiversity of Flora and Fauna	💵
Supporting Resilience of Ecosystem	🧠

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	🧮
Pollinator Services	
Erosion Control	🧠
Nutrient Cycle Control	💵
Infrastructure Protection	💵

CULTURAL BENEFITS

Sources of Cultural Identity	💵 🧠
Spiritual and Symbolic Interactions	👥
Education	🧠
Aesthetic Value	🧠
Recreational Value	💵
Social Well-Being	💵 🧠

💵 = Monetized Values
🧮 = Quantified Values
🧠 = Qualitative
👥 = Community Derived

Common Challenges

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a marsh protection, enhancement, or restoration project: .

Planning

Finding Site Specific Data

Enhancing, restoring, or creating a salt marsh requires a site-specific understanding of the local hydrology and geomorphology. Experts find it is important to develop a water budget and sediment budget to confirm the best project site. A water budget characterizes the hydrologic conditions of a project site and can be completed using resources such as the NJDEP Regionalized Water Budget Manual for Compensatory Wetland Mitigation Sites in New Jersey. A sediment budget is the "gold standard" for understanding the geomorphic mechanisms shaping the salt marsh habitat and create a strong foundation for marsh structure decision making (Ganju, NJCRC 2023). Resources to support the development of a sediment budget include USGS' marsh unit analyses in the northeast which is publishing data online at the US Coastal Wetland Geospatial Collection and the US Coastal Wetland Synthesis Applications.

Long-term Changes to the Environment

Sea level rise and future coastal flooding could alter future erosion of the coastline (Fanning et al. 2023). Considering future SLR and coastal flooding (intensity and frequency) is imperative for ensuring the long-term success of salt marsh protection, enhancement, and restoration projects.

Permitting

For an overview of permitting requirements for salt marshes visit NJDEP's wetland webpage. There are special requirements for wetland mitigation actions under the Coastal Zone Management Rules of New Jersey (NJDEP WLM 2022). Of note is that restoration projects that change open water to marsh land is considered "fill" and is considered development under NJDEP regulations which require additional permitting.

Logistics

Planting Vegetation

Bare sediment and silt alone after sediment placement at high elevations in a salt marsh can lead to a slow process of recovery because planted vegetation may not survive. Some salt marsh projects have had success with creating topographic features (~6 inches high and less than 100ft2 area) using municipal composted leaf material on top of bare sediment and silt at high marsh elevation to nourish new marsh plants (Smith, NJCRC 2023).

Sediment Sourcing

Clean fill (or "sediment") is necessary for a marsh protection, enhancement, or restoration project to ensure the health of the ecosystem. Clean fill can come in the form of "beneficial use of dredged material" which is the placement of dredged material to enhance, create, or restore a variety of habitats, as opposed to the usual practice of disposing of it in a confined disposal facility (TNC and NJDEP 2021, Chasten et al., 2016, USACE and DOT 2025, Harris et al., 2025). New Jersey's Beneficial Use Learning Network has several educational videos and resources aimed at advancing Mid-Atlantic restoration projects. Other networks for advice include the New Jersey Coastal Resilience Collaborative (NJCRC) which is a hub of on the ground information for restoration projects. Many resources are also available through the Seven Mile Island Innovation Laboratory, a collaborative forum between the U.S. Army Corps of Engineers, NJDEP, and The Wetlands Institute, which is (1) advancing the practice for dredging and placement projects in Cape May County as well as (2) conducting research for these techniques in back bay environments including a focus on sediment behavior and constructability of projects (Chasten et al., 2022, Perkey, et al., 2024).

Long-term Sediment Sourcing

Salt marshes that have undergone sediment placement as part of a protection, enhancement, or restoration project will require more than one round of sediment placement. Sediment is "lost" over time due to compaction (e.g., it can take about two years for sediment to compact, or settle, after placement) or from being overcome by natural events (e.g., an extreme storm that washes out sediment before it can be secured by vegetation). As such, sites may require sediment nourishment on cycles for 2-5 years following a project's initial construction to ensure project goals are being met. While it is challenging to source and transport said sediment to a project site, this kind of adaptive, phased approach helps to ensure the longevity of a project.

Uneven Sediment Placement

Renourishing salt marshes with sediment requires precise planning and an appreciation for imprecise nature of dredging and placement processes (e.g., dredging and placement involves pumping a lot of water and sediment in the coastal environment, sometimes in remote marsh environments where access during construction can be limited). For example, a marsh restoration project called for placing sediment between 3 and 6 inches deep over 1 acre as its original goal, but topographic surveys and depth measurements following the construction showed placement was uneven ranging from 0.5 to 9 inches (TNC and NJDEP 2021). Lessons learned from some of these original projects

show that a landscape approach with varying elevations and varying objectives is ideal for restoration projects as opposed to "thin" layer placement which is difficult to achieve and hard to define (Chasten, et al 2024). More guidance on constructing projects is available in USACE's guidelines on thin layer placement (Piercy et al., 2023). Designs must consider how to adaptively manage placements during construction, but must utilize proper planning and objectives that build in flexibility. Planning for flexibility and adaptive management during construction, and to manage expectations and meet objectives, is especially important for the permit development and coordination processes with the resource agencies and the public. Monitoring of, NBS projects is also important to evaluate if project objectives are being met or need to be adaptively managed as NBS features change over time in their natural setting.

Community Engagement

Education on Ecosystem Services

A salt marsh's ability to protect, or buffer, coastal areas from storm events is determined on a site-specific basis. Studies show salt marshes in New Jersey attenuate flooding and provide protection from storm surges and waves by reducing wave energy and dampening the flow of water inland (Weis et al., 2021, Shepard et al., 2011, Narayan et al., 2016, Moller et al., 2014, Narayan et al., 2017), but high storm surges can limit the effectiveness of salt marshes leaving areas like lagoonal-style developments in New Jersey vulnerable to sea-level rise and future storms (Lathrop et al., 2019). Moreover, homeowners perceive natural shorelines to be less durable and require more maintenance than vertical walls, when in reality vertical walls were reported by homeowners to be less durable and require more maintenance (Scyphers et al., 2014) it is important to educate the public on where salt marsh projects may be most appropriate to help garner community support for projects. Thorne et al. (2022) evaluated community engagement using mental modeling as part of Seven Mile Island Innovation Laboratory efforts for beneficial use of dredged material projects in Cape May County. For additional guidance documents on community engagement, see the *Community Engagement* of the Living Shorelines Profile (Section 3.2.1).

Open Space

Wetlands Pathway Protection requires undeveloped space for existing wetlands to migrate landward as sea levels rise. 76% of New Jersey's coastline is developed (Stockton 2024) which makes it challenging to find undeveloped areas where a wetland could migrate. Refer to Georgetown Climate Center's Managed Retreat Toolkit for Wetlands Migration for tips on identifying locations for and engaging community members on wetlands pathway protection.

Unintended Consequences

Odor and Visual Aesthetics

The soil of a salt marsh can be hypoxic (or have low oxygen levels) which can cause a rotten egg smell (Spencer 2020). Those downwind of the salt marsh may not enjoy the smell but could benefit from the coastal resilience the marsh provides. Additionally, during the construction and planting phase of a project, locals may be displeased by the project site looking like a mudflat while vegetation recovers. Community engagement and communication is key in mitigating this issue.

How can I monitor this NBS?

The type of monitoring conducted for a salt marsh may be mandated by various State programs and/or detailed by the funding source or agency. In the event a salt marsh funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a salt marsh installation.

The following are templates and resources to consider when planning a monitoring strategy for salt marshes (Appendix 4.2.4 provides additional information regarding the resources below):

- A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey (Yepsen et al., 2016)
- USACE – Maintaining Salt Marshes in the Face of Sea Level Rise – Review of Literature and Techniques (VanZomeren et al., 2019).
- NJDEP's Beneficial Use of Dredged Material Website
- Mapping and Assessing Tidal Marsh Condition via Multispectral Imaging (Wilburn et al., 2024)
- USGS Resources - There are national metrics that the USGS has completed that could be helpful for restoration projects including: Landsat UVVR from 1985-2013 and 2019-present (Ganju et al., 2022), aboveground biomass (Byrd et al., 2018), and relative tidal elevation (Holmquist and Windham-Myers 2022). To learn more, watch the NJ Coastal Resilience Collaborative webinar Mid-Atlantic Marshes: Biology, Processes, and Trends (2023).

Case Study of an Exemplary Project

Below are examples of a small- and large-scale salt marsh restoration project. The small-scale restoration project was a pilot program which generated many lessons learned and were applied to the large-scale restoration project. Additional case studies can be found at the GreenVest project website, NFWF Coastal Restoration Fund Dashboard, and on the NJ Department of Transportation website. For more case studies, please refer to Appendix 4.4.

Ring Island Salt Marsh Resilience Project – Middle Township, NJ

Scale of Project: Small
Cost: $684,000 ($42,000 development and design, $484,000 construction, $214,000 monitoring)
Project Timeline: August 2014 sediment placement, March 2017 marsh species planted, early 2018 placing of additional dredged material to restore elevation to upland nesting habitat by USACE in conjunction with NJFWS
Funding Source: USACE O&M funds to design, dredge, place and oversee project construction; and the National Fish and Wildlife Foundation's Hurricane Sandy Grant to monitor and assist with planning and construction oversight (for 2014 project only)

Figure 15. Construction of the Ring Island Salt Marsh restoration project (GreenVest 2024)

This project was designed to: create upland nesting habitat for birds; to restore and enhance the salt marsh habitat; as well as to investigate the effectiveness of using beneficial use of dredged material (Chasten et al., 2022, GreenVest 2024). At Ring Island, beneficial use sediment was used to elevate marsh platforms to create nesting habitat on degraded marsh that could be used by endangered shorebirds (GreenVest 2024). This project used sediment from the NJ Intracoastal Waterway using hydraulically dredged sand that was then sprayed up to 170 feet onto the marsh using a 14 inch pipe. Typically, a 12–14-inch dredge will allow sediment to spray up to 100 feet and higher-pressure spraying systems can allow material to travel up to 300 feet. The placed soil was then surveyed to ensure the dredged material had no extreme physical or chemical characteristics that may hinder plant survival. Three years after material placement, native salt marsh species were planted in the spring before birds' nest and the summer's high temperatures and lower rainfall. Three years of monitoring was conducted after initial construction, but the site was still changing at the end of the monitoring period with vegetation, soil, and wildlife use not aligning with base conditions. (TNC and NJDEP 2021) The Beneficial Use of Dredged Material to Enhance Salt Marsh Habitat in New Jersey provides additional detail and lessons learned for this project, as well as projects in Fortescue and Avalon (TNC and NJDEP 2021, GreenVest 2024). As a reminder, this was an early pilot study that generated many lessons learned for restoration specialists which were applied in the case study below.

Gull Island in the Seven Mile Island Innovation Laboratory Project – Cape May, NJ

Scale of Project: Large-scale (22 acres of marsh elevation, 5.5 acres of marsh edge protection)
Cost: Unknown
Project Timeline: Summer/Fall 2019 site selection, Summer 2019/2020 site assessment, Winter 2020 conceptual design, Summer 2020-Fall 2020 final design, Winter 2020 – Summer 2020 permitting, Fall 2020 sediment addition.
Funding Source: Unknown

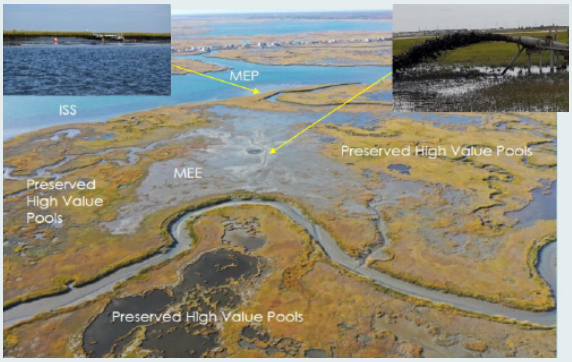


Figure 16. Aerial of the Gull Island salt marsh project (Chasten et al., 2022a)

Gull Island is a low-lying marsh island that was at risk of drowning. This 2020 project was designed to: enhance marsh elevation for high marsh nesting birds (indicated by "MEE" in image above) and establish a subtidal placement berm for marsh edge protection (indicated by "MEP" in above image) (Chasten et al., 2022b). Marsh elevation was completed using uncontained placement of sediment (mixed mud and fine sand) directly on the marsh as well as off the marsh edge using a floating pipe with a spreader plate so that the tidal channel networks could spread material naturally and build elevation capital (indicated by "ISS" in image above) (Chasten et al., 2022). The project utilized 40,000 cy of dredged material and was monitored after construction including: passive sensors to monitor wave attenuation, quarterly measurements of vegetation recovery, biweekly assessments of avian site usage during nesting season, annual elevation measurements, annual pre- and post-construction benthic/macroalgae surveys, and periodic aerial photography by drones (Tedesco and Chasten 2022). The MEE area received a placement thickness between 5.5 feet and zero feet with the thickest placement occurring near the pipe outflow (Tedesco and Chasten 2022). The MEP area received between 2.5 feet and one foot of elevation gain to allow for sediment exposure during mean lower low water (Tedesco and Chasten 2022). Through this project experts learned: (1) projects should be designed with multiple elevation goals and targets across a range of target elevations, (2) project goals should include habitat and species benefits during site recovery, and (3) vegetation recovery takes about two growing seasons to initiate and recovery has largely been accomplished through new seeding and below mean higher high water (USACE 2019, Chasten et al., 2021, Tedesco and Chasten 2022; Chasten et al., 2022b).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing the NBS listed above. In addition to the programs highlighted in the Living Shoreline Profile, several programs are highlighted below. Additional information about these programs is available in Appendix 4.2.4.

1. *NJ Natural Climate Solutions Grants Program, Regional Greenhouse Gas Initiative*
2. *New Jersey Corporate Wetlands Restoration Partnership*
3. *EPA Greenstream Listserv*
4. *Federal Wetland Restoration Funding, U.S. Environmental Protection Agency (EPA)*

Top Resources

1. NJ Restoration Tool Organization Suite's (NJResTOrS) Marsh Explorer Tool
2. Beneficial Use of Dredged Material to Enhance Salt Marsh Habitat in New Jersey – Project Summary and Lessons Learned (2021)
3. A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey (2016)

3.3 Regenerative Land Management

What profiles are in this NBS category?

RLM on Working Lands

NJ Conservation Foundation

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwater
- ✓Wildfire
- ✓Drought

Suitable Environments

- ✓Various

Key Takeaways

1. There are many NBS that follow RLM practices on working lands, each has its own suite of co-benefits and hazard mitigation.
2. Long-term habitat management is key to ensuring the success of these NBS.

RLM on Natural Lands

Synaptic Rehabilitation

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwate
- ✓Wildfire
- ✓Drought
- ✓Heat

Suitable Environments

- ✓Various

Key Takeaways

1. There are many NBS that follow RLM practices on natural lands, each has its own suite of co-benefits and hazard mitigation.
2. Long-term habitat management is key to ensuring the success of these NBS.

Information about RLM on natural lands, beyond what is covered in this profile, can be found in Appendix 4.2.6.

Introduction to Regenerative Land Management

Regenerative land management (RLM) is an approach to soil and land management that aims to restore soil and ecosystem health so the important ecosystem services that natural and working lands provide are maintained long-term or indefinitely. RLM practices are thousands of years old and were implemented by many indigenous populations, including Indigenous Americans (Heim 2020, Johnston 2022). RLM today is sometimes referred to as sustainable land management which is defined by the United Nation's Food and Agriculture Organization as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions," (FAO 2024). Experts in New Jersey generally prefer the term RLM because "regenerative" implies individuals must, and should, put effort into nourishing and improving soil, land, and ecosystem health rather than taking a more passive approach (CBF 2024).

Two NBS profiles are highlighted within this NBS category: RLM on working lands (*i.e.,* agricultural croplands) and RLM on natural lands (*i.e.,* forests and open space). Each profile highlights several NBS types that are consistent with the RLM approach. Below are a couple key takeaways from experts regarding these NBS:

1. **Diversity of RLM NBS-** These profiles highlight ten broad NBS types on working and natural lands, but there are a plethora of additional NBS within these ten NBS types and beyond that could be used on working and natural lands in New Jersey. These ten NBS serve as a foundation of options to highlight the breadth of co-benefits, challenges, and best practices in the RLM field.

2. **Importance of Long-Term Management –** RLM NBS are most successful when recommended long-term management techniques are used consistently into the future. Some RLM NBS in this profile require less maintenance than others but putting effort into nourishing and improving soil, land, or ecosystem health can provide a diversity of co-benefits.

3.3.1 RLM ON WORKING LANDS PROFILE

Introduction

Working lands in New Jersey include agricultural croplands and grasslands and cover about 543,469 acres, or about 12 percent of the state's land area (NJDEP 2021). As of 2017, 263 of New Jersey's 9,883 farms reported implementing a NBS consistent with RLM practices (USDA 2024a). Specifically, 2.7% of New Jersey farmers implemented windbreaks, silvopasture, riparian forest buffers, alley cropping, forest farming, or multi-story cropping as part of the 2017 Census of Agriculture (Smith et al., 2022, USDA 2024b). The 2022 Census of Agriculture showed similar results with 282 of the 9,998 farms in New Jersey (or 2.8%) engaging in these NBS (USDA 2024c). While these six NBS are only a sampling of the possible NBS that could occur on New Jersey working lands to achieve RLM (Wade et al., 2015), these statistics provide a good snapshot of the opportunities to implement NBS on working lands in the State.

This profile focuses on five categories of RLM NBS on working lands (Miralles-Wilhelm 2021, TNC 2021, Hallstein and Iseman 2021, Udawatta et al., 2023). For additional information on each RLM NBS type, refer to Appendix 4.2.5.

1. *Agroforestry* - The intentional integration of trees and shrubs into crop and animal farming systems (USDA 2024d) including alley cropping, forest farming, and silvopasture (USDA 2024e).
2. *Conservation Agriculture* - Activities that increase organic content in soils including conservation tillage (Claassen et al., 2018), conservation crop rotation (Claassen et al., 2018)., cover crops (Claassen et al., 2018)., organic agriculture (OSRA 2024) and rotational grazing (Undersander et al., 2016).
3. *Avoided Forest Conversion*- Conversion of forests to row crop agriculture, pasture, or development represent the largest loss of forests in the United States (USDA 2024g). "Avoided forest conversion" is any tactic that prevents forests from being cut down for agricultural and other development purposes.
4. *Riparian forest buffers*- Natural or re-stablished areas along rivers and streams made up of trees, shrubs, grasses, and/or other perennial plants. These buffers can help filter farm runoff while the roots stabilize the banks of streams, rivers, lakes and ponds to prevent erosion (USDA 2024h). Riparian forest buffers may include natural forests, nut/fruit trees and shrubs planted for harvest, and woody florals and forbs planted for aesthetic and ecosystem benefits (USDA 2024h):
5. *Windbreak* - Linear plantings of trees and shrubs designed to, primarily, slow wind speeds to create a more beneficial condition for soils, crops, livestock, wildlife, and people. Windbreaks are sometimes called "shelterbelts" (USDA 2024h). Windbreaks may include field windbreaks, livestock windbreaks, and living snow fences.
6. *Wetland Restoration on Agriculture Lands*- See the Freshwater Wetland Restoration Profile and the Salt Marsh Profile.

What hazards does this NBS address?

RLM NBS in working lands address a range of hazards. The primary hazards these NBS address are localized extreme heat via agroforestry; stormwater management, inland flooding, and erosion via conservation agriculture, avoided forest conversion, and riparian forest buffers; and wildfires via windbreaks. Additional resources are available to learn about the additional hazards RLM NBS address as highlighted in Table 1 (*e.g.,* NRDC 2021; TNC and AECOM 2021, specifically Table 3-2; Petry et al., 2023, specifically Exhibit 1).

Where should this NBS type go?

RLM NBS on working lands can be implemented on land owned by, or located near, farming operations in the State. Refer to the resources below for an in-depth assessment of the ideal conditions for each NBS for RLM on working lands (RFN-NJ 2025):

1. *Agroforestry* - Refer to the Handbook for Agroforestry Planning and Design (Gold et al., 2013) as well as the Training Manual for Applied Agroforestry Practices (Gold et al., 2013) to learn more about suitable environment for agroforestry practices.
2. *Conservation Agriculture* - A farmer's method for implementing conservation agriculture methods will be site specific and depend on crop choice, climate, soil productivity, soil erodibility, drainage, soil topography, among other variables. (Claassen et al., 2018) Refer to the *Sustainable Agriculture Research and Education* fact sheet on cover crops to learn about best practices based on land type for conservation agriculture practices (SARE 2015). Also consider RFN-NJ's *Agricultural Conservation Planning Tool* available here.
3. *Avoided Forest Conversion* – Avoided forest conversion will occur at sites with existing forest habitat and may require subsequent forest management to ensure a healthy forest environment. Landowners may consider implementing prescribed burning, deer management, disease and pest management, invasive species management, and other strategies (O'Lear et al., 2022) to ensure a healthy ecosystem.
4. *Riparian Forest Buffers* – The fact sheets below provide helpful tips on site suitability for riparian forest buffers:

    a. USDA Riparian Forest Buffers Factsheet (MacFarland et al., 2017) - outlines planning considerations for riparian forest buffers including site size, resilience goals, and unintended consequences (*e.g.,* likelihood of pest invasion).
    b. Forest Health by the Chesapeake Bay Program (Chesapeake Bay Program 2024)
    c. How to Plan for and Plant Streamside Conservation Buffers with Native Fruit and Nut Trees and Woody Floral Shrubs (Trozzo and Munsell 2013)
    d. Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality (Klapproth and Johnson 2009)
    e. Maintenance of Natural Sustainable Riparian Communities Fact Sheet Series (Meehan et al., 2011).

5. *Windbreaks* - Refer to this fact sheet by Kafer and Straight, 2022 which outlines planning considerations for windbreaks including continuity, height, density, orientation, and length of the windbreak.

What are the co-benefits of this NBS?

RLM NBS provide a great diversity of co-benefits (Morizet-Davis et al., 2023, de Groot et al., 2012), but a detailed characterization of these co-benefits, particularly monetized co-benefits, remains to be done (TNC 2021). These monetized co-benefits can be particularly challenging to pinpoint as values for ecosystem services are anticipated to change based on the demand for a given natural resource at any given time (Aziz et al., 2023). Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.5.

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a RLM NBS on working lands.

MATERIAL BENEFITS

Harvesting Organic Materials	Q
Improved Water Quality	M Q
Human Health	Q
Mental Health	Q

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	Q
Improved Habitat Connectivity	Q
Supporting Biodiversity of Flora and Fauna	Q
Supporting Resilience of Ecosystem	C

NATURAL PROCESSES BENEFITS

Air Quality Improvement	C
Climate Regulation	Q
Carbon Sequestration	C
Pollinator Services	Q
Erosion Control	Q
Nutrient Cycle Control	M C Q
Infrastructure Protection	Q

CULTURAL BENEFITS

Sources of Cultural Identity	CD
Spiritual and Symbolic Interactions	CD
Education	Q
Aesthetic Value	Q
Recreational Value	Q
Social Well-Being	CD

M = Monetized Values
C = Quantified Values
Q = Qualitative
CD = Community Derived

Planning

Short term costs vs. long term benefits

Depending on the scope and size of a RLM NBS project, there could be high upfront costs before the co-benefits of a project are realized. Moreover, farmers may see a reduced yield in the 3-5 years following the implementation of a RLM NBS as soil biology and moisture levels settle to their new normal (Petry et al., 2023, see Exhibit 2). Farmers that are able to weather initial financial stress will benefit from long-term crop yield increases (Sea Isle News 2023; Organic Farming Research Foundation 2024; Knapp and van der Heijden 2018; TNC 2021Fin). Farmers and other entities looking to implement projects may benefit from considering these costs, identifying programs to support these costs (AFT 2020), and anticipating long-term profits (Mishler 2023). Farmers and land managers may refer to this online questionnaire (AFT 2024) and resources provided by The Nature Conservancy (TNC 2024) to help determine what practices may be best for a given plot of land.

Logistics

Deer Management

An often-overlooked component of RLM NBS maintenance is deer management. Deer are herbivores and can eat up to 8 pounds of flowers, shrubs, and seedlings a day (NRCS 2019). New Jersey's white-tailed deer are overpopulated and are one of the greatest threats to forest regeneration in the State (O'Lear et al., 2022). Deer can easily browse on vegetation that is less than five feet from the ground unless precautionary management measures are taken to protect low lying vegetation. Deer exclosures, seedling protection, chemical deer repellents, and hunting (NJDEP 2024) can help control New Jersey's white deer population (NRCS 2019). Refer to this article by Penn State Extension to learn more about proper deer fencing techniques (PSE 2024).

Invasive Species

Invasive plants on farmlands are a growing threat to agricultural and native landscapes that makes it more difficult to manage the land (Noble Research Institute 2024). Care should be taken to utilize native species in RLM NBS projects and to take steps to protect projects from being colonized by invasive species (*e.g.,* clean equipment prior to onsite use to prevent it from introducing seeds from a prior job site, isolate questionable hay to a confined area and monitor for any invasives that may grow) (Noble Research Institute 2024). Refer to this fact sheet by the Rutgers NJ Agricultural Experiment Station to learn more about native alternative for landscapes (Rutgers 2024) and the NJDEP Invasive Species webpage for relevant State information on invasives. The State notes that current information on invasive species is collected and maintained by the NJ Invasive Species Strike Team (FOHVOS 2024). The Strike Team provides technical guidance on eradicating invasive species from New Jersey lands.

Unintended Consequences

Forests as Carbon Sources

Forests store carbon in the soil and in trees. Cutting down a live tree releases some of the carbon the tree was storing. If existing forests are thinned for agroforestry practices (Smith et al., 2022), the agroforestry operation may become a carbon source rather than a carbon sink. This is also true if trees are planted for agroforestry. Trees ability to operate as a carbon sink will depend on the growing conditions, the species of trees, age of trees, and number of trees cut or planted (Norman and Kreye 2023; USDA 2024f; Udawatta et al., 2023).

Silvopasture as a Carbon Source

Farmers generally prefer creating silvopasture by thinning established trees rather than planting trees in open pastures or fields because the former could earn them money from timber sales, while the latter creates financial risk. For example, even fast-growing trees take years to provide shade benefits to livestock and would take time and money to protect seedlings from animal browse (Smith et al., 2022).

How can I monitor this NBS?

The type of monitoring conducted for a RLM NBS project may be mandated by various State programs and/or detailed by the funding source or agency. In the event a funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a RLM NBS on working lands. Below are templates and resources to consider when planning a monitoring strategy for these projects (Appendix 4.2.5 provides additional information regarding the resources below):

1. Sustainable Agriculture Research and Education (SARE)'s Resources and Learning Website
2. National Invasive Species Information Center (NISIC) Monitoring Website

Case Study of an Exemplary Project

The project below is an exemplary example of conducing NBS on working lands in New Jersey. To find more case studies on agricultural land in New Jersey, visit NJ-RCD's River Friendly Farm's website at over 30 farms (list and additional information available here).

New Jersey Audubon Wattles Stewardship Center

Scale of Project: Large
Cost: >$36,000
Project Timeline: Unknown
Funding Source: Various

Figure 17. Completed Wattles Stewardship Center project site (Aerial of the Gull Island salt marsh project (Neff 2019).

The Wattles Stewardship Center is a 51-acre wildlife sanctuary which was originally the farm of Mr. Gurdon Wattles who donated the house, barn, and land to conservation through NJ Green Acres program. According to the sanctuary's website, "This site has both agricultural fields and land dedicated to wildlife habitat. Two of the Wattles fields are managed by a local farmer for commodity crop production such as corn, sunflower seeds, and soybeans. Other portions of the property serve as critical wildlife habitat that also provides important natural resource benefits to the region and to the on-site farming activities," (NJA 2024).

Conservation projects on site include (NJ Sustainable Business Registry 2024):

- 10.8 Acres of former crop land was converted to native warm-season grasses for wildlife habitat and soil and water quality improvement under the USDA-FSA programs: State Acres for Wildlife (SAFE) & Conservation Reserve Enhancement program (CREP)
- 12.7 Acres of Woodland are managed under a NJ State Approved Forest Stewardship Plan
- 4.33 acres of early successional habitat were created and are managed under the USDA-NRCS Wildlife Habitat Incentive Program
- A former in-ground pool was converted into a functional vernal pool (pictured above by John Parke) for amphibian breeding. This project won the NJ Soil & Water Conservation Society Ecological Award in 2014
- A 0.28 mile forested riparian buffer was installed by NJA along a C1 tributary of the Musconetcong River under a USFWS Partners for Fish and Wildlife Program with the help of NJ Youth Corps of Phillipsburg, as well as, the NJ Homeschool Groups of Warren County
- NJA also implemented a 0.36 mile stream restoration of the Musconetcong River under a USDA-NRCS Environmental Quality Incentive Program (EQIP) for stream bank stabilization, sediment control and creating and/or restoration habitat for brook trout and other associated aquatic species. This project was performed on an adjacent State Wildlife Management Area property which NJA manages for NJDFW. Cost of total project (including habitat restoration, interpretation and access improvements) was $35,980: Supplies (liner, plant material, equipment, sand, gravel) - $9,420; Labor - $7,000; Interpretative material (signs, kiosk, trail) $7,000; Trail construction/access improvements: $12,560. To learn more about this project, visit NJ Corporate Wetlands Restoration Partnership Website here.

This case study was chosen because it utilizes **Diverse Regenerative Land Management Strategies**. This site has implemented over six types of projects on one 51-acre plot of land. This demonstrates the coordination and long-term planning that can go into robust RLM decisions. This site also showcases how different funding sources can complement each other to create diverse and healthy land uses for RLM on working lands.

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing the NBS listed above. Key programs are highlighted below, additional information about these programs is available in Appendix 4.2.5.

1. *The Natural Resource Conservation Service, U.S. Department of Agriculture (NRCS, USDA)*
2. *The Conservation Reserve Enhancement Program, U.S. Department of Agriculture (CREP, USDA)*
3. *State Agricultural Development Committee (SADC) Programs*
4. *Conservation Cost Sharing, New Jersey Department of Agriculture*

Top Resources

1. North Jersey Resource Conservation and Development Program (NJ-RCDP)
2. NJ-RCDP Regenerative Farm Network
3. NJ Department of Agriculture Organic Sustainable, Regenerative Agriculture (OSRA)
4. NJ Conservation Blueprint

3.3.2 NATURAL LANDS

Introduction

New Jersey's natural lands are diverse including wetlands (tidal and non-tidal) and forests covering 21 and 40% of the State's total land area, respectively (NJDEP 2023). This profile on natural lands will focus on NBS that could be implemented in forested lands[4] and open space[5] with an emphasis on suburban and rural natural lands and spaces. This section will not address NBS related to wetlands or farmlands as those topics are covered elsewhere (see the Freshwater Wetland Restoration Profile and the Regenerative Land Management on Working Lands Profile).

Loss of natural land is a global problem. In the United States, estimates suggest a football field worth of natural land is lost every 30 seconds from human activities (Lee-Ashley et al., 2019). But this loss of natural land is not new. Experts estimate that the forested area of the US was reduced from 412 Mha to 305 Mha (*i.e.,* 46% to 34% of the total land area of the US) from 1630 to 1910 as a result of European settlement and other factors (USDA 2018, Udawatta et al., 2023). Today in New Jersey, forested land and other natural landscapes are being lost to due to urban growth (Hasse and Lathrop 2008). While some reports find the rate of loss seems to be slowing (Lathrop and Hasse 2020), there is growing concern regarding warehouse sprawl (Gilbert 2022) and the need to maximize the health and function of existing natural lands.

Experts estimate New Jersey is a carbon source with statewide land carbon sinks only able to compensate for 2% of the state's fossil fuel emissions (Lu et al., 2015). On average, a state's land carbon sink can compensate for 20% of the state's fossil fuel emissions (Lu et al., 2015, Figure 4). RLM on natural lands contributes to the state's carbon sink and is a nature-based way to wholistically restore damaged or lost habitats and ecosystems.

This profile focuses on five categories of RLM NBS on natural lands which are listed below (see Appendix 4.2.6 for more information):

1. *Acquisition and Development of Open and Green Space* – This NBS includes activities that protect, manage, or restore natural areas while simultaneously expanding access to outdoor recreation. Some examples include park creation or management, vegetated greenways, blue-acres buyout plot conversion, contaminated site remediation and development, and land preservation and management.

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[4] Per the Accountability Framework initiative, forested lands here refers to land spanning more than 1.24 acres with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds (TNC 2019, AFI 2024).

[5] Per the US Forest Service, open space includes all unbuilt areas, whether publicly or privately owned, protected or unprotected (USFS 2024).

2. *Fire Management – This NBS includes* activities that increase resilience to catastrophic fires. Resilience measures may be increasingly important as forests managed for their carbon offsets may be subject to additional wildfire risk (Herbert et al., 2022). Experts recommend a combination of two NBS (*i.e.,* prescribed fires and mechanical thinning) to effectively combat wildfires (Kittler 2022) in New Jersey.

3. *Native Tree Management- This NBS includes planting* and managing native trees to create or restore ecosystems. This includes afforestation, reforestation, forest restoration, reforestation, as well as urban and community forests (see the Urban Forestry Profile for more information on the latter).

4. *Wildlife Friendly Alternatives to Lawns - This NBS includes replacing* all or part of a lawn with native vegetation to create wildlife habitat. Example include pollinator gardens as well as meadows and prairies.

What hazard does this NBS address?

RLM NBS in natural lands address a range of hazards. The primary hazards these NBS address are localized extreme heat via Acquisition and Development of Open and Green Space; stormwater management, inland flooding, and erosion via Native Tree Management and Wildlife Friendly Alternatives to Lawns; and wildfires via Fire Management. Open and green spaces along the coast can also provide protection from storm surge (Burger et al. 2017). Additional resources are available to learn about the additional hazards RLM NBS address as highlighted in Table 1 (*e.g.,* Francoeur et al. 2021; TNC and AECOM 2021, specifically Table 3-2; Warnell et al., 2024, specifically page 192).

Where should this NBS type go?

RLM NBS on natural lands can be implemented on private or publicly owned lands consistent with local, State, and Federal regulations. Refer to the resources below for an in-depth assessment of the ideal conditions for each NBS for RLM on natural lands as well as Appendix 4.2.6 for additional information:

1. *Acquisition and Development of Open and Green Space* - There are many plans and resources in New Jersey that identify land areas most in need of RLM. This includes the Connecting Habitats Across NJ (CHANJ) strategic plan which identifies key areas to preserve and restore habitat connectivity for NJ's terrestrial wildlife (more information available here). Other priority sites for consideration include contaminated sites either through the state's known contaminated site repository (available here), the state's brownfield repository (available here), or the federal superfund sites through the national priority list (available here). Land acquisition can also occur in less expected areas such as near military installations (DOI 2025).

2. *Fire Management* - Identifying locations for prescribed burning is a job requiring knowledge of forest fuels, fire behavior, suppression techniques, local weather conditions, and fires effects. Consequently, a written plan must be developed well in advance of the proposed burn to allow time for review and the preparation of all necessary permits. To learn more about proper fire management techniques, refer to the following resources (NJDEP 2024) and The Allen and Oswego Road Fire Mitigation and Habitat Restoration Project (NJFS 2024).

3. *Native Tree Management* - The following resources will help identify the best locations for various native tree management RLM NBS projects:

   a. "NJ Conservation Blueprint" (Available here.)
   b. "Trees for NJ Streets" (NJ Shade Tree Federation 2016)
   c. "Planning for Greenways: A Guidebook for NJ Communities" (TNJ 2019)
   d. "Urban and Community Forestry Program: Reforestation, Tree Planting, and Maintenance Plan Guidelines" (NJFS 2021)
   e. "New Jersey State Forest Action Plan" (NJDEP-DPF 2020)

4. *Wildlife Friendly Alternatives to Lawns* – Generally meadows and pollinator gardens can be planted in areas of ample sunlight and terrain with a low slope. Refer to the following resources to help identify the best locations for these projects:

   a. "Wildflower Meadows" (Sutton 2006)
   b. "Meadows and Prairies: Wildlife-Friendly Alternatives to Lawn" (PSE 2024)
   c. "Ramapo Green Campus Meadow" (Wiener 2024)
   d."Department of Interior Nature-Based Solutions Roadmap" (Warnell et al., 2024)
   e. "A Garden for Butterflies: Crating a Butterfly Garden in the Northeast" (Duke Farms 2023)
   f. "Gardening for Butterflies" (Mank and Brittingham 2013)
   g. "Pollinator Conservation Resources: Mid-Atlantic Region" (XERCES Society 2024)
   h. "How to Build a Pollinator Garden" (Koenig 2024)
   i. "Transitioning from Traditional Lawn to Native Planting" (Judge 2024)
   j. "Native Groundcovers" (The Native Plant Society of NJ 2024)

What are the co-benefits of this NBS?

Natural lands provide important co-benefits including environmental, recreation, human health, and economic benefits (ANJEC 2021; Mitchell et al., 2024). *The Economic Impact of Protected Open Space in Mercer County, New Jersey* (ESI 2021) which provides detailed monetized estimates for the economic, environmental, and direct benefits to humans. Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.6.

MATERIAL BENEFITS

Harvesting Organic Materials	
Improved Water Quality	
Human Health	
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	
Improved Habitat Connectivity	
Supporting Biodiversity of Flora and Fauna	
Supporting Resilience of Ecosystem	

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	
Erosion Control	
Pollinator Services	
Nutrient Cycle Control	
Infrastructure Protection	

CULTURAL BENEFITS

Sources of Cultural Identity	
Spiritual and Symbolic Interactions	
Education	
Aesthetic Value	
Recreational Value	
Social Well-Being	

= Monetized Values
= Quantified Values
= Qualitative
= Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a RLM NBS on natural lands.

Planning

Acquisition of Land

RLM NBS on natural lands vary in geographic scope. Large projects may take decades to acquire the full area of land necessary to complete a project. Consider the Blue-Acres Program: if there was a severe flooding event in a coastal neighborhood with ten properties, experts caution that while seven of those homeowners may be interested in being bought out in the immediate aftermath of a storm, the remaining three properties may remain for 20-50 years thus extending the timeline for project completion.

Deer and Invasive Species Management

New Jersey's deer population is four- to ten-times higher than the historic population of 10 deer per square mile. These deer prefer to eat native plant species rather than invasive species which has contributed to natural lands shifting from native plant dominant to invasive plant dominant landscapes (Van Clef 2009). This shift, exacerbated by climate change, has caused ecological harm such that insect and bird populations in the state have declined over the last 50-years (Van Clef 2022). The NJ Fish and Wildlife Service have implemented measures to reduce deer populations (NJFWS 2024), but RLM NBS projects may benefit from integrating deer and invasive species management into the planning process. Refer the following resources:

1. Lower Hudson Partnership for Regional Invasive Species Management – Experts agree this is the gold standard for invasive species management in New Jersey.
2. USDA's Non-native Invasive Species Management Practices (2012)

Management of Recreation Spaces

New Jersey's open spaces are growing, but staffing and resources to support these public lands are dwindling. A report of New Jersey's State Parks, Forests, Wildlife Management Areas, and Natural Areas summarized the challenges and recommended solutions to mitigate the neglect (Van Clef 2022). The lessons learned in this report will prove helpful to those interested in creating recreation spaces in natural lands in an effective and efficient way.

For example, driving vehicles off-road through natural spaces can have wide-ranging negative impacts to natural resources including wildlife habitat fragmentation, poor water quality, and damage to vulnerable species (USGS 2007). In New Jersey, off-road vehicle (ORV) driving is illegal on public lands, but enforcement of the law has been spotty due to the cultural significance of the recreational activity (Van Clef 2022, Hurdle 2024). Engaging the community early and often in the development of a project regarding the types of allowable recreation opportunities on site is important to ensure the longevity of a project.

Public Access Issues

Many New Jersey residents do not have easy access to parks or open spaces. This lack of access is primarily due to (1) the distance residents would need to travel to engage in recreational opportunities at parks or open spaces, (2) the lack of public transportation options for those who cannot afford a vehicle, and (3) the lack of amenities on site for people with disabilities (Alexander et al., 2023, Bulger 2023). Consider planning natural lands projects with recreation or education opportunities that address these inequities so that the co-benefits of these spaces can be realized by all regardless of their socioeconomic or physical status.

Logistics

Acquisition of Native Species

The use of native plant species is highly encouraged for any project in this profile. Some experts have reported it challenging to acquire native species at the high volume and low cost necessary to complete a project within budget. The Native Plant Society of New Jersey has a list of nurseries carrying native plant stock to ameliorate this issue (available here).

Maintenance

Visitor Experience

Completed open space projects can include a public education component. Hiking trails with educational signs, classroom and outdoor education programs, and other activities are often implemented for public education purposes. One benefit of

environmental education is that it can lead to visitors' increased willingness to engage in environmental stewardship. However, if a visitor has an unenjoyable experience in the open space (*e.g.,* if they are not properly attired, are not equip for mosquitoes and other insects, overexert themselves on a hike) it may have a negative effect on the visitors' attitudes toward the environment (Smith-Sebasto and Cavern 2006). This is particularly true for individuals with disabilities (Alexander et al., 2023). Care should be taken to ensure visitors have a positive experience on site.

Community Engagement

Whether a project is large or small, community engagement early and often is important to ensure a NBS RLM project on natural lands is successful. Below are two resources to help project managers engage with community members in a meaningful way:

1. Appropriate Technology Transfer for Rural Areas' How to Start Community Agroforestry Projects: Advice from 11 Forest Gardens (2023)
2. Remediating and Redeveloping Brownfields in New Jersey: A Guide for Municipalities and Community Organizations (2021) – Refer to the section on "Key Stakeholders and Their Roles"

Unintended Consequences

Illegal Dumping

When public access to nature increases, so can illegal activities on that accessible land. A problem on New Jersey public lands is illegal dumping (Howell 2022): the active of dumping litter, garbage bags, tires, televisions, electronic waste, appliances, yard waste, and construction debris into natural lands. Illegal dumping can negatively impact the local environment, detracts from the natural beauty of our public lands, decreases property value, and can come with a high cleanup cost (NJDEP 2024b). The NJDEP's "Stop Illegal Dumping" website provide resources to help preclude and mitigate the impacts of illegal dumping on public land.

Ecological Changes

Afforestation changes the ecology of a habitat and, therefore, may cause a loss of existing ecological services on unforested land. For example, pollinators and grassland-dependent wildlife may rely on land in its current state but would be unable to thrive in a forested environment. These changes could also negatively impact threatened or endangered species. Evaluations should be conducted to ensure this unintended consequence is avoided (NWLS 2024)

Human Health Impacts

Prescribed burns may expose residents downwind to smoke which is linked to adverse human health conditions such as pulmonary diseases, which are more likely to adversely impact those with preexisting health conditions (Haikerwal et al., 2015, NWLS 2024).

How can I monitor this NBS?

The type of monitoring conducted for a RLM NBS project on natural lands may be mandated by various State programs and/or detailed by the funding source or agency. In the event a funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a RLM NBS on natural lands. Below are templates and resources to consider when planning a monitoring strategy for these projects:

1. NJDEP NJ Forest Stewardship Program – requirements for monitoring on private property.
2. NJ Urban and Community Forestry Program – requirements for monitoring on private property (see Appendix 5)
3. weADAPT Open Data Kit (Plant Your Future 2015)
4. Multiparty Monitoring and Assessment Guidelines for Community Based Forest Restoration in Southwestern Ponderosa Pine Forests (US Forest Service 2009)

Case Study of an Exemplary Project

Below are a small- and large-scale projects that pertain to RLM NBS in natural lands. To find more case studies, please refer to Appendix 4.4.

Blue Acres Buy-out with Plot Conversion in Linden, NJ

Scale of Project: Small
Cost: $2.7 million. This does not include the $5.6M Blue Acres spent to purchase the homes (Loyer 2015)
Project Timeline: Funds awarded in 2014, project near completion in 2019.
Funding Source: National Fish and Wildlife Foundation and US Department of Interior

Figure 18. Map of project area for the Linden Blue Acres Buy Out project (Princeton Hydro 2020).

Hurricane Sandy caused widespread destruction in Linden, NJ. The storm impacted 275 homes in the community, many in the low-lying Tremley Point area. Between 2013-2019, the State bought 22 properties that were badly damaged by Superstorm Sandy (Rutgers 2019). Currently, 25 properties in Linden have been acquired by Blue Acres and after flooding in 2021 and 2023, a few more are awaiting funding approval.

In 2014 several programs came together (i.e., Princeton Hydro, in collaboration with the City of Linden, Rutgers University, NJDEP, Phillips 66, National Fish and Wildlife Foundation, New Jersey Corporate Wetlands Restoration Partnership, and Enviroscapes) to plan and implement one of the first ecological restoration projects using Blue Acres acquired properties (Rutgers 2017; NJAWRA 2020). According to the project website, "The project included the development and implementation of an on-the-ground natural green infrastructure-focused floodplain enhancement design involving the restoration of native coastal floodplain forest and meadow, as well as floodplain wetlands. The restored area provides natural buffering to storm surge and enhances floodplain functions to capture, infiltrate, store, and slow excess stormwater to reduce the risk of future flood damage. In addition, it restores natural habitat and provides public recreation access on NJDEP Blue Acres property," (Princeton Hydro 2020, Princeton Hydro 2020b). The project site is located along Madison Street in Tremley, NJ near Marshes Creek.

This case study was chosen because it exemplifies a collaborative, long-term management approach to restoring flood prone open space and it highlights the importance of planning a project that offers protections for various, complex flood related hazards that can impact vulnerable neighborhoods:

1. **Long-Term Management:** Volunteers from Conserve Wildlife Foundation of NJ (CWFNJ) annually plant and clean-up the project site to maintain the health of the Blue Acres restoration site. Of note is that CWFNJ has helped to manage phragmites and other invasive vegetation on site since 2019. "Phragmites has become the dominant species along the creek edges and perimeter of the site, drying up the waterway and preventing the transition of the area into a wetland. Each fall, CWFNJ biologists have treated and cut back a significant portion of the phragmites, but it will take many more years of management and cooperation from the surrounding landowners for those efforts to take control over the invasive population," (Tirgrath 2023).

2. **The Importance of Protection from Flood Related Hazards:** Damage to property and human health during a flood event is not limited to exposure to water. For example, the Tremley Point residential area suffered loss and damage from flood waters but some nearby homes were also contaminated by a 7,700 gallon oil spill triggered by floodwaters hitting the industrial properties of the Phillips 66 Bayway Refinery (Spoto 2014; UCS 2015). NBS projects like the one implemented in Tremley Point could be designed at a larger scale to create protective buffers that would help protect residential and industrial areas from flood waters, thus mitigating the risk of flooding and reducing exposure to dangerous pollutants during and after a flood event.

Cramer Hill Waterfront Park in Camden, NJ

Scale of Project: Large
Cost: >$133 million
Project Timeline: First stage of project in 2006, park open in 2021
Funding Source: Private funds, public funds, New Jersey Hazardous Discharge Site Remediation Funds, and New Jersey natural resource damage settlement funds

Figure 19. Completed Cramer Hill Waterfront Park (SEPCO 2023).

At the intersection of the Delaware and Cooper Rivers in Camden, NJ the former Harrison Avenue Landfill was remediated and developed for the betterment of the local communities and environment. The 86-acre municipal landfill was open from 1952-1971 and was never properly capped or closed, causing human health and water quality concerns. In 2006, the Salvation Army used a $59 million donation to construct the Salvation Army Kroc Center on the northeastern 24 acres of the landfill which opened in 2014 and serves over 8,000 local residents. From 2006-2014 the landfill was remediated using $4 million in public funds and $22 million from NJDEP's Hazardous Discharge Site Remediation Funds. (With the breakdown of costs even more complicated per this Camden Redevelopment Agency Resolution from 2022). Starting in 2016, $48 million was then spent by NJDEP's Office of Natural Resource Restoration's natural resource damage settlement monies to transform the remaining 62 acres of the landfill into the Cramer Hill Waterfront Park. The Park opened in November 2021 and includes enhanced and expanded existing freshwater wetlands, 7 acres of new tidal freshwater wetlands, 450 feet of living shorelines, preserved mature trees for bald eagle foraging habitat, and over 375,000 new plants, shrubs and trees. Residents can enjoy a 2-acre fishing pond, kayak and canoe launch, 3 miles of hiking/biking paths, picnic areas, a playground, a sensory garden, and more (ONRR 2024).

This case study exemplifies the following qualities:

1. **Stakeholder Engagement:** Restoring the site and creating the Park took coordinated effort between the neighboring school (Mastery High School), nearby businesses, the Camden Housing Authority, and the adjacent Salvation Army Kroc Center which helped to gather and determine the mutual interests of nearby residents, employees, and visitors. This engagement is described in "Cramer Hill Now! Neighborhood Plan and Waterfront Park Plan" (Cramer Hill CDC 2009, NJDEP 2024c).
2. **Local and Regional Benefits:** This project serves diverse purposes both locally and regionally. Locally, the site provides recreational space for residents while contributing positively to environmental and human health. Regionally, this park is part of a larger envisioned 30-mile regional shared-use trail in New Jersey called the Delaware River Heritage Trail and the 3,000-mile East Coast Greenway.

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing the NBS listed above. Key programs are highlighted below, additional information about these programs is available in Appendix 4.2.6.

1. Outside, Together! A Statewide Comprehensive Outdoor Recreation Plan for New Jersey (2023-2027), NJ DEP
2. Green Acres, NJ DEP
3. Brownfield Remediation Funding Streams
4. Pinelands Preservation Alliance Landscape Makeover Program
5. Land Acquisition Programs
6. County and State Open Space Trust Funds

Top Resources

1. TNC Resilient Land Mapping Tool
2. The NJDEP Office of Natural Resource Restoration (ONRR)

3.4 Stream Restoration

What profiles are in this NBS category?

Dam Removal

NJDEP

Hazards Addressed

- ✓Inland Flooding
- ✓Human Safety

Suitable Environments

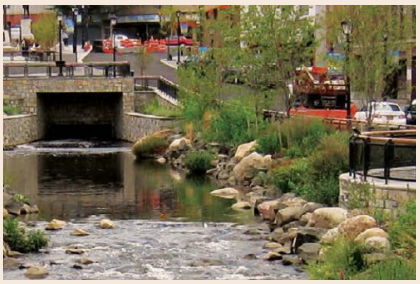
- ✓Where dam removal would provide net benefit to ecological health and community well-being

Key Takeaways

1. New Jersey's dam infrastructure is aging, with approximately 1/3 of dams categorized as high and significant hazard potential dams.
2. Successful dam removals integrate efficient ecological planning to ensure impacts are minimal and short-term.

Information about dam removal, beyond what is covered in this profile, can be found in Appendix 4.2.7.

Culvert Removal and Upgrades



American Rivers

Hazards Addressed

- ✓Inland Flooding
- ✓Heat

Suitable Environments

- ✓Daylighting Streams – sufficient land and low slopes necessary
- ✓Culvert Upgrades – targeted where ecological benefits needed

Key Takeaways

1. Stronger and more frequent storms have led older culverts to fail that can not handle the increased volume of water.
2. Improving urban culvert systems can provide many co-benefits to disadvantaged communities.

Information about culvert removal and upgrades, beyond what is covered in this profile, can be found in Appendix 4.2.8.

Vegetated Riparian Buffer Zone

Rick Obst

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwater

Suitable Environments

- ✓Wide riverine areas with a low slope

Key Takeaways

1.Riparian buffer zones reduce the impact of human development and pollution on aquatic ecosystems and downstream waters.
2. Management of invasive species is imperative, especially within the first five years of construction.

Information about vegetated riparian buffer zones, beyond what is covered in this profile, can be found in Appendix 4.2.9.

Freshwater Wetland

NJ Conservation Foundation

Hazards Addressed

- ✓Inland Flooding
- ✓Stormwater
- ✓Drought

Suitable Environments

- ✓At degraded wetlands with healthy soil and appropriate water quantity

Key Takeaways

1. Freshwater wetland restoration can occur in urban, suburban, and rural environments.
2. Freshwater wetlands provide a breadth of co-benefits for people and wildlife alike.

Information about freshwater wetlands, beyond what is covered in this profile, can be found in Appendix 4.2.10.

Introduction to Stream Restoration

Floodplains are flat areas of land adjacent to rivers or streams that regularly flood during and after storm events when water in rivers or streams overflows. This periodic flooding creates biodiverse habitats that can reduce downstream flooding, filter nutrients, and replenish groundwater. Natural floodplains are an important ecological feature for healthy watersheds. However, development has overtaken many of these natural areas which has caused a decrease in floodplain habitat either from (1) development of buildings and other infrastructure on the floodplain or (2) modifying a river's path and hardening a river's shorelines to preclude natural floodplain conditions (Wohl et al., 2005, Loos and Shader 2016).

New Jersey has over 8,600 miles of freshwater streams (NJFWS 2024) and has many rivers, particularly small streams, that have become disconnected from floodplains with over 1,700 dams in place today (TNC-NJ 2022, NJRCD 2024). The United States Army Corps of Engineers (USACE) has mapped 830 dams in the State which can be viewed on the National Inventory of Dams website.

Stream restoration, broadly, is the process of restoring a disturbed stream and surrounding ecosystem to its original characteristics. Large rivers will have larger floodplains such that stream restoration would require regional planning. Regardless of floodplain size, stream restoration requires a comprehensive understanding of all the elements within the stream system and its watershed. Restoration encompasses a wide range of actions including removing disturbances in the watershed that lead to stream instability and such as dams and culverts, improving streambank health by planting vegetation, and reshaping or replacing unstable stream segments to create well-designed, functional streams and their associated floodplains (Doll et al., 2003).

Four NBS profiles are highlighted within this NBS category including dam removal, culvert removal, vegetated riparian buffer zones, and freshwater wetland projects which contribute to stream restoration. Below are a couple key takeaways from experts regarding stream restoration:

- **Stream restoration requires collaboration:** Regardless of the size of a stream restoration project, collaboration among experts is key. Sharing case studies, resources, and long-term planning among different projects and watershed regions of New Jersey will help to implement successful projects that generate the most ecological and socioeconomic benefits.
- **Equity in Stream Restoration Projects –** Historically there have been racial and socioeconomic disparities regarding where stream restoration projects are conducted. Prioritizing projects that affect urban and tribal areas would help to address this gap. Focusing incentives on projects where these rights have been infringed would allow negative ecological and cultural impacts of manipulated streams to be mitigated (American Rivers, 2023).

3.4.1 DAM REMOVAL PROFILE

Introduction

The hundreds of dams in New Jersey were constructed for various purposes including navigation, flood control, and power generation. Well-managed dams offer many benefits including providing drinking water, recreation, irrigation, and power but can have negative impacts to riverine and floodplain ecosystems (Hamilton and Craig 2017). Dams disrupt the natural flow of water and sediment in a river which can harm populations of native fish, mussels, and other aquatic animals. Dam removal (or decommissioning) can restore a river's natural flow and allow for the unimpeded movement of fish, sediment, and nutrients further upstream and downstream (SDRP 2024). Dam removal can also result in increased safety for human communities.

There are approximately 1,700 regulated dams in New Jersey (*i.e.,* dams that are greater than 5 feet tall or higher than 8 feet tall in the Pinelands) and an unquantified number of unregulated dams (*i.e.,* dams that are less than 5 feet tall). Only a small amount of today's New Jersey dams provide hydropower or downstream flood control consisting of less than 2 and 6 percent of regulated dams respectively (Hamilton and Craig 2017).

The approach to dam removal is dependent on the size of the dam, the size of the impoundment behind it, and the amount of sediment that has built up. When small dam removals are well-planned, they can have a short-term impact on the river (*i.e.,* an impact like that of an above-average rainstorm). The dam removal process can be summarized in four general steps: (1) pre-planning of the removal and restoration process, (2) drawdown or draining of the impoundment, (3) removal of dam structure, and (4) post-removal environmental restoration.

What hazards does this NBS address?

Dam removal can mitigate flooding issues. While some dams in New Jersey were designed to regulate downstream flooding, dam removal can (1) reduce flood levels upstream of a dam and (2) remove the threat of flooding downstream from dam failure. New Jersey's dam infrastructure is aging and vulnerable to failure. USACE's National Inventory of Dams reports the average dam age in New Jersey is 93 years with (USACE 2024) with the American Society of Engineers reporting in 2016 that of the 1702 dams in New Jersey regulated by the Bureau of Dam Safety, 558 of those dams are high and significant hazard potential dams (ASCE 2016). In New Jersey the failure of high hazard potential dams may cause the probable loss of life or extensive property damage, while the failure of significant hazard potential dams may cause significant damage to property and project operation, but loss of human life is not expected (NJAC 7:20). Dams can be dangerous to individuals recreating (i.e., swimming, boating, fishing) nearby as accelerated and reversed currents created by the dam produce a drowning zone that can make rescue difficult (NOAA 2024, Figure 20) . Dam removal ameliorates this risk. For more on dam safety, visit the FEMA Pocket Safety Guide for Dams and Impoundments (2016). For a history of dam failures in New Jersey, visit NJDEP's Dam Safety Historical Events webpage.

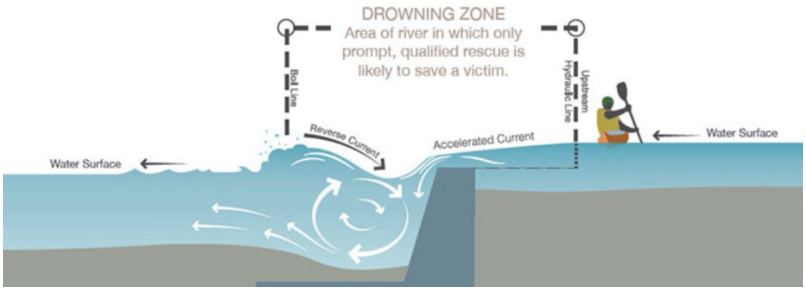


Figure 20. Schematic of the dam drowning zone (NOAA 2024).

Dam removal also improves the health of rivers and the surrounding ecosystem by restoring the natural flow of the waterway. Dam removal results in river hydrology changes but, generally, small dam removals have minimal impact on down river flooding and sediment deposition because most small dams are "run-of-river" dams (*i.e.,* dams that are constructed so that the river normally overflows from behind the dam structure from upriver to downriver) (ICF, 2005).

Where should this NBS type go?

Dam removal is most likely to occur on rivers and streams when:

✓ A dam is not considered a historical structure
✓ If the dam is no longer economically viable, and
✓ If dam removal would have a net benefit on ecological health

There is no authoritative, prioritized list of dams for removal in New Jersey. In lieu of a State or Federal strategy experts have generated the Northeast Aquatic Connectivity assessment which proposes prioritizing dams for removal that have the greatest ecological impact (2011). A more up to date resources, and more accurate according to experts,

is the National Aquatic Barrier Inventory and Prioritization Tool (2025). For more information on dam removal in New Jersey, visit New Jersey Statewide Dam Removal Partnership website. For a plain language summary of dam removal considerations, visit Wisconsin's Dam Removal: A Citizen's Guide to Restoring Rivers.

Additionally, the removal of small dams (*i.e.,* dams that are less than 15 feet high and has a drainage area of less than 150 acres, and the failure of which would cause little to no damage to property and no loss of human life consistent with NJDEP Dam Safety and Flood Control, Dam Safety Standards (NJAC 7:20) has gained support nationally given that small dams tend to age more rapidly than large dams, have an average life expectancy of 50 years, and can be removed more easily than large dams with fewer stakeholder concerns (Lindloff, 2017).

What are the co-benefits of this NBS?

Co-benefits of dam removal that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Where these values do not exist, qualitative descriptions of the co-benefits are provided. Published values for this NBS are listed in Appendix 4.2.7. For a brief summary of dam removal benefits, visit NJDEP's Division of Fish and Wildlife's dam removal website.

MATERIAL BENEFITS

Harvesting Organic Materials	
Improved Water Quality	
Human Health	
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	
Improved Habitat Connectivity	
Supporting Biodiversity of Flora and Fauna	
Supporting Resilience of Ecosystem	

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	
Erosion Control	
Pollinator Services	
Nutrient Cycle Control	
Genetic Diversity Control	
Infrastructure Protection	

CULTURAL BENEFITS

Sources of Cultural Identity	
Spiritual and Symbolic Interactions	
Education	
Aesthetic Value	
Recreational Value	
Social Well-Being	

= Monetized Values
= Quantified Values
= Qualitative
= Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a dam removal.

Planning

A successful dam removal requires careful planning to ensure possible negative impacts of dam removal are mitigated. Below are several considerations to ensure a safe, clean, and efficient dam removal process (additional information be found in Planning and implementing small dam removals: lessons learned from dam removals across the eastern United States (Tonitto and Riha 2016):

Ecological Planning

Ecological restoration plans should be a top priority throughout the project. This means creating carefully designed restoration plans before any work begins, with input from appropriate experts (*e.g.,* fluvial geomorphologists) and community members for the specific site. Depending on the site, actions may need to be taken during the dam's removal to aid in the river's self-restoration. The specific actions required will vary based on the site and the goals of the restoration plan.

Prevent Spread of Sediments Downstream

The removal of small dams, like large dams, can increase flooding downstream if the amount of sediment released during dam removal exceeds the river channel's capacity to manage the influx of sediment. This may lead to sediment accumulation downstream, known as aggradation. It's crucial to evaluate this risk, especially if considerable sedimentation has occurred upstream of the dam being considered for removal. A thorough assessment of sediment management options should be carried out to address these indirect consequences (ICF, 2005).

Preventing Spread of Harmful Sediments Downstream

When a dam is removed, it can disturb sediments causing harm to spawning areas, habitats, and water quality, particularly if the sediments contain harmful substances. For instance, when the Fort Edward Dam on New York's Hudson River was removed in 1973, large amounts of sediment containing toxic PCBs were washed downstream, impacting the health of humans and wildlife. However, problems with suspended sediment are typically temporary lasting only several days. There are ways to reduce suspended sediment problems, such as timing the release of sediments to avoid spring runoff, slowly lowering the reservoir level first, trapping sediment in screens, and removing the sediments from the reservoir (Cho, 2011).

Preventing Negative Impacts on Biota

Eliminating a dam on a polluted river can have negative ecological impacts. In certain situations, dams serve as barriers that protect upstream fish populations from downstream toxins. Moreover, dams can block the spread of invasive species from either side of the structure (American Rivers, 2023). To protect biota during dam removal in an otherwise healthy waterway, experts recommend controlled dam removal which limits the release of dammed sediment and is performed in the fall/winter to reduce stress on fauna and flora.

Permitting

It is important to engage permitting agencies early and often in project development to ensure alignment with proper dam removal permitting protocols. The New Jersey Statewide Dam Removal Partnership (SDRP) and experts have identified several permitting requirements for dam removal (for additional information visit the SDRP website):

- Freshwater Wetlands Permit: Under General Permit No. 18, General Permit No. 16.
- Dam Safety Permit: (N.J.A.C. 7:20) The Dam Safety Standards outline a framework for the safe removal of dams. When applicants seek to breach or remove a dam, the Bureau of Dam Safety and Flood Control reviews several items listed under NJAC 7:20-1.7(h) including sediment management, dewatering, notice to all adjoining property owners. environmental effects of the breach and impacts on downstream life and property.
- Flood Hazard Area Control Permit (N.J.A.C. 7:13).
- County Soil Conservation District (Soil Erosion Control) Permit.
- Water Lowering Permit.
- Coastal Permits (per NJDEP's Coastal Permitting website).

Community Engagement

Concerns about the impact of dam removal on property values and community development are significant for both local communities and property owners (Fox et al. 2016). Owners of properties along impoundments, who may have purchased homes or invested in boats, docks, and other facilities, could strongly oppose dam removal. Their investments were made with the expectation that the impoundment would remain. Indeed, residents in South Jersey living near an impounded lake upriver from a dam noted they did not want the dam to be removed as it would negatively impact their ability to recreate (Wyrick et al. 2009). As such, it is important to engage effected communities early and often to ensure community needs are met with a project's completion.

For example, during the planning process for the removal of the Columbia Dam along the Paulins Kill, project leaders met with locals who were opposed to the project and identified community goals which could be achieved from the dam removal process including maintaining electricity generation (the Columbia Dam generated electricity for about 200 homes) (Primerano 2021). In a compromise, project managers installed solar panels at the Pequest Trout Hatchery (Primerano 2021). Meaningful community engagement can be achieved through (1) interest-based negotiations where opposing parties compromise to identify win-win project opportunities (Harvard 2024) and (2) information sharing during the preliminary stages of a restoration project as detailed by Lyon et al. in the 2019 paper discussing best practices for engaging community members in floodplain restoration projects.

Unintended Consequences

Species Diversity

When dams are removed the diversity of certain organisms that thrive in lake-like conditions may decline. For example, when the Fulton Dam on the Yahara River in Wisconsin was removed, wet meadow grasses replaced species of cattail and sedge. As a result, duck and muskrat populations, which depended on cattail and sedge for their habitat, were negatively affected by the dam's removal. However, the removal of dam did not adversely impact many other native species in the region, such as turtles, amphibians, mink, raccoons, and skunks, all of which continued to thrive in the area afterward. Decision makers involved in the dam removal process should consider the full spectrum of ecological changes that may occur from a dam removal project (American Rivers, 2023).

Carbon Emissions

Dams in the United States can be a source of methane and other greenhouse gases through the creation, maintenance, and decommission stage (Song et al., 2018) and dam removal can decrease the carbon sink strength of reservoir footprints (as was the case for two large dams in Georgia) although experts note additional research is needed (Naslund 2024). Experts agree dam removal provides net positive benefits to New Jersey ecosystems.

How can I monitor this NBS?

Monitoring before, during, and after a dam is removed is important for ensuring the dam removal is achieving the intended project goals. Specific monitoring requirements may be issued by the State for consistency with applicable State law (including but not limited to sediment and geomorphology monitoring, fish monitoring, turbidity monitoring, mussel monitoring, hydrology monitoring, flooding monitoring, and floodplain restoration monitoring) (SDRP 2024b). Additional monitoring requirements may be issued by the agency or program funding the dam removal project.

In the absence of mandated monitoring requirements, the following are key resources that may aid in any dam removal monitoring efforts:

- Scientific Data Collection for Dam Removal Project Monitoring Presentation (SDRP)
- Stream Barrier and Removal Guide (2007)
- The Musconetcong Watershed Association's Dam Removal and Restoration Volunteer Monitoring Approach (2024)

Case Study of an Exemplary Project

There are various existing repositories of dam removal including SDRP's Case Study's website and resources from American Rivers including the 2023 US Dam Removals Summary. Below is one such dam removal project. To find more case studies, please refer to Appendix 4.4.

Columbia Lake Dam Removal on the Paulins Kill River, Knowlton Township, NJ

Scale of Project: Large
Cost: $5.9 million
Project Timeline: Ecosystem monitoring (2015-2025), design/permitting (2016-2017), initial habitat prep (2018), dam demolition (January 2019), stabilization/planting (March/April 2019)
Funding Source: Approximately $4 million were provided by the NJDEP Office of Natural Resource Restoration and Division of Fish and Wildlife from the Natural Resource Damage Funds, $1.4 million from The Nature Conservancy (Scruton 2018, NJDEP 2024a)

Figure 22. Columbia Lake dam removal before (top) and after (bottom) removal (modified from NJ Dams 2024).

The Paulins Kill is the third largest tributary to the Delaware River running more than 40-miles through New Jersey (TNC 2024a). The Columbia Lake Dam was built in 1909, was approximately 18 feet high and 330 feet long, and was used to generate hydropower (NJDEP 2024a). The dam impounded a 43-acre lake that ran more than 1.5 miles upstream of the dam, accumulated sediments that "choked fish and depleted the food supply for birds and other wildlife" (Primerano 2021), and blocked 10 miles of habitat for fish passage (e.g., American Shad, American Eel, Blueback Herring, Alewife, sea lamprey) (NJDEP 2024b, NJCWRP 2024). The structure was ranked within the top 5% of approximately 14,000 dams prioritized for removal by the Northeast Association of Fish and Wildlife Agencies due to its proximity to the Delaware River (less than half a mile) (Primerano 2021, TNC 2024a). The dam and surrounding land is managed by NJDEP's Division of Fish and Wildlife as part of the Columbia Wildlife Management Area (NJDEP 2024a).

The $5.9 million cost of this project included dewatering, dam demolition, sediment management, installation of bridge scour protection, floodplain restoration and in-stream habitat enhancement, and construction of access paths for recreation among other on-site work but does not include the cost of supplementary floodplain restoration work (e.g., reforesting 10 miles the Paulins Kill floodplain with over 37,000 trees, restoring river channels near the river's headwaters which were previously ditched and drained (TNC 2016, TNC 2024a) (NJCWRP 2024).

This case study was selected because it exemplified thoughtful planning, strong partnerships among project team, engagement with the local community, and robust information sharing.

1. **Thoughtful Planning:** Planning for the Paulins Kill dam removal started before 2015 and as part of a broader, large-scale effort to support floodplain restoration (TNC 2016). Indeed, the first tree planted in the Paulins Kill watershed was in 2012 and additional floodplain restoration efforts have occurred after the Columbia Dam removal (e.g., the removal of two dams upstream of the Columbia including the County Line Dam (removed in 2022, details available at NJCWRP 2024b and TNC 2024b) and the Paulina Dam (removed in 2024, details available at Princeton Hydro 2023 and Princeton Hydro 2024) bringing new partners and expertise (TNC 2020).

2. **Strong Partnerships and Community Engagement:** Partners for the Columbia Dam removal project included The Nature Conservancy, American Rivers, the US Fish and Wildlife Service, NJDEP's Division of Fish and Wildlife, SumCo Eco-Contracting and Princeton Hydro (NJDEP 2024a, SumCo 2024). Engagement with community members for the Columbia Dam removal consisted of the 2015 Paulin's Kill Community Workshop (details about the event which brought 140 local farmers, landowners, nonprofit and government partners are available in this event announcement (Cummins 2015)), the 2017 public hearing hosted by NJDEP (public hearing announcement available here), and more.

3. **Robust Information Sharing:** The resources available above highlight the breadth of information available to the public surrounding the Columbia Lake Dam removal and related restoration projects. Additionally, the resources below provide more detailed information regarding:

    - The 10-year monitoring strategy (TNC 2016) and possible avenues to accessing monitoring data (DiBlasio 2024).

    - The ecological preparations for the dam removal including lake lowering, fish/mussel salvage and relocation, remnant dam removal, and the construction of temporary fish passage during the dam removal process (NJDEP 2018) (NJDEP 2024b). To watch videos of the entire Columbia Dam removal process, visit Princeton Hydro's website here.

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing dam removals. Key programs are highlighted below with a complete list of resources identified in the Potential Funding Sources for Dam Removal in NJ Fact Sheet (NJSDRP 2019).

1. United States Army Corps of Engineers General Investigations Process (USACE)
2. North American Wetlands Conservation Act (NAWCA) US Standard Grants (USFWS)
3. Rehabilitation of High Hazard Potential Dam Grant Programs (USDHS and FEMA)

Top Resources

1. New Jersey Statewide Dams Removal Partnership
2. Federal Interagency Nature-Like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes (2016)

3.4.2 – CULVERT REMOVAL AND UPGRADES PROFILE

Introduction

During the United States' industrialization period and the growth of urbanized areas, many streams were channelized or buried to make way for buildings, roads, and other development (Trice 2016). One method for stream channelization or burial is through culverts. A culvert is a device (typically a pipe or arched tunnel that can be made of concrete, steel, plastic, or other materials) that is used to channel water under a road, railway, or another type of embankment (NJDEP 2024c). The diameter of a culvert can range from 6-inches to several feet (NJDOT 2009), but are typically no wider than 20 feet (NJDOT 2007). Older culverts may fail over time due to usage, age, or environmental conditions including culverts that may have been designed to channel a smaller volume of stormwater than what is

commonly generated by modern storms (*e.g.,* the 100-year storm of the early 20th century was less intense than today's 100-year storm, and the 100-year storms into the future) (Morrison 2023).

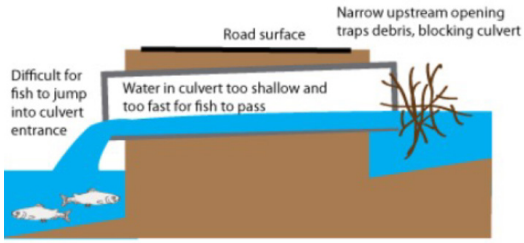
Stream daylighting refers to the process of revitalizing waterways by exposing some or all parts of a river, stream, or stormwater drainage that had been previously covered. The benefits of stream daylighting include increased hydraulic capacity for flood control, slowing water to reduce downstream erosion, water quality improvements, and community and ecological revitalization (Trice 2016). While most efforts in stream daylighting aim to restore a waterway to a more natural condition, there are also alternative forms of daylighting which including architectural restoration (where a stream is re-exposed but maintains concrete walls) and cultural restoration (where a buried stream is marked with art or educational signs) (Trice 2016).

Figure 23. Plan for a stream restoration project in Missouri (Morrison 2023).

This profile focuses on NBS that involve the removal or upgrade of culverts including:

1. **Stream Daylighting via Natural Restoration** – Restoring a stream to natural stream conditions (i.e., constructing a natural stream bed, channel, and riparian buffer) (Trice, 2016).

2. **Culvert Upgrades that Emulate Natural Streams** – Culverts can block the migration of fish and other aquatic species creating a disconnect within the floodplain ecosystem. These culvert design flaws include: culverts that are "perched" (i.e., have physical drop from outlet to receiving water body), culverts that are poorly sized or positioned (i.e., culverts that are too small or sloped can create currents that are too strong and are too turbulent for biota to migrate, culverts that are too large or horizontal can create inadequate water depths for biota to migrate), and culverts that are easily blocked by debris (USACE 2024). Upgrading these culverts can enhance the ecological functionality and connectivity of a floodplain (Princeton Hydro 2023).



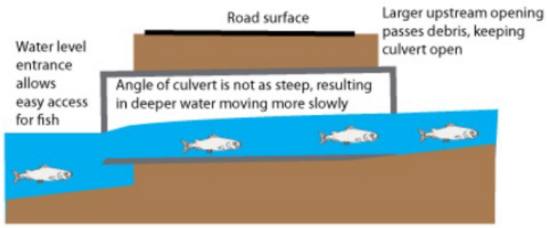


Figure 24. Schematic of culvert before (top) and after (bottom) upgrades (Princeton Hydro 2023).

What hazards does this NBS address?

Daylighting streams can mitigate flooding by creating a more natural ecosystem that mimics a natural floodplain. Floodplains have increased hydraulic storage capacity and slower flows than that of a culvert which (1) increases the volume of space available for water to accumulate during and after storm events and (2) lowers the risk of downstream flooding, respectively (Trice 2016). Where stream daylighting occurs in urban areas, the project may also help to mitigate urban heat by adding additional green space to a developed environment.

Culvert upgrades can also mitigate flooding when designed for (1) efficient water flow for modern and future storm conditions and (2) minimizing the risk of debris obstruction.

Where should this NBS type go?

A daylit stream functions best when the project site (additional information can be found in Appendix 4.2.8):

- ✓ Is wide enough to facilitate a natural flow of water with gentle, stable slopes
- ✓ Has ideal soil content
- ✓ Supports robust connections with existing upstream and downstream features

There is no authoritative list of streams for daylighting nor are there a set criteria to prioritize daylighting. Experts have suggested that after considering available space based on legal, technical, and economic constraints it may be beneficial to prioritize stream daylighting where social connectivity, environmental improvements, and economic benefits would be maximized (Wantzen et al., 2022).

For culvert upgrades, there are similar environmental, socioeconomic, and legal restrictions regarding where these projects can occur. A map of culverts in New Jersey is being updated as part of the State's updated stormwater regulations: a current version of the map is available here. For the most localized guidance on suitable environments for culvert upgrades, refer the NY-NJ Harbor Estuary Program Restoration Strategy Toolkit which can be used as a template for developing more resilient and environmentally friendly culvert infrastructure (Princeton Hydro 2023, Princeton Hydro 2024). Best practices for national culvert upgrade design can be found in the US Fish and Wildlife Service's Culvert Design Guidelines for Ecological Function (FWS 2024).

What are the co-benefits of this NBS?

Co-benefits of stream daylighting and culvert upgrades that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.8. Where these values do not exist, qualitative descriptions of the co-benefits are provided with the understanding that additional research is necessary to understand and quantify the full breadth of stream daylighting (Khirfan et al., 2020) and culvert upgrade (USFS 2024) benefits. For a brief summary of benefits relevant to these NBS, visit American Rivers' Daylighting Streams: Breathing Life into Urban Streams and Communities reference document (Trice 2016 and Wantzen et al. 2022) and An Economic Analysis of Improved Road-Stream Crossings (Levine 2013).

MATERIAL BENEFITS

Harvesting Organic Materials	Q
Improved Water Quality	Q
Human Health	Q
Mental Health	Q

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	Q
Improved Habitat Connectivity	Q
Supporting Biodiversity of Flora and Fauna	Q
Supporting Resilience of Ecosystem	Q

NATURAL PROCESSES BENEFITS

Air Quality Improvement	Q
Climate Regulation	Q
Carbon Sequestration	Q
Erosion Control	Q
Pollinator Services	Q
Nutrient Cycle Control	Q
Genetic Diversity Control	
Infrastructure Protection	M Q

CULTURAL BENEFITS

Sources of Cultural Identity	C
Spiritual and Symbolic Interactions	C
Education	Q
Aesthetic Value	M
Recreational Value	Q
Social Well-Being	Q

M = Monetized Values
Q = Qualitative
= Quantified Values
C = Community Derived

What are the common challenges?

The challenges associated with culvert removal and daylighting—such as logistics, community engagement, and outreach—are similar to those found in our profiles on riparian buffer zones, freshwater wetlands, and dam removal. For relevant information beyond the challenge highlighted below, refer to the previously mentioned profiles.

Planning

Anticipating Unexpected Costs

There can be extra costs regarding removing culverts and daylighting streams. Urban streams are frequently hidden beneath concrete, making extensive excavation necessary for watershed managers to secure funding. Additionally, finding adequate land suitable for redevelopment poses significant challenges that can hinder these efforts. Once the stream is brought back to the surface, agencies must also coordinate to establish ongoing maintenance responsibilities, which may require additional costs and staff resources (Kuester, 2024).

Unintended Consequences

Artifacts

Any major construction on culverts could unearth artifacts of archaeological importance, particularly near areas of historic importance in the State (Cultural Resources Consulting Group 2001). Project managers may benefit from reviewing the requirements of the National Historic Preservation Act (36 CFR 800) and the New Jersey Register of Historic Places Act of 1970, as well as consulting with local historic commissions (NJDEP, HPO 2022) to ensure construction aligns with applicable rules and policies.

How can I monitor this NBS?

Monitoring before, during, and after a stream daylighting or culvert upgrading project is important for ensuring the project goals are achieved. Specific monitoring requirements may be issued by the State for consistency with applicable State law, while some monitoring requirements may be issued by the funding agency or program.

Below is a list of resources to aid in any monitoring efforts:

- Vermont Stream Geomorphic Assessment, Culvert Assessment Field Form (VANR 2009)
- Culvert Design Guidelines for Ecological Function, Construction Checklist (FWS 2024) – provides a snapshot of culvert features to monitor.

Case Study of an Exemplary Project

There are various existing repositories of culvert removal or upgrades including ANJEC's Resource Paper on Municipal Techniques for water management (2020) and New Jersey's Green Infrastructure Municipal Toolkit (2024). Below is an example of a stream daylighting project. For an exemplary culvert upgrade case study, refer to Restoring Road-Stream Crossings to Support Fish Passage (Princeton Hydro 2023). To find more case studies, please refer to Appendix 4.4.

Assunpink Creek Daylighting Park Project in Trenton, NJ

Scale of Project: Large
Cost: $8 million (NJDHS 2017)
Project Timeline: 1997 initial project idea, 2006 culvert failure, 2007 feasibility study, 2018 park and stream restoration, 2021 project completed
Funding Source: Cost share between USACE (75%) and NJDEP (25%) via 319(h) funding and the Natural Resource Damages Program (NJDHS 2017), including $2 million from NJDEP's Office of Natural Resource Restoration (NJDEP 2024d)

Figure 22. Broad Street culvert collapse location (top) (USACE 2007) that led to stream daylighting project, with artistic rendering of stream daylighting result (bottom) (City of Trenton 2017).

Assunpink Creek is 25 miles long and drains approximately 91 square miles of land in central Jersey (USACE 2007). In the 1970s portions of the river were buried to make room for redevelopment projects that were never initiated (NJDHS 2017). This project focuses on the Broad Street culvert which buried 500 feet of the lower Assunpink Creek in downtown Trenton in a box culvert between South Broad Street and South Warren Street (see red box above, USACE 2007). The City of Trenton started discussing updates to this portion of the Assunpink Creek in 1997 when they considered a small-scale project to open the existing culvert. In 2006, a portion of the concrete lid of the Broad Street culvert failed which catalyzed action on daylighting this portion of the stream (artistic rendering in white box above, City of Trenton 2017). The goal of this daylighting project was to restore migratory fish habitat, improve the overall stream ecology of the Assunpink Creek (including improving local water quality), and enhance urban recreational opportunities (NJDEP 2024d). This project was delayed by 19 years due to challenges related to design, permitting, funding, and potential litigation. The benefits of this project are particularly meaningful given (1) the upstream and downstream areas immediately surrounding the culvert were not buried thus providing larger scale ecosystem services and (2) this daylighting processes was part of a larger effort to develop a Assunpink Creek Greenway across the 11 municipalities that intersect with the Assunpink (DVRPC 2000, DVRPC 2024). This includes the existing Mill Hill Park located immediately to the east of the daylighting site and an area 2 miles upstream (Amtico Square) which is slated to become a recreational hub for locals within the Greenway (Trenton 2021). This daylighting project has created two acres of green space (ANJEC 2020)

This case study was selected because it showcases the amount of time sometimes necessary to coordinate and complete these projects and because of the documentation available to the public.

The following additional resources may be particularly informative:

1. New Jersey Future Assunpink Daylighting Website - Lists many initial planning documents (e.g., USACE Restoration Feasibility Study, Archaeological Survey, Environmental Investigation Report) and community engagement documentation. This site is of historical importance as the Assunpink hosted many early factories and George Washington arranged the Continental Army on site during the Second Battle of Trenton (BRS 2024). Additional community engagement materials can be found on this additional NJ Future website.

2. Project Partners - The Assunpink daylighting project stalled in the early 2010s due to a funding gap. The NJDEP's Community Collaborative Initiative expanded their reach to Trenton in 2015 and were instrumental in finding funds to keep the project going (NJDHS 2017, NJDEP 2018).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing culvert removal and upgrades. Key programs are highlighted below:

1. US Department of Transportation National Culvert Removal, Replacement, and Restoration Grants (USDOT) (additional information available through the National Wildlife Federation)
2. National Fish Passage Program (USFWS)
3. Five Star Wetland and Urban Waters Restoration Grants (EPA)

Top Resources

1. American Rivers, Daylighting Streams: Breathing Life into Urban Streams and Communities (2016)
2. EPA Stream daylighting at Brownfield Sites (2016)
3. Halff, When to consider daylighting a stream (2018)
4. Stream daylighting offers ecological, economical benefits (Kuester 2024)
5. Deculverting: Reviewing the evidence on the 'daylighting' and restoration of Culverted Rivers (Wild et al. 2011)

3.4.3 VEGETATED RIPARIAN-BUFFER ZONE PROFILE

Introduction

A riparian buffer (sometimes referred to as a "riparian buffer zone") is a strip of land directly adjacent to a body of water where development is limited or banned. The principal function of a riparian buffer is to protect and separate a stream, lake, or wetland from development, disturbance, or encroachment (EPA, 2021). Riparian buffer zones are typically vegetated and help to reduce the impact of human development and pollution on aquatic ecosystems and downstream waters (Lathrop et al., 2021) by providing streambank stability and improved local water quality (NJDA 2024). However, the abundance of riparian buffers have changed over time with some areas of New Jersey seeing a decline in the size, continuity, and health of riparian buffers along bodies of water (Jones et al., 2010; Lathrop et al., 2021). As such, the presence of a riparian buffer is not always sufficient to achieve environmental goals and restoration is needed. Riparian buffer zone restoration involves various restoration management techniques so the ecosystem can reestablish its riparian functions and associated physical, chemical, and biological health within the terrestrial and aquatic ecosystems degraded by human impacts (USDA, 2004).

This profile focuses on riparian buffer zone creation and restoration projects. In general, there are two steps to creating or restoring a riparian buffer zone which include (DOI 2024):

1. Restoring a waterway's hydromorphology by regrading stream banks to create a flatter slope or reconfiguring stream channels to more natural (*i.e.,* less straight).
2. Restoring native vegetation to the stream bank and surrounding area.

For a more extended guide on the functions, design, establishment and management of riparian buffer zones visit the Natural Resource Conservation Service's New Jersey Conservation Practice Standard for Riparian Forest Buffers (available here), the Penn State Extension's Riparian Buffers website (available here), and the Chesapeake Bay Riparian Handbook (available here).

What hazards does this NBS address?

Riparian buffer zones can be effective at mitigating flooding conditions during and after storm events while also providing a range of other environmental and public benefits. These co-benefits include reducing stormwater, improving water quality and helping to mitigate flooding risks (EPA, 2021, SNEP 2024). Riparian zones act as natural absorbers for stormwater, reducing the volume and speed of the flow and mitigating the risk of floods (Singh et al., 2021).

Where should this NBS type go?

Riparian buffer zones function best when the area with vegetation (Brittingham and DeCecco 2024; NYSDEC 2024):

- ✓ The zone has less than a 6% slope to slow runoff
- ✓ Is a large enough and contiguous area that can process the volume of water from the runoff-contributing area
- ✓ Has healthy soil that can support native vegetation

For more information on design guidelines for riparian buffer zones in urban and rural environments, see Appendix 4.2.9.

What are the co-benefits of this NBS?

Riparian buffer zones with woody and vegetative plants improve ecosystem health as plant roots help stabilize stream banks, reduce stormwater flow rate, and enhance adsorption of excess water. Vegetative buffers also filter runoff, and provide shade to lower stream temperatures, improving stream health, and fish habitat. These environmental benefits have indirect co-benefits to people as well. A review of the co-benefits provided by riparian buffer zones is explored in Cole et al., 2020. Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.9.

MATERIAL BENEFITS

Harvesting Organic Materials	
Improved Water Quality	
Human Health	
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	
Improved Habitat Connectivity	
Supporting Biodiversity of Flora and Fauna	
Supporting Resilience of Ecosystem	

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	
Erosion Control	
Pollinator Services	
Nutrient Cycle Control	
Genetic Diversity Control	
Infrastructure Protection	

CULTURAL BENEFITS

Sources of Cultural Identity	
Spiritual and Symbolic Interactions	
Education	
Aesthetic Value	
Recreational Value	
Social Well-Being	

= Monetized Values
= Quantified Values
= Qualitative
= Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of a riparian buffer zone.

Planning

Local Planning

Riparian buffer zone establishment considerations vary widely depending on restoration goals, local design standards and site conditions including soil type, land use and topography. The cost of a project will also depend on available equipment and labor, the level of grading needed, noxious weed and invasive species control, and the vegetation

selected for planting (SERA-17, 2023). Design engineers should consult local permitting authorities at the start of the project to ensure they follow local design standards and obtain any required permits. The NRCS Riparian Buffer Guide (2008) provides a great primer for those considering a riparian buffer zone project.

Regional Planning

Stormwater and flooding issues have local impacts but regional causes. It is encouraged for riparian buffer zone projects to be implemented after a regional assessment of ecological and socioeconomic needs to maximize the benefits of a project. Additionally, riparian buffer zones can be implemented together with upstream stormwater controls and other local stormwater controls to wholistically and effectively manage stormwater discharge (EPA, 2021).

Permitting

Permit requirements will depend on the site and proximity to wetlands or flood zone designations. A USACE Nationwide Permit 27 for Aquatic Habitat Restoration, Enhancement, and Establishment Activities may be necessary as well as a USACE Section 404 Dredge and Fill Permit (EPA, 2021). Additional state and municipal permits may also be necessary consistent with state and local ordinances on stream protection (ANJEC, 2019). Due to this complexity, approval agencies may lack experience with riparian forest buffers which may result in longer approval processes (Dellinger, 2023).

Maintenance

Initial Time Commitment

Riparian buffers require more intensive maintenance in the first five years. Until the buffer reaches 60% canopy cover, frequent mowing and weeding are necessary to prevent other vegetation from outcompeting project plants. This may involve mowing existing grasses and forbs once or twice a year to limit their growth. Methods such as mowing, mulching, and using herbicides can effectively control herbaceous competition.

Invasive Species

Young plants and trees are vulnerable to invasive species, so regular checks and removal of these species are crucial to prevent additional expenses for the site owner (Dellinger, 2023). To control vines and woody species, similar procedures to those used for preparing early successional sites are needed. This may include selectively cutting trees and using basal sprays to manage undesirable species as the riparian trees grow (USDA, 1998).

Community Engagement

Engaging communities early and often in the planning of riparian buffer zones is essential, as is public education on the benefits of riparian buffer zones (NAS 2002). For tips on identifying communities that could be directly or indirectly affected by a proposed project, how to create a cohesive strategy for stakeholder outreach, maximizing each stakeholder engagement opportunity, and building trust with communities refer to: the WeAct Community Engagement Brief (2022) and Raw Earth's Best Practices for Effective Stakeholder Involvement (2024).

Unintended Consequences

Riparian buffer zones can increase local property values (Bin et al., 2009) which may cause "green gentrification" of the area. Green gentrification occurs when green infrastructure or ecological projects are completed and lead to the displacement and exclusion of vulnerable individuals who can no longer afford to live in the area (Assaad, 2024).

How can I monitor this NBS?

Monitoring before, during, and after a riparian buffer zone project is important for ensuring the project goals are achieved. Specific monitoring requirements may be issued by the State for consistency with applicable State law, while some monitoring requirements may be issued by the funding agency or program.

Below is a list of resources to aid in any monitoring efforts:

1. EPA Wetlands Monitoring and Assessment
2. Partnership for the Delaware Estuary Standard Methods Bank for Living Shorelines and Marsh Projects
3. NJDEP Monitoring Standards

Case Study of an Exemplary Project

Riparian zone buffer projects are abundant in New Jersey with projects being organized by many groups including the American Littoral Society (case studies here). Below is a small-scale riparian buffer zone project. To find more case studies, please refer to Appendix 4.4.

Forested Wetland Floodplain Restoration, Woodbridge, NJ

Scale of Project: Small
Cost: $101,080 (NJCWRP 2024)
Project Timeline: September 2021 – August 2024 (estimated)
Funding Source: unknown

Figure 26. Image of Woodbridge wetland flood restoration project (USACE).

Woodbridge Township, NJ is home to three rivers which can cause significant flooding for nearby neighborhoods: the Woodbridge River which bisects the town and the Heards Brook and Arthur Kill which bookend the town (Peters 2022). After 2012's Superstorm Sandy over 170 homes were bought out by the Blue Acres program. In subsequent years some portions of those properties have been re-engineered to create a more healthy floodplain including the planting of 2,000 native trees and shrubs, removal of two acres of impervious surface, and removing invasive species from five acres of land (Lowrie et al., 2023, NJCWRP 2024). The focus of this case study is a parcel of land with a wetland which was invaded by a Phragmites monoculture and was transformed into a native forested wetland.

The project seeks to divert stormwater and flood waters from the neighboring developed area to the Woodbridge River. The wetland design channels flow from three existing swales through a sequence of vegetated hollows, where water will be stored and purified temporarily. The design enhances the flood storage capacity of the current landscape using natural ecological elements and reintroduces native wetland plants suitable for the region and anticipated site conditions. This rehabilitated habitat will offer better water quality and greater biodiversity for wading bird species listed by the state, such as little blue herons and snowy egrets. The vertical structure of the forest could also serve as roosting habitat for black-crowned night herons and cattle egrets. For more information regarding this project such as detailed cost information visit NJCWRP's website.

To learn more about other projects implemented in Woodbridge, visit the following websites:

- **Woodbridge's Floodplain Management Website** - The Flood Protection Information Library provides a suite of baseline ecological monitoring and floodplain restoration planning for projects including the Open space and Floodplain Restoration Plan (restoration plan here, full website here, additional resources here).
- **Woodbridge/Rutgers Partnership** – Learn about the collaboration between experts in Woodbridge and scientists at Rutgers to do restoration work prior to 2022 (available here, additional information on Scientific American, educational video here).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing vegetative riparian buffer zones. Key programs are highlighted below:

1. New Jersey American Water's Environmental Grants (American Water and the American Water Charitable Foundation)
2. Water Quality Restoration Grants for Nonpoint Source Pollution (NJDEP)
3. Delaware Watershed Conservation Fund (NFWF)

Top Resources

1. Nature-based Solutions Roadmap (DOI 2024)
2. Creating Flood-Resilient Landscapes – A Primer for New Jersey Communities (Maslo 2023)
3. Chesapeake Bay Riparian Handbook (2016)
4. Partnership for the Delaware Estuary's Standard Methodologies Bank
5. USDA Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways (2008)
6. NYDEC Riparian Buffers
7. Managing Urban Rivers from Planning to Practice (2023)

3.4.4 FRESHWATER WETLAND PROFILE

Introduction

A wetland is a low-lying land area that is saturated with water, either permanently or seasonally, and contains hydric soils and aquatic vegetation. A freshwater wetland is a non-tidal wetland that can be found along non-tidal streams, rivers, and creeks as well as in poorly drained low-lying areas far from any waterway (NJDEP 2024, EPA 2024). Freshwater wetlands in New Jersey include marshes, swamps, forested swamps, shrub swamps, bogs, peatlands, and fens (Nelson 2024, EPA 2024). Freshwater wetlands are valuable ecosystems that provide habitats for wildlife, enhance water quality, control erosion, sequester pollutants, remove nutrients, maintain stream flows, absorb energy and store water during storms, recharge aquifers, and reduce flooding (VANR 2024, NPS 2024). New Jersey is estimated to have 613,500 acres of freshwater wetlands (FWS 2023), but it is estimated that approximately 150 acres of freshwater wetlands are disturbed each year from anthropogenic activities (Genievich et al., 2024). Wetland degradation can occur when a wetland is being directly disturbed (*e.g.,* when a wetland is filled, is graded, has vegetation removed) or indirectly disturbed (*e.g.,* changes to nearby land which causes an influx of surface water, sediments, and other pollutants into wetland, wetland fragmentation, loss of wetland recharge area) (Wardrop et al., 2019, Albert et al., 2020, MDE 2024). Wetland degradation has an impact on a wetland's hydrology, soils, and biota reducing the ecosystem's ability to perform important ecosystem services.

Wetland restoration is the State's preferred form of wetland mitigation (*i.e.,* activities to compensate for impacts to freshwater wetlands caused by regulated activities) (NJDEP 2024b). Other forms of mitigation include wetland creation, enhancement, purchase of credits from a mitigation bank, preservation, land donation, and monetary contribution (ANJEC 2018). There are two general categories of freshwater wetland restoration:

1. **Passive Restoration –** To re-establish, to the maximum extent possible, the natural wetland processes for a degraded wetland (*e.g.,* hydrologic, vegetative, and ecological processes), the first option for restoration is to remove any factors contributing to wetland degradation to see if the wetland can naturally restore itself (IWWR 2003).

2. **Active Restoration –** When a wetland is severely degraded, passive restoration will likely not be sufficient to re-establish, to the maximum extent possible, the wetland's natural processes. Active restoration consists of three general steps: site preparation, hydrology restoration, and revegetation (DOI 2024). Table 2 of the Interagency Workgroup on Wetland Restoration's Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement provides a detailed list of wetland stressors/damage and suggested active restoration techniques including, but not limited to, slope stabilization, removing or breaching dikes, backfilling ditches, and removing material. Specific wetland restoration techniques are developed on a site specific basis due to the unique characteristics of each wetland (Acreman and Holden 2013).

This profile focuses on wetland restoration NBS within the active restoration category above. For a comprehensive primer for freshwater wetland restoration, refer to the Manual for Freshwater Wetlands Protection in New Jersey (ANJEC 2018).

What hazards does this NBS address?

Healthy freshwater wetlands help to mitigate inland flooding. Wetlands serve as natural sponges that capture and gradually release various forms of water (*i.e.,* surface water runoff, rain, snowmelt, groundwater). The presence of trees, root mats, and other wetland vegetation helps to slow down the speed of floodwaters and disperses the water more gradually across the floodplain. This combined water storage and braking action effectively reduces flood heights and minimizes erosion. Wetlands located within urban areas and downstream play a crucial role in offsetting the drastic increase in the rate and volume of surface water runoff from paved surfaces and buildings (EPA, 2024).

Freshwater wetlands can also help reduce drought severity by capturing runoff and slowly recharging groundwater aquifers over time via percolation Biebighauser 2002, Uhlman et al., 2020.

Where should this NBS type go?

Wetland restoration can occur in locations that (Cole et al., 2024):

- ✓ Previously had a wetland
- ✓ Currently have hydric soils which are essential to wetland health
- ✓ Could have stable water levels or experience flood conditions

The Mitigation Technical Manual (2022) provides some details regarding the requirements and considerations for wetland restoration projects consistent with State and Federal law. Additionally, the Association of State Wetland Managers' Protecting and Restoring Wetlands: A Guide for Land Trusts provides a plain language primer on site prioritization, planning hurdles, among other helpful tips (Kusler 2009). For additional information, see Appendix 4.2.10.

What are the co-benefits of this NBS?

Freshwater wetlands provide a breadth of co-benefits including, but not limited to, the following (NJDEP 2024b):

1. Wetlands protect drinking water by filtering out chemicals, pollutants, and sediments that would otherwise clog and contaminate our waters.
2. Wetlands soak up runoff from heavy rains as snow melts, providing natural flood control.
3. Wetlands release stored flood waters during droughts.
4. Wetlands provide critical habitats for a major portion of the State's fish and wildlife, including. endangered, commercial and recreational species.
5. Wetlands provide high quality open space for recreation and tourism.

Co-benefits that have been quantified or monetized for freshwater wetlands in the New Jersey ecoregion are included in the list below where published values exist. Published values for this NBS are listed in Appendix 4.2.10. Another general resource is The Benefit Accounting of Nature-Based Solutions for Watersheds Guide which provides a starting point to help identify and measure the multiple benefits from NBS implementation, including wetland restoration (Brill et al., 2021). The most in depth assessment of freshwater wetland co-benefits is a 2016 study of the Chesapeake Bay (Tetra Tech 2016).

MATERIAL BENEFITS

Harvesting Organic Materials	
Improved Water Quality	
Human Health	
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	
Improved Habitat Connectivity	
Supporting Biodiversity of Flora and Fauna	
Supporting Resilience of Ecosystem	

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	
Erosion Control	
Pollinator Services	
Nutrient Cycle Control	
Genetic Diversity Control	
Infrastructure Protection	

CULTURAL BENEFITS

Sources of Cultural Identity	
Spiritual and Symbolic Interactions	
Education	
Aesthetic Value	
Recreational Value	
Social Well-Being	

= Monetized Values
= Quantified Values
= Qualitative
= Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of wetland restoration. Additional information can be found in the Wetland Restoration Contemporary Issues and Lessons Learned reference document by the national Association of State Wetland Managers (2017).

Planning

Identifying a Wetland to Restore

Many of New Jersey's freshwater wetlands are degraded. Efforts are underway in the state in collaboration with Rutgers to develop a Wetland Scoring Schema that could be used by practitioners to identify priority sites for restoration based on a variety of criteria. In the interim, a list of priority wetlands for protection was produced in 1994 (EPA 1994) and is mapped here with periodic updates provides a starting point for individuals thinking strategically about the freshwater wetlands where restoration efforts would have the greatest impact.

Permitting

Navigating Project Permitting Requirements

New Jersey has three categories of permits and approvals for wetlands including coastal wetland permits, freshwater wetlands permits, and transition area permits. Common activities that would require freshwater wetlands permit or transition area waiver include construction activities (*e.g.,* houses, swimming pools), disturbances to the soil (*e.g.,* excavation), disturbances to water levels (*e.g.,* any draining or ditching), the dumping of materials (*e.g.,* filling), and vegetation disturbances (*e.g.,* cutting down trees, spraying herbicides). A complete list of permitting requirements for wetland projects can be found on NJDEP's Wetland's website here. Additionally, the Land Resources Protection Web App has a Land Resources Screening Report which can help users identify whether a project is in an area that may have environmental features that impact a project (*e.g.,* a freshwater wetland or transition area) (NJDEP 2024).

Maintenance

Restored wetlands are designed to be self-sustaining in the long run (NAWM 2006), but may require regular maintenance in the years following construction, especially restored wetlands with water-control or earthen structures. It is encouraged for any restored wetland to be inspected early and often after construction to ensure any plants and seeds have propagated and to take any corrective actions if plants have not established themselves. Additionally, it is encouraged for water control structures to be inspected periodically to ensure leaves, twigs, and other debris have not accumulated and are not blocking the flow of water. These inspections are most needed during and after heavy storms. Experts recommend allocating 10% of implementation costs to project maintenance in the year after construction and allocating some budget for the 3-5 years following the construction of the wetland to provide additional maintenance as the wetland settles (NAWM 2017). Continued maintenance is likely in the event invasives need to be controlled, if sedimentation rates for the wetland are high, or if the watershed hydrology shifts over time. Maintenance in these situations may include additional water level manipulation, replanting, control of invasives, and protection of the wetland from human impacts (*e.g.,* off road vehicles, hikers compacting soil).

Unintended Consequences

Mosquitos

Mosquitos can be found in and around restored wetlands which can cause quality of life concerns for individuals living, working, or recreating near restoration sites (Dale and Connelly 2012). Mosquitos are a natural component of a wetland environment and can help control algal blooms and eutrophication in wetlands (DOI 2024). Experts recommend integrated mosquito management into project planning which includes incorporating education, surveillance, chemicals, biological control agents, habitat management, and other techniques to mitigate the negative impacts of mosquitos with minimal ecological intervention (Rey et al., 2012). Education is particularly important given the following unfounded assertions are frequently used by those against wetland restoration projects: "healthy unimpacted wetlands do not produce mosquitoes" and "wetlands are disease reservoirs that without routine mosquito control would produce regular disease epidemics among human and animal populations," (Rey et al., 2012). Indeed, mosquitoes that can harbor diseases harmful to humans generally prefer "anthropogenic habitats over ephemeral wetlands, and natural predation generally obviates the need for mosquito control [in any wetland]," (DOI 2024).

Invasive Plants

Restored wetlands can attract invasive and/or aggressive plant species, such as purple loosestrife (Lythrum salicaria), reed canary grass (Phalaris arundinacea), common reed (Phragmites australis), and cattails (Typha spp.). For guidance on how to manage these species visit Penn State Extension's "Managing Your Restored Wetland" guidance (2022) and the Friends of Hopewell Valley Open Space Technical Guidance on invasives (2024).

Nuisance Species

Wetlands offer a habitat for muskrats, but if they overpopulate, this species can become pests by consuming vegetation and causing damage to dams and dikes with their burrows. Mitigation measures include putting a physical barrier between the wetland and muskrats (*e.g.,* laying down six-inch layers of sand, gravel, or riprap, or even fencing a dike with wire mesh), increasing the thickness and slope of the dike to deter the animals, and humanly trapping and removing the animals from the site (Cole et al., 2022) .

Carbon Sequestration

Some wetland restoration projects include organic soil amendments to accelerate hydric soil development and provide nutrients for new vegetation. A study of Maryland wetland restoration found organic soil amendments were not necessary to support plant growth and could exacerbate atmospheric warming and the spread of invasive species in the mid-Atlantic (Baldwin et al., 2022). Additionally, depending on the site-specific characteristics and age of a freshwater wetland the ecosystem may release more methane than the carbon sequestered from the atmosphere (Taillardat et al., 2020). It is therefore imperative to ensure the hydrology of the restored wetland is optimized to allow the wetland to maximize its soil carbon sequestration and storage (Limpert et al., 2020).

How can I monitor this NBS?

Monitoring before, during, and after a wetland restoration project is important for ensuring the project goals are achieved. Specific monitoring requirements may be issued by the State for consistency with applicable State law (*e.g.,* an application for the restoration of a wetland mitigation proposal available here), while some monitoring requirements may be issued by the funding agency or program. Beyond project specific requirements, there is no standardized method for measuring freshwater wetland restoration success. However, experts agree the biological health of a wetland is the most robust indicator of overall wetland health.

Acute sampling of a wetland (*e.g.,* measuring the amount of a pollutant in the wetland's water or soil at one moment in time) provides a snapshot of wetland health, but measuring the health of the flora and fauna that live in the wetland provides an understanding of wetland health over a longer period. Generally, wetlands that are healthy will support a wide variety and high number of benthic macroinvertebrates, including many that are sensitive to pollution. Scientists in New Jersey established the Ambient Macroinvertebrate Network (AMNET) to measure the health of these benthic macroinvertebrates.

Below are various resources to help monitor a wetland restoration after construction (additional information available in Appendix 4.2.10):

1. NJDEP's Division of Water Monitoring and Standards, Freshwater and Biological Monitoring Strategies (2024).
2. Creating Indicators of Wetland Status (Quantity and Quality), Freshwater Wetland Mitigation in New Jersey (2002).
3. New Jersey Watershed Watch Network.
4. NJDEP's Community Water Monitoring.
5. Lower Raritan Watershed Partnership website and training resources.

Case Study of an Exemplary Project

Wetland restoration work is prevalent in New Jersey. Below is a small-scale wetland restoration project. To find more case studies, please refer to Appendix 4.4.

Pin Oak Headwaters Wetland Restoration – Woodbridge, NJ

Scale of Project: Large
Cost: $3.9 million (NJAWRA 2019)
Project Timeline: Funding awarded (2014), construction (2017), monitoring (through June 2022)
Funding Source: NJ Freshwater Wetland In-Lieu Fee Program

Figure 27. Image of completed Woodbridge wetland restoration project (Princeton Hydro 2018a)

The Middlesex County Parks Pin Oak Forest Wetland Enhancement and Stream Restoration Project include multiple wetland restoration projects to convert 29 acres of degraded freshwater wetlands, 0.33 acres of disturbed uplands with invasive species, and 1,108 linear feet of degraded or channelized streams into a healthier wetland complex (NJAWRA 2019, additional metrics on these sites available at NJFWMCM 2018). These projects were completed in the Pin Oak Forest Conservation Area which is a 97-acre tract of open space (Princeton Hydro 2018b). The surrounding county is highly developed with other wetland ecosystems that have become fragmented, ecologically impaired, and suffered biodiversity loss due to invasive species and shrinking habitat (Princeton Hydro 2024). Pin Oak Forest wetland was therefore prioritized for restoration as it improved valuable wetland habitat at the headwaters of Woodbridge Creek in Middlesex County. In 2014, a diverse group of partners (i.e., Middlesex County Office of Parks and Recreation, Woodbridge Township, Woodbridge River Watch, New Jersey Freshwater Wetlands Mitigation Council, GreenTrust Alliance, GreenVest, and Princeton Hydro) secured $3.8 million dollars of funding on behalf of the Middlesex County Parks Department to complete this work (Princeton Hydro 2018a; Green Trust Alliance 2018).

This project was chosen as an exemplary case study due to its diverse group of project collaborators long-term commitment to the project (i.e., different partners took responsibility for different elements of the project after construction including fiscal oversight, permit coordination, landowner access coordination, as well as maintenance and monitoring responsibilities), its watershed level planning (i.e., focusing on using limited funds to protect a headwater wetland ecosystem which can have benefits for the entire length of the Woodbridge Creek), as well as its ecological success (e.g., post construction monitoring found a variety of wildlife species including the state-threatened Black-crowned Night Heron and Red-headed Woodpecker) (Princeton Hydro 2018a).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing freshwater wetland restoration. Key programs are highlighted below:

1. NJDEP Water Quality Restoration Grant Unit (NJDEP)
2. Wetland Funding and Technical Assistance Programs (USFWS)
3. Delaware Watershed Conservation Fund (NFWF)

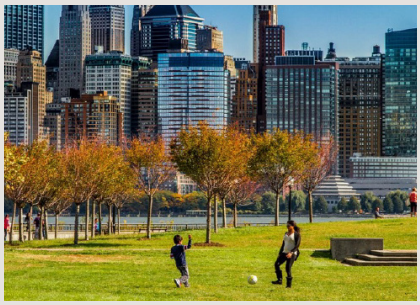
Top Resources

1. Manual for Freshwater Wetlands Protection in New Jersey (ANJEC 2018)
2. Association of State Wetland Managers' Wetland Restoration Contemporary Issues and Lessons Learned (2017)
3. PennState Extension's Managing Your Restored Wetland Guidance (2022)
4. NJDEP Land Resource Protection Web Application (application available here, user guide available here).
5. Compendium of NJDEP Wetlands Research

3.5 Urban Forestry

What profiles are in this NBS category?

Urban Forestry



Jersey Digs

Hazards Addressed

- ✓Heat
- ✓Stormwater
- ✓Inland Flooding

Suitable Environments

- ✓Locations unobstructed by underground or aboveground utilities

Key Takeaways

1. Advancing urban forestry requires coordination among the various sectors of urban planning and regional environmental management.
2. Tree maintenance is imperative to ensuring co-benefits of urban forestry are realized.

Information about urban forestry, beyond what is covered in this profile, can be found in Appendix 4.2.11.

Introduction to Urban Forestry

New Jersey has the fourth smallest area of any state and is the most densely populated state in the country (TNC 2024) with the greatest percent of urban land (Nowak and Greenfield 2018). Green spaces and tree planting in urban areas are known to provide physiological, socioeconomic, and ecological value by improving air quality, reducing stormwater runoff, providing habitat for animals, reducing noise, providing recreation space, reducing the impacts of urban heat island, and more (USDA 2024). Urban forestry is the study and management of these trees and forests in and around towns and cities (EPA 2021), including publicly and privately owned trees and vegetation along streets, parks, school yards, backyards, commercial spaces, and natural areas (SAF 2024). New Jersey is estimated to have 178.7 million trees in urban environments (Nowak and Greenfield 2018). Experts agree conserving and expanding these green spaces are essential as urbanization continues to increase in New Jersey and across the country (SAF 2024; TNC 2024; NJDEP NJDA 2024).

There is no exhaustive list NBS within urban forestry but these projects may include urban parks, street trees, gardens, green roofs, green coastal promenades, greenways, wetlands, nature preserves, shelter belts of trees, and working trees (*e.g.,* tree focused community gardens) (USDA 2024, DOI 2024).And indeed, it is possible to consider the entire urban forest as an NBS. Consequently, the care and maintenance of all urban trees is critical to ensure the widespread provision of ecosystem services.

One NBS profile is used within this NBS category due to the similarities among NBS methods in urban forestry. This profile focuses on tree planting and management through stormwater planters, tree filter boxes, and other methods detailed below:

1. **Stormwater Planters:** Vegetated structures that are built into sidewalks to intercept stormwater runoff from

Figure 28. Stormwater planter (RCEWRP 2023).

the roadway or sidewalk (Rutgers 2024). This NBS is a type of bioretention system and can be thought of as a rain garden completely surrounded by impervious surfaces.

2. **Tree Filter Boxes:** A pre-manufactured concrete box which is installed in-ground, filled with soil, and planted with a native tree or shrub and is designed to collect the first wash of stormwater and treat it before the water infiltrates into the ground or is discharged into the sewer system (Rector et al., 2013). These boxes can be elongated (sometimes called "extended tree beds" to provide additional soil volume to support the growth of larger trees (RCEWRP 2023).

3. **Other Methods**: Urban forestry pertains to trees in urban and suburban areas. As such, some trees in urban forestry are planted in soil independent of stormwater planters or tree filter boxes and are addressed within this profile.

Figure 29. Tree filter box (Rector 2023).

Several other urban forestry NBS are discussed in detail in other profiles (see profiles on Open and Green Space, Wildlife Lawns, Riparian Forest Buffers, Windbreaks). For a comprehensive primer on considerations for urban forestry, visit the Vibrant Cities Lab's Urban Forestry Toolkit (the U.S. Forest Service's step-by-step guide to implement urban forestry in communities here) and the US Department of Agriculture's Tips for Urban Forest Planning website.

Below are a couple key takeaways from experts regarding urban forestry:

1. **Coordination -** Advancing urban forestry requires coordination among the various sectors of urban planning and regional environmental management. The "Planning" subsection of this profile provides recommendations for coordination best practices.

2. **Maintenance –** Maintenance of urban trees and other vegetation is imperative to ensuring a healthy, long lifespan of the vegetation with experts recommend consulting an arborist before and after trees are planted. The "Maintenance" subsection of this profile provides resources to help ensure each species planted is properly maintained.

3.5.1 URBAN FORESTRY PROFILE

Introduction

Urban forestry, for the purposes of this profile, refers to the planting and management of trees and other vegetation in and around towns and cities (EPA 2021), including publicly and privately owned trees and vegetation along streets, parks, school yards, backyards, commercial spaces, and natural areas (SAF 2024). Common methods for planting trees in and around towns and cities include stormwater planters, tree filter boxes, and other methods as described above.

What hazards does this NBS address?

Urban forestry NBS address extreme heat while also addressing minor levels of inland flooding and stormwater. Heat is the biggest weather-related cause of death for the United States but only 17% of national climate adaptation actions addressing this human health concern (RPA 2024). The 2020 NJ Scientific Report on Climate Change (NJDEP 2020) found New Jersey is one of the fastest warming states in the country, prompting the publication of the 2024 New Jersey Extreme Heat Resilience Action Plan (NJDEP 2024) which identifies 135 actions to build resilience into communities and ecosystems to withstand extreme heat. Extreme heat conditions are expected to increase over time and occur in tandem and sequentially with other environmental stressors (*e.g.,* a heat wave after a tropical cyclone) exacerbating the impacts to humans and the environment (Horton 2021).

Urban heat islands are one such stressor and occur in urbanized areas where ambient air temperature is higher than the surrounding area. This is because the built environment (*e.g.,* roads, buildings, concrete) absorb and re-emit the sun's heat more than the natural environment (NJDEP 2024) causing local urban temperatures to be higher during both the day and night than less developed areas (EPA 2017a). In addition to urban heat, urban humidity can also be a problem. High humidity can reduce humans' and animals' ability to cool off during high heat conditions. Generally urban environments are considered less humid than more rural environments (Chakraborty et al., 2022) with urban green spaces reducing humid heat conditions at night (Yang et al., 2024) and enhanced urban convection efficiency (*i.e.,* the efficiency of an area to dissipate heat and water) important for moving humid air out of urban spaces (Silverman 2023). Urban forestry mitigates extreme heat by shading buildings, deflecting radiation from the sun, and through evapotranspiration where heat from the air is used to evaporate moisture released by trees and vegetation thus cooling the urban environment (USEPA 2017b).

Urban forestry can reduce inland flooding and stormwater conditions by reducing runoff and providing water pollution control (USDA 2020).

Where should this NBS type go?

Planting trees and vegetation in urban and suburban environments requires thoughtful planning and long-term maintenance to maximize the ecological, socioeconomic, and physiological benefits of trees. Generally, trees and vegetation function best when there is:

- ✓ Ample high-quality soil for the tree roots to grow
- ✓ Sufficient sunlight and water
- ✓ Distance from underground and aboveground utilities that could hinder the plant's growth

Appendix 4.2.11 contains a step-by-step guide of considerations for identifying the proper location for tree planting (Maidl 2021). Refer to the Natural Lands profile for tips on improving or building parks and greenways.

What are the co-benefits of this NBS?

Tree and vegetation planting provide important co-benefits including environmental, human health, and economic benefits (Hanson et al., 2017, USDA 2020, Pataki et al., 2021). There are existing tools available to help estimate the full spectrum of co-benefits urban forestry NBS can provide (*e.g.,* the CLASIC and GSI TBL tools developed by The Water Research Foundation available here, and the i-Tree suite of tools developed by USDA Forest Service and partners available here), but their applicability may be limited in New Jersey. Experts agree the most healthy urban forests consist of trees of different species, ages, and sizes because this diversity increases trees resilience to pests (*e.g.,* if a project used one tree variety in a project a bug infestation could kill all newly planted trees) and other stressors (*e.g.,* younger trees are more susceptible to drought) (USDA 2024b). Co-benefits that have been quantified or monetized for the New Jersey ecoregion are included in the list below where published values exist.

Published values for this NBS are listed in Appendix 4.2.11.

MATERIAL BENEFITS

Harvesting Organic Materials	
Improved Water Quality	
Human Health	
Mental Health	

HABITAT SERVICES BENEFITS

Provisioning of Habitat with Food, Shelter, and Nesting Materials	
Improved Habitat Connectivity	
Supporting Biodiversity of Flora and Fauna	
Supporting Resilience of Ecosystem	

NATURAL PROCESSES BENEFITS

Air Quality Improvement	
Climate Regulation	
Carbon Sequestration	
Erosion Control	
Pollinator Services	
Nutrient Cycle Control	
Genetic Diversity Control	
Infrastructure Protection	

CULTURAL BENEFITS

Sources of Cultural Identity	
Spiritual and Symbolic Interactions	
Education	
Aesthetic Value	
Recreational Value	
Social Well-Being	

= Monetized Values
= Quantified Values
= Qualitative
= Community Derived

What are the common challenges?

The following is a list of common challenges that may occur during the planning, implementing, or monitoring phase of planting trees and vegetation in urban and suburban environments.

Planning

A robust urban forestry program considers watershed scale planning, the impacts of climate change on tree health, and opportunities maximize the co-benefits with other urban planning initiatives. There are many planning resources available to support robust urban forestry programs in New Jersey which are highlighted below.

Watershed Scale Planning

Urban watershed forestry is the integration of urban and community forestry with watershed planning to create watershed-scale based goals for the management of urban forests as a whole rather than managing forests on a municipal scale. The Urban Watershed Forestry Manual Part 1 and Part 2 provides step-by-step instructions to assist individuals in thinking on a watershed scale for urban forest management.

Climate Change

Native New Jersey trees may become stressed as climate change accelerates brining more severe weather, higher temperatures, earlier springs interrupted by freezing conditions, as well as new pests and diseases (UMD 2024). Selecting trees that are adaptable and resilient to these changing environmental conditions will promote urban forest longevity and health. The USDA Forest Service's Climate Tree Atlas supports this long-term planning in New Jersey as it summarizes the adaptability and resilience of 125 tree species across the country.

Alignment with Other Urban Planning Efforts

Several State programs have implications for local urban forestry management decisions. This includes but is not limited to municipal separate storm sewer (MS4) program requirements as well as the requirements set by the New Jersey Urban and Community Forestry Program (NJUCF).

1. MS4 Program Requirements: Tier A MS4 municipalities are required to adopt and enforce a community-wide ordinance to control tree removal and replacement to reduce stormwater runoff and pollutants, and to promote infiltration of rainwater into the soil. Urban forestry planting will need to be consistent with this ordinance. For more information visit NJDEP's Municipal Stormwater Regulation Program website and refer to NJ Shade Tree Federations webinar on the ordinance.

2. NJUCF Program Requirements: NJUCF sets guidelines regarding forest planning and maintenance (resources available on the NJUCF website). Coordinating urban forestry planning with similar planning efforts that prioritize NBS like NJ's Complete Streets initiative (2017 guide available here, 2024 policy update and related materials available here) and 15-Minute Neighborhoods initiative (2024 overview of the initiative and a related municipal guide) will be prudent.

Maintenance

The lifespan of trees in urban environments is shorter than trees in more rural environments due to human caused tree damage (*e.g.,* improper planting techniques, damage to roots, compaction of soil, air pollution), poor tree management (*e.g.,* tree stakes or grates left on too long, lack of watering, competition from invasive plants), and natural processes (*e.g.,* damage from disease and insects) (CWP 2016c). An arborist should be consulted before and after trees are planted to ensure proper maintenance protocols are budgeted for an are implemented (recommended guidelines for identifying a tree care professional in New Jersey can be found at Grabosky et al., 2023). Best practices for tree management are summarized in the following resources:

- New Jersey Tree Foundation Resources and Education Materials (available here).
- Urban Tree Risk Management: A Community Guide to Program Design and Implementation (NJDEP 2003).
- Tree Owner's Manual for the Northeastern and Midwestern United States (USDA 2008).
- Rutgers NJ Agricultural Experiment Station: Tree, Shrub, and Flower Growing Fact Sheets and Bulletins (Rutgers 1993-2020).
- Rutgers Urban Forestry Outreach Program Fact Sheets (Rutgers 2024).
- New York State Urban and Community Forestry – How to Plant A Tree (NYDEC 2024).
- West Virginia Urban and Community Forestry - Parking Lots and Trees (WVDFUCF 2020).
- The Ultimate Guide to Planting and Caring for Trees in Maryland (Rasevic 2023).

Unintended Consequences

Thoughtful planning can help to mitigate the following common unintended consequences with urban forestry NBS:

Urban Forests as Carbon Source

Urban forests are considered carbon sinks, but when trees die and decay the tree releases stored carbon back into the atmosphere (Nowak and Crane 2002, NPS 2024) A study of street trees in Boston, MA found mean mortality rates of trees is double that of rural trees and has resulted in a net loss of street tree carbon storage over time (Smith et al. 2019). Proper planting and maintenance can help to ameliorate the chance of trees dying and becoming carbon sources. Decreasing carbon emissions associated with tree maintenance and disposal of removed trees to minimize decomposition can also contribute to the urban forest functioning as a carbon sink rather than a source (Nowak et al., 2002).

Urban Forests Can Decrease Air Quality

Trees have an overall net benefit on air quality, but can have a negative impact on air quality. This is because trees produce biogenic volatile organic compounds (bVOC) that can contribute to ground-level ozone formation when mixed with other urban air pollutants (Calfapietra et al., 2013). bVOC production does vary by species (Curtis et al.,

2014; i-Tree Species allows users to search for species with low bCOV emissions). Trees also produce pollen seasonally. Proper planning and species selection can optimize the beneficial effects trees have on air quality (Rutgers 2023).

Equity and Gentrification

Green spaces in urban environments traditionally have been prioritized in more wealthy, white neighborhoods. Individuals living in these underprivileged areas, as well those that experience dementia and mental issues, could benefit the most from street trees (Haas et al., 2021, Lin et al., 2021). Studies suggest that when neighborhoods experience increased canopy cover, green gentrification may occur where the beautification of a neighborhood can cause real estate prices and rents to increase (Nieuwenhuijsen 2020, Anguelovski et al., 2022). New Jersey has prioritized the planting of 250,000 street trees and shade trees by 2030 with an emphasis on low-income and disadvantaged communities and avoiding green gentrification (NJDEP 2024b). For more information on the equity of green spaces in New Jersey, visit the New Jersey Access to Open Space Report (2021).

How can I monitor this NBS?

Monitoring trees and other vegetation after being planted is important for ensuring an urban forestry NBS project is achieving the intended project goals. Specific monitoring requirements may be issued by the State for consistency with applicable State and local regulations. Additional monitoring requirements may be issued by the agency or program funding the urban forestry project. In the absence of mandated monitoring requirements, the following are key resources that may aid in any dam removal monitoring efforts:

- USDA's Urban Tree Monitoring Resource Guide (2020b).
- The NJ Shade Tree Federation Resource Document (NJSTF 2024).
- Making Your Community Forest-Friendly, A Worksheet for Review of Municipal Codes and Ordinances (USDA 2018).

Case Study of an Exemplary Project

A snapshot of urban forestry projects in New Jersey can be found on The Nature Conservancy of New Jersey's Cities Program website (here). Below is one such urban forestry. Additional case studies can be found in Appendix 4.4.

NJ Tree Foundation's Urban Airshed Reforestation Program (Camden, NJ)

Scale of Project: Large
Cost: $165,000 annually
Project Timeline: This nonprofit has operated continually since 2002 to plant trees in Camden and surrounding South Jersey Cities
Funding Source: Various

The NJ Tree Foundation (NJTF) is a state-wide nonprofit organization dedicated to planting trees in NJ's most urban communities. In 2002, NJTF partnered with the City of Camden to create the Urban Airshed Reforestation Program (UARP), a community-based street tree planting project designed to improve the environment and quality of life in Camden. From 2002 to 2013, UARP has planted over 4,000 trees of over 135 varieties and maintained a 95% tree survival rate (a map of tree planting locations between 2002 and 2011 is available here). The UARP's operating budget for planting 300 trees in 2012 was $165,000 plus $23,608 in in-kind donations ($6,308 in materials and $17,300 in volunteer labor). (NJTF 2012, Sustainable Jersey 2013)

This organization is being highlighted because of its integration into communities and educational resources (available here). For example, NJTF includes the TreeKeepers Program that trains volunteers in Camden and Newark to be stewards for tree planting efforts in their neighborhoods.

Figure 30. Airshed restoration project before and after tree planting (modified from 2025).

Where can I find funding for this NBS?

There are many programs in place to aid interested individuals in funding and implementing freshwater wetland restoration. Key programs are highlighted below:

1. New Jersey Urban and Community Forest Grants (New Jersey Forest Service)
2. New Jersey Tree Foundation Funding Programs (NJTF)
3. New Jersey Funding Navigator (NJ Future)

Top Resources

1. New Jersey Tree Foundation Resources and Education Materials
2. The Urban Watershed Forestry Manual Part 1 and Part 2
3. Vibrant Cities Lab's Urban Forestry Toolkit (the U.S. Forest Service's step-by-step guide to implement urban forestry in communities)
4. US Department of Agriculture's Tips for Urban Forest Planning
5. Sustainable Jersey Tree Planting Program

SECTION 4

Appendix

Courtesy of The Nature Conservancy

4.1 CHECKLIST FOR NATURE-BASED SOLUTIONS PROJECT PLANNING

1. Getting Started

1.1. Have you determined the location of the NBS project?

1.1.1. Is the environment type suitable for the proposed NBS type?

1.2. Have you defined the goals of the project?

1.2.1. Do the goals relate to community-identified values and concerns?

1.2.2. Do the goals relate to mitigating a hazard of concern?

1.3. Have you chosen a planning horizon for the NBS project?

1.4. Have you created an adaptive management plan?

1.5. Have you created a monitoring plan?

1.5.1. What metrics will be used to track project performance?

2. Funding

2.1. Have you identified at least one funding source for your NBS project?

2.1.1. Does the funder goals and mission broadly align with the goals of the project?

2.1.2. Does the funder limit how long funding is available for use once awarded?

2.1.3. Does the funder limit what awarded money can be spent on?

2.2. Does the funding application require…

2.2.1. Matching funds?

2.2.2. Benefit-cost analysis or cost-effectiveness analysis?

2.2.3. Letters of support?

2.2.4. Pre-project permitting approval?

2.3. Have you created a project budget that includes pre-planning, implementation, and maintenance and monitoring costs?

2.3.1. Have you determined who is responsible for ongoing maintenance and monitoring of the project?

2.3.1.1. Does this require a different funding source?

2.3.2. Have you determined what the up-front project costs are?

2.3.2.1. Does this require a different funding source?

2.4. Do you need to acquire a loan to fund the NBS project?

2.5. Have you identified what resources or technical assistance you need to acquire?

2.5.1. Are there funders that provide in-kind resources or technical assistance and expertise that you can apply for?

3. Hazards

3.1. Have you identified the current hazards at the project location?

3.2. Have you identified the future hazards at the project location?

- Examples of hazards include Increased precipitation, inland flooding, coastal flooding, sea-level rise, storm inundation, high tide flooding, extreme heat, saltwater intrusion, etc.

3.3. For coastal locations, have you identified what the projected sea-level rise values are for 2050 through 2100?

3.4. For inland locations, have you identified what the projected increase in precipitation values are for 2050 through 2100?

3.5. Have you determined how current and future hazards would potentially impact the NBS?

4. Permitting & Coordination

4.1. Do you know who owns the property of the proposed project location?

4.2. Do you know if there are any protected species or environments in or around the project location?

4.2.1. Do these protected species or environments restrict construction or disturbance of any kind, or is work allowed with approved permits?

4.3. Do you know if there are any seasons or times of the year that construction cannot occur due to environment or species restrictions?

4.4. Do you know what permits you need to construct the project?

4.4.1. Are there any special permits needed for the specific site location?

4.4.2. Do you know what permits must be obtained through federal or state agencies?

4.5. Have you established contact with the permitting agencies in advance of submitting any applications to ensure all requirements are met?

4.6. Have you determined what portions of the project can be completed in-house and what portions need to be outsourced?

4.6.1. What contractors, consultants, and engineers need to be hired to implement, construct, or maintain the project?

5. Community

5.1. Have you created a community outreach and engagement plan?

5.1.1. Does the plan include communicating the potential benefits and drawbacks of the NBS?

5.1.2. Does the plan include an education component?

5.1.3. Does the plan take place over the full lifespan of the project?

5.2. Have you determined what groups of people, neighborhoods, etc. this project will directly and indirectly impact?

5.2.1. Have you considered both the positive and negative impacts?

5.3. Have you spoken to the community, including but not limited to...

5.3.1. County and Municipal staff?

5.3.2. Community members?

5.3.3. Local non-profits?

5.3.4. Community organizations?

5.4. Have you determined how you are planning to incorporate the community's feedback and participation in the development of the project?

5.5. Does your project or planning committee include members and representatives of the community?

5.5.1. Are these members and representatives from one or multiple groups within the community?

5.5.1.1. Do they include people from the areas most likely to be impacted (both positively and negatively) by the NBS project?

5.5.2. Have you determined what level of authority and decision-making power they will have?

5.6. Do you know what the community values?

5.7. Have you discussed what the community's needs are with them?

5.7.1. Does the NBS align with and address their needs?

5.8. Do the goals of the project align with the values and needs of the community?

6. Plans

6.1. How does the NBS project align with existing plans?

6.2. Do you know what the zoning and proposed land-use is of the NBS project site and surrounding area?

6.2.1. Have you considered how land development and population changes could impact the NBS project?

6.3. Do you know if there are there existing county, municipal, or local initiatives to fund or encourage NBS?

6.3.1. Have you considered how this could be taken advantage of for the NBS project?

6.4. Do you know what hazards and associated mitigation actions are included in the County Hazard Mitigation Plan?

6.4.1. Does your NBS project address any hazards of concern and offer risk reduction?

4.2 ADDITIONAL INFORMATION - NATURE-BASED SOLUTION PROFILES

This appendix provides additional information for the NBS profiles. The table below provides an overview of the hazards address and co-benefits provided by each NBS and is a duplicate of Table 1 provided at the start of Section 4.

	Environmental Hazard Addressed							Co-Benefits	**Material Benefits**				**Natural Process Benefits**							**Habitat Service Benefits**					**Cultural Benefits**							Profile Tag	Appendix Tag
	Inland Flooding and Stormwater	Coastal Flooding	Storm Surge	Wildfire	Drought	Heat			Harvesting Organic Materials	Improved Water Quality	Improved Human Health	Improved Mental Health	Air Quality Improvement	Climate Regulation	Carbon Sequestration	Pollinator Control	Erosion Control	Nutrient Cycle Control	Infrastructure Protection	Habitat Provisioning	Improved Habitat Connectivity	Supporting Biodiversity	Supporting Ecosystem Resilience	Source of Cultural Identity	Spiritual and Symbolic Interactions	Educational Opportunities	Aesthetic Value	Recreational Value	Improved Social Well-Being		
Bioretention Systems																														**3.1**	
Rain Garden	X				X	X			X	X	X	X	X	X	X	X		X	X	X	X	X				X	X		X	**3.1.1**	**4.2.1**
Bioswale	X				X	X			X	X	X	X	X	X	X	X		X	X	X	X	X				X	X		X	**3.1.2**	**4.2.2**
Coastal Habitats																														**3.2**	
Living Shoreline			X						X	X	X				X		X	X	X	X		X	X			X	X			**3.2.1**	**4.2.3**
Salt Marsh		X	X						X	X	X	X		X	X		X	X	X	X		X	X		X	X	X	X		**3.2.2**	**4.2.4**
Regenerative Land Management																														**3.3**	
Working Lands																														**3.3.1**	**4.2.5**
Agroforestry	X				X	X			X	X	X		X		X		X	X	X	X						X	X				
Conservation Agriculture	X				X				X	X	X		X		X		X	X									X				
Avoided Forest Conversion	X				X	X				X	X		X	X	X		X	X	X	X		X	X			X	X				
Riparian Forest Buffers	X				X					X	X		X	X	X		X	X	X	X	X					X	X				
Windbreak				X	X				X	X	X		X	X	X		X	X		X						X	X				
Natural Lands																														**3.3.2**	**4.2.6**
Open and Green Space	X		X		X	X				X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X			
Fire Management				X						X							X	X		X	X										
Native Tree Management	X									X	X	X		X	X	X		X	X	X		X		X	X	X					
Wildlife Lawns	X					X				X	X	X	X					X	X	X			X		X		X				
Stream Restoration																														**3.4**	
Dam Removal	X								X		X	X				X	X	X	X	X	X	X					X	X		**3.4.1**	**4.2.7**
Culvert Removal and Upgrades	X									X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X		**3.4.2**	**4.2.8**
Vegetated Riparian Buffer Zone	X								X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X		**3.4.3**	**4.2.9**
Freshwater Wetland	X				X				X	X	X	X		X	X		X	X	X	X	X	X		X	X	X	X	X		**3.4.4**	**4.2.10**
Urban Forestry																														**3.5**	
Tree planting, etc.	X					X			X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X		**3.5.1**	**4.2.11**

4.2.1 –RAIN GARDEN ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the rain garden profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Rain Garden Profile in Section 3.1.1.

Where should this NBS type go?

A rain garden functions best when located near an impervious surface that will generate runoff, on land with less than a 12% slope, and with soil that has good drainage (Obropta and Bergstrom 2024). The following is an overview of the key steps to identifying the suitable habitat for a rain garden (modified from RCEWRP 2015).

1. **Assess Existing Stormwater Issues**
   Conduct or refer to existing impervious cover assessment to identify the stormwater reduction goals in a given location.

2. **Identify Site Opportunities**
   Rain gardens are just one low-cost option to address stormwater issues. Consider all options available to handle stormwater, including eliminating impervious surfaces or convert existing impervious surfaces to ensure socioeconomic and ecological goals are met. See the *Site Evaluation Framework* provided by Obropta and Bergstrom 2023 to aid in this decision process.

3. **Evaluate Rain Garden or Bioswale Feasibility**
   Several tests and planning decisions are needed to ensure a rain garden is built to maximize stormwater management and co-benefits to the area. These tests include (Wilson et al., 2020).

   Soil Conditions
   Soil testing is necessary to ensure the project location: is not impacted by groundwater which could keep the rain garden from draining; has soil that can easily absorb water (this is achieved through an infiltration or percolation test); and has healthy soil (e.g., soil fertility and soil texture tests which cost about $50 to complete).

   Drainage Area
   NJDEP BMPs codify the maximum contributory drainage areas (MCDA) that can be used for each BMP, including rain gardens (referred to as “small-scale bioretention systems” by NJDEP). A rain garden’s MCDA is 2.5 acre area (NJDEP 2021).

   Maintenance
   Rain gardens are low maintenance and will require the least maintenance when the selected plants align with the growing region (e.g., native plants can thrive without extensive care, extra water, fertilizers, or pesticides).

4. Design Practice
   Determining the depth and size of a rain garden will depending on whether the rain garden is being built to handle a Water Quality Design Storm (NJDEP 2021; Obropta et al., 2023), a two-year storm (RCEWRP 2015), or another storm event. A rain garden must also be the correct size for its catchment area: if the rain garden is too

small it will overflow during most rain events, if the rain garden is too big the plants growing in the garden may not receive enough water to survive (Hartman and Robinson 2017). In general, a rain garden will be twice as long as it is wide to maximize stormwater infiltration and the site will likely require some grading, soil texture amendments (e.g., adding sandy soil to the system), or soil quality amendments (e.g., adding gypsum, lime, fertilizer, or other organic matter).

Plant location in the rain garden will depend on the amount of sunlight, wind, and heat the location receives. Hardy, native perennial plant species with roots that can survive in wet and dry conditions are best and can sometimes require less maintenance than turf-style grass.

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for rain gardens where published values exist.

Material Benefits

- Harvesting Organic Materials
  - Rain gardens can be hosts to edible plants and food gardens rather than aesthetic plantings both abroad (Richards et al., 2017) and in New Jersey (see Jonathan Dayton High School case study below) without causing negative health impacts (Tom et al., 2021).

- Improved Water Quality
  - Bioretention system vegetation filters pollutants and reduces impacts to groundwater (Wilson et al., 2020).
  - A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $100.88 for the water supply benefits green infrastructure, including bioretention basins, provides (Wieczerak et al., 2022).
  - Bioretention systems and the plants therein (1) remove metals, hydrocarbons, pathogens, and emerging contaminants and (2) can reduce the temperature of stormwater which protects temperature sensitive species like trout that may live in water bodies affected by stormwater (Muerdter et al., 2018).

- Improved Human Health
  - Rain gardens in urban areas have been found to improve “thermal comfort and urban livability in hot environments” (Wang et al. 2024).
  - Green stormwater management creates better air and reduces heat islands in New Jersey (Evans 2025)

- Improved Mental Health
  - Green space can have a positive impact on mental health and wellbeing (Wendelboe-Nelson et al. 2019)

Natural Processes Benefits

- Air Quality Improvement
  - A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $122.72 for the air quality benefits green infrastructure, including bioretention basins, provide (Wieczerak et al., 2022).

- Climate Regulation
  - A 2016 survey of Elizabeth, NJ residents found respondents were willing to pay for bioretention systems and other green infrastructure annually or as a one-time payment to protect against flooding and water pollution issues. No monetized estimates of ecosystem services were calculated in this study (Wiczerak et al., 2021).

- A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $55.79 for the reduced energy use green infrastructure, including bioretention basins, provides (Wieczerak et al., 2022).

- Carbon Sequestration
  - Rain gardens sequester carbon, and can offset their carbon footprint more if the carbon emissions associated with the production, transportation and construction phases were reduced (Kavehei et al. 2018).

- Pollinator Services
  - Bioretention systems with vegetation can support pollinators, and pollinators are responsible for one third of global food production providing up to $167 billion in ecological services (Nicole 2015, Gallai et al., 2009).

- Nutrient Cycle Control
  - Bioretention systems and the plants therein (1) remove total suspended solids, nitrogen, and phosphorus and (2) can reduce the need for supplemental irrigation and fertilization in an area (Muerdter et al., 2018).

- Infrastructure Protection
  - A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $132.03 for the water retention services green infrastructure, including bioretention basins, provides (Wieczerak et al., 2022).
  - The Willingness to Pay (WTP) was calculated for residents of Champaign-Urbana, Illinois who experience stormwater runoff issues in their homes and neighborhood public areas. Illinois residents valued low impact stormwater management solutions (Cadavid and Ando 2013).

Habitat Service Benefits

- Habitat Provisioning
  - Rain gardens provide habitat for pollinators and other wildlife (TNC 2023).

- Improved Habitat Connectivity
  - Rain gardens can enhance habitat connectivity, particularly when small pockets of green space are planned as part of a larger green landscape (Kasprzyk et al. 2022).

- Supporting Biodiversity
  - Bioretention systems using native plants can provide habitat for wildlife and pollinators (Wilson et al., 2020).
  - A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $55.17 for the habitat creation green infrastructure, including bioretention basins, provides (Wieczerak et al., 2022).

- Supporting Ecosystem Resilience
  - Rain gardens enhance the resilience of an ecosystem by effectively managing stormwater, filtering pollutants, recharging groundwater, and more to create an environment that can better withstand disturbances.

Cultural Benefits

- Source of Cultural Identity
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's cultural ties to green space.

- Spiritual and Symbolic Interactions
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to green space.

- Educational Opportunities
    - Bioretention systems with educational signage can provide public education on water quality and quantity issues. When vegetation is involved, this can draw more positive interest in the site and the educational materials there (Muerdter et al., 2018).

- Aesthetic Value
    - A study of Newark, Patterson, and Elizabeth township found residents were willing to pay (lump sum) up to $209.81 for the aesthetic value green infrastructure provides to their own property, and up to $187.55 for the aesthetic value provided if the NBS were located within a block of their property (Wieczerak et al., 2022).

- Recreational Value
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's plan to recreate around this green space.

- Social Well-Being
    - Green space can have a positive impact on mental health and wellbeing (Wendelboe-Nelson et al. 2019)

What are the common challenges?

All relevant information is found in the Rain Garden Profile in Section 3.1.1.

How can I monitor this NBS?

The type of monitoring conducted for a rain garden may be mandated by various State programs and/or detailed by the funding source or agency. In the event a rain garden funding source or agency does not have monitoring requirements, there is no standard method to monitoring the success of a rain garden installation.

The following are templates and resources to consider when planning a monitoring strategy for rain gardens:

1. Rain Garden Measurement and Evaluation Guide (2017): This guide created by the Landscape Architecture Foundation and Rutgers Masters of Landscape Architecture Program provides a worksheet individuals may use to measure the stormwater performance, soil characteristics, plant diversity, ecological health, and aesthetic nature of rain gardens over time.

2. Hey and Associates of Chicago Case Study (2012): A case study regarding the performance of rain gardens and a bioswale in Chicago details how Hobo Weather Station Range Gauge Smart Sensor from Onset (to measure local precipitation), two groundwater-monitoring wells with water-level meters (to measure the amount of water stored above ground surface), and a Hobo Weather S-SMA Station Soil Moisture Smart Sensor was installed at a depth were used to measure infiltration at each NBS site. Similar methods were used in Harrison, NY to test the performance of a bioswale near a large parking lot (Tevnan 2024).

Where can I find funding for this NBS?

The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. North Jersey Resource Conservation and Development Rebate Program - Eligible residents near Neshanic River and Back Brook can receive up to $500 rebate toward materials and supplies for building a rain garden.

2. Pinelands Preservation Alliance Rebate Program - Eligible residential and municipal rain gardens are eligible for up to $450 in rebates for materials and supplies for building green stormwater infrastructure, including rain gardens.

Hudson Raritan Estuary Urban Rain Garden Grant - $2 million were available in 2022 via Natural Resource Damage (NRD) settlements to design and construct urban rain gardens. While this funding source is not available at the time of publication, NRD settlements and State funding is another means to receive funding for rain gardens.

4.2.2 – BIOSWALE ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the bioswale profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction
All relevant information is found in the Bioswale Profile in Section 3.1.2.

Where should this NBS type go?
Bioswales function best when located near an impervious surface that will generate runoff, on land with a gentle slope (typically between 2 and 10% slope), and with soil that has good drainage (NJFuture 2020). A bioswale can be designed to have trapezoidal, parabolic, or v-shaped cross sectional shapes with a maximum side slope of 3:1, but with 4:1 being preferred (NJFuture 2020, JSWCD 2021).

Key steps to identifying the suitable habitat for a bioswale are nearly identical for those identified for rain gardens, with one exception. Bioswales require additional calculations to ensure that the peak flow during a storm event can travel through the bioswale without causing erosion or scouring. This is because high velocity water could exceed the allowable erosive velocity for the soil texture and plant material in the bioswale. The maximum velocity calculated should be a 10-year frequency storm, unless communities prefer to design the bioswale to handle a larger storm event for reasons of safety and compatibility with other stormwater management measures (RCEWRP 2015).

What are the co-benefits of this NBS?
All relevant information is found in the Bioswale Profile in Section 3.1.2.

What are the common challenges?
All relevant information is found in the Bioswale Profile in Section 3.1.2.

How can I monitor this NBS?
All relevant information is found in the Bioswale Profile in Section 3.1.2.

Where can I find funding for this NBS?
The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. Water Quality Funding - Programs that fund efforts to reduce stormwater and water pollution include the US Environmental Protection Agency 319 Nonpoint Source Program (more information available at NJDEPb 2024) and the Urban Waters Small Grants Program (more information available at EPA 2024).

2. Economic and Community Development Funding - Bioretention systems can create jobs, increase economic activity, and increase property values in the area surrounding these projects. As such, the Community Development Block Grant program is a possible avenue for funding (more information available at HUD 2024).

3. Disaster Recovery Funding - Local governments can include NBS projects in disaster recovery plans to mitigate stormwater. FEMA's Hazard Mitigation Assistance programs provide funding for stabilizing soil in developed areas (*e.g.,* bioswales) (more information available at FEMA 2024).

4. Transportation Funding - Bioretention projects are eligible for transportation funding as these projects provide aesthetic improvements to an area while also efficiently and cost effectively reducing street, sidewalk, and trail flooding. Programs to consider for funding include the US Department of Transportation's Transportation Alternatives Program (DOT 2024a), the Congestion Mitigation and Air Quality Program (DOT 2024b), and the Transportation Investment Generating Economic Recovery Program (DOT 2024c).

4.2.3 –LIVING SHORELINE ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the living shoreline profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Living Shoreline Profile in Section 3.2.1.

Where should this NBS type go?

Living shorelines function best in estuaries, bays, tributaries, and other sheltered shorelines (NOAA 2024). High wave energy environments, like beaches and the open ocean, are not suitable for living shorelines. The general factors to consider when choosing the best location for a living shoreline include (Miller et al., 2022, DOI 2023):

(1) Hydrodynamic Characteristics

Low to moderate wave energy environments.

Living shorelines are impacted by natural waves, wind-driven waves, and boat wakes. A living shoreline will perform best in areas of low fetch and in shallow waters which produce the desired low to moderate wave energy environments. Fetch is the distance wind travels over open water without obstruction: a low fetch (less than 5 miles) yields smaller waves and implies the living shoreline is in a sheltered area. Shallow water is best for living shorelines to reduce wave energy as coastal areas with a steep drop-off have a wave regime and sediment transport that is not conducive to living shorelines. (Miller et al., 2022, DOI 2023).

Proper placement in tidal prism.

Tidal range impacts the position of the living shoreline and flora/fauna health:

- The position of a living shoreline's crest (i.e., the highest point of the structure) relative to the water level and wave height impacts the structure's ability to dissipate wave energy. The width of a living shoreline's crest is also important, especially if the structure is fully submerged.

- The health of vegetation that is either planted or natural is dependent on the elevation of substrate.

High soil bearing capacity.

Living shorelines are typically heavy and may compact sediment where the structure is built. Soil bearing should be no less than 500 psf to support a living shoreline (Miller et al., 2022).

Presence of ice.

Living shorelines are generally more fragile than traditional hard structures and are thus more susceptible to damage during ice conditions (Miller et al., 2022). There is currently little information regarding what areas of New Jersey's coastline experience ice nor are there design guidelines to make a living shoreline more resilient to ice conditions. The magnitude of the influence of ice on an installed living shoreline is likely dependent on the durability/structural integrity of the material components. For example, rock can withstand the impact of ice better than coir logs.

(2) Terrestrial Characteristics

Erosion rates.

Sites with severe erosion are generally not suitable for living shorelines (DOI 2023) but, a hybrid approach that includes gray infrastructure and NBS, living shorelines can successfully be built in areas of high erosion. The amount of armoring needed will likely increase with erosion rates depending on the erosion type (undercutting vs. retreat vs. platform scour).

Slope Angle.

Site suitability will be impacted by the upland slope, shoreline slope, and nearshore slope of land.

Nearby Land Use.

Hardened shorelines allow for heavy development of a coastline (*e.g.,* piers, boardwalks, and residences can be built directly on a hardened shoreline) while living shorelines do not. Groups interested in building living shorelines should be willing to keep anthropogenic infrastructure away from living shorelines (DOI 2024).

(3) Biological Characteristics

Studies suggest it is challenging to achieve both ecological and wave attenuation goals with living shoreline projects. For example, a comparison of various designs of oyster living shorelines in the Atlantic and Gulf coasts found that oyster living shorelines that spent less than 50% of time under water were not a suitable habitat for oysters but created 68% reduction in wave height (i.e., did not meet ecological goals but did meet wave attenuation goals) and oyster living shorelines that spend more than 50% of time under water were suitable habitat for oysters but only reduced wave height by 5% (i.e., did meet ecological goals but did not meet wave attenuation goals) (Morris et al., 2021). This difference can be attributed to poor living shoreline design: one consideration is that oysters do not need to colonize the entire breakwater - oysters can exist in the submerged portion to meet ecologic goals, and not on the emergent portion where wave attenuation goals can be met.

Additionally, a 2010 project in New York Harbor found high turbidity, strong currents, high energy waves, and low salinity conditions contributed to poor natural recruitment of oysters during the Oyster Restoration Research Project (Hopkinson 2020). This is supported by findings from the USDOT that abrasion from wave action can potentially limit the successful attachment and growth of juvenile oysters and other shellfish (USDOT 2019). Additionally, there needs to either be refuge for emergent populations or low predation for populations to jump-start. Recruitment and food availability are immediate concerns for persistence as well.

It is therefore essential to consult shellfish experts when developing a living shoreline to enhance the likelihood of good oyster recruitment and survival on a living shoreline project. Additionally, the considerations outlined in Gilby et al., 2017 provide insights to maximize the benefits of oyster reef restoration for finish and their fisheries.

For a more in-depth assessment of suitable habitat, refer to the following detailed resources:

1. NJ Restoration Tool Organization Suite, Living Shorelines Explorer
2. Stevens Institute of Technology's Living Shorelines Engineering Guidelines
3. Stevens Institute of Technology's Ecoshorelines on Developed Coasts Guidance and Best Practices

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for living shorelines where published values exist.

Material Benefits

- Harvesting Organic Materials
  - Oyster reefs support commercially and recreationally important finfish stocks (Gilby et al., 2018).
  - Restored oyster reefs that are harvested for commercial fishing grounds have been shown to generate biomass increases for certain fish and shellfish species that lead to increases in seafood harvest and regional economic impacts in the Chesapeake Bay region (Knoche et al., 2020).
- Improved Water Quality
  - Oysters ability to remove nitrogen from the water was valued at $1,385-6,617 per ha/year for nitrogen removal in 2011 dollars in North Carolina (Grabowski et al., 2012).
  - Oysters assimilate nitrogen and phosphorus into their bodies and improve local water quality (Caretti et al., 2023).
  - New Jersey Ribbed mussels (Moody and Kreeger 2020) and oysters (Barr et al., 2023) clear the water column of particulate matter at different seasonal rates.
  - Water supply in estuaries valued at $49/acre in 2004 dollars (Costanza et al., 2006).
- Improved Human Health
  - Oysters are a good source of protein, but the State has regulations that prohibit the construction of living shorelines in polluted waters to protect people from adverse health impacts from consumption. If living shorelines are constructed in clean waters, the living shoreline could be a source of food local communities or businesses.

Natural Processes Benefits

- Carbon Sequestration
  - Subtidal living shorelines in shallow water are a carbon sink on par with vegetated coastal habitats (this is not universal among all living shorelines) (Fodrie et al., 2017). In some cases, oyster reefs can be carbon sources rather than sinks (Fodrie et al., 2017).
- Erosion Control
  - Oyster reef stabilization valued at $640/linear meter based on average cost of other shore stabilization devices (Grabowski et al., 2012).
  - Resources on Ribbed mussel ability to mitigate erosion (VIMS 2024).

- Nutrient Cycle Control
  - Nutrient regulation valued at $10,658/acre in 2004 dollars (Costanza et al., 2006).

  - A survey of New Jersey residents, and other states, found New Jersey residents were willing to pay $141,191 per acre for a 1000 acre oyster restoration project, $99,311 per acre for a 2500 acre project, $40,367 per acre for a 5000 acre project, and $16,735 per acre for a 10,000 acre project (Hicks, Haab, Lipton 2004).

- Infrastructure Protection
  - Oyster living shorelines provide the following avoided maintenance (Scyphers et al., 2014: $31/month to maintain bulkhead as average for 195 homeowners in Alabama) and replacement ($200/linear foot for wooden bulkhead once every 25 years) costs of a bulkhead (NOAA 2021).

  - A dichotomous-choice contingent-valuation survey was conducted in Mississippi to estimate residents' willingness to pay (WTP) for restoration projects to protect barrier islands (Petrolia and Kim 2009).

Habitat Services Benefits

- Habitat Provisioning
  - Living shorelines help preserve habitats - $4,700.50 per ha/year (Grabowski et al., 2012).

  - Oyster reefs contribute to nutrient removal and create habitat for other marine organisms (Mykoniatis and Ready 2015).

- Improved Habitat Connectivity
  - Living shorelines help to create a shoreline continuum parallel to the shore extending from the shoreline toward water. This can improve habitat connectivity across the water-land interface (NYDS 2024).

- Supporting Biodiversity
  - Living shorelines can increase biodiversity (Suedel et al. 2022)

  - Oysters filtering increases water clarity and can improve conditions for species like seagrasses and support habitat recovery (Rose et al., 2021).

- Supporting Ecosystem Resilience
  - Living shorelines can enhance the resilience of the coastal ecosystem by creating areas less susceptible to coastal erosion and storm surge such that the area can better withstand disturbances.

Cultural Benefits

- Source of Cultural Identity
  - Healthy estuaries have $15/acre of cultural and spiritual value in 2004 dollars (Grabowski et al., 2012).

- Spiritual and Symbolic Interactions
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to natural shorelines.

- Educational Opportunities
  - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021).

- Aesthetic Value
  - Healthy estuaries have $715/acre (as a mean value of 9 peer reviewed) aesthetic value in 2004 dollars (Grabowski et al., 2012).

- Recreational Value
  - Healthy nearshore environments, like those supported by living shorelines, provide ample recreational opportunities (kayaking, sport fishing, bird watching) (NJ Resilient Coastlines Initiative 2019)

  - Healthy estuaries have $281/acre (as a median value of 9 peer reviewed) recreational value in 2004 dollars (Grabowski et al., 2012)

  - Anglers (*i.e.,* party/charter, private/rental, shore) in the Chesapeake Bay are willing to pay up to $42.18/trip for oyster restoration projects if it means they will have an increase in catch rates (this report has several additional WTP values) (Hicks 2004).

- Social Well-Being
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express improvements to a community's well-being derived from a living shoreline.

What are the common challenges?

Below is additional detail regarding the planning process for a living shoreline.

Planning

The list is a summary of the recommended questions to answer prior to developing a living shoreline, and much of this information can be found in various tools of NJResTOrS:

1. What are the project's goals?
2. What candidate sites, tactics, and materials exist to address the project's goals?
3. What information and datasets exist to characterize current conditions at prospective sites (energy, distance to opposite bank, slope, vegetation, soil type, soil firmness, boating activity, presence of invasive species)?
4. Which types of living shorelines would be most successful at the site (*e.g.,* a softer tactic or a harder tactic, will beneficial reuse be utilized)?
5. If the installation is successful, how much new habitat would need to be created to reach stated goals? How many acres of tidal wetlands would be protected by the installation?
6. Is there a particular time of year to target to minimize risks or maximize biological stability?
7. Are there potential downsides or habitat tradeoff issues to address?
8. What would a monitoring plan look like to track progress towards goals?
9. If unexpected issues develop, how is the project team prepared to handle those challenges?

How can I monitor this NBS?

All relevant information is found in the Living Shoreline Profile in Section 3.2.1.

Exemplary Case Study

Below is a cost summary provided by Rutgers University Institutional Planning and Operations for the Living Shoreline at Rutgers Aquaculture Innovation Center in North Cape May, NJ case study (Table 2).

Table 2. A summary table of the costs associated with creating the Living Shoreline at Rutgers Aquaculture Innovation Center in North Cape May, NJ case study featured in the Living Shoreline Profile (Section 3.2.1). This table of costs does not reflect the costs affiliated with the design and permitting phase. Note: costs were incurred in 2020.

LINE ITEM	TOTAL	COMMENTS
OYSTER CASTLE	19,235.00	1' W x 1' L x 6" H (8" H top of cleats): ESTIMATE INCLUDES PLUS 10% TO ACCOUNT FOR BREAKAGE AND FIELD ADJUSTMENTS
SHELL BAG - STORMWATER CHANNEL TOE	3,604.00	ASSUMED AVERAGE DIMENSIONS: 6" H X 10" W X 14" L
SHELL BAG - OYSTER CASTLE TOE	2,203.00	
SHELL BAG - HALF DIAMONDS AT EDGE OF OYSTER CASTLE	227.00	
48" X 3/4" X 1.5" SURVEY STAKES/ ANCHORS (25 PK)	290.00	KILN DRIED TO 15% MOISTURE, PLANED 4 SIDES, CHISEL POINT, 99% KNOT FREE, 25 PACK, SURVEY SUPPLY, INC. MILFORD, DE; ALTERNATIVE OPTION IS TO USED EARTH ANCHORS IN PLACE OF STAKES. FIELD DETERMINATION DURING INSTALLATION FOR BEST HOLDING STRENGTH.
36" X 3/4" X 1.5" SURVEY STAKES/ ANCHORS (25 PK)	363.00	
GRAY PARACORD 1/8" X 500' SPOOL (ITEM #: 70160)	109.00	EVERBILT BRAND (OR SIMILAR), LOCALLY AVAILABLE
HARDIENBACKER 3 FT. X 5 FT. X 1/4 IN. CEMENT BOARD	397.00	TO BE USED AS NECESSARY FOR UNEVEN OR PROBLEMATIC SURFACES DURING OYSTER CASTLE INSTALLATION.
PLANTS 1.5 FT. O.C.	6,406.00	SPARTINA ALTERNIFLORA
DELIVERY	6,600.00	OYSTER CASTLES, SHELL BAGS, PLANTS, STAKES MISC. MATERIALS
ACCESS RAMPS AND MATERIAL SLIDES	347.00	TO BE CONSTRUCTED IN THE FIELD, WORK AREA WALKING RAMPS AND MATERIAL SHOOTS
MISCELLANEOUS PERISHABLES	688.00	MARKERS, DRINKS, HAND TOOLS, PPE, H&S, ETC.
MATERIAL TOTAL	40,469.00	
TRAVEL	10,780.00	MILEAGE, HOTELS, FOOD
LABOR	46,000.00	MOB, DEMOB, INSTALLATION OF SHELL BAG, OYSTER CASTLES, PLANTINGS, R5 BY HAND; A LITTLE OVER 3.5 WEEKS OF WORK BY A TRAINED INSTALLATION TEAM.
TOTAL	97,249.00	

Where can I find funding for this NBS?

The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. National Coastal Resilience Fund (NCRF) - The National Fish and Wildlife Foundation's (NFWF) NCRF funds projects that restore, increase, and strengthen natural infrastructure to protect coastal communities while also enhancing habitats for fish and wildlife. To learn more about the program, visit NFWF's NCRF website here.
2. Readiness and Environmental Protection Integration Program (REPI) - REPI's 2024 Resilience Project Funding Guide provides a description, eligibility requirements, and application information for programs of importance to the US Department of Defense and others that build climate resilience.
3. National League of Cities (NLC) - An article published by NLC in 2024 provides a sampling of programs that prioritize nature-based solutions including programs within the Federal Emergency Management Agency (*e.g.,* Building Resilient Infrastructure and Communities Program, the Hazard Mitigation Revolving Loan Funds, the Flood Mitigation Assistance Grants), The Housing and Urban Development Agency's Community Development Block Grant, the National Oceanic and Atmospheric Administration's Climate Ready Coasts Initiative, and more (Adams et al., 2024).

4.2.4 – SALT MARSH ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the salt marsh profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

Below is additional information regarding each NBS type within the marsh profile.

(1) Living Shorelines

Living shorelines are a NBS to reduce shoreline erosion and develop or maintain habitat, including salt marsh erosion. Living shorelines function best in estuaries, bays, tributaries, and other sheltered shorelines (NOAA 2024). To learn more about living shorelines, review the Living Shorelines profile. Living shorelines usually attend to horizontal protection. For the remainder of this section, we will focus on salt marsh platform and vertical processes behind the land/water interface.

(2) Sediment Manipulation

A healthy marsh is able to maintain vegetation, support fauna, and accrete sediment and plant matter to gain elevation over time (TNC and NJDEP 2021). Many marshes in New Jersey are unhealthy because they are threatened by standing water (*i.e.,* saltwater which does not leave portions of the marsh during low tide). Standing water is damaging to a marsh because the water can down plants, compress root structures of dying plants (DeLaune et al., 1994), and cause erosion that can lead to the gradual sinking of the marsh which turns high marsh to low marsh or mud flats (Geiger 2024). Marshes can have naturally unvegetated areas including pannes (areas that retain sea water for short periods of time) and pools (areas of permanent water inundation), but areas of shallow standing water that are continuously expanding can have negative consequences (Besterman 2021). There are several methods of manipulating the sediment on existing marshes to mitigate marsh decline:

- *Runnels*- Small channels that are dug along the surface of a marsh to create a tidal connection between shallow water on the marsh surface and a creek or ditch (Besterman 2021). The channel follows topographical low areas or existing flow paths. For this process to be effective, experts agree the pools of water must be at a higher elevation than the ditches. Runnels were previously used for mosquito control, but were the shallowest form of drainage ditching (being no more than 30 cm deep and 60 cm wide) and have recently been implemented successfully as a form of marsh adaptation (Wolfe 1996; Besterman et al., 2022). Experts recommend creating runnels in stages and including sills within runnels to prevent erosion of marsh (Besterman 2021). Additionally, runnels should not be used on marshes that are too degraded as degraded marshes will need restoration before runnels are added to the system.

- *Marsh elevation*- Placing large amounts of sediment on top of a marsh can increase the elevation of a marsh and, with proper management, can be the first step toward a healthy marsh habitat. Marsh elevation can be small or large. “Thin-layer” placement includes projects where just enough sediment is added to the system to allow marsh plants to survive (*i.e.,* elevating the marsh several inches or a “small” amount), while other projects would raise the marsh higher (*e.g.,* raising portions of a marsh more than 1 foot above NAVD88 elevation) (USACE 2023; Tedesco et al., 2023). These projects require the use of clean fill (GCC 2024), or sediment, which can include dredged material that would have otherwise been disposed of in a confined disposal facility (Doerr 2021; TNC-NJ 2022). Successful marsh elevation projects do not necessarily include the planting of grass and other native vegetation as anthropogenic planting can be ineffective (Tedesco 2024). Although, planting plugs of native species tends to have higher survival rates than transplanting plants from adjacent sites (Rabinowitz et al., 2022). For additional information regarding the impact of sediment removal and placement in coastal barrier island systems can be explored in this USGS 2021 report.

(3) Phragmites management

Phragmites australis, known as the Common Reed, is an invasive species of grass that spreads quickly, can grow up to 20 feet tall, and grows in dense formations in wetlands across New Jersey which alter the marsh elevation and tidal reach within the marsh (Princeton Hydro 2020). Phragmites can change the ecosystem of a marsh when their fast growth eliminates the intertidal channels and pool habitats used by wildlife (Princeton Hydro 2020), but Phragmites have been shown to build marsh resilience to sea-level rise as this invasive grass can enable marshes to increase their elevation more quickly than native species (NJDEP 2020). Phragmites can be managed by mechanical removal, applying herbicides, mowing, grazing, flooding area, and prescribed burns to preclude Phragmites colonization (Smith-Fiola and Ayeni 1998, Hazelton et al., 2014).

(4) Wetlands Pathway Protection

Protecting open space landward of a marsh provides space for wetlands to migrate as sea-levels continue to rise. Wetlands may experience the "coastal squeeze" problem where roads, buildings, and other development have depleted the stock of natural land marshes can gradually migrate into (NJDEP 2020). Wetland pathway protection requires working with local governments to develop a comprehensive wetland migration strategy (considerations for which are summarized in the Georgetown Climate Center's Managed Retreat Toolkit for Wetlands Migration).

Where should this NBS type go?

All relevant information is found in the Salt Marsh Profile in Section 3.2.2.

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for marshes where published values exist.

Overall Benefits

- The value of salt marshes to provide raw materials/food, coastal protection, erosion control, water purification, fisheries services, carbon sequestration, and tourism/recreation/education/research is assessed (Barbier et al. 2011).

- Co-benefits of constructed wetlands and oyster reefs are explored (Mason et al. 2024).

Material Benefits

- Harvesting Organic Materials
  - The Barnegat Bay watershed contributes over $4 billion in annual economic activity including fish/wildlife value ($189 million) (Kauffman and Cruz-Ortíz 2012).

- Improved Water Quality
  - The Barnegat Bay watershed contributes over $4 billion in annual economic activity including water quality ($245 million) and water supply ($59 million) benefits (Kauffman and Cruz-Ortíz 2012).

- Improved Human Health
  - Wetlands can reduce the presence of surface water near population centers which can limit rates of human exposure to pathogens (Lafferty 2009, Horwitz and Finlayson 2011).

- Improved Mental Health
  - Reduces soil erosion and redistribution maintaining soil depth and water retention (TNC 2021Lit, Keeler et al., 2012; Breitburg et al., 2009).

  - Salt marshes provide life satisfaction and happiness from reducing hazard risks, providing recreation opportunities, and providing aesthetic beauty (Rendón et a. 2019).

Natural Processes Benefits

- Climate Regulation
  - Wetlands play a role in modulating local temperatures along with other fauna (Wichansky et al. 2008)

- Carbon Sequestration
  - Wetlands sequester carbon with New Jersey's coastal marshes and seagrasses estimated to store 60 million metric tons of CO_{2e} and sequester an additional 215,000 metric tons each year (Warnell 2024). However, wetlands can generate greenhouse gases in the form of methane which can have a global warming potential that is 25-83 times higher than CO2 (EPA 2024, NJDEP and NJDA 2024). "Methane release from salt and brackish marshes is currently thought to be low enough that both protection and restoration provide a net carbon sequestration benefit as well as providing enhanced coastal resilience. In brackish and freshwater wetlands (including freshwater tidal wetlands and inland wetlands such as tidal freshwater marshes, red maple swamps, calciferous fens, etc.), the methane release is highly variable and, in some cases, high enough that restoration of freshwater wetlands may lead to net emissions of warming greenhouse gasses rather than net sequestration. Research is needed to determine what types of wetlands would have a net sequestration benefit." (NJDEP and NJDA 2024). As such knowing the site-specific conditions of a marsh is important prior to including a greenhouse gas sequestration estimate in a BCA.

  - Coastal wetlands' ability to store carbon in the Delaware Estuary are monetized using different discount rates (Carr et al., 2018). For global estimates, refer to Doolan and Hynes (2023) and the Ecosystem Services Valuation Database (de Groot et al., 2020).

  - Tidal wetlands will sequester more carbon under high emissions scenarios (Wang et al. 2019)

- Erosion Control
  - Coastal marshes reduce erosion (Shepard et al. 2011)

  - Salt marshes can be two to five times cheaper than a submerged breakwater for wave heights up to half a meter (Narayan et al. 2016)

- Nutrient Cycle Control
  - The salt marshes of New Jersey treat waste which is valued at $5,413 per acre per year in 2004 dollars (Costanza et al., 2006).

  - *"Salt marshes are one type of estuarine habitat that acts like an enormous filter, removing pollutants such as herbicides, pesticides, and heavy metals out of the water flowing through it,"* (Pétillon et al., 2023, NOAA 2024). The salt marsh's ability to filter water benefits human health and the nearby habitats which could be degraded by nutrients and pollutants in the absence of the marsh (Barbier et al., 2011, see Table 3 for global monetized salt marsh ecosystem service values).

- Infrastructure Protection
  - Wetlands avoided $625 million in direct flood damages during Hurricane Sandy across the 12 coastal states that were affected by the storm (including NJ) (Narayan et al. 2017).

  - A 2017 paper (Loerzel et al., 2017) studied the coastal protection provided by 61,318.71 acres of marsh at the Jacque Cousteau National Estuarine Research Reserve (via avoided damages) caused by a simulated Hurricane Sandy event, a 50-year storm event, and a 25-year storm event at two time periods: current (~2016) and future (2050) marsh cover and sea levels. For example, the marsh resulted in ~$8.34 million

in avoided damages during a simulated Hurricane Sandy event under current conditions (such that each acre of marsh is valued at $136). (Additional methods and analyses related to this site are available at Rezaie et al., 2020).

- The restoration of 226 ha of tidal salt marsh in Greenwich, NJ along the Delaware Bay would yield and estimated total economic value (TEV) of goods and service provided annually from $2.05 – 2.39 million if the tidal salt marsh was restored, in part, using a mobile gate system (Weinstein et al., 2021).

- The salt marshes of New Jersey mitigate coastal disturbances valued at $310 per acre per year in 2004 dollars (Costanza et al., 2006).

- The expected economic value of wetlands in mitigating the impacts of 88 tropical storms between 1996 and 2016 along all counties in the Atlantic and Gulf Coasts is calculated (Sun and Carson 2020).

- Calculated value of wetlands to protect against hurricanes in New Jersey based on estimated annual storm probabilities (Costanza et al. 2008)

- Value of Gulf Coast marshes to reduce storm damage, deaths, and injuries (Barbier 2015)

Habitat Services Benefits

- Habitat Provisioning
  - The salt marshes of New Jersey provide habitat and refuge for species valued at $201 per acre per year in 2004 dollars (Costanza et al., 2006).

  - Hurricane Sandy is estimated to have caused minimal, low, moderate and severe damage to salt marshes in New Jersey worth $88.34 million, $407.13 million, $630.73 million, and $840.97 in damages respectively (Hauser et al., 2015).

  - Wetlands can reduce the effects drought and heat have on wildlife by providing a source of water or moist, cool microclimates (Shoo et al., 2011; DEW 2024).

- Improved Habitat Connectivity
  - Any increase in healthy marsh habitat helps to improve habitat connectivity by providing new areas for natural processes to occur and wildlife to move without obstruction.

  - Healthy wetlands connect the intertidal and subtidal water column, and provide resources to adjacent flora and fauna to promote habitat connectivity (Weinstein et al. 2005)

- Supporting Biodiversity
  - Using natural capital as a measure of value, habitat in the Barnegat Bay watershed provides $2.3 billion annually in ecosystem goods and services in 2010 dollars, with a net present value (NPV) of $73.3 billion, calculated over a 100-year period (Kauffman and Cruz-Ortíz 2012). This includes $7,236 per acre per year for saltwater wetland habitats ($6269 per acre per year as a low range value, and $28,146 per acre per year as the high range) (see tables 32, 33, and 34 respectively of Kauffman and Cruz-Ortíz 2012).

- Supporting Ecosystem Resilience
  - Healthy salt marsh habitat can enhance the resilience of the coastal ecosystem by creating areas less susceptible to coastal erosion and storm surge such that the area can better withstand disturbances like flood events.

Cultural Benefits

- Source of Cultural Identity
  - The salt marshes of New Jersey provide cultural and spiritual value worth $180 per acre per year in 2004 dollars (Costanza et al., 2006).

  - Salt marshes provide social cohesion through access to wild food and recreation opportunities (this can also be a source of spiritual and cultural fulfilment) (Rendón et a. 2019).

- Spiritual and Symbolic Interactions
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to salt marsh habitat.

- Educational Opportunities
  - Restored salt marshes that are publicly accessible can provide educational benefits to visitors (Mazzotta et al. 2018)

  - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021).

- Aesthetic Value
  - "A thriving salt marsh is a place of beauty, providing open, green space that increases property values in neighboring communities and enriches the visual landscape for residents and visitors alike," (Dionne et al., 2004).

- Recreational Value
  - The Barnegat Bay watershed contributes over $4 billion in annual economic activity including recreation value ($1.527 billion) and public parks benefits ($1.77 billion) (Kauffman and Cruz-Ortíz 2012). Table 7 of the report highlights the published literature (*i.e.,* study sites) used for the economic valuation.

  - The salt marshes of New Jersey provide aesthetic and recreational value worth $26 per acre per year in 2004 dollars (Costanza et al., 2006).

- Social Well-Being
  - The Barnegat Bay watershed is estimated to directly and indirectly support 60,000 jobs with over $2 billion in annual wages (Kauffman and Cruz-Ortíz 2012)

  - Salt marshes are "places of peace and serenity for those hoping to reconnect with nature," (Dionne et al., 2004).

What are the common challenges?

All relevant information is found in the Salt Marsh Profile in Section 3.2.2.

How can I monitor this NBS?

Monitoring before, during, and after a salt marsh project is constructed is important, and sometimes required by the State and funding agency, for ensuring the project is achieving the intended goals. There are no universal standardized

methods for measuring the success of these salt marsh projects, but below are several resources that outline more specific best practices for monitoring these projects:

- A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey (Yepsen et al., 2016) developed by TNC New Jersey and the Partnership for the Delaware Estuary provides guidance on how to plan, to identify monitoring metrics, and develop a monitoring plan for coastal wetland restoration projects in New Jersey. The USACE also has helpful guidance on maintaining salt marshes in the face of sea level rise to aid in salt marsh planning efforts (VanZomeren et al., 2019).

- NJDEP's Beneficial Use of Dredged Material Website – From 2014 to 2017, NJDEP and partners conducted three pilot beneficial use of dredged material projects with each site yielding a unique elevated marsh platform: thin layer sediment placement, filling in expanding pools and pannes, and creating elevated nesting habitat for threatened and endangered species. The website includes monitoring plans, project summaries, and lessons learned from each project among other resources that could aid in coastal NBS monitoring.

- Mapping and Assessing Tidal Marsh Condition via Multispectral Imaging (Wilburn et al., 2024) – This report highlights how multispectral drone equipment could be used as a proxy for on-the-ground traditional monitoring of tidal marshes. While there is no standard protocol for monitoring wetland conditions using drone imagery at this time, this report provides a snapshot of methods which could be used.

- USGS Resources - There are national metrics that the USGS has completed that could be helpful for restoration projects including: Landsat UVVR from 1985-2013 and 2019-present (Ganju et al., 2022), aboveground biomass (Byrd et al., 2018), and relative tidal elevation (Holmquist and Windham-Myers 2022). To learn more, watch the NJ Coastal Resilience Collaborative webinar Mid-Atlantic Marsh: Biology, Processes, and Trends (2023).

Where can I find funding for this NBS?

The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. NJ Natural Climate Solutions Grants Program - This program is funded by the Regional Greenhouse Gas Initiative which provides the State with funding for projects that create, restore, and enhance New Jersey's natural carbon sinks.
2. New Jersey Corporate Wetlands Restoration Partnership - Provides funding for public-private partnerships to restore, preserve, enhance, and protect aquatic habits on public land in New Jersey.
3. EPA Greenstream Listserv - The US Environmental Protection Agency will frequently advertise federal and non-federal funding for green infrastructure.
4. Federal Wetland Restoration Funding - This EPA website provides a list of EPA and other Federal agencies' funding programs for wetland program development, urban wetlands, wetlands to mitigate nonpoint source pollution, wetland conservation, and flood prevention.

4.2.5 – RLM on Working Lands Additional Information

This appendix contains additional information discussed briefly in the working lands profile. Additional information is organized by the same headers used in the main profile. Headers are omitted below if there is no additional information to share.

Introduction

Below is additional information regarding each NBS type within the working lands profile.

(1) Agroforestry

Definition: The intentional integration of trees and shrubs into crop and animal farming systems (USDA 2024d)

Examples:

- Alley cropping – Planting crops between rows of trees. In this system there is no pre-existing forest: crops are planted to provide income while trees mature. This technique is sometimes called "intercropping" if trees and crops are not planted in defined rows.
- Forest Farming - Managing an existing forest for optimal canopy coverage to grow crops. This technique is sometimes called "multistory cropping."
- Silvopasture – Trees and livestock are farmed together. Silvopasture occurs when trees are introduced into a pasture or when forage is introduced to a woodland or tree plantation (USDA 2024e).

(2) Conservation Agriculture

Definition: Activities that increase organic content in soils.

Examples:

- Conservation tillage – Tillage management practice that result in a Soil Tillage Intensity Rating (STIR) of less than or equal to 80 (Claassen et al., 2018).
- Conservation crop rotation – A sequence of crops on the same field for the purpose of supporting soil health, conserving natural resources, and improving environmental outcomes from farming that includes at least one high-residue crop (e.g., corn) and at least one low-nitrogen crop (e.g., grass or legume) (Claassen et al., 2018).
- Cover crops – Planting a crop for seasonal cover (e.g., planting annual ryegrass during the winter between cash crops) (Claassen et al., 2018).
- Organic agriculture – Organic agriculture is more than omitting synthetic fertilizers and pesticides from the food growing and distribution process. The USDA describes organic agriculture as the application of a set of cultural, biological, and mechanical practices that support the cycling of on-farm resources, promote ecological balance, and conserve biodiversity. To learn more, visit New Jersey's Department of Agriculture's Organic Sustainable, Regenerative Agriculture website (OSRA 2024).
- Rotational grazing – Subdividing pasture land so only one portion of a pasture is grazed at a time while the remainder of the pasture "rests." Resting allows forage plants to renew energy reserves, deepen their root system, and support long-term maximum production (Undersander et al., 2016).

(3) Avoided Forest Conversion
Definition: Conversion of forests to row crop agriculture, pasture, or development represent the largest loss of forests in the United States (USDA 2024g). "Avoided forest conversion" is any tactic that prevents forests from being cut down for agricultural and other development purposes.

Examples (USDA 2024g):
- Designation of conservation easements on forested lands.
- Use of protective guidelines and best management practices that avoid unintentional loss of forest cover or soil carbon.
- Reducing forest displacement for development activities (e.g., plan roads that minimize number of trees felled).

(4) Riparian Forest Buffers
Definition: Natural or re-stablished areas along rivers and streams made up of trees, shrubs, grasses, and/or other perennial plants. These buffers can help filter farm runoff while the roots stabilize the banks of streams, rivers, lakes and ponds to prevent erosion (USDA 2024h).

Examples (USDA 2024h):
- Natural forest managed to ensure health of wild tree populations.
- Managed nut/fruit trees and shrubs planted by landowner for possible harvest and ecosystem benefits.
- Managed woody florals and forbs planted by landowner for possible aesthetic and ecosystem benefits.

(5) Windbreak
Definition: Linear plantings of trees and shrubs designed to, primarily, slow the wind to create a more beneficial condition for soils, crops, livestock, wildlife, and people. Windbreaks are sometimes called "shelterbelts" (USDA 2024h).

Examples:
- Field windbreaks – Windbreaks reduce wind speed, alter the microclimate in sheltered areas, reduce erosion of soil (NRCS 2017), reduce damage to crops sensitive to wind-blown soil (Hodges and Brandle 2024), improve water use efficiency, and reduce risks associated with drought.
- Livestock windbreaks - Reduce livestock mortality from cold weather, animal stress, and feed consumption, all of which lead to increased weight gain and milk production. Windbreaks also help reduce visual impacts, noise (USDA 2011a), and odors (USDA 2011b) from livestock operations.
- Living snow fences – Windbreaks can be designed to spread snow across a large area or to confine it to a relatively small storage area to increase spring soil moisture (Brandle and Nickerson 2024).

(6) Wetland Restoration on Agriculture Lands
See the Salt Marsh Profile (Section 3.2.2) and the Freshwater Wetland Profile (Section 3.4.4).

Where should this NBS type go?
All relevant information is found in the RLM on Working Lands Profile in Section 3.3.1.

What are the co-benefits of this NBS?
Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for working lands where published values exist.

Overall Benefits

Farmers who engaged with the Conservation Reserve Program (CRP) in Iowa, USA implemented expanded row crop agriculture, and a study found the ecosystem service benefits to these CRP lands exceeded the cost farmers were paid to implement those services. Meaning, farmers may be underpaid under existing programs for the co-benefits RLM practices create (Johnson et al. 2016).

Material Benefits

- Harvesting Organic Materials
  - "In 2022 in State's almost 10,000 farms generated cash receipts of nearly $1.5 billion" with the nursery/greenhouse/sod industry generating the most revenue followed by fruites and vegetables, field crops, equine, poultry and eggs, and dairy (NJDA 2025)

  - The following is also of value (Morizet-Davis et al. 2023):
    Value of food grown to feed people.
    Value of food/biomass grown to feed livestock.
    Value of fiber used for clothing and other materials.
    Value of food grown as fertilizer for other crops.
    Value of food grown to cultivate and refine high quality chemicals and pharmaceuticals.
    Value of organic material used for fuel.

- Improved Water Quality
  - Estimate of national and regional potential for water quality co-benefits on working lands from GHG mitigation strategies in US agriculture. Values are derived for the northeast in general, so not on a farm by farm basis. (Pattanayak et al., 2005).

  - Value of increased water storage.
    Conservation agriculture reduces agriculture water demands with appropriate cover crops (TNC 2021Lit, Derpsch et al., 2010).

  - Value of functioning watershed.

    – Maine (Kroeger 2008).
    – North Carolina - residents willing to pay $139 per taxpayer for five years to protect current levels of water quality and that this payment scheme would save $95 million over the cost of water quality implementation practices (Eisen-Hect and Kramer 2022).
    – New York - New York City invested in the protection and restoration of the Catskill-Delaware watershed, which now provides clean drinking water for 90% of the city's population at a rate of roughly 6.8 billion liters (1.8 billion gallons) of water a day. Land was acquired and managed at a cost of ~2.06 billion whereas a new filtration plant would have cost $8 billion plus $300 million in annual operation costs (Dlugolecki 2012).

- Improved Human Health
  - Improved water quality from RLM increases opportunities for recreation and health benefits (TNC 2021Lit, Smith et al., 2013).

  - RLM can provide protection from sun harmful rays (USDA 2007).

- Improved Mental Health
  - Access to cleaner air, water, and healthier ecosystems can improve a person's mental health (Wutich et al. 2020).

Natural Processes Benefits

- Air Quality Improvement
  - RLM reduces dust (CA Natural and Working Lands Strategy, 2024)
  - PM2.5 emissions from farming are reduced using conservation tillage. Nationwide, you'd prevent 1000 annual deaths if we shifted from conventional to conservation tillage (Pokharel et al., 2023).

- Climate Regulation
  - Vegetation can cause a moderation of temperature extremes and the force of winds (USDA 2007).

- Carbon Sequestration.
  - Estimates of forest buffer carbon sequestration values near Chesapeake Bay.
    Implementing 190,500 acres of forest buffers by 2025 would remove more than 173,000 metric tons of carbon dioxide annually (CBF 2024).
  - Estimates of global carbon sequestration values for avoided forest conversion, fire management practices, cropland nutrient management, conservation agriculture, trees in croplands (windbreaks, alley cropping), among others (TNC 2021Lit).
  - Ecosystem service valuation techniques for carbon sequestration that incorporates the variables that influence a New Jersey farm's ability to sequester carbon (Rutgers 2021).

- Pollinator Services
  - Planting vegetation that attracts pollinators can increase the abundance of pollinators locally and support a healthy regional population.

- Erosion Control
  - Reduces soil erosion and redistribution maintaining soil depth and water retention (TNC 2021Lit, Keeler et al., 2012; Breitburg et al., 2009).

- Nutrient Cycle Control
  - Conservation agriculture provides soil health improvements (Palm et al., 2014).
  - Better nutrient management retains soil fertility and reduce ammonia and nitric oxide emissions (TNC 2021Lit, Smith et al., 2013).
  - Estimates of rotational grazing pollution reductions.
    Farms in the Chesapeake Bay watershed that converted conventional farmland to rotationally grazed pasture found an average pollution reductions of 63 percent, 67 percent, and 47 percent for nitrogen, phosphorus, and sediment, respectively (CBF 2018, CBF 2024).
  - Monetized Values for Agroforestry
    Agroforestry estimated to provide, at most, $400 per kg nitrogen removal in New Zealand (Monge et al., 2016).

- Infrastructure Protection
  - Restored wetlands on farmland can reduce flooding. Along the Mississippi River, cost comparisons have been made between wetlands and water reclamation plant treatments (Hey et al., 2005, Prato and Hey 2006).
  - Monetized values for afforestation to reduce flooding in Scotland (Dittrich et al., 2018).

Habitat Service Benefits

- Habitat Provisioning
  - (TNC 2021Lit) - Agroforestry provides habitat for species (Derpsch et al., 2010).
  - Forests create habitat for wildlife.

- Improved Habitat Connectivity
  - (TNC 2021Lit) - Agroforestry supports habitat connectivity (Derpsch et al., 2010).

- Supporting Biodiversity
  - RLM can expand wildlife corridors and support climate adaptation pathways (CA Natural and Working Lands Strategy, 2024)
  - Forests can increased fish species richness and abundance (TNC 2021Lit, Breitburg et al., 2009).

- Supporting Ecosystem Resilience
  - RLM NBS for working lands can enhance the resilience of ecosystems by creating healthier ecosystems that have a buffering capacity against natural and anthropogenic disturbances, such as extreme weather.
  - In a 1993 WTP study, Martha's Vineyard, Massachusetts residents reported a willingness to pay an average of $131 a year to protect island tidal ponds for ecological benefits (Karou 1993).

Cultural Benefits

- Source of Cultural Identity and Spiritual and Symbolic Interactions
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's cultural and spiritual ties to these NBS.

- Educational Opportunities
  - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021)

- Aesthetic Value
  - Natural landscapes have aesthetic value (USDA 2007).

- Recreational Value
  - Improved water quality from RLM increases opportunities for recreation and health benefits (TNC 2021Lit, Smith et al., 2013).

- Social Well-Being
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express the impacts of a NBS project to a community's well-being.

What are the common challenges?

All relevant information is found in the RLM on Working Lands Profile in Section 3.3.1.

How can I monitor this NBS?

Below is additional detail regarding monitoring resources for projects on working lands:

1. Sustainable Agriculture Research and Education (SARE): SARE offers farmer-driven, grassroot grants and education programs that focus on implementing sustainable agriculture on farms and ranges across the United States. Refer to SARE's Resources and Learning page of their website to find helpful resources for monitoring different elements of a RLM NBS project.

2. National Invasive Species Information Center (NISIC): The USDA's NISIC website's monitoring page provides an overview of methods that have been used across the country to precent, control, or eradicate invasive species on working and natural lands (USDA 2024). To find monitoring templates for specific species scroll to the bottom of the page and select "view and filter all monitoring resources" which will take you to a repository of NISIC resources (USDA 2024b).

Where can I find funding for this NBS?

The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. Natural Resources Conservation Service, U.S. Department of Agriculture New Jersey State Programs

- NJ Conservation Stewardship Program (CSP)
  - Via the CSP, NRCS works one-on-one with producers to develop a conservation plan that outlines and enhances a landowner's existing efforts for RLM on farms. The CSP commits to five-year contracts with landowners to implement conservation activities where the landowner is paid a minimum of $1,500 a year. Conservation activities implemented are individualized and based on management objectives for each farmers' operation (NRCS 2024k).

- The NJ Agricultural Management Assistance Program (AMA)
  - AMA provides financial assistance up to 75 percent of the cost of installing conservation practices including constructing or improving water management structures or irrigation structures; planting trees for windbreaks or to improve water quality; and mitigating risk through production diversification or resource conservation practices, including soil erosion control, integrated pest management, or transition to organic farming (NRCS 2024a).

- NJ Regional Conservation Partnership Program (RCPP)
  - RCPP is a partner-driven approach to conservation that funds solutions (both projects and easements) to natural resource challenges on agricultural land. (NRCS 2024b).

- NJ Agricultural Conservation Easement Program (ACEP)
  - ACEP helps private landowners, land trusts, and others with two types of easements: agricultural land easements (limits non-agricultural uses of land through a conservation easement) and wetland reserve easements (protects, restores and enhances wetlands that were previously degraded due to agricultural uses) (NRCS 2024d).

- NJ Conservation Innovation Grants (CIG)
  - CIG is a competitive grant program where landowners, state or local governments, and non-government organizations can apply for projects that enhance natural resource conservation on private lands (NRCS 2024e).

- NJ Environmental Quality Incentives Program (EQIP)
  - EQIP provides financial and technical assistance to agricultural producers and non-industrial forest managers to address natural resource concerns. EQIP funds on the ground projects for individual farmers as well as planning projects (e.g., funding to develop Conservation Activity Plans) (NRCS 2024f). EQUIP also offers Conservation Incentive Contracts that can serve as a stepping stone to correct resource issues on specific land units that could later be scaled up to their entire operation (NRCS 2024g). Refer to this fact sheet for tips to apply for EQIP funding (Miller et al., 2008).

- NJ Emergency Watershed Protection (EWP)
  - The EWP Program offers technical and financial assistance to help local communities relieve imminent threats to life and property caused by floods, fires, windstorms and other natural disasters that impair a watershed. This can include establishing vegetative cover on critically eroding lands, reshaping and protecting eroded streambanks (NRCS 2024i)

- NJ Working Lands for Wildlife
  - This partnership uses innovative approaches with farmers, ranchers and forest landowners to restore and protect priority habitat areas for selected wildlife species (NRCS 2024h).

- NJ Wetland Reserve Easements (WRE)
  - WRE help private and tribal landowners protect, restore and enhance wetlands which have been previously degraded due to agricultural uses (NRCS 2024j).

2. The Conservation Reserve Enhancement Program, U.S. Department of Agriculture (CREP, USDA)

- Part of the USDA's Conservation Reserve Program and administered by the Farm Service Agency, CREP leverages federal and non-federal funds to target specific State, regional, or nationally significant conservation concerns. In exchange for removing environmentally sensitive land from production and establishing permanent resource conserving plant species, farmers and ranchers are paid an annual rental rate along with other federal and non-federal incentives as specified in each CREP agreement. Participation is voluntary, and the contract period is typically 10-15 years. Learn more about the program here. Additional conservation programs facilitated by the USDA are listed here. New Jersey's Draft Programmatic Environmental Assessment for the NJ CREP is available here.

3. State Agricultural Development Committee (SADC) Programs

- Explore programs facilitated by the State Agricultural Development Committee for landowners interested in protecting farmlands from development (e.g., residential housing developments, warehouses) (SADC 2024). These programs include: the County Planning Incentive Grant Program, the Municipal Planning Incentive Grant Program, the State Direct Easement Program, and the Nonprofit Program. An additional option for landowners is the Term Farmland Preservation System where landowners can choose to preserve farms for 8- or 16-years rather than permanent which makes landowners eligible for soil and water conservation grants.

4. Conservation Cost Sharing

- Learn more about conservation cost sharing for farmers and landowners on the New Jersey Department of Agriculture webpage here.

4.2.6 – RLM ON NATURAL LANDS ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the natural lands profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

Below is additional information regarding each NBS type within the RLM on Natural Lands Profile.

(1) Acquisition and Development of Open and Green Space

Definition: Activities that protect, manage, or restore natural areas while simultaneously expanding access to outdoor recreation.

Suburban Examples:

- Park Creation or Management: Green spaces in suburban and urban environments provides environmental, health, and socioeconomic benefits to nearby residents and the surrounding communities (Mitchell 2024). Creating or improving parks with new landscaping or features can restore these habitats and their ability to provide ecosystem services (NJDEP-OT 2024).

- Vegetated Greenways: Corridors in rural and suburban communities that are established to serve a range of environmental, recreational, and transportation purposes. A vegetated greenway can serve as a linear park with hiking trails and recreational facilities or a means to connect parks and neighborhoods.

- Blue-Acres Buyout Plot Conversion – Property sold to the state via the Blue-Acres program (a state-led flood buyout program that works with willing sellers to purchase their home that has been damaged by storm events or is prone to future flooding) becomes open space ripe for management to unlock the co-benefits the land could provide. Unlike other programs (see Funding section below) the Blue-Acres program is a method to remove development from land: additional funding would need to be secured to implement RLM NBS strategies on the property.

- Contaminated Site Remediation and Development: New Jersey is estimated to have over 23,000 contaminated sites, 10,000 of which are brownfield sites (NJDEP 2006). A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant (ANJEC 2024). Brownfields are a large class of properties not to be confused with the superfund sites, the latter generally having more complex or dangerous contamination and are overseen by the US EPA. New Jersey has 114 superfund sites (EPA 2024) with some undergoing remediation and reuse actions (EPAb 2024). Contaminated site locations are recorded by NJDEP (map available here) as are brownfield locations (map available here). It is a local, state and national priority to put these sites back into productive reuse including creating green space. This Guide for Municipalities and Community Organizations regarding redeveloping brownfields in New Jersey provides details and supporting resources that serve as a guidepost for anyone considering undertaking contaminated site remediation in the state (ANJEC 2021).

Rural Examples:

- Land Preservation and Management: Land preservation transactions involve landowners selling their land, or selling the rights to develop their land, temporarily and permanently to a responsible conservation authority. This conservation authority will then manage the land in perpetuity to maintain the habitats for generations to come.

(2) Fire Management
Definition: Activities that increase resilience to catastrophic fires. Resilience measures may be increasingly important as forests managed for their carbon offsets may be subject to additional wildfire risk (Herbert et al., 2022). Experts recommend a combination of the two NBS below to effectively combat wildfires (Kittler 2022) in New Jersey.

Examples:

- Prescribed Fires – Controlled burning to fire-prone forest that reduces the likelihood of more intense wildfires (Miralles-Wilhelm 2021, O'Lear et al., 2022). The NJ Forest Fire Service is a recommended partner to develop prescribed burns.
- Mechanical Thinning – The process of removing trees in overgrown forests to reduce the risks of extreme wildfires (Westover 2021, Warnell et al., 2024).

(3) Native Tree Management
Definition: Planting and managing native trees to create or restore ecosystems.

Examples: Below is the suite of native tree management methods as described by the Forest Resource Considerations for a New Jersey Natural and Working Lands Strategy (O'Lear et al., 2022). Experts agree New Jersey's many ecosystems can benefit from diversifying management through different combinations of these methods as opposed to prioritizing one strategy over another (NJDEP 2020).

- Afforestation – Planting trees in areas where there were no forests before. A 2022 report prepared by Rutgers identifies candidate locations for afforestation in the State (O'Lear et al., 2022).
- Reforestation – The reestablishment of forest cover to restore forest function.
- Forest Restoration – Methods to improve and maintain health and resilience of the forest ecosystem.
- Proforestation – Actions to allow forests to reach their ecological potential by keeping them intact.
- Urban and Community Forests – See the profile on this topic to learn more.

(4) Wildlife Friendly Alternatives to Lawns
Definition: Replacing all or part of a lawn with native vegetation to create wildlife habitat.

Examples:

- Pollinator Garden – Pollinators (e.g., honeybees, butterflies, bats) pollinate flowering plants and food crops to ensure these plants reproduce and generate enough seeds for the next growing season (USDA 2024i). Pollinator populations are declining due to habitat loss and other environmental factors (USDA 2024ii). Replacing a lawn with native plants creates new habitat (i.e., a pollinator garden) to support these pollinators and the important ecosystem services the pollinators provide.
- Meadows and Prairies – These grassy habitats contain a mixture of native grasses and wildflowers, with prairies typically thriving more in warm seasons and having a higher percentage of grasses than meadows (Sullivan and Brittingham 2024). Meadows and prairies provide many co-benefits including air and water quality improvement as well as providing essential habitat for wildlife (Snow 2020). Creating meadows and prairies in suburban and rural landscapes is a low-maintenance way (Sutton 2019) to provide these important habitats (Dunne 2006).

Where should this NBS type go?

Below is additional information regarding where each NBS type within the natural lands profile may be constructed.

RLM NBS on natural lands can be implemented on private or publicly owned lands consistent with local, State, and Federal regulations. Refer to the resources below for an in-depth assessment of the ideal conditions for each NBS for RLM on natural lands:

(1) Considerations for Acquisition and Development of Open and Green Space

- Target Priority Sites - There are many plans and resources in New Jersey that identify land areas most in need of RLM. For example, the Connecting Habitats Across NJ (CHANJ) is an initiative to help animals move through the landscape of NJ in the face of urbanization and dense road networks. CHANJ's strategic plan identifies key areas to preserve and restore habitat connectivity for NJ's terrestrial wildlife (more information available here). Prioritizing sites, like those identified in CHANJ, for land acquisition and development would bolster the co-benefits a RLM NBS project could provide most in need of preservation and management. Other priority sites could be contaminated sites either through the state's known contaminated site repository (available here), the state's brownfield repository (available here), or the federal superfund sites through the national priority list (available here).
- Think Long-Term – Depending on the program funding land acquisition and development, it could take decades to acquire the full area of land for a RLM NBS to be built on. Consider the Blue-Acres Program: if, hypothetically, there was a severe flooding event in a coastal neighborhood with ten properties, experts caution that while seven of those homeowners may be interested in being bought out in the immediate aftermath of a storm, the remaining three properties may remain for 20-50 years.

(2) Considerations for Fire Management

- Identifying locations for prescribed burning is a job requiring knowledge of forest fuels, fire behavior, suppression techniques, local weather conditions, and fires effects. Consequently, a written plan must be developed well in advance of the proposed burn to allow time for review and the preparation of all necessary permits. To learn more about proper fire management techniques, refer to the following resources (NJDEP 2024), The Allen and Oswego Road Fire Mitigation and Habitat Restoration Project offers a good snapshot of the planning and coordination involved in fire management (NJFS 2024).

(3) Considerations for Native Tree Management

- The following resources will help identify the best locations, and practices, for various native tree management RLM NBS projects:
    - "NJ Conservation Blueprint" (Available here.)
    - "Trees for NJ Streets" (NJ Shade Tree Federation 2016)
    - "Planning for Greenways: A Guidebook for NJ Communities" (TNJ 2019)
    - "Urban and Community Forestry Program: Reforestation, Tree Planting, and Maintenance Plan Guidelines" (NJFS 2021)
    - "New Jersey State Forest Action Plan" (NJDEP-DPF 2020)

(4) Wildlife Friendly Alternatives to Lawns

- Refer to the following resources to help identify the best locations for meadows and pollinator gardens. Locations for these projects are largely unlimited but do best in areas of ample sunlight and flatter terrain.

Meadows:

- "Wildflower Meadows" (Sutton 2006)
- "Meadows and Prairies: Wildlife-Friendly Alternatives to Lawn" (PSE 2024)
- "Ramapo Green Campus Meadow" (Wiener 2024)
- "Department of Interior Nature-Based Solutions Roadmap" (Warnell et al., 2024)
- "A Garden for Butterflies: Crating a Butterfly Garden in the Northeast" (Duke Farms 2023)
- "Gardening for Butterflies" (Mank and Brittingham 2013)

Pollinator Garden

- "Pollinator Conservation Resources: Mid-Atlantic Region" (XERCES Society 2024)
- "How to Build a Pollinator Garden" (Koenig 2024)
- "Transitioning from Traditional Lawn to Native Planting" (Judge 2024)
- "Native Groundcovers" (The Native Plant Society of NJ 2024)

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for natural land NBS where published values exist.

Material Benefits

- Harvesting Organic Materials
  - RLM NBS on natural lands can provide raw materials for use in food, feed, fiber, chemicals, or fuels depending on what is planted on those natural lands.

- Improved Water Quality
  - An acre of forest in Maryland's ability to recharge groundwater was valued at $305.35/year (Campbell 2018).
  - An acre of forest in Maryland's ability to mitigate stormwater runoff was valued at $2,418.09/year (Campbell 2018).
  - An acre of New Jersey forest's ability to provide water is valued at $9/year in 2004 dollars (Costanza 2007).

- Improved Human Health
  - Preserved open space provides low-cost or free recreational opportunities to residents and promotes health and wellbeing. Parks and preserves throughout the state offer hiking, biking, birding, dog walking, paddling, fishing, horseback riding and more. Physically active people who use outdoor open spaces have lower incidences of cardiovascular diseases, diabetes, depression, certain cancers, and obesity (NJ Conservation Foundation 2024).
  - Open space in Mercer County, NJ encourages residents to engage in outdoor recreation and become more physically active. It is estimated that moderate and strenuous activity of visitors to the open space in the county avoids $84.1 million in medical costs annually (ESI 2021).

- Improved Mental Health
  - Experiencing nature at parks and open spaces provides a feeling of peace and serenity, boosting mental health. It is estimated that activities on protected open space account for millions of dollars in avoided medical costs annually, plus millions more in avoided losses from reduced productivity at work (NJ Conservation Foundation 2024).

Natural Processes Benefits

- Air Quality Improvement
  - Protected open space removes pollution from the air (NJ Conservation Foundation 2024).
  - In Fairfax, VA, open space trees and buffers are estimated to have reduced the cost of traditional air pollution controls by over $4.5 million in 1995 (Palone and Todd 1998).

- Climate Regulation
  - Loss of forests leads to increase in local average and extreme temperatures, which can expose people to heat stress (WRI 2022).
  - An acre of New Jersey forest's ability to regulate climate is valued at $60/year in 2004 dollars (Costanza 2007).

- Carbon Sequestration
  - A hectare of forest in Maryland's ability to sequester carbon was valued at $126.03/year (Campbell 2018).
  - Trees on Mercer County, NJ protected open space store enough carbon such that it would cost the county $108 million to replicate (ESI 2021).

- Pollinator Services
  - Meadows with native wildflowers provide beautiful wildlife habitat. Supporting pollinator populations, and require minimal maintenance (e.g., only needing to be mowed once per year, don't require fertilizer or pesticides, don't require to be watered after the first year) (Ramapo College 2024).
  - An acre of New Jersey forest's ability to contribute to pollination is valued at $162/year in 2004 dollars (Costanza 2007).

- Erosion Control
  - A hectare of forest in Maryland's ability to prevent erosion was valued at $11.47/year (Campbell 2018)

- Nutrient Cycle Control
  - A hectare of forest in Maryland's ability to uptake nutrients was valued at $366.28/year (Campbell 2018)
  - Protected open space in Mercer County, NJ avoids $66.8 million of capital cost for stormwater infrastructure construction and an additional $8.9 million to operate and maintain the additional infrastructure. Protected open space avoids an additional annual investment of $102 million to remove annual pollutant loadings from the county (ESI 2021)

Habitat Service Benefits

- Habitat Provisioning
  - A hectare of forest in Maryland's ability to provide wildlife habitat was valued at $2,539.44/year (Campbell 2018).
  - An acre of New Jersey forest's ability to provide habitat and refuge for wildlife is valued at $923/year in 2004 dollars (Costanza 2007).

- Improved Habitat Connectivity
  - Adding forested areas creates wildlife habitat for forest-dependent species, which can help to increase the connectivity of forested habitats, reducing habitat fragmentation (CHANJ 2019).

- Supporting Biodiversity
  - Open space in Mercer County, NJ provides $97.6 million in environmental services (i.e., those related to replenishment of water supply, water quality improvement, flood mitigation, wildlife habitat, air pollution removal, and carbon storage). This is reflective of the value gained and the avoided costs of having to replace the ecological services currently being provided by the open space in Mercer County (ESI 2021).
- Supporting Ecosystem Resilience
  - RLM NBS on natural lands can enhance the resilience of a terrestrial ecosystem by creating areas less susceptible to extreme heat, stormwater, inland flooding, erosion, wildfires, and storm surge such that the area can better withstand disturbances.

Cultural Benefits

- Source of Cultural Identity
  - A New York Superfund site cleanup identified and documented over 145,000 Native American and Civil War era artifacts in Foundry Cove and adjacent areas near Cold Spring, NY. These recovered artifacts were preserved and have been used to document the area's rich history (EPA 2022).

- Spiritual and Symbolic Interactions
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to green space.

- Educational Opportunities
  - The New Jersey School of Conservation (NJSOC) located on a 240-acre tract of land in Stokes State Forest in Sussex County, NJ has provided programing for more than 500,000 students and teachers in its 71-year history (NJSOC 2024). 7th graders who visited the NJSOC for a 3-day, 2-night environmental education program and enjoyed their experience, left with more positive attitudes toward the environment (Smith-Sebasto and Cavern 2006).

- Aesthetic Value
  - Well-designed green spaces in urban and suburban environments provide aesthetic beauty and stress reduction (Wang et al. 2019; Ma et al. 2020).

- Recreational Value
  - Outdoor recreation generates $12.6 billion in New Jersey representing 1.7% of the State's GDP, generating 122,048 jobs, and $6.6 billion in salaries (ORIA 2022).
  - Local parks and recreation agencies in NJ generated $1.17 billion in economic activity, $531 million in income, and provided 10,913 jobs in 2021 (NRPA 2023).
  - An acre of New Jersey forest's ability to provide aesthetic and recreation opportunities is valued at $130/year in 2004 dollars (Costanza 2007).

- Social Well-Being
  - Property values increase when located near protected open space as buyers are willing to pay more for properties near and adjacent to green spaces. (Keep it Green 2019, NJ Conservation Foundation 2024).
    - The average home value increases 16% when it is located within 1,500 feet of natural areas. (Lutzenhiser et al., 2001).
    - The average home value increases 8-10% adjacent to parks (within 500-600 feet) and community-size parks greater than 40 acres (within 2,000 feet). In some cases, homes immediately adjacent to parks did not experience this premium due to negative factors (e.g., congestion, vandalism, noise, lights) (Crompton and Nicholls 2019).
    - Homes in Mercer County, NJ on average increased in value by $7,100 when located within ½ mile from protected open space. This increase in value per household generated $791 million in increased property value which increased property tax revenues by $21.5 million per year (ESI 2021).
  - Business Productivity
    - Open space in Mercer County, NJ avoids $65.2 million in lost productivity costs annually by local businesses (ESI 2021).

What are the common challenges?

All relevant information is found in the RLM on Natural Lands Profile in Section 3.3.2.

How can I monitor this NBS?

All relevant information is found in the RLM on Natural Lands Profile in Section 3.3.2.

Where can I find funding for this NBS?

The following list identifies a sampling state, federal, private, and public funding opportunities for this NBS profile. Funding opportunities listed are current as of the publication of this document, but may be subject to change. For additional funding opportunities, see Appendix 4.5.

1. **Outside, Together! A Statewide Comprehensive Outdoor Recreation Plan for New Jersey (2023-2027) (NJDEP 2024)**
   Section 11 of this plan lists State (e.g., Inclusive Healthy Communities Grant, Local Recreation Improvement Grant, Preserve New Jersey Historic Preservation Fund, Municipal Aid, Safe Streets to Transit, Brownfields Loan Program) and Federal funding sources (e.g., Outdoor Recreation Legacy Partnership, Recreational Trails Program, Conservation Innovation Grant, NJ Conservation Stewardship Program, Urban and Community Forest Program, Wildlife Crossings Pilot Program, Brownfields Program, Climate Pollution Reduction Grants, Environmental Justice Government to Government Program, Forest Legacy Program, Delaware Bay Coastal Program, and State Wildlife Grants) to create and expand parks and open spaces. Review Tables 7 and 8 of the "Outside, Together!" plan for an overview of each program and links to each program.

2. **Green Acres:**
   Green Acres was created in 1961 to effectively drive land preservation in the state. The program acquires open space and parkland for the state and funds local and nonprofit land acquisition, park development, and stewardship projects across New Jersey. Areas of focus include improving urban parks, preserving historic sites, increasing resilience to flooding and climate change, and protecting important state resource areas. The program receives approximately $156.6 million annually. To learn more about the program, visit the Green Acres website.

3. **Brownfield Remediation Funding Streams**
   There are various State and Federal programs with funding to support brownfield remediation work. Those State programs include Hazardous Discharge Site Remediation Fund grant program, the New Jersey Environmental Infrastructure Trust, and the NJ Economic Development Authority. Those Federal programs include the EPA's Brownfields Program. To learn more, visit the New Jersey Site Remediation Program website here.

4. **Land Acquisition Programs**
   The New Jersey Conservation Foundation (NJCF 2024), the NJ Natural Areas Program (NJDEP 2024), and the NJ Natural Lands Trust (NJDEP 2024) acquire land for preservation. To learn more about opportunities within each organization and program, select the respective links above.

5. **County and State Open Space Trust Funds:**
   Each of New Jersey's 21 counties and more than 220 of the State's municipalities have funding sources that are used to acquire open space.

4.2.7 – DAM REMOVAL ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the dam removal profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction
All relevant information is found in the Dam Removal Profile in Section 3.4.1.

Where should this NBS type go?
All relevant information is found in the Dam Removal Profile in Section 3.4.1.

What are the co-benefits of this NBS?
Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for dam removals where published values exist.

Provisioning Services

- Harvesting Organic Materials
    - Controlled dam removal (i.e., dam removal which limits the release of dammed sediment and is performed in the fall/winter to reduce stress on fauna) can create habitat that is suitable for freshwater mussels (Galbraith et al. 2018) and other fauna used by recreational fishermen.

- Improved Water Quality
    - Changes to water quality after a dam removal is site specific (Velinsky et al. 2006) but ecosystems are expected to be healthy and regenerate after the water levels equilibrate after construction (Wyrick et al. 2009). See erosion control and nutrient cycle control below for additional information.

- Improved Human Health
    - Dams can be public safety hazards both due to dam failure and unsafe recreation near dams. Controlled dam removal eradicates the risk of injury, loss of life, and property destruction from dams (Hamilton and Craig 2017).

- Improved Mental Health
    - Job retention improves a person's mental health. Dam removal projects can support 12 to 15 jobs for every $1 million invested (MDER 2019; American Rivers, 2023).

Regulating Services

- Erosion Control
    - Dams can cause downstream erosion when water flowing past a dam is nutrient poor. Dam removal eliminates this negative impact of some dams (USFWS 2024).

- Nutrient Cycle Control
    - Dams can increase nitrogen, phosphorus, silicon, and carbon in the area immediately upriver from the dam (Wang et al. 2022) which can have cascading effects to the up- and down-river ecosystems depending on local hydrodynamics.

- Infrastructure Protection
    - Dam maintenance is expensive in the United States, often costing 10-30 times more than dam removal (Grabowski et al 2018, Perera and North 2021).

Habitat Services

- Habitat Provisioning
    - Large and small dams impact river ecosystems in the mid-Atlantic (Brown et al. 2024).

- Improved Habitat Connectivity
    - After dam removal, a floodplain and it's nearby aquatic and terrestrial habitats are reconnected which enhances connectivity for the movement of resident and migratory fish (Hamilton and Craig 2017).
    - Dam removal can improve ecosystem functionality, especially for migratory fish which hold economic and cultural value. The Federal Interagency Fish Passage Task Force 2022-2024 Accomplishments Report highlights some of these benefits (USFWS 2024).

- Supporting Biodiversity
    - Removal of dams in the United States increases the quality and quantity of fish habitat (Perera and North 2021).
    - After dam removal seasonal and weather-induced flows, temperatures and oxygen levels return to their natural variations and normally associated flora and fauna (Hamilton and Craig 2017).
    - Dams, culverts and waterfalls preclude fish species from migrating in New Jersey (Meixler 2021).
    - No adult river herring were detected upstream of Bloede Dam in the four years prior to its removal near Baltimore, Maryland, but were observed after dam removal (Huang et al. 2023).
    - American eel abundance in headwater streams increased significantly after the removal of Embrey Dam in Virginia (Hitt et al. 2012).
    - Dams can cause genetic diversity loss among freshwater fish populations (Zarri et al. 2022).

- Supporting Ecosystem Resilience
    - Removing dams can displace warm-water species that prefer lake-like environments, but it can support fish populations that thrive in colder-water rivers, such as trout, shad, and striped bass to recover (American Rivers, 2023). These colder water environments are sometimes referred to as cold water refugia which can help create a buffering capacity against warming river waters (EPA 2012, Johnson et al. 2024).

Cultural Services

- Source of Cultural Identity
    - Indigenous populations have historical ties to native fish species that may be blocked from migrating to tribal lands because of dams, like the herring of Tauton, Massachusetts which were found upriver from a removed dam during post-project monitoring (TNC 2019).

- Spiritual and Symbolic Interactions
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to a landscape after dam removal

- Educational Opportunities
    - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021)

- Aesthetic Value
    - The removal of a dam will change the aesthetics of a landscape with areas upstream likely to experience a reduction or loss of lake/pond habitats. While the reduction of these habitats is likely, ecosystems upstream of the dam removal can be maintained as a natural ecosystem that provides aesthetic value to communities (Wyrick et al. 2009).

- Recreational Value
    - The restoration of free-flowing rivers can offer valuable recreational opportunities such as boating and fishing (American Rivers, 2023).

- Social Well-Being
    - Shad have returned to the river after the removal of New Jersey's Columbia Dam. Locals are excited because, "Dam removals are so important for future generations...It is my kids and grandkids who will see the real benefits to this river," (TNC 2019).

What are the common challenges?

All relevant information is found in the Dam Removal Profile in Section 3.4.1.

How can I monitor this NBS?

All relevant information is found in the Dam Removal Profile in Section 3.4.1.

Where can I find funding for this NBS?

All relevant information is found in the Dam Removal Profile in Section 3.4.1.

4.2.8 – CULVERT REMOVAL AND UPGRADES ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the culvert removal and upgrade profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Culvert Removal and Upgrades Profile in Section 3.4.2.

Where should this NBS type go?

Below is additional information regarding where culvert removals or upgrades may be most appropriate.

Stream daylighting projects require enough width to facilitate a natural flow path with gentle, stable slopes. This often means that a considerably larger area is needed than what a buried stream occupies. In heavily dense urban settings, pre-existing buildings, roadways, and underground utility lines can greatly hinder the ability to create a channel effectively. Although built infrastructure can always be moved, the expenses related to such relocations can be prohibitively high, particularly in urban areas where land values are high. For this reason, daylighting in densely populated areas is frequently incorporated into larger economic revitalization initiatives that can take advantage of the new environmental features offered by the daylighted stream. (NRC 2017) Furthermore, it is crucial to comprehend the soil types and channel materials (like silt, clay, sand, or gravel) for any daylighting project. This understanding ensures that the project is designed appropriately and will function as intended. Additionally, existing conditions will have a substantial impact on project costs (Halff, 2018).

For a summary of technical considerations for a daylighting project, visit EPA's Stream Daylighting factsheet (2021) which also encourages project managers to consider: the seasonal effects and precipitation effects on streamflow, the location of the water table relative to the stream, the outflow of water through the channel's sides and bottom, the stability of the stream bank, and how the daylit stream will connect with existing upstream and downstream features.

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for dam removals where published values exist.

Overall Value

- A 2010 report found the value of removing barriers within a river system is $515,000 per river mile in 2010 dollars (Levine 2013).
- The ecosystem service values for freshwater wetlands, open fresh water, riparian buffers, and urban greenspace for water regulation, water supply, nutrient cycling, habitat, aesthetic and recreation, as well as cultural and spiritual is provided (Costanza et al. 2007).
- The non-use value of rivers based on studies published between 1978 and 2000 ranged from $17 to $262 with an average value of $108 per household in 2003 dollars (Levine 2013).

Material Benefits

- Harvesting Organic Materials
    - Depending on local water quality at the project site, communities may be able to fish at locations where culverts have been removed or upgraded.

- Improved Water Quality
    - Upgraded and well designed culverts are less likely to cause erosion and scour in the stream and are less likely to fail. Erosion, scour, and culvert failure can degrade local water quality (Levine 2013).
    - Upgraded culverts can improve drinking water quality (Moore 2017),

- Impact to Human Health
    - Upgraded culverts are resilient to extreme precipitation events which may cause aging culverts to fail and result in damage to roads and the isolation of households that may prevent emergency services from reaching individuals in need of medical assistance during and after storm events (Levine 2013).

- Impact to Mental Health
    - Upgraded culverts that are resilient to extreme precipitation events can preclude road closures that may cause travel delays, loss of tourism revenue, and lost income for those who may miss work if they are not able to access their place of employment (Levine 2013).

Natural Processes Benefits

- Air Quality Improvement
    - Culvert removal and upgrades, depending on the volume of heavy machinery involved may "release fossil fuel emissions and particulate matter into the air from excavation and grading procedures, and deposition of backfill material. The impacts to air quality from construction activity on a local and regional scale will be minor and limited to the construction period. No long-term impact to air quality will result from construction activity" related to culvert removal and upgrades (DonTingny et al. 2017).

- Climate Regulation
    - Stream daylighting can help to lower nearby air temperatures, particularly in more urban environments (Khirfan et al. 2020).

- Carbon Sequestration
    - Floodplain restoration projects can enhance the environment's capacity for carbon sequestration with site specific variables informing how to maximize carbon sequestration abilities (Hinshaw and Wohl 2023) especially where riparian vegetation is implemented.

- Pollinator Services
    - Planting native plants that attract pollinators can support local wildlife and the aesthetics of a stream daylighting project (CHA 2024).

- Erosion Control
    - Upgrade culverts can reduce streambed and streambank erosion (Levine 2013).

- Nutrient Cycle Control
    - Daylighting streams provides nutrient retention benefits by allowing nutrients to be stored and transformed over time rather than being transported in quick pulses of nutrients that may result in algal blooms downriver (Trice 2016).

- Infrastructure Protection
    - The cost of repairing a road impacted by a washed out culvert in Vermont after Tropical Storm Irene was $1.1 million (Gillespie et al. 2014).
    - Cost of culvert replacements in New Jersey are provided at NJDOT's Cost Estimating Guideline Reference Document (2019).

Habitat Service Benefits

- Habitat Provisioning
  - Buried urban streams prevents light and the direct organic matter inputs into streams from the riparian zone which can have negative impacts on stream ecology (Arango et al. 2017).

- Improved Habitat Connectivity
  - Culverts can have a negative impact on freshwater biota and on entire stream ecosystems and culvert upgrades can increase local ecological health and connectivity (Frankiewicz et al. 2021).

- Supporting Biodiversity
  - Upgraded culverts yield healthier rivers and streams as well as populations of fish and other wildlife (Levine 2013).
  - A daylit stream in Norway experienced colonization of benthic algae and macroinvertebrates within 9 months of project completion (Baho et al. 2021).

- Supporting Ecosystem Resilience
  - Daylit streams and upgraded culverts can enhance the resilience of an aquatic ecosystem by creating areas less susceptible to flooding and urban heat such that the area can better withstand disturbances like extreme rainfall and temperatures.

Cultural Benefits

- Source of Cultural Identity
  - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's cultural and spiritual ties to the more natural ecosystems established by daylighting a stream or upgrading culverts.

- Spiritual and Symbolic Interactions
  - See "Source of Cultural Identity" above.

- Educational Opportunities
  - Deculverting streams can provide recreational and educational opportunities for children, enhancing pedestrian and cycle routes, and bringing nature closer to people (Wild et al., 2011).

- Aesthetic Value
  - Daylighting a stream in Kalamazoo, Michigan (uncovered 1,550 feet of Arcadia Creek costing $18 million) resulted in $200 million in private development, an increase in annual property tax revenues from $60,000 to $400,000, and $12 million annually from festivals that are held on site (Kuester 2024).

- Recreational Value
  - Daylighting a portion of Pittsburg, PA's Nine Mile Run in 2006 (Kuester 2024) included the creation of the Nine Mile Run Trail which provides recreational value to visitors and locals (Sharper 2014, Williams 2024).
  - Upgraded culverts can yield healthier fish populations and improved movement of fish which can result in better opportunities for recreational fishing (Levine 2013).

- Social Well-Being
  - "The social benefits associated with improved stream crossings are primarily the result of avoided or reduced flood impacts and/or culvert failure" (Levine 2013).

What are the common challenges?
All relevant information is found in the Culvert Removal and Upgrades Profile in Section 3.4.2.

How can I monitor this NBS?
All relevant information is found in the Culvert Removal and Upgrades Profile in Section 3.4.2.

Where can I find funding for this NBS?
All relevant information is found in the Culvert Removal and Upgrades Profile in Section 3.4.2.

4.2.9 – VEGETATIVE RIPARIAN BUFFER ZONE ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the vegetative riparian buffer zone profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Vegetative Riparian Buffer Zone Profile in Section 3.4.3.

Where should this NBS type go?

Below is additional information regarding the design of vegetative riparian buffer zones that may inform where construction of these NBS would be most appropriate.

Experts have created guidance materials to help land managers build riparian buffers suitable to their environmental hazard (Brittingham M. & DeCecco J., 2024; NYDEC, undated). Factors to consider before implementing riparian zones include:

- ✓ Steepness of slope – A slope of less than 6% is recommended to slow runoff through riparian buffers (ACES, undated).
- ✓ Soil characteristics, such as clay content, organic material, and infiltration rate.
- ✓ Size of runoff-contributing area.
- ✓ Existing vegetation.
- ✓ Availability of native vegetation adaptable to the area.
- ✓ Climatic conditions at planting times.
- ✓ Possible combinations of conservation practices upslope of the riparian zone to reduce erosion, slow runoff velocity, and ensure uniform flow through practice.

Riparian buffer zones are recommended to be at least 50 to 100 feet wide and can be expanded in certain conditions. The width of the buffer zone depends on factors such as pollutant type, field length, slope, soil texture, and field management. The recommended width by the U.S. Forest Service in the Northeast region is 75 ft. on both sides of a stream-based system for improved water quality purposes (SERA-17, 2023).

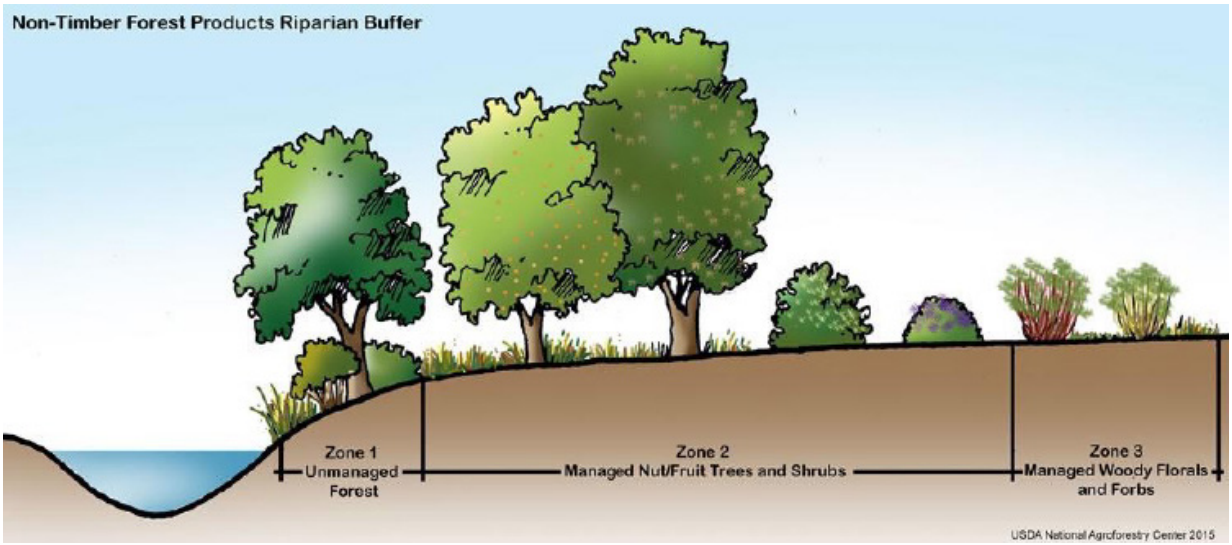
Riparian buffer zones are important in both rural and urban environments but creating a riparian buffer zone in and around urban environments come with additional challenges. For example, high flow rates can be present in urban areas due to paved terrain and compressed surfaces, e.g., turf and compacted soil. If those high flow rates discharge towards a riparian buffer, their effectiveness would be reduced and could potentially cause erosion to both the buffer and the banks of the stream.

Guidance materials regarding best management practice for building and maintaining riparian buffer zones exist (e.g., the Association of New Jersey Environmental Commission's Protecting Our Streams Report (2019) restoration is the three-zone concept which consists of the following:

- Zone 1: The area closest to the waterbody should be planted with native, water-tolerant trees and shrubs with no harvesting. This zone provides stabilization and organic material to the stream by leaf litter which serves as food to animals. Trees cool the stream by shading it and offer better conditions for cold water-dependent fish such as trout. This zone should be at least 15 feet wide.

- Zone 2: The zone upland from Zone 1 should be planted with faster-growing, smaller, and shade-tolerant native trees or shrubs. This zone alleviates water runoff by absorbing it and holding it onto the soil; nutrients and other pollutants are filtered as well. The reason to plant fast-growing plants is their ability to uptake and store nutrients. Zone 2 can range from 20 to 60 feet in width.

- Zone 3: The farthest zone from the waterbody should be planted with native grasses, wildflowers, or other herbaceous plants. As well as with Zone 2 these plants aid in filtering water runoff and sediment. This area should range from 15 to 60 feet in width.



In total, the riparian buffer should measure at least 100 feet as it provides the minimum protection for water quality and stream protection. Wider buffers provide higher levels of stream protection and wildlife habitat. A wide diversity of plants is key in each zone. Zones with more biodiversity are more resilient to extreme weather events and animal disturbance (i.e. deer or rodents), as well as more competitive against invasive species or pests (NYDEC).

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for vegetative riparian buffer zones where published values exist.

Material Benefits

- Harvesting Organic Materials
    - Some riparian buffers are planted with fruit or nut trees that can be harvested as food.

- Improved Water Quality
    - Riparian buffers improve water quality and sequester carbon in the Mid-Atlantic near agricultural lands which is valued at $70.6 million for 30 meter buffers and $431.2 million for 60 meter buffers including more than 10 states, including NJ (Jager et al. 2023)
    - Riparian-buffer zones are part of a healthy riparian environment as they provide water quality benefits such as reduced nutrient pollution (i.e., RBZ trap nitrate without starving the water body of natural organic matter) and temperature regulation (Correll, 2005).

- Improved Human Health
    - Urban freshwater systems can protect human health and support well-being by masking traffic noise, reducing summer temperatures, and providing space for physical activity, social interaction, and recreation (Higgins et al. 2019).

- Improved Mental Health
    - Blue space (e.g., natural waterways surrounded by vegetation) are restorative and promote relaxation (Higgins et al. 2019).

Natural Processes Benefits

- Air Quality Improvement
    - Riparian buffers in the Delaware River Basin provide air quality benefits by capturing and storing airborne particles, nitrogen, and sulfur dioxides that could harm human health. This service is valued at $3 to $132 per acre per year (ECONorthwest 2018).

- Climate Regulation
    - Riparian buffers can create shade over a waterbody which help to cool waters in the summer and can decrease the abundance of fish kills and algae blooms in a water body (ECONorthwest 2018).

- Carbon Sequestration
    - Riparian buffers in the Delaware River Basin provide carbon storage valued at $4,762 to $8,477 per acre per year (ECONorthwest 2018)

- Erosion Control
    - Vegetated riparian buffer zones reduce erosion by (1) providing habitat for plant species with deeper roots that support the riverbank and reduce erosion and (2) preventing livestock from congregating at the riverside for drinking and thus reducing bank erosion (Cole et al. 2020).

- Pollinator Services
    - Vegetated riparian buffer zones planted with appropriate foliage may increase the presence of pollinators on site.

- Nutrient Cycle Control
    - Riparian buffers in the Delaware River Basin provide nutrient retention valued at $87 to $4,789 per acre per year (ECONorthwest 2018).

- Infrastructure Protection
    - Increase surrounding property values. (EPA, 2021). Riparian buffer zones can cause an increase in local property values when compared to properties that do not benefit from the riparian buffer zone flood mitigation abilities and aesthetic value. A study from the University of Maryland compared sales data for riparian and nonriparian land parcels adjacent to the Neuse River. The study concluded that riparian properties experienced a 26% premium over an otherwise equivalent property (Shinde et al., 2024).
    - Riparian buffer zones protect property by providing an area to safely store floodwater (Shinde et al., 2024).

Habitat Service Benefits

- Habitat Provisioning
    - A riparian buffer zone creates habitat for wildlife and can increase terrestrial and aquatic biodiversity (Cole et al. 2020).

- Improved Habitat Connectivity
    - Riparian buffers can be conduits for daily movement and annual migration of species as they serve as connections between isolated habitats (ECONorthwest 2018).

- Supporting Biodiversity
    - Riparian buffers provide aquatic and terrestrial habitat for wildlife (ECONorthwest 2018).
    - RBZ also provide habitat for many species such as eastern cottontail, white-footed mouse, and meadow vole (Jessop et al., 2015; Brittingham M. & DeCecco J., 2024)

- Supporting Ecosystem Resilience
    - Riparian buffers are part of a healthy watershed ecosystem. Monetized values for the Delaware River basin are detailed by Kauffman (2016).

Cultural Benefits

- Source of Cultural Identity
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's cultural and spiritual ties to the aquatic and terrestrial habitats vegetated riparian buffer zones provide.

- Spiritual and Symbolic Interactions
    - See "Source of Cultural Identity" above.

- Educational Opportunities
    - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021)

- Aesthetic Value
    - Riparian buffers in the Delaware River Basin provide aesthetic values reflected in an increase of 1% to 26% in property prices (ECONorthwest 2018)

- Recreational Value
    - Riparian systems help in enhancing the environment for recreational uses such as camping, parks, boating, and fishing. They also provide and improve wildlife habitat that in turn enhances the quality of fishing, hunting, wildlife viewing, nature photography, and other wildlife-depending activities (Shinde et al., 2024).
    - Riparian buffers in the Delaware River Basin provide recreation opportunities valued at $63 per acre per year by providing recreational fishing opportunities, hunting and wildlife viewing opportunities, and more (ECONorthwest 2018)

- Social Well-Being
    - See "Improved Human Health."

What are the common challenges?
All relevant information is found in the Vegetative Riparian Buffer Zone Profile in Section 3.4.3.

How can I monitor this NBS?
All relevant information is found in the Vegetative Riparian Buffer Zone Profile in Section 3.4.3.

Where can I find funding for this NBS?
All relevant information is found in the Vegetative Riparian Buffer Zone Profile in Section 3.4.3.

4.2.10 – FRESHWATER WETLAND ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the freshwater wetland profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Freshwater Wetland Profile in Section 3.4.4.

Where should this NBS type go?

Below is additional detail regarding the planning process for a freshwater wetland that may inform where construction of this NBS would be most appropriate.

The following steps are an overview of the general process to identifying the suitable project location and restoration action:

1. Contact your local NRCS Service Center to help elucidate the location of a former wetland and soil characteristics.
2. Identify environmental stressors that may have damaged an existing wetland.
3. List your project goals and timeline as some wetland restoration projects may take several years until the full suite of ecological benefits are realized. This is due, in part, to the time it takes full plant diversity at a wetland restoration site to exist. For example, restoring a shallow marsh community with some open water offers the best chance for success with emergent plants like grasses and sedges becoming established within a few years. However, larger plants like trees and shrubs will take longer and may not fully develop due to unstable water levels or floods (Cole et al. 2024).
4. Engage landowner(s) and local community to educate, gather feedback on the project idea, and modify site plans accordingly.
5. Conduct a site assessment to understand the past and current conditions of a project site. This assessment will help to identify: whether a wetland previously existed on the site if NRCS and other State resources are inconclusive, factors contributing to wetland loss, former conditions of the site (such as the presence of toxic materials), and the current condition of the site (including topography, erosion, evidence of drainage and water movement patterns, vegetation, human structures and land use, and adjacent land uses). It is recommended that the area being considered for a transition area (i.e., buffer zone between wetland area and surrounding area) be included in this site assessment. (ANJEC 2019).

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for freshwater wetlands where published values exist.

Provisioning Services

- Harvesting Organic Materials
    - Wetlands provide a variety of natural resources such as fish, shellfish, blueberries, cranberries, and timber. Their soil and plants are source of some medications and the fishing and shellfish industries depend on wetland-dependent species for their harvest (EPA, 2024).

- Improved Water Quality
    - Wetlands contribute to the enhancement of water quality, such as drinking water, by capturing surface runoff and eliminating or holding in inorganic nutrients, managing organic wastes, and decreasing suspended sediments before they enter open water (EPA, undated).
    - New Jersey's freshwater wetlands are estimated to provide $5,957 per acre annually in water regulation services and $1,161 per acre annually in water supply services (Costanza et al. 2006).

- Improved Human Health
    - Wetlands contribute positively to water quality, human nutrition (i.e., food from wetland system and food from agricultural operations that may rely on water from wetlands for irrigation), and medicines (Horowitz and Finlayson 2011). A wetland can be negatively impacted by poor adjacent environmental conditions (e.g., poor sanitation that pollutes the wetland) which could cause the wetland to be a vector for diseases (Dale and Connelly 2012), but proper watershed scale management can mitigate these negative impacts.

- Improved Mental Health
    - An English study found freshwater wetlands provide significant improvement to mental health across a range of indicators including mental wellbeing, anxiety, stress and emotional well being (Maund et al. 2019; global: Dale and Connelly 2012)

Regulating Services

- Climate Regulation
    - Wetland restoration is a long-term natural climate solution (Schuster et al. 2024)
    - Wetlands can cause significant reductions in air temperature, especially in urban or arid areas, helping mitigate heat. Because cooling ability becomes marginally smaller as the wetland increases in size, smaller ephemeral wetlands have a greater cooling potential than larger wetlands per acre (Wu et al. 2021).

- Carbon Sequestration
    - Freshwater wetland restoration can effectively turn degraded wetlands from net carbon sources into carbon sinks (Schuster et al. 2024)

- Erosion Control
    - Freshwater wetlands reduce erosion (Johnston 2009)

- Nutrient Cycle Control
    - Freshwater wetlands reduce the turbidity and suspended solids concentrations in surface waters while retaining phosphorus and contaminants in the wetland itself (Johnston 2009).

- Infrastructure Protection
    - A 2007 456-acre ecological restoration of Lower Cape May Meadows included freshwater wetland restoration, construction of a sand dune, and two miles of beach replenishment which is estimated to have provided $9.6 million in avoided costs from flooding over 50 years as well as generating $313 million annually for birding activities and $11-12.5 million annually in beach recreation which includes the value visitors place on habitat for wildlife from increased beach width (Schuster 2014).

Habitat Services

- Habitat Provisioning
    - Fish and wildlife utilize wetlands to different extents based on the species. Some species live exclusively in wetlands throughout their lives, while others need wetland habitat for part of their life cycle. Some use wetlands primarily for feeding, while for others, wetlands serve as crucial seasonal habitats with abundant food, water, and cover (EPA, undated).
    - New Jersey's freshwater wetlands are estimated to provide $5 per acre annually in habitat/refugia value (Costanza et al. 2006).

- Improved Habitat Connectivity
    - The value of US geographically isolated wetlands is estimated at $191.82 billion (Viteritto 2024).

- Supporting Biodiversity
    - Wetlands are often referred to as "biological supermarkets" due to their ability to create significant amounts of food that attract a wide variety of animal species. The complex and ever-changing feeding connections among the organisms residing in wetland environments are called food webs. The combination of shallow water, abundant inorganic nutrients, and high levels of primary productivity (the production of new plant biomass through photosynthesis) in many wetlands is perfect for the growth of organisms that serve as the foundation of the food web. (EPA, undated)

- Supporting Ecosystem Resilience
    - Freshwater wetlands enhance the resilience of an ecosystem by effectively managing runoff, filtering pollutants, recharging groundwater, and more to create an environment that can better withstand disturbances such as precipitation and storm events.

Cultural Services

- Source of Cultural Identity
    - The Pateira de Fermentelos freshwater wetland (Portugal) cultural value has been valued at 1.5 million euros per year and up to 2.02 million euros per year if surface waters are good quality (Roebeling et al. 2016).

- Spiritual and Symbolic Interactions

    No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to a wetland.

- Educational Opportunities
    - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021)

- Aesthetic Value
    - See recreational value below.

- Recreational Value
    - New Jersey's freshwater wetlands are estimated to provide $1,571 per acre annually in aesthetic and recreational value (Costanza et al. 2006).
    - Wetlands provide habitat for plants and animals that people enjoy for recreational and economic

purposes. People visit wetlands to observe bald eagles, osprey, and other wetland animals and plants. Some go for photography or painting, others for hunting, and some for hiking or canoeing. While water is a significant part of the experience, it's the unique species that inhabit wetlands that make it a distinct and special experience compared to being on an open lake or hiking in the woods. Over half of U.S. adults participate in hunting, fishing, birdwatching, or wildlife photography, generating significant income for communities near wetlands. (NPS, 2015)

- Social Well-Being
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express the anticipated benefits to a community's well being where wetlands are restored or preserved.

What are the common challenges?

All relevant information is found in the Freshwater Wetland Profile in Section 3.4.4.

How can I monitor this NBS?

Below is additional detail on the various resources available to help monitor a wetland restoration after construction:

1. Freshwater and Biological Monitoring of Habitat Health – NJDEP conducts habitat surveys when conducting biological monitoring of project sites. A "high gradient habitat assessment" is used in the northern portions of New Jersey (north of the fall line), while a "low gradient habitat assessment" is used in the coastal plain of southern New Jersey. To learn more about these sampling methods and to download the habitat assessment forms, visit NJDEP's Division of Water Monitoring and Standards here.
2. Creating Indicators of Wetland Status (Quantity and Quality), Freshwater Wetland Mitigation in New Jersey (2002) – A diverse group of experts outlined indicators of progress toward the State's wetland mitigation goals which is summarized in this report. The monitoring metrics therein could be a good starting point for measuring wetland restoration at a project level. Suggested monitoring techniques include measuring the wetland area achieved, a concurrence evaluation (i.e., a measure of the degree to which the mitigation achieved is consistent with restoration plans) and a wetland mitigation quality assessment.
3. Community Monitoring – Engaging community volunteers in wetland monitoring is a great way to build public wetland literacy. There are numerous resources available regarding water quality monitoring at wetlands:

    - To learn more about active water quality monitoring efforts that may supplement wetland restoration monitoring, visit the New Jersey Watershed Watch Network.
    - For education materials, trainings, and templates for community water monitoring, visit NJDEP's Community Water Monitoring website.
    - Examples of local water quality monitoring can be seen on the Lower Raritan Watershed Partnership's website and training video.

Where can I find funding for this NBS?

All relevant information is found in the Freshwater Wetland Profile in Section 3.4.4.

4.2.11 – URBAN FORESTRY ADDITIONAL INFORMATION

This appendix contains additional information discussed briefly in the urban forestry profile. Additional information is organized by the same headers used in the main profile. Headers are from the main profile are omitted below if the main profile covers all relevant information.

Introduction

All relevant information is found in the Urban Forestry Profile in Section 3.5.1.

Where should this NBS type go?

Below is additional detail regarding the planning process for a urban forestry NBS that may inform where construction of these NBS would be most appropriate.

Planting trees in urban and suburban environments requires thoughtful planning and long-term maintenance to maximize the ecological, socioeconomic, and physiological benefits of trees. The following is an overview of considerations for identifying the proper location for tree planting (refer to the Natural Lands profile for tips on improving or building parks and greenways) (Maidl 2021):

1. **Determine Planting Goals:** Individuals planning a tree planting project should first identify the purpose for planting a tree (e.g., mitigating stormwater issues, reducing urban heat, improving quality of life for locals). These goal(s) help to prioritize sites for additional suitability analyses. Best practices for planting trees to cool buildings can be found in the EPA's Reducing Urban Heat Islands: Compendium of Strategies (2017), while identifying sites for tree boxes can be found on Rutgers' Green Infrastructure Practices: Tree Boxes Fact Sheet (2013). Refer to the Common Challenges section below for tips on planning and thinking regionally about tree planting.
2. **Confirm Available Space:** Trees have a critical root zone (CRZ) which is the root area around a tree that is necessary for a tree to survive. A CRZ extends radially from a tree's base by 1 to 1.5 feet for every inch of the tree's diameter (e.g., a mature oak tree that is 38 inches in diameter would benefit from undisturbed soil anywhere within 38 feet of the tree; EPA 2021). Tree growth may also be hindered by underground and aboveground utilities (e.g., pipes, powerlines) as well as other structures (e.g., buildings) that may be in the way of tree branches as the tree grows. It may be beneficial to also consider a tree's proximity to streets, sidewalks, and other paved areas as tree roots that grow under these structures may cause damage (Macie and Workman 2019).
3. **Ensure Sufficient Sunlight, Water, Soil Volume, and Soil Quality:** Trees require adequate sunlight, water, and healthy soil to survive. Where soil conditions are not ideal, soil amendments can be applied (e.g., compost) and invasive species can be removed to reduce competition. Refer to the Stormwater Tree Bed Guidance Manual (available here) and the Center for Watershed Protection's Urban Reforestation Site Assessment (available here) for additional information on these topics.
4. **Selecting Tree Species:** Planting trees may introduce pollen that can cause health problems (Sicard et al. 2018) as well as fruit and leaf litter which could contribute to increased seasonal maintenance costs (Keeler et al. 2019; Drew-Smyth et al. 2023). Proper tree selection would mitigate these concerns. Additional characteristics to consider are trees that can tolerate and filter pollution, withstand drought, provide tree canopy, and are aesthetically pleasing. Granted, increasing the number of characteristics required for a planting project can severely constrain the list of potential species to choose from. Species recommendations and checklists can be found on Cornell University's Urban Horticulture Institute website (accessible here) which includes The Recommended Urban Tree Guide: Site Assessment and Tree Selection for Stress Tolerance (Bassuk et al. 2009).

What are the co-benefits of this NBS?

Below is a detailed list of the co-benefits that have been quantified or monetized for the New Jersey ecoregion for living shorelines where published values exist.

Material Benefits

- Harvesting Organic Materials
    - Planting fruit and nut-bearing trees, especially in low-income neighborhoods, can produce food in public areas and improve food security (Wilson 2011). The Philadelphia Orchard Project is a nearby success story which supports over 69 urban orchards that accomplish this co-benefit.

- Improved Water Quality
    - Stormwater planters and tree beds reduce runoff and water pollution (RCEWRP 2023).

- Improved Human Health
    - Urban trees that are planted in a high biodiversity pattern (with different tree species adjacent to one another) is associated with lower mortality rates for heart disease and stroke (Giacinto et al. 2021)
    - Living in urban areas with more green spaces was associated with improved cardiovascular health in people free of acute myocardial infarction and heart failure but not among individuals who have already developed these conditions (Chen et al. 2020)
    - Prenatal and perinatal exposure to air pollutants can cause respiratory diseases in children and adults (Kim et al. 2020). While exposure to air pollutants at a young age are strongly associated with asthma exacerbations of children (Tosca et al. 2014), urban forest environments seem to help protect children from respiratory morbidity (e.g., wheezing, sneezing, runny nose, itchy eyes) (Almeida et al. 2020)
    - Reduced gun violence – fewer gunshot assaults have been found in areas of high tree coverage. It is also important to design landscaping with "Crime Prevention Through Environmental Design" techniques in mind (e.g., reduce shrubbery to improve sightlines and sense of security) (Wolf et al. 2010, Kondo et al. 2017, Lee 2021, Nuccitelli er al. 2023)
    - Cancer protection - trees can reduce the risk of skin cancer due to shade protection (Moreno et al. 2015)

- Improved Mental Health
    - Stress reduction and social cohesion (sense of safety, beauty) – social cohesion also reduces premature deaths because individuals feel connected to their communities. (Vincent et al. 2017)
    - Trees provide a sense of place – A survey of Sydney, Australia residents with low educational levels (vocational or less) who were asked about their tree planting preferences noted they value trees mainly for their aesthetic value and because of "generational legacy" (Saldarriaga 2020)
    - Trees increase a student's ability to succeed in school and are linked to improved student performance, stress reduction, increased concentration, reducing ADD/ADHD symptoms, increase in attention, and increase in self-discipline (Turner-Skoff and Cavender 2020).
    - Prevalence of trees in urban environments are associated with improved academic performance in school aged children (Sivarajah et al. 2018)

Natural Process Benefits

- Air Quality Improvement
    - Urban and community forests in New Jersey in 2000 were estimated to remove 30,070 metric tons of total pollution annually including carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter with a diameter of 10 microns or less (PM10) providing an ecosystem service valued at $244.2 million annually (Nowak and Greenfield 2009).
    - Urban forests in New Jersey using 2014 tree cover estimates and 2010 pollution conditions are estimated to remove 22,000 tons of air pollution per year providing an ecosystem service valued at $219.8 million annually (Nowak and Greenfield 2018).

- Climate Regulation
    - Street trees reduce summer high heat exposure (New Jersey Watson 2023; Washington, Ettinger et al. 2024).
    - Urban forests in New Jersey alter building energy use by shading buildings, cooling air temperatures, and altering wind speeds around buildings. This is estimated to provide $219.8 million in energy savings (± $10 million) annually and save $57 million in avoided emissions (± $2.6 million) (Nowak and Greenfield 2018).

- Carbon Sequestration
    - Urban and community forests in New Jersey in 2000 were estimated to store carbon providing an ecosystem service valued at $663.5 million. These forests also sequester carbon at a value of $21.9 million annually. (Nowak and Greenfield 2009)
    - Urban forests in New Jersey (based on 2010 urban land estimates, 2014 tree cover estimates, and 2015 carbon values) are estimated to sequester over 1.1 million tons of carbon annually, providing an ecosystem service valued at $146.6 million annually (Nowak and Greenfield 2018).

- Nutrient Cycle Control
    - Estimates for the amount of pollutants different trees (i.e., conifers and deciduous trees) can remove from the environment are highlighted in the USDA's Urban Forest Systems and Green Stormwater Infrastructure fact sheet (2020).

- Erosion Control
    - Urban green open space reduces erosion which provides an ecosystem service valued at $68 per acre annually (in 2021 dollars) (FEMA 2022).

- Pollination Control
    - Urban green open space is valued at providing pollinator services valued at $305 per acre annually (in 2021 dollars) (FEMA 2022).

- Infrastructure Protection
    - Urban green open space is valued at providing flood hazard risk reduction valued at $316 per acre annually (in 2021 dollars) (FEMA 2022).

Habitat Services Benefits

- Habitat Provisioning
    - Street trees create habitat for wildlife (TNC 2024)

- Improved Habitat Connectivity
    - Urban ambient noise is also well recognized to reduce bird species richness (McCloy et al. 2024)
    - Supporting Biodiversity
    - Small (less than 2 hectares) and large urban green spaces that use native plant species, particularly trees, support songbird populations (Hursh et al. 2024).
    - Public parks and private yards are key to supporting native bird diversity with bird abundance and diversity varying across seasons and in adjacent towns (Illinois; Pollock et al. 2024)
    - Urban tree corridors have increased biodiversity of insects, small mammals, and native plants (Arborist Now 2024)

- Supporting Ecosystem Resilience
    - Urban forests can increase the resilience of nature and people to anthropogenic and natural stressors, but there is no standardized threshold for what makes an urban forest more resilient (Huff et al. 2020).

Cultural Benefits

- Source of Cultural Identity
    - Oak trees are a symbol of endurance and longevity and hold a cultural role in United States inspiring place names, are depicted in stories and art, and appear on flags and coins (Bocsi et al. 2021)

- Spiritual and Symbolic Interactions
    - No monetized or quantified values were found for this co-benefit. However, this does not indicate the co-benefit does not exist. Qualitative description can be used to express a community's spiritual ties to green space.

- Educational opportunities
    - Educational materials distributed to communities before, during, and after a NBS project is completed (including signs at the NBS location) can serve as a public education tool to enhance the public's understanding of NBS and help connect them with nature. Some tools to measure this connection are discussed in Improving Assessments of Connection to Nature: A Participatory Approach (Salazar et al. 2021)

- Aesthetic Value
    - Urban greenspace in New Jersey is estimated to provide $2,131 per acre annually in 2004 dollars (Costanza et al. 2006).

- Recreational Value
    - New Jersey open spaces have a recreational value for those interested in engaging in those open spaces both actively and passively (Airola and Wilson 1982)

- Social Well-Being
    - Restoration activities create jobs for environmental consultants, engineers, construction workers, geologists, project managers, fishermen, biologists and divers (Samonte et al. 2017).
    - Access to parks and nature can improve well-being by increasing social connections, increasing public safety, and improve mental health (City Health 2023)

What are the common challenges?

All relevant information is found in the Urban Forestry Profile in Section 3.5.1.

How can I monitor this NBS?

All relevant information is found in the Urban Forestry Profile in Section 3.5.1.

Where can I find funding for this NBS?

All relevant information is found in the Urban Forestry Profile in Section 3.5.1.

4.3 GENERAL RESOURCES

The following table includes resources that relate to NBS. Resources include nationwide and global sources. Where no information could be found or accessed, this is indicated with the "–" symbol. Please note this is not necessarily a comprehensive list and more information may be available online. Where original links are no longer accessible, the Internet Archive Wayback Machine has been used to create functional links to original sources.

Title	Author	Link	Industry Type	Pub Date	Media Type
Cost estimates for flood resilience and protection strategies in New York City	Aerts, Jeroen C.; Botzen,Wouter J.; de Moel, Hans; Bowman, Malcolm	https://doi.org/10.1111/nyas.12200	Academia	2013	Doc
Green Street Infrastructure as a Coastal Resilience Strategy and Route 35 Rain Garden Feasibility Study	Bartolone, Richard; Messina, Darlene	https://issuu.com/mrkleier/docs/raingarden	Academia	2012	Doc
Creating Flood Resilient Landscapes	Brooke Maslo	https://rcei.rutgers.edu/resources/flood-resilient-new-jersey/	Academia	2023	Doc
The value of coastal wetlands for hurricane protection	Costanza, Robert; Perez-Maqueo, Octavio; Martinez, M. Luisa; Sutton, Paul; Anderson, Sharolyn J.; Mulder, Kenneth	https://doi.org/10.1579/0044-7447(2008)37[241:TVOCWF]2.0.CO;2	Academia	2008	Doc
Greauxing Resilience at Home City of North Miami, Florida: Good Neighbor Stormwater Park and Repetitive Loss Master Plan	Georgetown Climate Center	https://www.georgetownclimate.org/files/Louisiana%20Regional%20Vision/Greauxing_Resilience_%20North_Miami.pdf	Academia	2022	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Towards a comprehensive green infrastructure typology: a systematic review of approaches, methods and typologies	Koc et al. 2017	https://link.springer.com/article/10.1007/s11252-016-0578-5	Academia	2016	Doc
The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA	Narayan, Siddharth; Beck, Michael W.; Wilson, Paul; Thomas, Christopher J.; Guerrero, Alexandra; Shepard, Christine C.; Reguero, Borja G.; Franco, Guillermo; Carter Ingram, Jane; and Trespalacios, Dania	https://www.nature.com/articles/s41598-017-09269-z	Academia	2017	Doc
Mitigating Shore Erosion along Sheltered Coasts	National Research Council	https://nap.nationalacademies.org/catalog/11764/mitigating-shore-erosion-along-sheltered-coasts	Academia	2007	Doc
Municipal initiatives for managing dunes in coastal residential areas: a case study of Avalon, New Jersey, USA	Nordstrom, Karl. F.; Jackson, Nancy, L.; Bruno, Michael, S.; de Butts, Harry A.	https://www.sciencedirect.com/science/article/abs/pii/S0169555X02000843?via%3Dihub	Academia	2002	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Nature-based Solutions Valuation Report Incorporating climate-informed cost-benefit analysis into assessment of Nature-based Solutions in Latin America and the Caribbean	Northeastern University School of Public Policy and Urban Affairs	https://cssh.northeastern.edu/policyschool/wp-content/uploads/sites/2/2021/07/Northeastern-NbS-report-final.pdf	Academia	2021	Doc
Valuing Natural Habitats for Enhancing Coastal Resilience	Rezaie, Ali Mohammad; Loerzel, Jarrod.; Ferreira, Celso M.	https://doi.org/10.1371/journal.pone.0226275	Academia	2020	Doc
Coastal marshes provide valuable protection for coastal communities from storminduced wave, flood, and structural loss in a changing climate	Sheng, Peter Y.; Paramygin, Vladimir A.; RiveraNieves, Adail A.; Zou, Ruizhi; Fernald, Sarah; Hall, Timothy; Jacob, Klaus	https://doi.org/10.1038/s41598-022-06850-z	Academia	2022	Doc
Understanding the Effectiveness of Coastal Nature-based Solutions: Practitioner-based Learning	University of Arizona: Center for Climate Adaptation Science & Solutions	https://ccass.arizona.edu/sites/default/files/2023-06/CASC%20NbS%20Report%20Final.pdf	Academia	2023	Doc
Automating the Labor of Decision: The Contradictions of Cost-Benefit Analysis	A. Campbell, P. Bond and I. Yanez, eds., The Radical Political Economy of the Environment	https://www.thecornerhouse.org.uk/sites/thecornerhouse.org.uk/files/CBA%20SUPER-SHORT%20VERSION.pdf	Academia	2023	Publica-tion

Title	Author	Link	Industry Type	Pub Date	Media Type
Beneficiaries, Equity, and Trade-Offs in Estuarine and Coastal Ecosystem Services	Arkema et al. 2024	https://static1.squarespace.com/static/53c8c0c7e4b0b8f450cea5bb/t/65bb2a3c596f292a603a38f0/1706764869435/Arkema+et+al.+2024.pdf	Academia	2024	Publication
The Value of Estuarine and Coastal Ecosystem Services	Barbier et al. 2011	https://pdfs.semanticscholar.org/9a19/6633d12a16f3d6a2aed1e6d551129e872ed9.pdf	Academia	2011	Publication
What are ecosystem services? The need for standardized environmental accounting units	Boyd and Banzhaf	https://www.sciencedirect.com/science/article/abs/pii/S0921800907000341	Academia	2007	Publication
Climate Change Adaptation Case Study: Benefit-Cost Analysis of Coastal Flooding Hazard Mitigation	Cooper, Will; Garcia, Federico; Pape, Diana; Ryder, David; Witherell, Ben	https://doi.org/10.15351/2373-8456.1059	Academia	2016	Publication
Valuing New Jersey's Natural Capital: An Assessment of the Economic Value of the State's Natural Resources, April 2007	Costanza 2007	https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1008&context=iss_pub	Academia	2007	Publication

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Understanding the value and limits of nature-based solutions to climate change and other global challenges	Department of Zoology University of Oxford	https://royalsocietypublishing.org/doi/pdf/10.1098/rstb.2019.0120	Academia	2020	Publication
Cost effective conservation Planning	Duke et al. 2013	https://www.sciencedirect.com/science/article/abs/pii/S030147971300220X	Academia	2013	Publication
The California Coast and Living Shorelines - A Critical Look	Gary B Griggs	https://www.mdpi.com/2077-1312/12/2/199	Academia	2024	Publication
The Cost of Shoreline Protection: A Comparison of Approaches in Coastal New England and the Mid-Atlantic	Gonyo, Sarah Ball; Zito, Ben; Burkart, Heidi	https://doi.org/10.1080/08920753.2023.2186091	Academia	2023	Publication
Economics Valuation of Ecosystem Services Provided by Oyster Reefs	Grabowski et al. 2012	https://academic.oup.com/bioscience/article/62/10/900/238172	Academia	2012	Publication
Public perceptions of the functions of natural and engineered infrastructure in coastal hazards mitigation: the cases of two communities in the Raritan bayshore, New Jersey	Gray 2017	https://digitalcommons.njit.edu/dissertations/14/	Academia	2017	Publication

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Global estimates of the value of ecosystems and their services in monetary units	Groot et al. 2012	https://www.es-partnership.org/wp-content/uploads/2020/08/2012-De-Groot-et-al-Global-Estimates.pdf	Academia	2012	Publication
Dam and reservoir removal projects: a mix of social-ecological trends and cost-cutting attitudes	Habel et al. 2020	https://www.nature.com/articles/s41598-020-76158-3	Academia	2020	Publication
Prioritizing land for investments based on short- and long-term land potential and degradation risk: A strategic approach	Herrick et al. 2019	https://www.sciencedirect.com/science/article/abs/pii/S1462901118310566	Academia	2019	Publication
Developing guidance for the application of Natural and Nature Based Features (NNBF) on developed shores: A case study from New Jersey, USA	Jon Miller (Stevens IT)	https://www.sciencedirect.com/science/article/abs/pii/S2352485523001482	Academia	2023	Publication
Urban heat mitigation by green and blue infrastructure: Drivers, effectiveness, and future needs	Kumar et al. 2024	https://www.sciencedirect.com/science/article/pii/S2666675824000262?via%3Dihub	Academia	2024	Publication

Title	Author	Link	Industry Type	Pub Date	Media Type
The limited role salt marshes may have in buffering extreme storm surge events: Case study on the New Jersey shore	Lathrop et al. 2019	https://www.sciencedirect.com/science/article/pii/S0964569118305933?casa_token=IKIev4IieekAAAAA:xrA3nj8Wqr-zRLCm_VgesuDzWvzFHkUwQczRH_8axshYOy7ZX0tRnzn1u3mcuCDUlyhz4FgM	Academia	2019	Publication
Valuing New Jersey's Ecosystem Services and Natural Capital: A Spatially Explicit Benefit Transfer Approach	Liu, S., Costanza, R., Troy, A., JohnMates, W. (2010)	https://link.springer.com/article/10.1007/s00267-010-9483-5	Academia	2010	Publication
Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey	Loomis et al. 2000	https://www.sciencedirect.com/science/article/abs/pii/S0921800999001317?via%3Dihub	Academia	2000	Publication
Social success of in-stream habitat improvement: from fisheries enhancement to the delivery of multiple ecosystem services	Marttila, M., K. Kyllönen, and T. P. Karjalainen. 2016	https://www.ecologyandsociety.org/vol21/iss1/art4/	Academia	2016	Publication
From grey to green: efficacy of eco-engineering solutions for nature-based coatal defense	Morris et al. 2018	https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.14063	Academia	2018	Publication

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The application of oyster reefs in shoreline protection: Are we over-engineering for an ecosystem engineer?	Morris et al. 2019	https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.13390	Academia	2019	Publication
Challenges to realizing the potential of nature-based solutions	Nelson et al. 2020	https://www.sciencedirect.com/science/article/pii/S1877343520300750?casa_token=op4Z-rrSXUkAAAAA:W1uL3LGCggJaR4W-a1ys2zJ0d2CwFI--c4hrxH2da31_oIlSd4r7vSsXcuo5FAZXQPRz_x2l	Academia	2020	Publication
Innovations in Coastline Management With Natural and Nature-Based Features (NNBF): Lessons Learned From Three Case Studies	Palinkas et al. 2022	https://www.frontiersin.org/articles/10.3389/fbuil.2022.814180/pdf	Academia	2022	Publication
Water Quality Co-Effects of Greenhouse Gas Mitigation in U.S. Agriculture	Pattanayak et al. 2005	https://link.springer.com/article/10.1007/s10584-005-5925-0	Academia	2005	Publication
Identifying where nature-based solutions can offer win-wins for carbon mitigation and biodiversity across knowledge systems	Raymond et al. 2023	https://www.nature.com/articles/s42949-023-00103-2	Academia	2023	Publication

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Toward Indigenous visions of nature-based solutions: an exploration into Canadian federal climate policy	Reed et al. 2022	https://www.tandfonline.com/doi/full/10.1080/14693062.2022.2047585#abstract	Academia	2022	Publication
Comparing the cost effectiveness of nature-based and coastal adaptation: A case study from the Gulf Coast of the United States	Reguero et al. 2018	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0192132	Academia	2018	Publication
Chapter 4: An ecosystem services approach to natural resource and environmental economics	Robert J. Johnston	https://www.elgaronline.com/edcollchap/edcoll/9781788114271/9781788114271.00013.xml	Academia	2022	Publication
Guidance to Enhance the Validity and Credibility of Environmental Beneft Transfers	Robert J. Johnston	https://link.springer.com/article/10.1007/s10640-021-00574-w	Academia	2021	Publication
The Potential of Valuation	Robert J. Johnston	https://scholar.google.com/citations?view_op=view_citation&hl=en&user=1U1j7okAAAAJ&cstart=20&pagesize=80&sortby=pubdate&citation_for_view=1U1j7okAAAAJ:ymY9cBF3mdcC	Academia	2022	Publication

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Understanding the value and limits of nature-based solutions to climate change and other global challenges	Seddon et al. 2020	https://royalsocietypublishing.org/doi/10.1098/rstb.2019.0120	Academia	2020	Publication
Role of wetlands in reducing structural loss is highly dependent on characteristics of storms and local wetland and structure conditions	Sheng, Y. Peter; Rivera-Nieves, Adail A.; Paramygin, Vladimir A.	https://www.nature.com/articles/s41598-021-84701-z	Academia	2021	Publication
Unsettling NbS: A pathway towards shifting colonial power relations in nature-based solutions research and practice	Simon Fraser University	https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000307	Academia	2023	Publication
Ecosystem accounting and the need to recognise Indigenous perspectives	The Australian National University	https://www.nature.com/articles/s41599-022-01149-w	Academia	2022	Publication
Community Engagement for Nature-Based Solutions	University of Sheffield	https://orda.shef.ac.uk/articles/report/Community_Engagement_for_Nature-Based_Solutions/21997478?file=39360767	Academia	2023	Publication
On the cost-effectiveness of Nature-based Solutions for reducing disaster risk	Vicarelli et al. 2024	https://doi.org/10.1016/j.scitotenv.2024.174524	Academia	2024	Publication

Title	Author	Link	Industry Type	Pub Date	Media Type
Comparing Green and Grey Infrastructure Using Life Cycle Cost and Environmental Impact: A Rain Garden Case Study in Cincinnati, OH	Vineyard et al. 2015 EPA	https://onlinelibrary.wiley.com/doi/abs/10.1111/1752-1688.12320	Academia	2015	Publication
Knowledge gaps and future research needs for assessing the non-market benefits of Nature-Based Solutions and Nature-Based Solution-like strategies	Viti et al. 2022	https://www.sciencedirect.com/science/article/pii/S0048969722037330?via%3Dihub	Academia	2022	Publication
Protecting People and Property While Restoring Coastal Wetland Habitats	Weinstein, M.P., Guo, Q. & Santasieri, C. 2021	https://link.springer.com/article/10.1007/s12237-021-00900-x	Academia	2021	Publication
The status and future of tidal marshes in New Jersey faced with sea level rise	Weis et al. 2021	https://cdnsciencepub.com/doi/full/10.1139/anc-2020-0020	Academia	2021	Publication
Federal Cost-Benefit Analysis Policies for Evaluating Nature-Based Solutions	Duke Nicholas Institute	https://www.youtube.com/watch?v=M6CjmM1IOA8	Academia	2023	Video
Fact Sheet: Nature-Based Solutions to Climate Change	American University	https://www.american.edu/sis/centers/carbon-removal/fact-sheet-nature-based-solutions-to-climate-change.cfm	Academia	2020	Website

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Federal Resource Management and Ecosystem Services Guidebook	Duke Nicholas Institute	https://nespguidebook.com/	Academia	2016	Website
Nature-Based Solutions to Climate Change	Nature-based Solutions Initiative	https://nbsguidelines.info/	Academia	2021	Website
Green Infrastructure and Living shorelines	University of Connecticut	https://circa.uconn.edu/living-shorelines/	Academia	2024	Website
A Community on Ecosystem Services	University of Florida IFAS	https://conference.ifas.ufl.edu/aces/index.php	Academia	2024	Website
Living Shorelines	VIMS	https://www.vims.edu/ccrm/outreach/living_shorelines/	Academia	2020	Website
Quantification of Flood Event Forcing and the Impact of Natural Wetland Systems: Great Bay Boulevard, Ocean County, New Jersey	McKenna, Kim; DiCosmo, Nick; Greenfeld, Bari; Gebert, Jeff; Jensen, Heather U.S. DOT FHA	https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/new_jersey/#exec	Academia Federal Government	2018	Doc

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Operationalizing equity for integrated water resources management	Seigerman et al. 2022 USACE	https://onlinelibrary.wiley.com/doi/10.1111/1752-1688.13086	Academia Federal Government	2022	Doc
Ten-Year Urban Forestry Action Plan: 2016 -2026	University of Virginia Institute for Environmental Negotiation USDA Forest Service Urban and Community Forestry Program	https://urbanforestplan.org/wp-content/uploads/2015/11/FinalActionPlan_Complete_11_17_15.pdf	Academia Federal Government	2015	Doc
Nature-Based Solutions & Risk Management: Recommendations for Integrating Nature into Risk Science & Insurance	Kelso et al. 2024 USACE	https://escholarship.org/uc/item/9305j0t4	Academia Federal Government	2024	Publica-tion
Ecoshorelines on Developed Coasts - Guidance and Best Practices	Stevens Institute of Technology NJ DEP	https://www.nj.gov/dep/bcrp/docs/nj-dev-eco.pdf	Academia State Government	2022	Doc
Living Shorelines Engineering Guidelines	Stevens Institute of Technology NJ DEP	https://www.nj.gov/dep/bcrp/docs/njlseg-update.pdf	Academia State Government	2022	Doc

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Defining, Valuing, and Providing Ecosystem Goods and Services	USDA, THOMAS C. BROWN,- JOHN C. BERGSTROM" & JOHN B. LOOMIS*	https://www.fs.usda.gov/rm/pubs_other/rmrs_2007_brown_t001.pdf	Academia	2007	Publica-tion
FEMA National Resilience Guidance	FEMA	https://www.fema.gov/emergency-managers/national-preparedness/plan/resilience-guidance	Federal Government	2024	Doc
Economic Benefits of Protecting Healthy Watersheds: A Literature Review	Laura Dlugolecki	https://www4.des.state.nh.us/blogs/watershed/wp-content/uploads/2012/06/Economic-Benefits-of-Protecting-HealthyWatersheds_final.pdf	Federal Government	2012	Doc
Flood Damage Avoided by Potential Spending on Property-Level Adaptations: Working Paper 2024-03	Congressional Budget Office	https://www.cbo.gov/publication/58168?utm_source=feedblitz&utm_medium=FeedBlitzEmail&utm_content=812526&utm_campaign=Express_2024-05-28_14:30:00&utm_medium=FeedBlitzEmail&utm_content=812526&utm_campaign=Express_2024-05-28_14:30:00	Federal Government	2024	Doc

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Building Resilience: FEMA's Building Codes Policies and Considerations for Congress	CRS	https://crsreports.congress.gov/product/pdf/R/R47612	Federal Government	2023	Doc
Cost-Benefit Analysis and Financial Regulator Rulemaking	CRS	https://crsreports.congress.gov/product/pdf/R/R44813	Federal Government	2017	Doc
Cost-Benefit Analysis in Federal Agency Rulemaking	CRS	https://crsreports.congress.gov/product/pdf/IF/IF12058	Federal Government	2022	Doc
Ecosystem Restoration in the IIJA: Overview and Isues for congress	CRS	https://crsreports.congress.gov/product/pdf/R/R47263	Federal Government	2022	Doc
Federal Grants to State and Local Governments - A Historical Perspective on Contemporary Issues	CRS	https://crsreports.congress.gov/product/pdf/R/R40638	Federal Government	2019	Doc
FEMA Hazard Mitigation: A First Step Toward Climate Adaptatoin	CRS	https://crsreports.congress.gov/product/pdf/R/R46989/6	Federal Government	2022	Doc
FEMA's Hazard Mitigation Grant Program: Overview and Issues	CRS	https://crsreports.congress.gov/product/pdf/R/R40471/5	Federal Government	2009	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Flood Risk Reduction from Natural and Nature-based Features: Army Corps of Engineers Authority	CRS	https://crsreports.congress.gov/product/pdf/R/R46328	Federal Government	2020	Doc
Natural Resources Policy: Management, Institutions, and Issues	CRS	https://crsreports.congress.gov/product/pdf/RL/RL33806	Federal Government	2007	Doc
Nature Based Infrastructure (NOAA's Role)	CRS	https://sgp.fas.org/crs/misc/R46145.pdf	Federal Government	2020	Doc
Enhancing Benefits Evaluation For Water Resources Projects Towards A More Comprehensive Approach For Nature-Based Solutions: Consideration Of Nature-Based Solutions In USACE Planning Studies	Engineering with Nature USACE	https://ewn.erdc.dren.mil/publications/archive/enhancing-benefits-evaluation-for-water-resources-projects-towards-a-more-comprehensive-approach-for-nature-based-solutions-consideration-of-nature-based-solutions-in-usace-planning-studies/	Federal Government	2022	Doc

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Enhancing Benefits Evaluation For Water Resources Projects Towards A More Comprehensive Approach For Nature-Based Solutions: Evolution Of Benefits Evaluation And Prioritization Of Water Resources Projects	Engineering with Nature USACE	https://ewn.erdc.dren.mil/publications/archive/enhancing-benefits-evaluation-for-water-resources-projects-towards-a-more-comprehensive-approach-for-nature-based-solutions-evolution-of-benefits--evaluation-and-prioritization-of-water-resources-proj/	Federal Government	2022	Doc
Enhancing Benefits Evaluation For Water Resources Projects Towards A More Comprehensive Approach For Nature-Based Solutions: Planning And Valuation Methods For Case Study Analysis	Engineering with Nature USACE	https://ewn.erdc.dren.mil/publications/archive/enhancing-benefits-evaluation-for-water-resources-projects-towards-a-more-comprehensive-approach-for-nature-based-solutions-planning-and-valuation-methods-for-case-study-analysis/	Federal Government	2023	Doc
Guidelines for Preparing Economic Analyses (2016)	EPA	https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses-2016	Federal Government	2016	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Reducing urban heat islands: compendium of strategies	EPA	https://www.epa.gov/heatislands/heat-island-compendium	Federal Government	2008; Cool Pavements chapter was updated in 2012	Doc
Building Community Resilience with Nature-Based Solutions, Strategies for Success	FEMA	https://www.fema.gov/sites/default/files/documents/fema_nbs_community-resilience-strategies-success_102023.pdf	Federal Government	2023	Doc
Building Community Resilience with Nature-Based Solutions: A Guide for Local Officials	FEMA	https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf	Federal Government	2021	Doc
FEMA Ecosystem service value updates	FEMA	https://www.fema.gov/sites/default/files/documents/fema_ecosystem-service-value-updates_2022.pdf	Federal Government	2022	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
FEMA Policy: Benefit-Cost Analysis Discount Rate and Streamlined Cost Effectiveness for Hazard Mitigation Assistance and Public Assistance Programs	FEMA	https://www.fema.gov/sites/default/files/documents/fema_policy-206-23-001-bca-discount-rate-and-streamlined-approaches_april-24-2024.pdf	Federal Government	2024	Doc
Innovative Drought and Flood Mitigation Projects	FEMA	https://www.fema.gov/sites/default/files/documents/fema_innovative-drought-flood-mitigation-projects.pdf	Federal Government	2017	Doc
ARMY CORPS OF ENGINEERS Consideration of Project Costs and Benefits in Using Natural Coastal Infrastructure and Associated Challenges	GAO	https://www.gao.gov/assets/gao-19-319.pdf	Federal Government	2019	Doc
Assessment Methodology for Economic Analysis	GAO	https://www.gao.gov/assets/gao-18-151sp.pdf	Federal Government	2018	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Options to Enhance the Resilience of Federally Funded Raods and Reduce Fiscal Exposure	GAO	https://www.gao.gov/assets/gao-21-436.pdf	Federal Government	2021	Doc
Economic Valuation of Shoreline Protection within the Jacques Cousteau National Estuarine Research Reserve	Loerzel, Jarrod; Gorstein, Matt; Mohammad Rezaie, Ali; Ball Gonyo, Sarah; Fleming, Chloe S.; and Orthmeyer, Angela	http://doi.org/10.7289/V5/TM-NOS-NCCOS-234	Federal Government	2017	Doc
Federal interagency nature-like fishway passage design guidelines for atlantic coast diadromous fishes	NOAA	https://repository.library.noaa.gov/view/noaa/28919	Federal Government	2016	Doc
Natural and Structural Measures for Shoreline Stabilization	NOAA USACE	https://coast.noaa.gov/data/digitalcoast/pdf/living-shoreline.pdf	Federal Government	2024	Doc
Guidance for Considering the Use of Living Shorelines	NOAA Living Shorelines Workgroup	https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf	Federal Government	2015	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction	NOAA OCM Digital Coast	https://coast.noaa.gov/digitalcoast/training/gi-cost-benefit.html	Federal Government	2015	Doc
Circular No. A-4	OMB	https://web.archive.org/web/20250118023038/https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf	Federal Government	2023	Doc
Guidance For Assessing Changes In Environmental And Ecosystem Services In Benefit-Cost Analysis	OMB	https://web.archive.org/web/20250116091909/https://www.whitehouse.gov/wp-content/uploads/2024/02/ESGuidance.pdf	Federal Government	2024	Doc
Nature-Based Solutions for Coastal Highway Resilience	U.S. DOT FHA	https://web.archive.org/web/20241006085138/https://highways.dot.gov/public-roads/autumn-2021/02	Federal Government	2021	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide	U.S. DOT FHA	https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/implementation_guide/	Federal Government	2019	Doc
Hudson-Raritan Estuary Comprehensive Restoration Plan	USACE	https://www.nan.usace.army.mil/Missions/Environmental/Comprehensive-Restoration-Plan-for-the-Hudson-Raritan-Estuary/	Federal Government	2014	Doc
Advancing the Frontiers of Benefit-Cost Analysis	White House	https://web.archive.org/web/20250118014802/https://www.whitehouse.gov/wp-content/uploads/2023/12/FINAL-SFBCA-Annual-Report-2023.pdf	Federal Government	2023	Doc
Nature-based solutions resource guide compendium of federal examples, guidance, resource documents, tools, and technical assistance	White House	https://web.archive.org/web/20250118020831/https://www.whitehouse.gov/wp-content/uploads/2022/11/Nature-Based-Solutions-Resource-Guide-2022.pdf	Federal Government	2022	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Opportunities To Accelerate Nature Based Solutions: A Roadmap For Climate Progress, Thriving Nature, Equity, & Prosperity a Report to The National Climate Task Force	White House	https://web.archive.org/web/20250118020859/https://www.whitehouse.gov/wp-content/uploads/2022/11/Nature-Based-Solutions-Roadmap.pdf	Federal Government	2022	Doc
Compendium of Federal Nature-Based Resources for Coastal Communities, States, Tribes, and Territories	White House Coastal Resilience Interagency Working Group	https://www.noaa.gov/sites/default/files/2022-11/V1.2-Nature-based-Solutions-Compendium-11822.docx.pdf	Federal Government	2022	Doc
Adaptive Management The U.S. Department of the Interior Technical Guide	DOI	https://www.doi.gov/sites/doi.gov/files/uploads/TechGuide-WebOptimized-2.pdf	Federal Government	2009	Publication
Enhancing Benefits Evaluation For Water Resources Projects Towards A More Comprehensive Approach For Nature-Based Solutions: Case Study Analysis Results And Recommendations	Engineering with Nature USACE	https://ewn.erdc.dren.mil/publications/archive/enhancing-benefits-evaluation-for-water-resources-projects-towards-a-more-comprehensive-approach-for-nature-based-solutions-case-study-analysis-results-and-recommendations/	Federal Government	2023	Publication

Title	Author	Link	Industry Type	Pub Date	Media Type
Engineering With Nature An Atlas, Volume 3	Engineering with Nature USACE	https://ewn.erdc.dren.mil/atlas-series/volume/engineering-with-nature-an-atlas-volume-3/	Federal Government	2024	Publication
Assessing benefit transfer for the valuation of ecosystem services	Mark Plummer NOAA	https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/080091	Federal Government	2009	Publication
Benefit Transfer Challenges: Perspectives from U.S. Practitioners	Newbold et al. 2019 EPA	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6011777/	Federal Government	2019	Publication
Research Reveals the Potential of Nature-Based Solutions for Increasing Resilience to Sea Level Rise	NOAA NCCOS	https://coastalscience.noaa.gov/news/nbs-increasing-resilience-to-slr/	Federal Government	2023	Publication
Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems	Sutton-Grier et al. 2015 NOAA	https://www.sciencedirect.com/science/article/pii/S1462901115000799	Federal Government	2015	Publication

Title	Author	Link	Industry Type	Pub Date	Media Type
Engineering With Nature Principles in Action: Islands	Whitfield, Paula E.; Suedel, Burton C.; Egan, Kelly A.; Corbino, Jeff M.; Davis, Jenny L.; Carson, David C.; Tritinger, Amanda S.; Szimanski, Danielle M.; Balthis, William L.; Gailani, Joe Z.; King, Jeffrey K.	http://dx.doi.org/10.21079/11681/44940	Federal Government	2022	Publication
Engineering With Nature: International Guidelines On Natural And Nature-Based Features For Flood Risk Management	Engineering with Nature USACE	https://ewn.erdc.dren.mil/international-guidelines-on-natural-and-nature-based-features-for-flood-risk-management/	Federal Government	2020	Website
Benefits of Green Infrastructure	EPA	https://www.epa.gov/green-infrastructure/benefits-green-infrastructure	Federal Government	2024	Website
Green Infrastructure Cost-Benefit Resources	EPA	https://web.archive.org/web/20240119144244/https://www.epa.gov/green-infrastructure/green-infrastructure-cost-benefit-resources	Federal Government	2024	Website

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Urban Waters and the Passaic River/ Newark (New Jersey)	EPA	https://www.epa.gov/urbanwaterspartners/urban-waters-and-passaic-rivernewark-new-jersey	Federal Government	2023	Website
Navigating Federal Funding for Green Infrastructure and Nature-Based Solutions	EPA	https://www.epa.gov/system/files/documents/2021-11/navigating-federal-funding_green-infrastructure_508.pdf	Federal Government	2021	Website
Types of Nature-Based Solutions	FEMA	https://www.fema.gov/emergency-managers/risk-management/climate-resilience/nature-based-solutions/types	Federal Government	2023	Website
Living Shorelines: NOAA funded projects since 1998 through the Community-Based Restoration Program	NOAA Fisheries	https://storymaps.arcgis.com/stories/edc3cc67b37f43a5a815202f81768911	Federal Government	2024	Website
Evaluating Nature-Based Solution Performance	NOAA NCCOS	https://coastalscience.noaa.gov/project/evaluating-nature-based-solution-performance/	Federal Government	2022	Website

Title	Author	Link	Industry Type	Pub Date	Media Type
Restoration and Nature-Based Solutions	NOAA NCCOS	https://coastalscience.noaa.gov/science-areas/climate-change/restoration-and-nature-based-solutions/	Federal Government	2024	Website
Economic Approaches for Decision-Making	NOAA OCM Digital Coast	https://coast.noaa.gov/digitalcoast/training/econ-decision-making.html	Federal Government	2024	Website
Funding and Financing Coastal Resilience	NOAA OCM Digital Coast	https://coast.noaa.gov/digitalcoast/topics/funding-coastal-resilience.html	Federal Government	2024	Website
Natural Infrastructure	NOAA OCM Digital Coast	https://coast.noaa.gov/digitalcoast/topics/green-infrastructure.html	Federal Government	2024	Website
Using Economics to Inform Decisions	NOAA OCM Digital Coast	https://coast.noaa.gov/digitalcoast/training/econ-decisions.html	Federal Government	2024	Website
North Atlantic Coast Comprehensive Study	USACE	http://www.nad.usace.army.mil/compstudy	Federal Government	2015	Website

Title	Author	Link	Industry Type	Pub Date	Media Type
Northeast Region Urban Landscapes Capabilities Team	USGS	https://www.usgs.gov/centers/new-york-water-science-center/science/northeast-region-urban-landscapes-capabilities-team	Federal Government	2017	Website
Research to Inform Planning and Implementation of Nature-based Solutions	USGS	https://www.usgs.gov/programs/climate-research-and-development-program/news/research-inform-planning-and-implementation	Federal Government	2023	Website
CMRA: Federal Climate Resilience Policy	White House	https://web.archive.org/web/20250117214457/https://resilience.climate.gov/pages/policy/#nature-based-solutions	Federal Government	2024	Website
2025 U.S. National Adaptation and Resilience Planning Strategy	United Nations Framework Convention on Climate Change	https://unfccc.int/sites/default/files/resource/US-National-Adaptation-and-Resilience-Planning-Strategy-2025.pdf	Federal Government	2025	Doc
Department of the Interior Nature-Based Solutions Roadmap	DOI Duke University Nicholas School of the Environment	https://nicholasinstitute.duke.edu/project/nature-based-solutions-roadmap	Federal Government Academia	2023	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration	USDA Holmes et al. 2004	https://www.sciencedirect.com/science/article/abs/pii/S0921800904000254?via%3Dihub	Federal Government Academia	2004	Publication
Nature-Based Solutions: Evidence for Hazard Risk Reduction and Ecosystem Services	White House Office of Science and Technology Policy IDA Science and Technology Policy Institute	https://www.ida.org/-/media/feature/publications/n/na/nature-based-solutions-evidence-for-hazard-risk-reduction-and-ecosystem-services/3003750.ashx	Federal Government Non-Profit	2024	Doc
Communities Use a Regional Planning Framework to Identify Investments in Nature-Based Projects	NOAA The Nature Conservancy	https://coast.noaa.gov/digitalcoast/training/nature-based-projects.html	Federal Government Non-Profit	2024	Website
Finance and Business Models Guidebook	Connecting Nature Project	https://connectingnature.eu/guidebooks	International Government	2023	Doc
Ecosystem Services Valuation Database (ESVD) Update of global ecosystem service valuation data	Department for Environment, Food and Rural Affairs (Defra, UK)	https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf	International Government	2020	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
EU-funded NBS Research Project Tackle the Climate and Biodiversity Crisis	Euopean Union	https://rea.ec.europa.eu/funding-and-grants/horizon-europe-cluster-6-food-bioeconomy-natural-resources-agriculture-and-environment/nature-based-solutions_en	International Government	2023	Doc
Calculating the Economic Value of Clean Water in the New York-New Jersey Harbor Estuary	Hudson River Foundation	https://www.hudsonriver.org/article/calculating-the-economic-value-of-clean-water	NGO	2023	Doc
Upscaling Nature-Based Solutions for Climate Change Adaptation	Atlantic Council	https://www.atlanticcouncil.org/wp-content/uploads/2018/03/Climate_Change_WEB.pdf	Non-Profit	2018	Doc
The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits	Center for Neighborhood Technology	https://cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and	Non-Profit	2011	Doc
Green Values Strategy Guide: Linking Green Infrastructure Benefits to Community Priorities	Center for Neighborhood Technology	https://cnt.org/sites/default/files/publications/Green%20Values%20Strategy%20Guide.pdf	Non-Profit	2020	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Green Stormwater Infrastructure Impact On Property Values	Center for Neighborhood Technology SB Friedman	https://cnt.org/sites/default/files/publications/GSI-Impact-on-Property-Values.pdf	Non-Profit	2020	Doc
In the Face of Rising Sea Levels, Experts Call for Nationwide Coastal Management Approach	Environmental and Energy Study Institute	https://www.eesi.org/articles/view/in-the-face-of-rising-sea-levels-experts-call-for-nationwide-coastal-management-approach	Non-Profit	2023	Doc
Ecosystem Services in Working Lands Practice and Policy of the U.S. Northeast	Extension Foundation	https://legislature.vermont.gov/Documents/2024/WorkGroups/Senate%20Agriculture/Ecosystem%20Services%20and%20Soil%20Health/W~Mario%20Machado~Ecosystem%20Services%20in%20Working%20Lands%20Practice%20and%20Policy%20Presentation~2-21-2023.pdf	Non-Profit	2022	Doc
Aquatic Connectivity Through Climate-Ready Infrastructure	Hudson River Foundation	https://www.hudsonriver.org/article/actcri	Non-Profit	2022	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
The Economic and Market Value of Coasts and Estuaries: What's At Stake?	Linwood H. Pendleton Restore America's Estuaries	https://estuaries.org/wp-content/uploads/2020/02/The-Economic-and-Market-Value-of-Coasts-and-Estuaries-What%E2%80%99s-at-Stake_2008.pdf	Non-Profit	2009	Doc
Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-based Models to Assess Natural Defenses in the Northeastern USA	Narayan, S.; Beck, M.W.; Wilson, P.; Thomas, C.; Guerrero, A.; Shepard, C.; Reguero, B.G.; Franco, G.; Ingram, C.J.; Trespalacios, D.	https://www.nature.org/content/dam/tnc/nature/en/documents/Coastal_wetlands_and_flood_damage_reduction.pdf	Non-Profit	2016	Doc
Benefits, Applications, and Opportunities of Natural Infrastructure	National Academies	https://nap.nationalacademies.org/catalog/26660/benefits-applications-and-opportunities-of-natural-infrastructure-proceedings-of-a	Non-Profit	2022	Doc
Reducing Coastal Risk on the East and Gulf Coasts	National Academies	https://nap.nationalacademies.org/catalog/18811/reducing-coastal-risk-on-the-east-and-gulf-coasts	Non-Profit	2014	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Incorporating Nature-based Solutions into Community Climate Adaptation Planning	National Wildlife Federation	https://www.nwf.org/Educational-Resources/Reports/2022/Incorporating-Nature-based-Solutions-into-Community-Climate-Adaptation-Planning	Non-Profit	2022	Doc
Evaluation of Hurricane Sandy Coastal Resilience Program	NFWF	https://www.nfwf.org/sites/default/files/hurricanesandy/Documents/hurricane-sandy-evaluation-final-report.pdf	Non-Profit	2019	Doc
Living Shorelines from barriers to opportunities	Restore America's Estuaries	https://estuaries.org/wp-content/uploads/2018/08/RAE_LS_Barriers_report_final.pdf	Non-Profit	2015	Doc
A framework for mobilizing private finance and tracking the delivery of adaptation benefits	Stockholm Environment Institute (SEI)	https://www.sei.org/publications/a-framework-for-mobilizing-private-finance-and-tracking-the-delivery-of-adaptation-benefits/	Non-Profit	2019	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Benefit Accounting of Nature-Based Solutions for Watersheds	The Nature Conservancy	https://www.nature.org/content/dam/tnc/nature/en/documents/BenefitAccounting_NBSforWatersheds.pdf	Non-Profit	2021	Doc
Expanding the Role of Nature-Based Solutions in FEMA's Hazard Mitigation Assistance Programs: Lessons and Recommendations	The Nature Conservancy	https://www.scienceforconservation.org/assets/downloads/TNC_FEMA_NBSLessonsRecommendationsReport_jmeR5.pdf	Non-Profit	2023	Doc
Green stormwater infrastructure for urban flood resilience: opportunity analysis for dallas, texas	The Nature Conservancy	https://www.nature.org/content/dam/tnc/nature/en/documents/GSIanalysisREVFINAL.pdf	Non-Profit	2014	Doc
The Economic Benefits of Natural Climate Solutions in Minnesota	The Nature Conservancy	https://www.nature.org/content/dam/tnc/nature/en/documents/EarthEconomics_2023EconomicBenefitsofNaturalClimateSolutions.pdf	Non-Profit	2023	Doc
Nature-Based Solutions for Urban Stormwater Management	The Nature Conservancy	https://www.scienceforconservation.org/assets/downloads/TNC_UrbanConservation_NBS_Case_Studies.pdf	Non-Profit	-	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
A Guide For Incorporating Ecosystem Service Valuation Into Coastal Restoration Projects	The Nature Conservancy NOAA	https://www.nature.org/media/oceansandcoasts/ecosystem-service-valuation-coastal-restoration.pdf	Non-Profit	2015	Doc
A Framework for Developing Monitoring Plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey	The Nature Conservancy NOAA Partnership for the DE Estuary	https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/Framework-Coastal-Wetland-Shoreline-Projects-New-Jersey.pdf	Non-Profit	2016	Doc
Equitable Investments in Resilience: A review of benefit-cost analysis in federal flood mitigation infrastructure	Urban Institute	https://www.urban.org/research/publication/equitable-investments-resilience	Non-Profit	2021	Doc
Not Just Carbon: Capturing All the Benefits of Forests for Stabilizing the Climate from Local to Global Scales	World Resources Institute (WRI)	https://catalogue.unccd.int/1968_wri_not-just-carbon.pdf	Non-Profit	2022	Doc
Scaling protection and restoration of natural infrastructure to reduce flood impacts and enhance resilience	Environmental Defense Fund	https://www.edf.org/sites/default/files/documents/cunniff_87_4color.pdf	Non-Profit	2019	Publica-tion

Title	Author	Link	Industry Type	Pub Date	Media Type
Key Considerations for the Use of Nature-Based Solutions in Climate Services and Adaptation	National Wildlife Federation EcoAdapt	https://www.mdpi.com/2071-1050/14/24/16817	Non-Profit	2022	Publica-tion
Stakeholder Engagement Guide For Nature-Based Solutions	Pacific Institute United Nations Global Compact CEO Water Mandate	https://pacinst.org/wp-content/uploads/2022/11/CEOWater_SEG_Final.pdf	Non-Profit	2022	Publica-tion
COMMUNITY-BASED MANAGEMENT OF FRESHWATER RESOURCES A Practitioners' Guide to Applying TNC's Voice, Choice, and Action Framework	The Nature Conservancy International Food Policy Research Institute	https://www.conservationgateway.org/ConservationPractices/Freshwater/fcbc/Documents/TNC%20Pratitioners'%20Guide_English.pdf	Non-Profit	2020	Publica-tion
Strengthening monitoring and evaluation of multiple benefits in conservation initiatives that aim to foster climate change adaptation	Wildlife Conservation Society	https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.12688	Non-Profit	2022	Publica-tion
Growing Stronger: The Sustainable Roots of Indigenous Agriculture	Environmental and Energy Study Institute	https://www.eesi.org/articles/view/the-sustainable-roots-of-indigenous-agriculture	Non-Profit	2023	Website

Title	Author	Link	Industry Type	Pub Date	Media Type
A National Framework for Sustainable Urban Forestry to Combat Extreme Heat	Federation of American Scientists	https://fas.org/publication/urban-forest-heat-health/	Non-Profit	2024	Website
Improving benefit-cost analyses for rural areas	Headwaters Economics	https://headwaterseconomics.org/equity/improving-benefit-cost-analyses/	Non-Profit	2021	Website
Ecosystem Services	National Wildlife Federation	https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services	Non-Profit	2024	Website
Strategies	Naturally Resilient Communities	https://nrcsolutions.org/strategies/	Non-Profit	-	Website
New Jersey	NFWF	https://www.nfwf.org/2022-conservation-investments/new-jersey	Non-Profit	2022	Website
The State of Climate Adaptation Planning Today	Regional Plan Association	https://rpa.org/work/reports/climate-adaptation-planning-today	Non-Profit	2024	Website

Title	Author	Link	Industry Type	Pub Date	Media Type
Coastal Restoration Toolkit	Restore America's Estuaries	https://restoreyourcoast.org/coastalerosion/great-lakes/funding-sources/	Non-Profit	2024	Website
Natural Climate Solutions Resource Center	The Nature Conservancy	https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/natural-climate-solutions-science/	Non-Profit	2024	Website
Mussel Powered Living Shorelines for Salt Marsh Erosion Control	Kreeger, Danielle; Bushek, David; Whalen, Laura; Moody, Joshua; Padeletti, Angela	https://jcnerr.org/pdfs/NJ%20SLR%20-%20DELSI%204-1-10.kreeger.pdf	Non-profit Academia	2009	Doc
Living shorelines in the Delaware estuary: best practices from lessons learned and information collected by the partnership for the Delaware estuary and the Rutgers Haskin shellfish research laboratory, 2008-2012	Partnership for the Delaware Estuary	https://delawareestuary.s3.amazonaws.com/pdf/Living%20Shorelines/living_shorelines_best_practices.pdf	Non-profit Academia	2013	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Floodplain Buyouts: Challenges, Practices, and Lessons Learned	The Nature Conservancy University of Delaware	https://www.nature.org/content/dam/tnc/nature/en/documents/Buyouts_Lessons_Learned_Siders_Gerber_Chavez_TNC_Full_Report_2021.pdf	Non-Profit Academia	2021	Doc
Planning and Technical Support for Incorporating Green Infrastructure in Long Term Control Plans	Hudson River Foundation eDesign Dynamics	https://www.hudsonriver.org/article/actcri	Non-profit Private	2022	Doc
Promoting Nature-Based Hazard Mitigation Through FEMA Mitigation Grants	The Nature Conservancy AECOM	https://www.nature.org/content/dam/tnc/nature/en/documents/Promoting-Nature-Based-Hazard-Mitigation-Through-FEMA-Mitigation-Grants-05-10-2021-LR.pdf	Non-Profit Private	2021	Doc
Building Ecological Solutions to Coastal Community Hazards	National Wildlife Federation NJ DEP	https://www.nj.gov/dep/bcrp/docs/bescch-final.pdf	Non-Profit State Government	2017	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Developing Monitoring Plans for Living Shoreline Projects in Delaware:A Goal-Based Framework	Delaware Living Shorelines Committee	https://static1.squarespace.com/static/59b69f4f2994caee6bf52abe/t/5c2f944ec2241b6e53673b3a/1546622031144/DELS+Framework+V.2.0._Final.pdf	Other	2018	Doc
Techniques and Application of Living Shorelines in Delaware	Delaware Living Shorelines Committee	https://static1.squarespace.com/static/59b69f4f2994caee6bf52abe/t/656e37c905afc05d70acded3/1701722074723/Techniques+and+Application+of+Living+Shorelines+in+Delaware.pdf	Other	2023	Doc
Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers	The World Bank	https://www.worldbank.org/en/news/feature/2023/05/22/assessing-the-benefits-and-costs-of-nature-based-solutions-for-climate-resilience-a-guideline-for-project-developers	Other	2023	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Optimizing Green Infrastructure and Low Impact Development to Mitigate Impacts on Freshwater Systems	New Jersey Sea Grant	https://njseagrant.org/research/optimizing-green-infrastructure-and-low-impact-development-to-mitigate-impacts-on-freshwater-systems/stakeholder-survey/	Other	-	Website
Living Shorelines Group	Northeast Regonal Ocean Council	https://www.northeastoceancouncil.org/committees/coastal-hazards-resilience/living-shorelines-group/	Other	2022	Website
National Monitoring, Evaluation, and Learning Systems for Climate Change Adaptation	International Institute for Sustainable Development	https://www.iisd.org/publications/report/monitoring-evaluation-learning-systems-adaptation	Other	2024	Doc
New Jersey Extreme Heat Resilience Action Plan	NJ DEP	https://dep.nj.gov/climatechange/resilience/resilience-action-plans/	State Government	2024	Doc

Title	Author	Link	Industry Type	Pub Date	Media Type
Higbee Beach Wildlife Management Area (WMA) Restoration Project	NJ DEP WSP	https://www.nj.gov/dep/nrr/restoration/docs/higbee-beach-public-meeting-presentation20240208.pdf	State Government	2024	Doc
Statewide shoreline monitoring framework	NY Department of State	https://dos.ny.gov/system/files/documents/2023/06/phase_ii_final_report_2022.pdf	State Government	2022	Doc
Cloudburst Resiliency Planning Study	NYC Environmental Protection	https://www.nyc.gov/assets/dep/downloads/pdf/climate-resiliency/nyc-cloudburst-study.pdf	State Government	2017	Doc
NYCHA: South Jamaica Houses Cloudburst Master Plan 2018	NYC Environmental Protection NYCHA	https://www.nyc.gov/assets/nycha/downloads/pdf/NYCHA-South-Jamaica-Clouburst-Plan-Report-2019.pdf	State Government	2018	Doc
The Value of New Jersey's Ecosystem Services and Natural Capital	NJ DEP	https://njseagrant.org/wp-content/uploads/2000/10/The-Value-of-New-Jerseys-Ecosystem-Services-and-Natural-Capital-1.pdf	State Government	2006	Publica-tion

Title	Author	Link	Industry Type	Pub Date	Media Type
Living Shorelines	CT Department of Energy & Environmental Protection	https://portal.ct.gov/deep/coastal-resources/coastal-management/living-shorelines	State Government	2020	Website
Resiliency Through Restoration Initiative	MD Department of Natural Resources	https://dnr.maryland.gov/ccs/Pages/Resiliency-through-Restoration.aspx	State Government	2024	Website
Benficial Use of Dredged Material Pilot Projects	NJ DEP	https://dep.nj.gov/dsr/beneficial-use-of-dredged-material/	State Government	2023	Website
Case Studies/Projects Living Shorelines Projects	NJ DEP	https://www.nj.gov/dep/bcrp/case-studies-projects/living-shorelines-projects.html	State Government	2024	Website
Nature-Based Solutions	Resilient Massachusetts	https://resilient.mass.gov/mvp/content.html?toolkit=nature_based	State Government	2024	Website

4.4 NATURE-BASED SOLUTIONS CASE STUDIES

The following table highlights relevant NBS case studies from the Mid-Atlantic and Northeast regions of the United States. Where no information could be found or accessed, this is indicated with the "–" symbol. Please note this is not necessarily a comprehensive list and more information may be available online.

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Mordecai Island Ecosystem Restoration	2023	Barnegat Bay, New Jersey	USACE NJDEP Mordecai Land Trust	USACE	Wetland Restoration	Continuing Authorities Program 1135 (WRDA)	-	$7,961,000	https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/25093
Swan Island Restoration	2018	Chesapeake Bay, Maryland	USACE	USACE	Wetland Restoration	-	-	-	https://ewn.erdc.dren.mil/built-projects/swan-island-chesapeake-bay-maryland/
Removal of the Columbia Dam	2017	Knowlton, New Jersey	The Nature Conservancy	NJDEP	Dam Removal	Natural Resource Damage Assessment and Restoration Program	-	$5,958,749	https://www.njcwrp.org/columbia-dam-removal

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Removal of the County Line Dam	2022	Stillwater, New Jersey	The Nature Conservancy	The Nature Conservancy	Dam Removal	National Fish Habitat Action Plan funding	-	$645,000	https://www.njcwrp.org/county-line-dam#:~:text=Project%20Purpose:%20Removal%20of%20the,had%20annual%20migrations%20of%20shad.
Maquoit Bay Living Shoreline	2019	Brunswick, Maine	The Nature Conservancy	NOAA	Living Shoreline	2017 Coastal Resilience Grant Federal Funding Opportunity Award Number NA17NOS 4730141	-	$25,000	https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/northeast-living-shorelines-case-studies/
Wagon Hill Farm	2017	Durham, New Hampshire	The Nature Conservancy	New Hampshire Department of Environmental Services (NHDES)	Living Shoreline	NHDES Aquatic Resource Mitigation (ARM) fund	$250,000	$290,000	https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/northeast-living-shorelines-case-studies/

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Collins Cove	2017	Salem, Massachusetts	Salem Sound Coastwatch	Massachusetts Office of Coastal Zone Management (CZM)	Living Shoreline	Coastal Resilience Grant Program	$216,550	$345,290	https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/northeast-living-shorelines-case-studies/
Rose Larisa Park	2017	Rose Larisa Park, Rhode Island	The Nature Conservancy	NOAA	Living Shoreline	Coastal Resiliency Fund	$232,000	$232,000	https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/northeast-living-shorelines-case-studies/
Stratford Point	2014	Stratford Point, Connecticut	The Nature Conservancy	USACE	Living Shoreline	2017 Coastal Resilience Grant	-	$734,130	https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/northeast-living-shorelines-case-studies/

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Blackwater National Wildlife Refuge	2016	Cambridge, Maryland	U.S. Fish and Wildlife Service	NFWF	Wetland Restoration	Hurricane Sandy Coastal Resiliencey Competitive Grant	$1,100,000	-	https://www.cakex.org/sites/default/files/documents/Blackwater%20National%20Wildlife%20Refuge%3A%20Marsh%20Restoration%20%7C%20Dredge%20America.pdf
Phoenix Park	2013	Camden, New Jersey	Camden County Municipal Utilities Authority	New Jersey Environmental Infrastructure Trust Camden County Open Space Trust Fund Urban Waters Federal Partnership	Open Space Bioswale	-	-	-	https://njawra.org/phoenixpark

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Hunter's Point Park	2012	Long Island City, Queens, New York	NYC Economic Development Corporation	Department of Housing Preservation and Development (NYDHP)	Open Space Bioswale	Department of Housing Preservation and Development (NYDHP)	-	$70,000,000	https://www.hunterspointparks.org/hppc-blog/2020/7/3/green-infrastructure-amp-hidden-sustainability-in-hunters-point-south-park
Fire Island to Montauk Point Coastal Storm Risk Management Project	2020	Fire Island, New York	USACE	USACE	Living Shoreline Salt Marsh Restoration	Hurricane Sandy Disaster Relief Appropriations Act of 2013	$1,759,459,000	$1,913,413,000	https://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/Fire-Island-to-Montauk-Point/
New York-New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study (HATS)	2021	New York New Jersey	USACE	NYSDEC & NJ DEP cost share thru 2022 Federal funds thereafter	Living Shoreline Wetland Restoration	Federal Funding	-	$19,400,000	https://www.nan.usace.army.mil/Portals/37/NYN-JHAT%20Presentation_Jan2023_for_upload_1.pdf https://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/New-York-New-Jersey-Harbor-Tributaries-Focus-Area-Feasibility-Study/

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
LaVallette Avenue project	2014	Norfolk, Virginia	EPA City of Norfolk	EPA	Living Shorelines	Supplemental Environmental Project (SEP)	$90,000	-	https://www.epa.gov/va/enforcement-action-protects-shoreline#:~:text=Two%20sections%20of%20%E2%80%9Cliving%20shoreline,vulnerable%20to%20sea%20level%20rise.
Eastern Shore Barrier Island Stabilization and Marsh Habitat Engineering Design and Permitting	2022	Cedar Island, Virginia	Virginia Institute of Marine Science	NFWF	Wetland Restoration	National Coastal Resilience Fund	$310,309.00	-	https://www.nfwf.org/grants/grants-library/profile?egid=75573
Final Floodplain Habitat Design To Establish Green Infrastructure along Woodbridge River	2022	New Jersey	Rutgers, The State University of New Jersey	NFWF	Wetland Restoration	National Coastal Resilience Fund	$397,600	$608,100	https://www.nfwf.org/sites/default/files/2022-08/nfwf-ncrf-20220816-aug-gs.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Final Designs to Improve Coastal Resiliency at Gull Cove and Quonochontaug Pond Breachway	2022	Rhode Island	Rhode Island Department of Environmental Management, NBNERR	NFWF	Living Shoreline Wetland Restoration	National Coastal Resilience Fund	$200,200	$250,200	https://www.nfwf.org/sites/default/files/2022-08/nfwf-ncrf-20220816-aug-gs.pdf
Cohanzick Nature Reserve	2023	Salem County, New Jersey	Native American Advancement Corporation (NAAC)	-	Regenerative Land Management	-	-	-	https://www.nature.org/en-us/news-room/new-jersey-lands-returned-indigenous-peoples/
Berkeley Island Park	2016	Berkeley Township, New Jersey	Berkeley Township	NJ DEP	Living Shoreline	-	$6,900,000	$7,000,000	https://www.wsp.com/en-us/insights/berkeley-island-county-park-restoration
Forked River Beach Living Shoreline	2021	Forked River Beach, New Jersey	American Littoral Society	NJ DEP	Living Shoreline	-	$1,000,000	-	https://www.njspotlightnews.org/2021/11/erosion-barnegat-bay-living-shoreline-beachfront-houses-beachfront-soft-structure-hard-structure/

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Shooting Island Shoreline Restoration	2018	Ocean City, New Jersey	NJ DEP	NFWF	Living Shoreline Salt Marsh Restoration	Hurricane Sandy Disaster Relief Appropriations Act of 2013	$2,300,000	-	https://www.ocnj.us/media/Projects/Bay/NJCWRP%20Oyster%20Upweller%20Presentation%20REV190930.pdf
Gandy's Beach Project	2013	Cumberland County, New Jersey	U.S. Fish and Wildlife Service The Nature Conservancy	NFWF	Living Shoreline Wetland Restoration	Hurricane Sandy Disaster Relief Appropriations Act of 2013	$880,000	-	https://www.fws.gov/story/2021-06/learning-living-shoreline
Seven Mile Island Innovation Lab	2019	Seven Mile Island, New Jersey	USACE The Wetlands Institute State of New Jersey	USACE	Wetland Restoration	-	-	-	https://www.nap.usace.army.mil/Portals/39/docs/Civil/Coastal/SMILL-Fact sheet-Overview-Update.pdf?ver=2019-12-13-120119-930
South Riverside Drive Living Shoreline	2022	Neptune Township, New Jersey	American Littoral Society	FEMA	Living Shoreline	-	-	-	https://www.littoralsociety.org/south-riverside-drive.html

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Northwest Resiliency Park	2020	Hoboken, New Jersey	City of Hoboken	FEMA	Bioswale	BRIC	$10,000,000	$50,000,000	https://rebuildbydesign.org/news-and-events/press/hoboken-flood-resiliency-park-awarded-14-million-grant-to-help-complete-project/
Stormwater Projects Improve Water Quality in the Lower Section of the Raritan River	2001	Raritan River Watershed, New Jersey	New Jersey Water Supply Authority	EPA	Habitat Restoration	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$410,000	-	https://www.epa.gov/system/files/documents/2023-03/NJ_Raritan%20River_2083_508.pdf
Project Evaluates Subsurface Gravel Wetland Treatment Design Alternatives for the Barnegat Bay Watershed	2013	Lakewood, New Jersey	Rutgers Cooperative Extension Water Resources Program	EPA	Wetland Restoration	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$250,000	-	https://www.epa.gov/system/files/documents/2022-11/NJ_Metedeconk%20River_Barnegat-Bay_2084_508.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Conducting Cover Crop Aerial Seeding and Watershed Education Improved Water Quality in the Neshanic River	2012	Hunterdon County, New Jersey	North Jersey Resource Conserva-tion & De-velopment Council	EPA	Bioswale Regenerative Land Management	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$541,300	-	https://www.epa.gov/system/files/documents/2021-12/nj_neshanic-river_1977_508.pdf
Implement-ing Green Infra-structure Projects Improved Water Quality in the Rahway River	2010	Rahway River, New Jersey	Rutgers University	EPA	Bioswale	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$512,000	-	https://www.epa.gov/sites/default/files/2020-01/documents/nj_rahwayriver_1842_508.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Green Infrastructure and Restoration Projects Improve Water Quality in the Cooper River	2007	Cooper River Watershed, New Jersey	Camden County Soil Conservation District	EPA	Bioswale Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$1,100,000	-	https://www.epa.gov/sites/default/files/2018-10/documents/nj_cooperriver_508_updated_0.pdf
Ramanessin Brook Restoration Projects Improve the Navesink River	2005	Monmouth County, New Jersey	Monmouth County	EPA	Bioswale Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$1,383,900	-	https://www.epa.gov/sites/default/files/2017-12/documents/nj_navesinkriver_1607_508.pdf
Stormwater BMP Project Improves Water Quality at Wanaque River/ Greenwood Lake	1999	Wanaque River/ Greenwood Lake, New Jersey	West Milford Township	EPA	Habitat Restoration	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$1,000,000	-	https://www.epa.gov/sites/default/files/2017-02/documents/nj_wanaque_508.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Riparian Restoration Projects to Improve Water Quality in the Lower Musconetcong River	2000	Lower Musconetcong River, New Jersey	North Jersey Resource Conservation & Development Council	EPA	Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$592,000	-	https://www.epa.gov/sites/default/files/2015-12/documents/nj_lower-muscon_0.pdf
Riparian Restoration and Watershed Stewardship Improve Water Quality in Bear Brook	1998	East Windsor Township, New Jersey	Stonybrook Millstone Watershed Association	EPA	Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$132,000	-	https://www.epa.gov/sites/default/files/2020-07/documents/nj_bear-508.pdf
Restoring Riparian Areas and Enhancing Stormwater Management Improved Water Quality in the Lower Pequest River	2000	Warren County, New Jersey	North Jersey Resource Conservation & Development Council	EPA	Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$412,000	-	https://www.epa.gov/sites/default/files/2020-07/documents/nj_pequest-508.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Agricultural Nonpoint Source Controls Improve Water Quality in Wallkill River at Hamburg	2002	Sussex County, New Jersey	North Jersey Resource Conserva-tion & De-velopment Council	EPA	Regenerative Land Management	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$122,000	-	https://www.epa.gov/sites/default/files/2015-10/documents/nj_wallkill_ham-burg-2.pdf
Stream Restoration Project Improves Water Quality of Wallkill River	2002	Wallkill River, New Jersey	Township of Sparta	EPA	Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$62,440.00	-	https://www.epa.gov/sites/default/files/2015-10/documents/nj_wallkill.pdf
New Jersey's Stony Brook-Millstone River	1998	Stony Brook-Millstone River watershed, New Jersey	NJ DEP SBM Watershed Association	EPA	Riparian Buffer Zone	Clean Water Act Section 319(h) Nonpoint Source Pollution Control Grant Program	$132,000	-	https://www.epa.gov/sites/default/files/2015-10/documents/2009_12_23_nps_success319_state_nj_stony.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
City of Hoboken Southwest Park Expansion Project	2022	Hoboken, NJ	City of Hoboken	FEMA	Open Space Bioswales	BRIC	$6,240,000	-	https://www.fema.gov/case-study/new-jersey-city-hoboken-south-west-park-expansion-project
Oil Cottage Street Park Flood Mitigation Project	2021	Bayonne, NJ	City of Bayonne	FEMA	Bioswale	BRIC	$4,460,000	-	https://www.fema.gov/case-study/bayonne-new-jersey-oil-cottage
Newark Ironbound Resiliency Hub	2021	Newark, NJ	City of Newark	FEMA	Bioswale	BRIC	$10,580,000	$14,000,000	https://www.fema.gov/case-study/newark-new-jersey_https://www.njit.edu/tarp/sites/njit.edu.tarp/files/NJIT%20Hazard%20Mitigation%20Workshop_Newark%20Ironbound%20Resilience%20Hub_2023%20%281%29.pdf
Jersey City McGovern Park Resilience Project	2022	Jersey City, NJ	Jersey City	FEMA	Open Space Bioswale	BRIC	$3,840,000	-	https://www.fema.gov/case-study/new-jersey-jersey-city-mcgovern-park-resilience-project

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
High-lands and Monmouth Hills Flood Mitigation and Green Infrastruc-ture Project	2022	Highlands, NJ	FEMA	FEMA	Bioswale	BRIC	$12,190,000	-	https://www.fema.gov/case-study/new-jersey-highlands-and-monmouth-hills-flood-mitigation-and-green-infrastruc-ture
Borough of West Wildwood Living Shoreline Restoration	2022	West Wildwood, NJ	Borough of West Wildwood	FEMA	Living Shoreline	Flood Mitigation Assistance Grant Program	$1,930,000	-	https://www.fema.gov/case-study/new-jersey-bor-ough-west-wild-wood-living-shoreline-restoration
County of Hunterdon Acquisition of Repetitive Loss Property	2022	Delaware Township, New Jersey	FEMA	FEMA	Property Acquisition	Flood Mitigation Assistance Grant Program	$444,515	-	https://www.fema.gov/case-study/new-jersey-coun-ty-hunterdon-ac-quisition-repeti-tive-loss-property
Land Acquisition for Open Space	2023	Montgomery Township, New Jersey	Montgomery Township	FEMA	Property Acquisition Open Space	Pre-Disaster Mitigation Grant Program	$1,212,000	-	https://www.fema.gov/sites/default/files/documents/fema_informa-tion-bulletin-483.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Removing Derelict Crab Pots to Reduce Wildlife Entangle-ments in Coastal Marsh Waters	2021	Barnegat Bay, New Jersey	Conserve Wildlife Foundation of New Jersey	NFWF	Habitat Restoration	Fishing for Energy Fund	$14,960	-	https://www.nfwf.org/sites/default/files/2021-08/NFWF_FFE-20210714-GS.pdf
Restoring Bay Islands for Community Resiliency	2021	Long Beach Township, New Jersey	Long Beach Township	NFWF	Habitat Restoration	National Coastal Resilience Fund	$89,691	$197,231	https://www.nfwf.org/sites/default/files/2021-11/NFWFncrf20211117GSfinal.pdf
Coastal Landscape Enhance-ment for Community Resilience at the Waretown Lighthouse Center	2022	Waretown, New Jersey	National Resource Education Foundation of NJ	NFWF	Wetland Restoration	Emergency Coastal Resilience Fund	$138,100	$189,400	https://www.nfwf.org/sites/default/files/2022-06/NFWF-ECRF-20220531-GS-Fi-nal.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Evaluating and Creating a Pipeline of Salt Marsh Restoration Projects	2023	New Jersey	The Nature Conservancy	NJWF	Wetland Restoration	National Coastal Resilience Fund	$982,700	$1,195,100	https://www.nfwf.org/sites/default/files/2023-11/NFWF-NCRF-20231114-GS.pdf
Wetland Migration Pathway Planning, Prioritization, and Community Engagement	2022	FL, MA, NC, NJ, RI, SC	Rhode Island Department of Environmental Management, NBNERR	NFWF	Wetland Restoration	America the Beautiful Challenge	$551,800	$651,800	https://www.nfwf.org/sites/default/files/2022-11/NFWF-ATBC-20221108-GS.pdf
Nellie Bennett Marsh Restoration Planning	2022	New Jersey	Barnegat Bay Partnership	NFWF	Wetland Restoration	Emergency Coastal Resilience Fund	$234,900	$246,900	https://www.nfwf.org/sites/default/files/2022-06/NFWF-ECRF-20220531-GS-Final.pdf
Ecological Restoration of a Former Cranberry Farm in Burlington County	2018	Burlington County, New Jersey	New Jersey Conservation Foundation	NJDEP	Regenerative Land Management	Delaware Watershed Conservation Fund	$146,996	$294,663	https://www.nfwf.org/sites/default/files/2020-09/dwcf-2020-grant-slate.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
A Green Schoolyard at PS 107X: Providing Community Green Space and Improving Water Quality	2020	Bronx, New York	The Trust for Public Land	NFWF	Bioswale Open Space	Long Island Sound Futures Fund	$242,372	$1,967,372	https://www.nfwf.org/sites/default/files/2020-12/long-island-sound-futures-fund-2020-grant-slate.pdf
Establishing "Sea Lab" to Serve the Community	2023	New York	The Research Foundation for the State University of New York (SUNY-Maritime College)	NFWF	Habitat Restoration	Long Island Sound Futures Fund	$51,500	$83,200	https://www.nfwf.org/sites/default/files/2023-12/nfwf-lisff-20231127-gs.pdf
Final Flood-plain Hab-itat Design To Establish Green Infrastruc-ture along Woodbridge River	2022	Woodbridge River, NJ	Rutgers, The State University of New Jersey	NFWF	Riparian Buffer Zone	National Coastal Resilience Fund	$397,600	$608,100	https://www.nfwf.org/sites/default/files/2022-08/nf-wf-ncrf-20220816-aug-gs.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Designing a Nature Based Shoreline for Naval Weapons Station Earle	2021	Raritan Bay Coast, New Jersey	NY/NJ Baykeeper	NFWF	Living Shoreline	National Coastal Resilience Fund	$621,576	$1,743,625	https://www.nfwf.org/sites/default/files/2021-11/NFW-Fncrf20211117GS-final.pdf
Urban Riparian Restoration and Community Engagement in Elizabeth, New Jersey	2021	Elizabeth, New Jersey	Groundwork Elizabeth	NFWF	Riparian Buffer Zone	Five Star and Urban Waters Restoration Program	$38,858	$94,358	https://www.nfwf.org/sites/default/files/2021-09/NFWF-20210818-Five-Star-GS.pdf
Saturdays on the Sound: Community Stewardship of Long Island Sound Coastal Forest	2022	Soundview Park, Bronx, NY	The Bronx is Blooming	NFWF	Habitat Restoration	Long Island Sound Futures Fund	$50,000	$306,500	https://www.nfwf.org/sites/default/files/2022-12/NFWF-LISFF-20221128-GS-Final.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Green School-yards in the South Bronx	2023	Bronx, New York	The Trust for Public Land	NFWF	Bioswale Open Space	Long Island Sound Futures Fund	$493,400	$3,193,400	https://www.nfwf.org/sites/default/files/2023-12/nfwf-lisff-20231127-gs.pdf
Engaging Local Youth Through Seaweed Farming to Improve Water Quality in the Long Island Sound	2021	Long Island Sound, New York	Rocking the Boat	NFWF	Regenerative Land Management	Long Island Sound Futures Fund	$72,163	$120,622	https://www.nfwf.org/sites/default/files/2021-12/LISFF-Grant-Slate-Final-2021.pdf
Marshes and Mussels: New Tools to Enhance Coastal Restoration and Resilience	2021	Centerport Harbor, New York	Cornell Cooperative Extension of Suffolk County	NFWF	Living Shoreline	Long Island Sound Futures Fund	$249,046	$729,606	https://www.nfwf.org/sites/default/files/2021-12/LISFF-Grant-Slate-Final-2021.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Kimbles Beach Restoration and Shoreline Stabilization	2021	Cape May County, New Jersey	American Littoral Society	NFWF	Habitat Restoration	Delaware Watershed Conservation Fund	$560,800	$1,122,649	https://www.nfwf.org/sites/default/files/2021-09/NFWF-DWCF-20200916-GS.pdf
Activating Restoration in Three Underrepresented Communities in the Choptank Watershed	2021	Maryland	Shorerivers	NFWF	Habitat Restoration	Chesapeake Bay Small Watershed Grants Program	$79,886	$106,515	https://www.nfwf.org/sites/default/files/2021-10/NFWF-Chesapeake-NSRGP-2021019-GS.pdf
Building Capacity for Habitat Restoration and Education in the Caesar Rodney School District	2021	Caesar Rodney School District, Delaware	Caesar Rodney School District	NFWF	Habitat Restoration	Delaware Watershed Conservation Fund	$227,700	$461,000	https://www.nfwf.org/sites/default/files/2022-08/nfwf-dwcf-20220822-gs.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Hoffman's Mill Dam Removal	2024	Pennsylvania	Brandywine Conservancy	NFWF	Dam Removal	Delaware Watershed Conservation Fund	$151,723	-	https://www.brandywine.org/conservancy/blog/hoffmans-mill-dam-removal#:~:text=After%20careful%20consideration%2C%20the%20removal,of%20American%20Shad%20up%20the
Restoration of American Shad and Fish Passage on the Brandywine River	2019	Brandywine River, Delaware	Brandywine Shad 2020	NFWF	Dam Removal	Delaware Watershed Conservation Fund	$445,000	-	https://www.nfwf.org/2021-conservation-investments/delaware
Enhancing Habitat to Benefit Golden-Winged Warbler, Bobwhite Quail, American Black Duck and Bog Turtle	2022	New Jersey	New Jersey Audubon Society	NFWF	Regenerative Land Management Wetland Restoration	Conservation Partners	$425,500	$875,500	https://www.nfwf.org/sites/default/files/2022-05/NFWF-CPP-20220516-GS.pdf

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Nature-Based Solutions to Flooding in Giampietro Memorial Park	2021	Giampietro Memorial Park, New Jersey	American Littoral Society	NFWF	Wetland Restoration Bioswale	Delaware River Restoration Fund	$170,000	$261,725	https://www.nfwf.org/sites/default/files/2021-09/NFWF-DRRF-20210916-GS.pdf
Watt Avenue South Salt Marsh Restoration	2004	Pelham Bay Park, New York	Long Island Sound-keeper	NOAA	Wetland Restoration	NOAA Community-based Restoration Program	$20,000	$90,000	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?754
Hudson-Raritan Liberty Flats Oyster Reef Restoration	2000	New Jersey	American Littoral Society	NOAA	Living Shoreline	NOAA Community-based Restoration Program	$10,000	$105,500	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?165
Rahway River Flood Plain Restoration Project	2001	New Jersey	American Littoral Society	NOAA	Riparian Buffer Zone	NOAA Community-based Restoration Program	$70,000	$686,640	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?343

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Navesink River Riparian Restoration	2002	New Jersey	Red Bank Borough Board of Education	NOAA	Riparian Buffer Zone	NOAA Community-based Restoration Program	$15,000	$114,255	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?658
Shrewsbury Island Habitat Enhancement	2007	Monmouth Beach, New Jersey	American Littoral Society	NOAA	Wetland Restoration	NOAA Community-based Restoration Program	$7,127	$16,739	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?2357
Roberts Swamp Brook Restoration	2001	Manasquan, New Jersey	New Jersey Community Water Watch	NOAA	Wetland Restoration	NOAA Community-based Restoration Program	$715	$31,430	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?293
Barnegat Bay Shellfish Restoration Project-Good Luck Point Reef	2010	New Jersey	American Littoral Society	NOAA	Living Shoreline	NOAA Community-based Restoration Program	$185,339	$414,428	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?2948
Mullica River Oyster Restoration	2008	New Jersey	New Jersey Division of Fish and Wildlife	NOAA	Living Shoreline	NOAA Community-based Restoration Program	$22,362	$44,724	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?1609

Project Title	Year of Project	Location	Project Lead	Funder	NBS Project Type	Project Funding Source	Amount of Money Awarded	Total Project $	Weblink
Shellfish Reef Enhancement Along Eroding Marshes	2009	New Jersey	Partnership for the Delaware Estuary	NOAA	Living Shoreline	NOAA Community-based Restoration Program	$44,971	$75,165	https://www.fisheries.noaa.gov/data-tools/noaa-restoration-project?2524

4.5 TOOLS AND DATA

The following table highlights tools and data that are deemed relevant to NBS, including but not limited to information on environmental, climate, ecological, biological, demographic, natural hazards, and infrastructure data. Please note this is not necessarily a comprehensive list and more information may be available online. Where original links are no longer accessible, the Internet Archive Wayback Machine has been used to create functional links to original sources.

Name	Agency/Organization	Link
Green Values: Stormwater Management Calculator	Center for Neighborhood Technology	https://greenvalues.cnt.org/
CO-IMPACT	Connecting Nature Project	https://co-impact.app/
Nature-based Solutions Evidence Platform	Conservation International Nature-based Solutions Initiative	https://www.naturebasedsolutionsevidence.info/
Climate Resilience Resource Library	Department of Defense Readiness and Environmental Protection Integration Program	https://web.archive.org/web/20240518154136/https://repiprimers.org/resilience/resources/
Environmental Valuation Reference Inventory	Environment and Climate Change Canada	https://evri.ca/en
BCA Toolkit	FEMA	https://www.fema.gov/grants/tools/benefit-cost-analysis#toolkit
EbA Tools Navigator	Friends of EbA	https://toolsnavigator.friendsofeba.com/search
Federal Flood Standard Support Tool	National Climate Task Force's Flood Resilience Interagency Working Group	https://floodstandard.climate.gov/pages/nature-based-solutions
Where We Work	National Fish and Wildlife Foundation	https://www.nfwf.org/where-we-work

Name	Agency/Organization	Link
Coastal Resilience Evaluation and Siting Tool (CREST)	National Fish and Wildlife Foundation	https://resilientcoasts.org/#Home
Coastal Ecological Restoration and Adaptation Planning (CERAP) Explorer	NJ DEP Rutgers University	https://njrestors.rutgers.edu/nj-cerap/
New Jersey Green Infrastructure Municipal Toolkit	NJ Future	https://gitoolkit.njfuture.org/
Coastal County Snapshot	NOAA Digital Coast	https://coast.noaa.gov/snapshots/
Green Infrastructure Effectiveness Database	NOAA Digital Coast	https://coast.noaa.gov/gisearch/#/
Sea Level Calculator	NOAA Digital Coast	https://bit.ly/428dkZK
Digital Coast Trainings	NOAA Digital Coast	https://coast.noaa.gov/digitalcoast/training/
Coastal Flood Exposure Mapper	NOAA Office for Coastal Management	https://coast.noaa.gov/floodexposure/#-10575352,4439107,5z
Sea Level Rise Viewer	NOAA Office for Coastal Management	https://coast.noaa.gov/slr/
Virtual- Economic Guidance for Coastal Management Professionals	NOAA Office for Coastal Management	https://coast.noaa.gov/digitalcoast/training/econ-guidance.html
Northeast Ocean Data	Northeast Regional Ocean Council	https://northeastoceandata.org/data-explorer/
U.S. Climate Resilience Toolkit	OSTP (U.S. Global Change Research Program)	https://toolkit.climate.gov/

Name	Agency/Organization	Link
NY-NJ Harbor Estuary Program Restoration Strategy Toolkit	Princeton Hydro Hudson River Foundation	https://www.hudsonriver.org/wp-content/uploads/2023/04/PH_HEP_Restoration_Toolkit_Narrative-FOR-PUBLIC.pdf
NJ Restoration Tool Organization Suite (ResTOrS)	Rutgers University	https://njrestors.rutgers.edu/
NJ Flood Mapper	Rutgers University	https://www.njfloodmapper.org/
NJ Adapt	Rutgers University	https://njclimateresourcecenter.rutgers.edu/nj-adapt/
InVEST	Stanford University	https://naturalcapitalproject.stanford.edu/software/invest
BlueValue	Texas A&M	https://www.bluevalue.org/
A Compendium of Tools and Methods to Estimate Environmental Benefits for Nature-Based Solutions	U.S. EPA	https://www.epa.gov/system/files/documents/2024-11/co-benefit-accounting-summary_508.pdf
Clearinghouse for Environmental Finance	U.S. EPA	https://web.archive.org/web/20250202220234/https://ordspub.epa.gov/ords/wfc/f?p=165:1::::::
Climate Resiliency and Green Infrastructure	U.S. EPA	https://www.epa.gov/green-infrastructure/climate-resiliency-and-green-infrastructure
Green Infrastructure Modeling Toolkit	U.S. EPA	https://www.epa.gov/water-research/green-infrastructure-modeling-toolkit
National Stormwater Calculator	U.S. EPA	https://www.epa.gov/water-research/national-stormwater-calculator
Natural Infrastructure Opportunities Tool - Connecting Resources to Needs	USACE	https://www.arcgis.com/apps/MapSeries/index.html?appid=18079f5b628b4a7bb52acbe089d80886

Name	Agency/Organization	Link
USACE GIS Data	USACE	https://geospatial-usace.opendata.arcgis.com/
i-Tree	USDA Forest Service	https://www.itreetools.org/
Adaptation Workbook	USDA Northern Forests Climate Hub	https://adaptationworkbook.org/
Hazard Exposure Reporting and Analytics	USGS	https://www.usgs.gov/apps/hera/
Digital Shoreline Analysis System	USGS	https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas?qt-science_center_objects=0#qt-science_center_objects
Protected Areas	USGS	https://www.usgs.gov/programs/gap-analysis-project/science/protected-areas
Urban Forestry Toolkit	Vibrant Cities Lab	https://vibrantcitieslab.com/toolkit/
Shoreline Decision Support Tool	Virginia institute of Marine Science	https://cmap2.vims.edu/LivingShoreline/DecisionSupportTool/index.html
Wetlands Assessment Tool for Conditions and Health (WATCH)	Partner for the Delaware Estuary	https://njrestors.rutgers.edu/pde-watch/

4.6 FUNDING OPPORTUNITIES FOR NATURE-BASED SOLUTIONS

The following table identifies state, federal, private, and public funding opportunities for NBS. The table contains links to external websites that maintain larger lists of funding programs. Funding opportunities listed may be subject to change. Please note this is not necessarily a comprehensive list and more information may be available online. Where original links are no longer accessible, the Internet Archive Wayback Machine has been used to create functional links to original sources.

Name	Agency/ Organization	Link	Type
Climate Resilience and Adaptation Funding Toolbox	U.S. EPA	https://www.epa.gov/resilient-investments	Repository
Climate Resilience Funding Directory	Resilient NJ	https://experience.arcgis.com/experience/196a9c8077e847c3b4a815d7c814930c?views=View-24	Repository
Nature-based Solutions Funding Database	National Wildlife Federation	https://fundingnaturebasedsolutions.nwf.org/	Repository
Green Infratructure Funding and Technical Assistance Opportunities	U.S. EPA	https://www.epa.gov/green-infrastructure/green-infrastructure-funding-and-technical-assistance-opportunities	Repository
Flood Funding Finder	American Flood Coalition	https://floodcoalition.org/fundingfinder/#home	Repository
Navigating Federal Funding for Green Infrastructure and Nature-Based Solutions	U.S. EPA	https://www.epa.gov/system/files/documents/2024-02/navigating-federal-funding-for-gi-and-nbs-master-summary_02_12_2024-508.pdf	Repository

4.7 GLOSSARY

Cultural Services: A type of ecosystem service which includes but it not limited to aesthetic, recreation, inspiration, spiritual experience, cognitive development, social well-being, and mental-health benefits. These values are often non-monetary in nature and more difficult to measure in a CBA compared to other more direct benefits (e.g., avoided damages from flooding).

Discounting: The process of adjusting benefits and costs that occur across different periods into comparable, present-value terms. Discounting reflects the time value of money, or that a dollar received today is worth more than one received in the future. Accordingly, the value of benefits enjoyed in future years is thus discounted to reflect that preference. Discounting therefore reflects how much future benefits and costs are worth today, or in present-value terms.

Discount Rate: An estimate of how rapidly the value of money changes over a particular period. For example, the Office of Management and Budget (OMB) for analysis of federal regulatory actions suggests an annual compound discount rate of 2% per year (OMB, 2024).

Ecosystem Services: The services provided by the Earth's ecological systems and resources. These services can support both human life (e.g., reduced flood risk, improved recreation and tourism, water purification) and the greater ecosystem (e.g., improved biodiversity and habitats for native species).

Net Benefits (NBs): The total benefits of a project or decision minus its total costs. A positive net benefit suggests a favorable outcome, while a negative net benefit indicates that costs exceed benefits.

Net Present Value (NPV): A metric which calculates the present value of a project's expected net benefits by discounting future costs and benefits to account for the time value of money. A positive NPV indicates that the benefits (in present value terms) exceed the costs.

Opportunity Cost: The value of the best alternative foregone when a choice is made. In CBA, it represents the benefits missed by investing resources in one option over another. For example, the opportunity costs associated with investing in 'Project A' are the benefits which could have been realized if instead investing in 'Project B.' Policy Site: The chosen project site that values are being estimated for in a CBA.

Study Site: Comparable sites which have previously completed project construction and operation. Due to their comparability, study sites are used in a CBA to reference and estimate values for the policy site by utilizing benefit transfer.

Time Value of Money: A concept that the value of money today is greater than the value of the same money in the future because people prefer consumption today more than consumption tomorrow.

Total Benefits: The total benefits of a project, which can include both use and non-use values. For example, use values include reduced flood risk, improved water purification, and recreational value, while non-use values include existence or option value. The total benefits of a project can also be categorized by direct, indirect, and intangible benefits. Direct benefits include the primary goals of the project (e.g., reduced flood risk), indirect benefits include secondary goals of the project (e.g., improved water quality, improved fish health), and intangible benefits include non-use or more abstract values which are non-monetary or difficult to measure (e.g., valuing the continued existence of a beach).

Total Costs: The total costs of a project, which can include labor costs, capital expenditures, operation costs, maintenance costs, and other related expenses. Labor and capital costs are often upfront costs occurring during project construction, while operation and maintenance occur in future years over the lifetime of the project.

Willingness To Pay (WTP): The maximum amount an individual is willing to spend to either acquire a good or service or to avoid an undesirable outcome. When discussing the maximum amount to spend to avoid an undesirable outcome, the concept is often referred to as 'willingness to avoid' (WTA). The concept of WTP and WTA underpin much of economic theory and help assess the value of the benefits of a project in a CBA.

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Section 3: Nature-Based Solutions Profiles

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