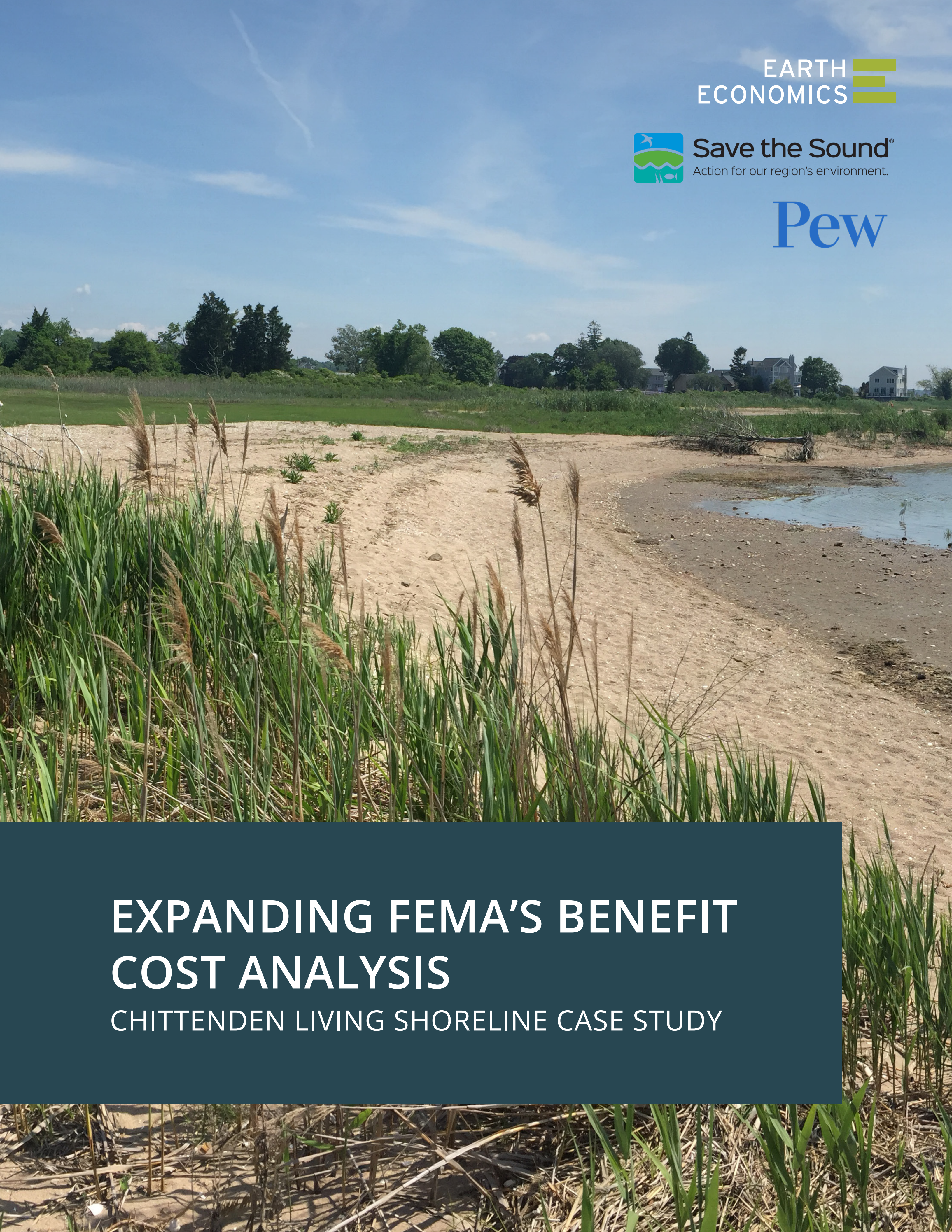

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EXPANDING FEMA'S BENEFIT COST ANALYSIS

CHITTENDEN LIVING SHORELINE CASE STUDY

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Earth Economics acknowledges that we operate on the lands of the Coast Salish peoples, specifically the ancestral homelands of the Puyallup Tribe of Indians, and the 1854 Medicine Creek Treaty.

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Introduction

The Federal Emergency Management Agency (FEMA) is responsible for helping communities prepare for, respond to, and mitigate natural hazards. FEMA invests in cost-effective projects—to demonstrate this, applicants must establish a benefit-cost ratio (BCR) greater than 1.0 (i.e., benefits are greater than costs). To ensure that projects are evaluated on a level playing field, FEMA developed its own Benefit-Cost Analysis (BCA) Toolkit to standardize analyses.

The BCA Toolkit was originally developed to analyze the benefits and costs of acquiring properties to limit flood damage to people and property. A series of policy changes and Toolkit updates have focused on incorporating the value of ecosystem services supported by various mitigation strategies, updating how such values can be used within BCA processes. The latest version of Toolkit (v 6.0) includes other hazard types and a multitude of (pre-) disaster mitigation project types. FEMA Policy 108-024-02, published in 2020, removed the BCR threshold that limited when ecosystem services could be included, and the Toolkit now includes more pre-approved values for multiple land-cover based ecosystem services and urban green infrastructure types. Although these are significant advancements, there is still room for improvement. In particular, benefits falling outside of the pre-approved values must be justified with significant documentation. This is sensible, as FEMA has a strong interest in ensuring that projects are cost-effective, and analyses are technically sound. At the same time, the additional technical work to justify new values and methods presents a significant barrier for many prospective applicants, discouraging more innovative solutions to integrate natural systems into hazard mitigation strategies.

For these more innovative projects, the barriers that inhibit inclusion of the full range of benefits also limit the competitiveness of those proposals. The purpose of this report is to explore FEMA's new BCA policies by reviewing its Toolkit v6.0 to identify opportunities for expansion and to suggest an "expanded BCA" that would address such opportunities. We present the *Chittenden Park Living Shoreline* project as a thought experiment to identify specific limitations of current BCA processes. Finally, we use this project concept to demonstrate how nonmarket valuation methods (including revealed and stated preference methodologies, such as travel cost or contingent valuation) could be brought to bear on the BCA, highlighting how such methods are widely accepted by other state and federal decisionmakers. It should be noted here that the Chittenden thought experiment is not a formal application to FEMA but instead is a means of eliciting new approaches to the valuation of similar project types.

We find three areas for expansion and present three potential solutions to support a reframing of FEMA's BCA Toolkit. These improvements focus on providing a more extensive framework that will enable users to easily quantify the benefits of non-traditional and innovative nature-based solutions for hazard mitigation. The report begins by reviewing how other federal agencies account for ecosystem services in their investment decisions. Ecosystem services are currently being incorporated in federal decision-making frameworks outside of FEMA, showing that there are many, evolving ways to account for nature's value. We then present the Chittenden thought experiment where we attempt to characterize a nontraditional project within current FEMA BCA processes and comment on the limitations that emerge. We close with a hypothetical expanded BCA, drawing on ecosystem service valuation practices employed elsewhere and our own experience as ecological economists, where we suggest methods and valuation frameworks that will make it easier to evaluate non-traditional project types and further promote innovation and resilience in hazard mitigation planning.

Chittenden Park Living Shoreline

This report uses the *Chittenden Park Living Shoreline* project currently under design in Guilford, CT as a case study to propose expanding the current FEMA BCA model to more comprehensively incorporate ecosystem services and promote sustainable mitigation planning. This project would implement nature-based erosion control designs to protect and restore the 155-acre seaward edge of the West River Marsh. Project designs include restoring and elevating existing tidal marshes to combat expected sea level rise, adding rock sills for erosion control and off-shore breakwaters to diminish wave energy.

The West River Marsh is part of the 1,100+ acre East/West River Marsh complex, one of the largest and most ecologically important within the Long Island Sound, ranking 8th of 487 within Connecticut by the Saltmarsh Sparrow Habitat Prioritization Tool (Atlantic Coast Joint Venture, 2020). Significant rates of erosion currently threaten the area. Analysis has shown that erosion combined with sea level rise has significantly impacted the area, with almost 500 feet of beach and marsh lost over the last 50 years (Whelchel et al., 2017). This area may lose approximately 100 feet inland every 10 years at this observed rate. Due to the ecological importance and threat of erosion, this marsh complex has been identified as a priority for restoration/conservation within Guilford's Harbor Management Plan, Hazard Mitigation Plans, and Community Coastal Resilience Plan. The Chittenden project is unconventional when compared to traditional FEMA project types. As such, it provides a unique opportunity to suggest new approaches for the BCA framework to ensure flexibility so that it can reliably analyze a broader range of project types and to promote innovative and sustainable solutions to mitigate hazards.

What makes this project atypical is that it would not directly protect built infrastructure, a FEMA priority. Instead, it seeks to reduce future losses by protecting coastal wetlands that mitigate flood damages to built infrastructure. Through the direct protection of the larger wetland complex (which buffers homes, businesses, and critical infrastructure such as roads and rail lines from the impacts of coastal flooding), the Chittenden project would ensure the future resilience of the Guilford community. Without action, it is expected that these wetlands will continue to erode and increase Guilford's vulnerability to coastal hazards. Natural resource conservation has been highlighted by Guilford's local government as a flood hazard mitigation strategy (South Central Regional Council of Governments, 2018). However, FEMA's current BCA framework has no way to account for such complex interactions, limiting the eligibility and competitiveness of *Chittenden Park Living Shoreline* for mitigation funding. While this dynamic is discussed in detail in the expanded BCA section, it is important to understand why significant aspects of this project are effectively excluded in FEMA's BCA Toolkit.

Ecosystem Services Within Federal Frameworks

Federal Emergency Management Agency (FEMA)

FEMA's mission is to help people prepare for, respond to, and recover from all natural hazards (FEMA, 2023). To accomplish this, the agency offers grants to cost-effective projects that are shown to increase community resilience. To ensure that proposals satisfy all grant requirements, FEMA developed the BCA Toolkit to help applicants estimate and record project benefits and costs. Traditionally, benefits have included any service disruptions or damages to property and persons that can be avoided with the proposed intervention. Costs include both construction and labor costs associated with implementation, as well as ongoing operations and maintenance (O&M) costs throughout the project lifespan. In the past decade, FEMA has modified its framework to support the inclusion of ecosystem service benefits provided by nature-based solutions. Ecosystem services are the direct and indirect benefits provided by the natural environment, such as cleaner air, wildlife habitat, or recreational opportunities (FEMA, 2022). This update reflects the increased popularity of sustainable planning and design that integrates nature-based solutions or natural features into built environments to promote resiliency.

Proponents of nature-based solutions have argued that traditional FEMA BCA guidelines limit the benefits associated with natural features, placing such projects at a disadvantage. Nature-based solutions produce valuable services such as hazard mitigation (e.g., flood risk reduction), but their full value includes a broader range of ecosystem goods and services—often referred to as co-benefits. In this way, nature-based solutions can increase adaptability and resiliency while offering additional improvements to the quality of life for nearby residents.

FEMA has recognized the advantages nature-based solutions offer in a series of policy reforms. In 2013, FEMA modified the BCA Toolkit to allow select ecosystem services to be included, based on precalculated estimates for riparian areas and green open space (FEMA, 2013). The value of services for these two landcover types were quantified on a dollar per acre per year basis, allowing for easy transferability. While it was a good first step, it effectively ruled out benefits produced by projects that incorporate other natural features.

In 2016, FEMA updated those precalculated benefits to include four additional landcover types: wetlands, forests, estuaries, and marine ecosystems (FEMA, 2016). FEMA also expanded eligible activities to include floodplain restoration, green infrastructure, post-wildfire mitigation, and aquifer storage or recovery. However, these precalculated benefits were only allowed to be included in a project's BCA if "traditional" benefits produced a benefit cost ratio above 0.75. In other words, projects unable to show a return of at least $3 for every $4 invested before accounting for ecosystem service benefits were not allowed to include ecosystem services in the BCA (FEMA, 2016).

This limitation was critiqued by supporters of nature-based solutions. To address their concerns, FEMA updated its ecosystem service framework again in 2020, removing the benefit cost ratio requirement and allowing all projects to quantify and integrate ecosystem services (FEMA, 2020). Again, FEMA added new landcover types and updated the precalculated monetary benefits. Figures 1 and 2, Tables 3 and 4 from *FEMA Ecosystem Service Value Updates* (2022), below compare these reforms and the associated values. This is the framework that FEMA currently applies to applications for hazard mitigation funding.

Figure 1. "Summary of Changes to Land Cover Categories and Ecosystem Service Values" (FEMA, 2022, pg. 11)

Table 3. Summary of Changes to Land Cover Categories and Ecosystem Service Values

2016 Adopted Values		2022 Proposed Values	
Land Cover Category	Value (2014 USD/acre/year)	Land Cover Category	Value (2021 USD/acre/year)
Forest	554	Forest	12,589
Green Open Space	8,308	Urban Green Open Space	15,541
		Rural Green Open Space	10,632
Riparian	39,545	Riparian	37,199
Wetland	6,010	Coastal Wetland	8,955
		Inland Wetland	8,171
Marine and Estuary	1,799	n/a*	n/a
n/a	n/a	Coral Reefs	7,120
n/a	n/a	Shellfish Reefs	2,757
n/a	n/a	Beaches and Dunes	300,649

*The Marine and Estuary category (and most of its associated values) was merged with the Coastal Wetland category

Figure 2. "Summary of Proposed Land Cover Categories and Ecosystem Service Values" (FEMA, 2022, pg. 12)

Table 4. Summary of Proposed Land Cover Categories and Ecosystem Service Values

Ecosystem Service	Value by Land Cover Category (2021 USD/acre/year)								
	Urban Green Open Space	Rural Green Open Space	Riparian	Forest	Coastal Wetland	Inland Wetland	Coral Reefs	Shellfish Reefs	Beaches and Dunes
Aesthetic Value	7,010	7,505	767	1,477	1,648	1,303	327	-	223,840
Air Quality	201	-	254	711	-	-	-	-	-
Biological Control	-	-	199	-	-	-	-	-	-
Climate Regulation	54	77	96	199	125	56	-	-	-
Erosion Control	78	78	13,823	1,672	-	-	-	-	-
Existence Value	-	-	-	7,531	-	-	-	-	-
Flood and Storm Hazard Reduction	316	-	6,052	368	1,035	1,264	3,269	-	-
Food Provisioning	-	-	736	-	-	-	18	1,905	-
Habitat	5,890	2,021	2,547	-	2,420	1,416	2,222	-	-
Pollination	350	350	-	-	-	-	-	-	-
Recreation/Tourism	1,642	601	6,215	94	1,624	1,906	1,261	253	76,809
Research and Education	-	-	-	-	-	-	23	-	-
Water Filtration	-	-	6,239	435	1,558	1,584	-	600	-
Water Supply	-	-	272	103	544	643	-	-	-
Total Estimated Benefits	15,541	10,632	37,199	12,589	8,955	8,171	7,120	2,757	300,649

National Oceanic and Atmospheric Administration (NOAA)

NOAA does not have a detailed framework to analyze or quantify ecosystem services for consideration in management decisions. Instead, it adopted an Ecosystem-Based Management approach, by which it filters agency actions and select appropriate alternatives. This reflects NOAA's vision to protect and enhance ecosystems, communities, and economies so that they are resilient to environmental change (NOAA, 2023). While it primarily manages marine resources, NOAA also has a large marine data collection and research role. In the context of marine environments, it is interested in recording how ecosystem health impacts the production and function of ecosystem services, as well as how such impacts affect the ways people interact with the environment. NOAA aims to be the leading entity to provide data for innovative federal decision making.

NOAA's consideration and inclusion of ecosystem services can be seen in multiple contexts. First, when managing fisheries NOAA employs what is known as an *integrated ecosystem assessment*, which ensures that management decisions are assessed for impacts on people and ecosystems, as well as any tradeoffs. Second, NOAA has expanded its approach to restoration to the watershed level because it realized that to protect species, habitat must also be protected. This clearly demonstrates a recognition and inclusion of ecosystem services within regional place-based analyses. Finally, NOAA aims to produce critical information about the links between ecosystem health and function and the services provided by those ecosystems. In summary, NOAA has adjusted how it analyzes and prioritizes management decisions to promote more environmentally and socially sustainable outcomes.

United States Army Corps of Engineers (USACE)

The USACE began as a producer of engineering solutions to aid the navigation of the country's waterways. Over time, it assumed responsibility for flood control, and more recently, stewardship of the environmental restoration of water resources (USACE, n.d.). As the Corps' role expanded, it adjusted planning strategies to better address the challenges of restoration management. To guide its staff, the USACE developed a framework to analyze management actions. It is through this framework that it identifies, and weighs benefits and trade-offs associated with different alternatives.

As this framework evolved, the USACE became interested in ecosystem services so it could more comprehensively analyze the cumulative effect of its management plans. To identify the opportunities and challenges associated with integrating ecosystem services, the USACE tasked a work unit with exploring a practical framework that could be implemented within its planning processes (NESP, 2016). In 2013 it released two reports, "Incorporating Ecosystem Goods and Services in Environmental Planning – Definitions, Classification, and Operational Approaches" and "Using Information on Ecosystem Goods and Services in Corps Planning: An Examination of Authorities, Policies, Guidance, and Practices," to help guide the inclusion of ecosystem services within the agency. Despite these efforts, no official framework has been adopted to standardize how the agency addresses ecosystem services in its planning process. Yet it is apparent through its recent publications that ecosystem services are at least considered in qualitative terms (Reed et al., 2013; Murray et al., 2013). However, the *Engineering with Nature Program* is committed to promoting innovative nature-based hazard mitigation solutions by updating internal policies, developing resource materials, and creating a BCA framework to quantify the ecosystem services provided by nature-based solutions (USACE, 2023).

Bureau of Land Management (BLM)

The BLM manages a wide range of landscapes and land uses, from arid deserts to forests, livestock grazing, and recreational lands. Congress has given the Bureau a dual mandate, tasking the agency with managing its resources to support multiple uses and sustained yield, while conserving natural, historical, and cultural icons (BLM, 2023). To ensure that the BLM manages its lands in alignment with the mandate, the agency develops regional resource management plans with multiple management strategies. These strategies are analyzed based on the expected physical, biological, economic, and social impacts (NEPS, 2016). Once a management plan has been accepted, the process is repeated to identify tradeoffs associated with proposed land use activities. Although there is no specific framework mandating the inclusion of ecosystem services in management plans, such processes ensure that the Bureau considers ecosystem benefits when prioritizing resource uses.

United States Department of Agriculture (USDA)

The Water Resources Development Act of 2007 prompted the USDA (among other federal agencies) to develop frameworks for analyzing water resource projects. USDA's framework was shaped by the Principles, Requirements, and Guidelines established in the Act. To comply with the standards, the USDA created a BCA process where the lifetime benefits and costs of both action and no-action scenarios are considered. While project impacts vary depending on the scope and scale of each project, the USDA promotes watershed-scale analyses to ensure that both on and off-site impacts are captured. The intention is to identify tradeoffs and to minimize negative environmental, social, and economic impacts of federal actions.

The USDA requires each BCA to apply the best-available science to monetize all project benefits with appropriate economic methodologies, with ecosystem services benefits organized within the Millennium Ecosystem Assessment (MEA) framework. Researchers are to include all services that are likely to be impacted. The USDA does not restrict benefit types and has approved both use and non-use values, and although primary methods are to be prioritized when quantifying ecosystem services, benefit-transfer is accepted where these are infeasible. Approved primary methods include avoided cost, replacement cost, contingent valuation, agent-based modeling, travel cost, hedonic modelling, or changes in net income. By comparing project alternatives inclusive of ecosystem services, the USDA seeks to provide resource solutions for communities while enhancing ecosystem health and resilience.

United States Forest Service (USFS)

The USFS has also been mandated by Congress to ensure its lands support healthy and functioning forest ecosystems critical to maintain public welfare (NEPS, 2016). Following this mandate, the USFS develops management plans to consider overall impacts on the environment and people. In 2012, the agency established a new planning rule to guide the inclusion of ecosystem services within management plans so that projects are ecologically, socially, and economically sustainable (National Forest System Land Management Planning, RIN 0596–AD02, 2012). The USFS process does not quantify the value of benefits provided by ecosystems, but links to human wellbeing are identified and related impacts are to be considered. The USFS created the National Ecosystem Services Strategy Team (NESST) to develop frameworks and integrate processes and tools within agency policy to enable the inclusion of ecosystem services (USFS, 2023).

Conclusion and Policy Gaps

As the only federal agency that has constructed a standardized valuation framework, FEMA has made the most progress in incorporating ecosystem services benefits. The USDA's framework is more comprehensive but lacks standardized practices to ensure consistency. While other agencies do not have rigorous frameworks or tools to help calculate the value of ecosystem services, the frameworks do qualitatively address the impacts of management decisions on ecosystem health and what this might mean for communities and the economy.

Integrating ecosystem services in management decisions is a daunting task, especially attempting to do so consistently across large agencies. Each agency is specialized and has developed its own methods for integrating ecosystem services into its processes—as such, each has its own strengths and limitations. One solution could be to pursue cross-agency collaboration to establish a single BCA framework for all federal agencies. If this is not feasible, then FEMA could create an internal task force to develop a more inclusive framework that would leverage a more complete picture of a project's benefits.

FEMA's Traditional Benefit-Cost Analysis Toolkit 6.0

FEMA's BCA Toolkit is rigid by design, due to an internal need for standardized practices and procedures. As a result, some project types are better served by the framework than others. Based on FEMA's latest updates regarding use of the BCA Toolkit, we find three areas for improvement that would aid in the comprehensive analysis of a project's benefits:

1. FEMA's preference to directly protect discrete properties and built infrastructure with built solutions limits the competitiveness of projects proposing innovative nature-based solutions.
2. The use of national economic values for each landcover type, regardless of location, does not account for the unique features or services that could be present and can underestimate the value of ecosystem services.
3. Finally, FEMA does not accommodate projects that protect natural resources as a hazard mitigation action. The toolkit will not accept ecosystem service values that are outside a project's intervention boundaries, even if such assets would be lost with a no-action alternative and expose communities to additional future hazards.

To explore how this framework affects the competitiveness of some projects, we present a thought experiment to show how the Chittenden Park Living Shoreline project would be assessed by the BCA Toolkit. This section explains key steps for completing a BCA, highlighting where the framework falls short for projects like Chittenden. We then summarize how limitations within the FEMA BCA process disadvantages projects like the Chittenden Park Living Shoreline.

Case Study: Chittenden Park Living Shoreline

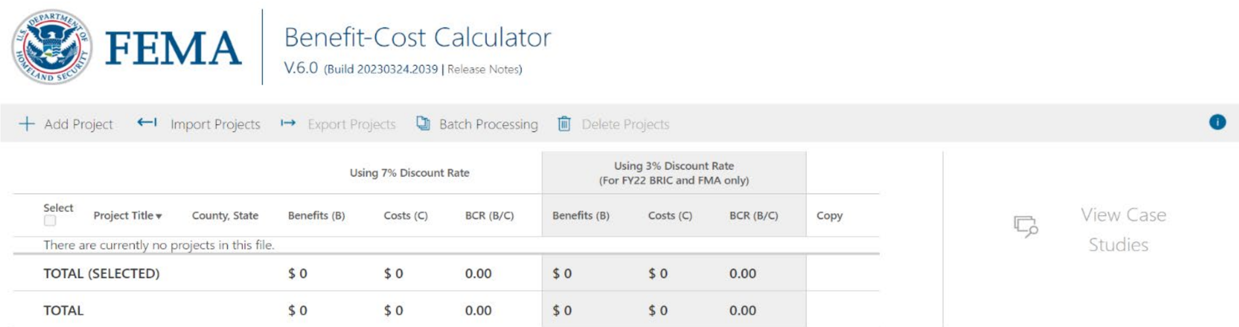
The proposed Chittenden Park Living Shoreline project is just now shifting to final design processes and could be implemented in various ways. To account for this uncertainty, we developed five implementation scenarios to show how slight changes to the project costs or the land cover types restored through the project could significantly alter its cost-effectiveness through the lens of FEMA's BCA. This project directly aligns with Guilford's hazard mitigation plan by enhancing and conserving natural resources to combat against coastal hazards, thus making it an interesting thought experiment to explore how FEMA may view these community approved nature-based hazard mitigation solutions (South Central Regional Council of Governments, 2018). In this section, one of the potential scenarios—in which no beach or dune is presumed to be part of the restored condition—is presented. All modeled scenarios are based on concept designs and budget estimates previously prepared for the project and/or provided by Save the Sound. The results of the remaining scenarios and the associated BCRs can be found in the Appendix.

The FEMA BCA Toolkit is a Microsoft Excel add-in that must be downloaded from the "insert" tab under Excel's add-ins icon. Further instructions on how to download and install the Toolkit can be found on FEMA's resource page.[1] When the tool is first opened, the window shown below appears. This is where projects to be evaluated can be added for analysis. All offsite properties expected to be impacted by the mitigation action must be added to the Toolkit to record the avoided damages (including loss of services). All project elements must be added as other properties, including construction and O&M costs, as well as the ecosystem services provided by the project site. The Toolkit calculates the cost-effectiveness of an

[1] Toolkit instructions available at www.fema.gov/grants/tools/benefit-cost-analysis#toolkit

intervention action by analyzing every impacted property/structure, aggregating all structures at the end to calculate an overall project benefit-cost ratio (Figure 3).

Figure 3. Preview of the FEMA Benefit-Cost Calculator V.6.0



Once all mitigation actions and structures have been added to the project, the benefits, costs, and BCR will be presented on the page shown above. FEMA will present the results adjusted with its standard seven percent discount rate, as well as an alternative three percent discount rate. The latter is accepted for projects which return a BCRs above 0.75 at the seven percent discount rate and also benefit disadvantaged or socially vulnerable communities. Projects are considered cost-effective if it achieves a BCR greater than 1.0 with the seven percent discount rate, or if they benefit vulnerable populations and have BCR greater than 1.0 at the three percent discount rate (FEMA, 2016).

Once a project has been created, the project configuration and cost estimation page will appear (Figure 4). The project configuration section will ask for data about the type of structure being analyzed, the mitigated hazard type, and the mitigation action type. Analysts must also select the methodology used to estimate the damages avoided due to mitigation actions. Based on these settings, the Toolkit will request specific additional information from the user.

Modeled damages require extensive data analysis prior to entry into the BCA Toolkit. For example, for flood mitigation, the user must know how the project will impact flood heights for each property (this process will be explained further in upcoming sections). A *historical damages* approach uses damage data reported over multiple periods (e.g., 5, 50, or 100 years) to estimate the likely value of avoided future damages. Finally, the *professional expected damages* approach requires a qualified individual to forecast the damages that would occur for specific hazard and frequency intervals.

Next, the cost estimation section is where the project useful life (number of years project will function) and construction and O&M costs must be added (Figure 5). These are projected for the full project lifetime to calculate the total costs to construct and maintain the project. In the end, these costs will be compared to total benefits to create the BCR.

Figure 4. Project Configuration for the FEMA Benefit-Cost Calculator

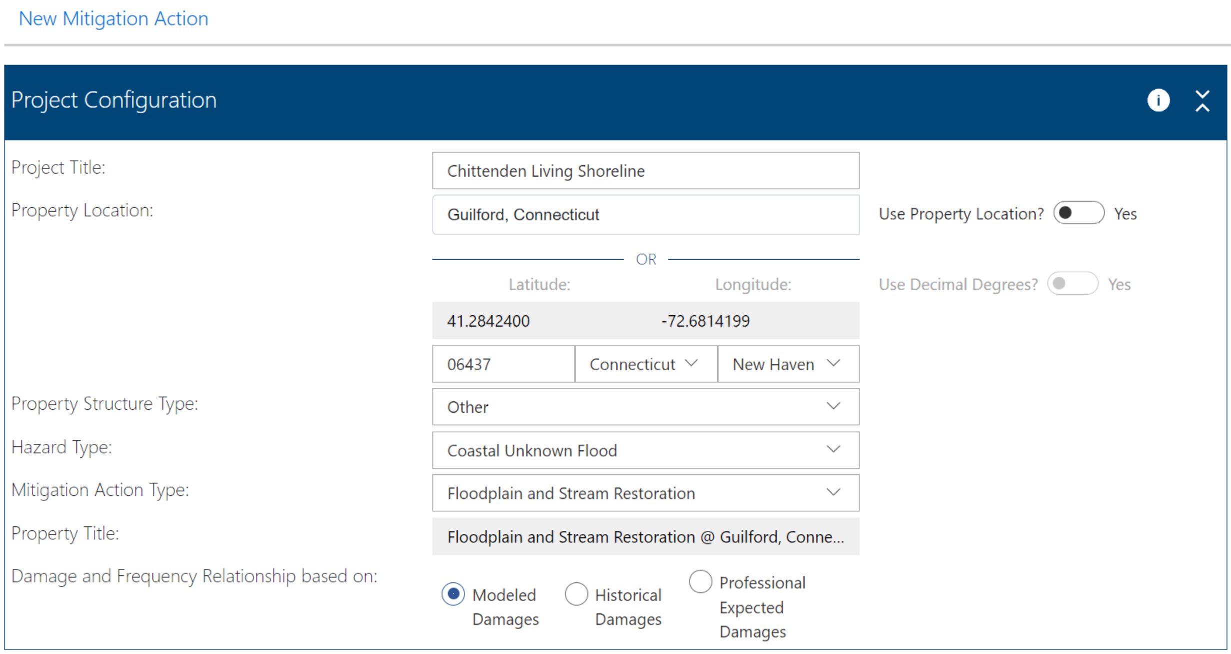
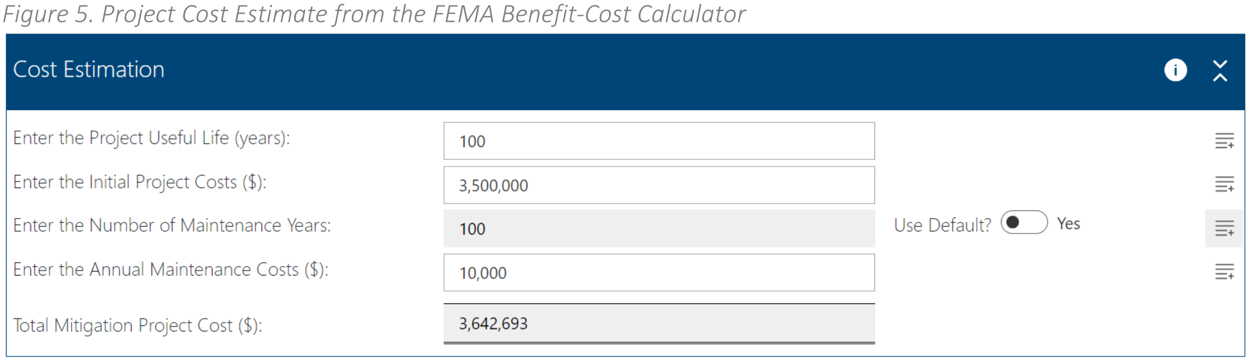


Figure 5. Project Cost Estimate from the FEMA Benefit-Cost Calculator



The specific method chosen to estimate avoided damages will affect the input data required, and the dialogue boxes for each approach are different. Using modeled damages in the BCA Toolkit requires detailed data and analysis of full project implementation and operating costs, as well as details on how avoided damages are projected. The dialogue box focuses on gathering data on hazard probability for a specific property, structure engineering and layout details, structure contents, number of occupants, lost income or services, volunteer costs, and ecosystem services. In addition, it requires an in-depth analysis on how the mitigation action will impact the structure exposure to a given hazard. For the Chittenden project, this would explore how a living shoreline could impact the height of flood waters at each structure location. To obtain such results, a qualified engineer must develop a Hydrologic and Hydraulic (H&H) model.

Once the base flood elevations of each structure under both pre- and post-mitigation scenarios have been entered, the tool calculates expected damages for both scenarios to determine the marginal change. FEMA estimates damages based on the structure's specific details/contents value and applies a depth-damage curve, a model of the proportion of a structure that would be damaged based on the depth of flooding within the structure. This percentage is applied to the structure's value resulting in a dollar value of predicted (avoided) flood damages.

Without this information, the Toolkit cannot estimate the value of mitigation—meaning that the scenario cannot be included in the BCA. If a modeled damages approach is infeasible, users could choose to apply historical or professional damage methods. For the Chittenden project this section was left empty, as historical damage data were not available, and no H&H model has been developed (in fact, no professional was contacted for this project, as the avoided damages are predicted to be low since the intervention area is not surrounded by built infrastructure). Due to the lack of nearby buildings and infrastructure, it was anticipated that this project would not be of interest to FEMA.

FEMA Benefit-Cost Limitations: Case Study Insights

Limitation 1: Mission and Capacity

The first limitation of FEMA's framework is its mission and resulting benefit preferences. The primary focus for FEMA is to determine whether projects will *directly* protect people and built property in a cost-effective manner, which aligns with its historic approaches to hazard mitigation. The tool was designed for conventional project types that maximize direct disaster risk reduction benefits, specifically property acquisition and gray infrastructure project types—it was not designed to analyze the full benefits of nature-based solutions projects. Moreover, state offices may lack the capacity to provide additional support for novel hazard mitigation solutions that are not represented fairly within the toolkit. For projects such as the *Chittenden Park Living Shoreline*, this presents a key barrier to entry. Since the Chittenden project is not adjacent to built infrastructure and the project is not a clean fit for the toolkit, the project team originally chose not to pursue the analyses required to develop a FEMA sub-application (Figure 6).

After avoided damages have been calculated, users must also include displacement costs, the loss of services, and/or volunteer costs—additional costs that would not be incurred if the mitigation action is pursued. The tool requests the number of residents per structure, the operating budget for commercial structures, and number of volunteers and days volunteered required to recover from a natural hazard and recurrence interval.

Once conventional avoided costs have been quantified, the next step is to estimate the value of the ecosystem service benefits. FEMA's ecosystem services framework uses a simplified benefit transfer approach, with nationwide, standardized annual economic values for nine landcover types. These are FEMA's accepted estimates for the value of ecosystem services provided by one acre of the landcover type over one year, allowing users to easily scale those values based on the extent of each landcover type in their project design.

Limitation 2: A Simplistic Ecosystem Services Framework

While supporting ecosystem services for multiple landcover types is an improvement, the use of standardized economic estimates for the value produced by each landcover type omits considerable nuance in the form and magnitude of project benefits. For example, this approach assumes that one acre of coastal wetlands provides the same value as inland wetlands, ignoring the relationship between specific hazards, exposed assets, and the way in which wetlands are able to mitigate disaster risk. Limitations of this approach include:

1. nationwide estimates by landcover type, regardless of location or context

2. it ignores the relative scarcity of specific landcovers
3. it ignores the potential for unique locational characteristics (e.g., endangered species habitat)

We know that not every acre of a given landcover type is the same or provides the same type or magnitude of benefits. Historical coastal wetland losses mean that any remaining wetlands are even more important, as they often provide scarce habitat and rare opportunities for recreation, science and education, or even aesthetic benefits. By failing to account for the unique characteristics of the coastal wetlands at Chittenden, the BCA Toolkit does not capture its full range or full value of those benefits.

Figure 6. Before and After Hazard Probability Parameters from the FEMA Benefit-Cost Calculator

Project Name: Chittenden Living Shoreline **Hazard Type:** Coastal Unknown Flood **Mitigation Action Type:** Floodplain and Stream Restoration **Property Type:** Other

Hazard Probability Parameters - Flood

Enter the Lowest Floor Elevation of the Property (ft):	0
Enter the Ground Surface Elevation (ft):	0
Enter the Base Flood Elevation (ft):	0
Enter Additional Projected Sea Level Rise above BFE (ft):	0

Enter below the Recurrence Interval and corresponding Water Surface Elevation:

Use Default Recurrence Intervals? Yes

BEFORE MITIGATION	
Recurrence Interval (years)	Stillwater Elevation (ft)
10	0
50	0
100	0
500	0

AFTER MITIGATION	
Recurrence Interval (years)	Stillwater Elevation (ft)
10	0
50	0
100	0
500	0

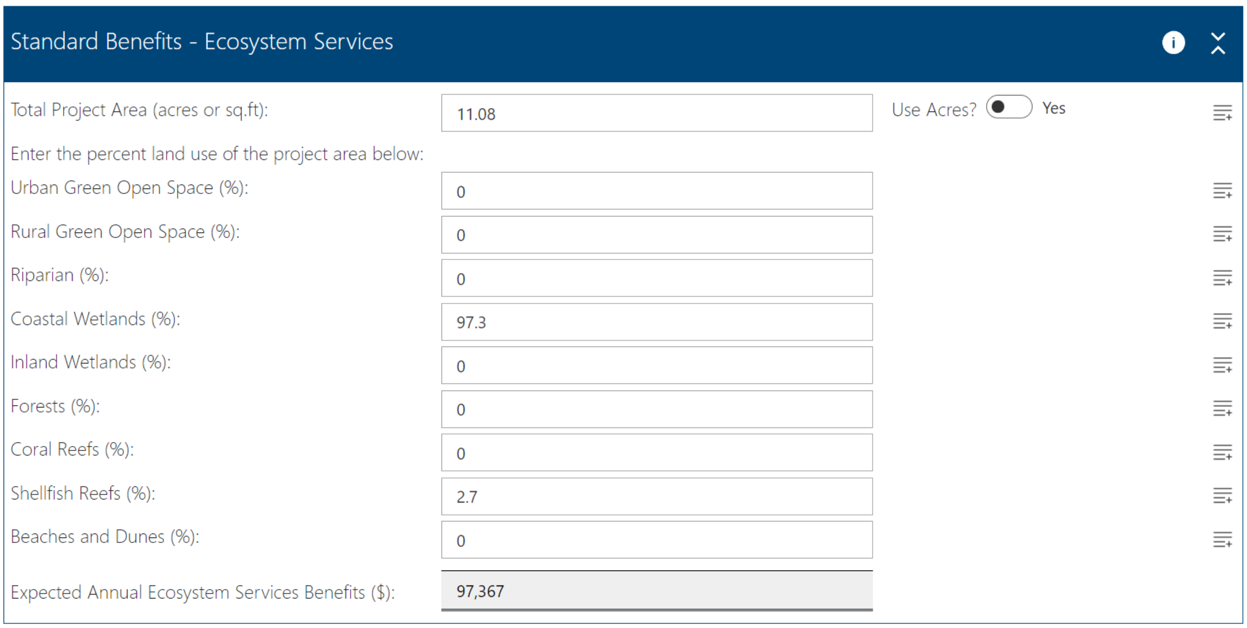
The Toolkit requires the *total site extent* and the *extent of every landcover type* within the intervention area. This way it can select the appropriate standardized values and apply them to the associated landcover extents. The Chittenden project is essentially a floodplain restoration project for coastal wetlands; most of the land is expected to be restored as coastal wetlands with some beach or dune areas and/or shellfish reef constructed in the shallows. Once a user enters the required landcover data, the tool will automatically apply the standardized values. These are then projected and discounted across the lifetime of the project to calculate the total benefits provided in net present value terms.

Limitation 3: Site boundaries and Natural Infrastructure

FEMA only allows ecosystem service benefits that have been directly linked to intervention sites. This greatly limits the benefits of projects that protect or preserve other larger natural resources which also produce ecosystem services. The Chittenden project will protect a larger extent of coastal wetlands that would be eroded without the intervention, but there is no apparent way to include those benefits in the project BCA.

This approach is not consistent with how FEMA analyzes the traditional avoided damages to people, property, and infrastructure. When considering the approach for these benefits, FEMA does not limit the inclusion of benefits strictly to the intervention site boundaries. It allows all avoided damages for all infrastructure to be included within the project's BCA. This inconsistency diminishes the competitiveness of projects that protect or enhance other natural capital. The protection of natural capital is valued less than protecting built capital, even though both impact human wellbeing and community resilience.

Figure 7. Standard Ecosystem Services Benefits from the FEMA Benefit-Cost Calculator



Standard Benefits - Ecosystem Services

Total Project Area (acres or sq.ft):	11.08	Use Acres? Yes
Enter the percent land use of the project area below:		
Urban Green Open Space (%):	0	
Rural Green Open Space (%):	0	
Riparian (%):	0	
Coastal Wetlands (%):	97.3	
Inland Wetlands (%):	0	
Forests (%):	0	
Coral Reefs (%):	0	
Shellfish Reefs (%):	2.7	
Beaches and Dunes (%):	0	
Expected Annual Ecosystem Services Benefits ($):	97,367	

As ecosystem service benefits are quantified, a dialogue box presents the lifetime summary of all benefits and costs, as well as the benefit-cost ratio for each individual structure. The process repeats for all structures that will be impacted by mitigation actions. Once all structures have been entered into the Toolkit, a project summary screen will show the total benefits and costs, and a BCR for the entire project lifetime. The Toolkit provides two sets of results, one discounted at seven percent, and the other at a three percent discount rate. Since it is unclear whether structures would be directly protected due to the Chittenden project, only one property has been added to capture the ecosystem services provided.
As can be seen below (Figure 8), one possible scenario for the Chittenden project where the restored condition is comprised of coastal wetland and shellfish reefs provides nearly $1.39 million in total lifetime benefits at a cost of just over $3.64 million. However, the estimated BCR is 0.38 indicating that the project is not cost-effective when viewed through FEMA's BCA Toolkit.

Figure 8. Scenario Results from the FEMA Benefit-Cost Calculator

Home | Add Mitigation Action | Delete Mitigation Actions | View Report

					Using 7% Discount Rate			Using 3% Discount Rate (For FY22 BRIC and FMA only)		
Select	Map Marker	Mitigation Title	Property Type	Hazard	Benefits (B)	Costs (C)	BCR (B/C)	Benefits (B)	Costs (C)	BCR (B/C)
☑	1	Floodplain and Stream Restoration @ Guilford, Connecticut	•••	DFA - Coastal V Flood	$ 1,389,357	$ 3,642,693	0.38	$ 3,076,697	$ 3,815,989	0.81
TOTAL (SELECTED)					**$ 1,389,357**	**$ 3,642,693**	**0.38**	**$ 3,076,697**	**$ 3,815,989**	**0.81**
TOTAL					**$ 1,389,357**	**$ 3,642,693**	**0.38**	**$ 3,076,697**	**$ 3,815,989**	**0.81**

Summary

We have shown several misalignments between the Chittenden Park Living Shoreline project and the FEMA framework, as implemented in its BCA Toolkit. First, the project does not fully align with internal agency preferences concerning benefit types. Because the project is not located near enough to critical or valuable built infrastructure, the avoided damages to buildings are expected to be low. More generally, innovative strategies such as living shorelines require additional effort from state disaster management offices, who may already face capacity limits that affect their ability to support new project types. For example, the complexity of the proposed project will require additional documentation for justification which results in prolonged review processes that increase workloads for overburdened employees.

Second, FEMA's BCA tool is not designed to consider a project's full range or value of ecosystem services. Specifically, standardized values do not allow for full consideration of site characteristics. This affects the Chittenden project because coastal wetlands are scarce in Connecticut, with an estimated 27 percent of tidal wetlands lost between 1880 and the early 2000s and an additional 20-45 percent losses expected this century (Basso et al., 2015). Without a means of modifying the standardized values, the real benefits of the project are obscured.

Third, FEMA's approaches to assessing impacts on natural and built infrastructure is biased towards the latter. The Living Shoreline project would reduce erosion and protect a much larger area of wetlands. Without the project, those inland wetlands will continue to shrink, further exacerbating flood risk and reduce environmental benefits for residents. This is because the current FEMA framework does not allow applicants to include avoided damages to natural infrastructure in project BCAs. Such limitations mean that it is likely that FEMA would be critical when analyzing applications like the Chittenden Living Shoreline.

Proposed Expanded BCA

Considering the limitations of the BCA Toolkit, this section proposes an *expanded BCA* that would support the full range benefits of projects such as the Chittenden Living Shoreline. The goal is to address the limitations identified in the previous section while still producing rigorous estimates of project value. An expanded BCA would more comprehensively analyze project benefits and promote a more sustainable lens within FEMA's natural hazard mitigation. Primarily, FEMA's framework is limited in the way it views nature and the Toolkit methods for quantifying ecosystem services. Our proposed expanded BCA makes the case to:

1. view the environment as critical natural capital/infrastructure
2. use new methodologies to incorporate more precise ecosystem service and recreational values
3. incorporate non-use values.

Through these improvements, the FEMA BCA Toolkit could better support communities seeking to engage in comprehensive hazard mitigation efforts. In this section, we propose a framework better suited to pragmatically address the complexities of sustainable, nature-based hazard mitigation.

Nature as Critical Infrastructure and Loss of Services

The primary difference between FEMA's BCA and the proposed "expanded BCA" is that in the latter, the environment as seen as critical infrastructure. FEMA focuses on avoided damages to built infrastructure and associated loss of services to nearby residents. While the Agency has gradually expanded how it addresses ecosystem services provided by nature-based solutions, that has not (yet) extended to damages to natural capital or disruptions to the services provided by nature. By limiting avoided losses of natural infrastructure to site boundaries, FEMA may be ignoring considerable avoided costs, as is the case of the Chittenden project. This directly impacts the competitiveness of projects that protect nature as a mitigation strategy and thus limits long-term community resilience. The argument presented here intends to demonstrate that the natural environment is also essential for community wellbeing and should be acknowledged on the same terms as built infrastructure. This section presents the basic logic for a natural capital approach to hazard mitigation planning, documents where it has been adopted by others, and discusses its applicability to the Chittenden project.

Natural Capital in Hazard Mitigation Planning

Natural capital provides a broad range of ecosystem services supporting the everyday needs of society, such as clean air and water, food and habitat, and urban temperature regulation. Yet the ability of nature to mitigate natural disasters such as flooding is often ignored or undervalued—current hazard mitigation frameworks favor built infrastructure. There are three issues with this approach:

1. it does not account for the full range of interactions between society and the environment,
2. it does not promote future resiliency,
3. it is not sustainable.

One way of reframing FEMA's mission is that it supports disaster mitigation projects that provide the most benefits for the least cost. If a project protects both built and natural capital, then the avoided damages to both should be included in the BCR. Society depends on the services provided by the natural environment—without an appropriate balance of both natural and built infrastructure, the equilibrium is disrupted, leading to negative economic, environmental, and health consequences (OSTP et al., 2022). All project benefits—including avoided damages to both built and natural capital—should be integrated into the BCA framework.

Favoring grey infrastructure strategies over nature-based solutions to hazard mitigation limits the ability of a community to promote long-term resiliency. Some projects centered on built infrastructure solutions may anticipate how environmental change might impact the severity of natural hazards, but the resulting infrastructure is not able to readily adapt to changing conditions. For example, levees are built to protect against current hazards but may be insufficient for hazards augmented by climate change. By comparison, nature-based hazard mitigation solutions are inherently adaptable (Luedke, 2019). Rather than constructing more levees, existing coastal wetlands and dunes could be conserved and enhanced, increasing sediment deposition to expand wetlands and thus naturally increasing project effectiveness and resilience, while still providing a broader range of benefits to nearby communities (Luedke, 2019; Depietri & McPhearson, 2017).

The ability of natural capital to adapt to environmental conditions also promotes sustainability and cost-effectiveness, especially when compared to built infrastructure. Engineered solutions typically require extensive O&M and have relatively short life expectancies when compared to nature-based solutions. The FEMA standard for the useful life for built infrastructure is 50 years. Natural infrastructure typically requires less O&M and if appropriately managed, can persist in perpetuity (Depietri & McPhearson, 2017; Chausson et al., 2020). A longer lifetime, lower lifetime costs, and the inherent ability to adapt to change often make nature-based solutions more sustainable.

Ignoring the mitigation value of projects that protect natural capital (as well as built infrastructure) limits the long-term effectiveness of current hazard mitigation planning. Continuing along this path will lead to additional loss of ecosystem services, impaired resilience, and higher costs to mitigate ongoing risk.

Adoption of Natural Capital

In recent decades, the concept of natural capital has been adopted by many federal institutions. Last year, the Office of Science and Technology Policy collaborated with the Office of Management and Budget and the Department of Commerce to address the integration of natural capital into federal decision making. Its report *National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics* specifically acknowledges the essential relationship between society, the environment, and the economy. It argues that natural capital should be considered national assets that promote economic activity and human wellbeing, outlining a framework for measuring natural capital and including it in federal decision making.

The Living Shorelines Act of 2019 established a grant to preserve coastal wetlands. Facilitated by NOAA, the grant enables communities to fund sustainable resiliency projects (Laforcade, 2019). Other relevant laws include the Climate Stewardship Act of 2021, which funds climate stewardship actions, conservation practices, reforestation, and restoration (Climate, 2021). Both laws acknowledge that mitigating future natural hazards in a changing world will require the conservation and enhancement of natural resources.

The complex interactions between ecosystems and natural hazard events are heavily discussed and have been the subject of numerous studies. Reguero et al. applied a quantitative risk assessment to analyze the cost-effectiveness of coastal nature-based solutions along the U.S. portion of the Gulf of Mexico shoreline (2019). They calculated expected coastal storm damages for two scenarios, with and without nature-based solutions, and found that the restoration of coastal wetlands could offset losses by more than $50 billion, resulting in a BCR above 3.5. A similar study by Narayan et al. found that coastal wetlands in the northeastern seaboard reduced total damages from Hurricane Sandy by approximately 1 percent, saving $625 million (2017). Also see the U.S. Fish and Wildlife Service (2015) report, *Status and trends of wetlands in the Long Island Sound Area: 130 year assessment,* for an overview of the ecological benefits and economic value of tidal wetlands.

Applicability to Chittenden Living Shoreline Project

Were these suggested improvements integrated into FEMA's BCA framework, the competitiveness of projects like Chittenden would greatly improve. The proposed living shoreline project would halt the observed high rates of erosion of coastal wetlands by elevating the marsh and building structures to attenuate wave energy, thereby conserving (and perhaps eventually expanding) the remaining wetlands while building taller dunes to support flood mitigation. Those wetlands provide a significant buffer between the ocean and the Guilford community, and particularly the homes and businesses along Seaside Avenue, which is directly adjacent to the wetlands. Wetlands also provide other significant ecosystem services, such as habitat and water quality improvement. Under the current FEMA framework, the value of the flood mitigation benefits of the living shoreline is limited to the effects on built infrastructure, but the adjacent wetlands also mitigate future storm damages. Without the living shoreline it is likely that these coastal wetlands would be significantly eroded, leading to greater flood risk that will endanger citizens and critical infrastructure as well as diminish ecosystem service benefits for the community and wildlife. With an expanded BCA, all avoided damages (including the loss of services provided by the adjacent wetland) would be included in the analysis. The result would promote climate resilience while reducing future hazard mitigation and recovery costs.

Additional Ecosystem Service Values

This section seeks to address the issues associated with standardizing ecosystem service values within the BCA Toolkit. FEMA's intention was to make it easier for applicants to include ecosystem services benefits, but this approach may underestimate the total value provided by landcover types in specific contexts.

Regional Estimates

Rather than providing a single national economic estimate for the value of each landcover type, we recommend that at a minimum, FEMA develop regional estimates. This approach could better capture differences in the importance of species, habitat, and ecosystem functions at regional levels. While it would still likely limit the place-centric value of recreational opportunities, the relative scarcity of landcover types at local levels, and habitat for endangered species, it would help to address some of the variation in the value provided by some landcover types and improve the external validity of BCA estimates.

Recreation

Estimating the local value of recreational opportunities is typically accomplished in one of two ways. The more accurate (but also more resource and time-intensive) approach is to conduct primary research to estimate consumer surplus values. Willingness-to-pay surveys of actual users can be compared to their reported travel costs give a precise estimate consumer surplus, or the value associated with recreational opportunities beyond the costs incurred to visit a given site. Yet implementing and analyzing such surveys for every site requires considerable effort, cost, and expertise. Another less-intensive approach requires only that supported activities and annual visitation numbers per activity be recorded. FEMA could develop spending profiles by activity and visitor type (e.g., day vs. overnight trips) to support more accurate consumer surplus estimates for each activity and site. Once research into consumer spending by activity was completed, those profiles could be integrated into the BCA Toolkit, requiring only that users enter the activities supported by a site and the number of visitors by activity. This would support more precise localized recreational benefit estimates at a relatively low cost.

Scarcity and Endangered Species

Localized scarcity of some landcover types and the presence of endangered species could both be addressed by using weighted multipliers, which would then be applied to standardized benefit estimates. Multiplier values could be informed by the severity of localized scarcity or loss (based on historic land cover) for each landcover type, or the number of federally listed or endangered species using the project site or adjacent habitats that would be protected by project features. By acknowledging the localized significance of these features, the unique site characteristics could be more fully addressed within FEMA's BCA framework.

Non-use values of habitat and endangered species

While FEMA does account for non-use value (sometimes known as existence value), it does not account for the value of conserving unique environments or endangered species. We have suggested that multipliers might help to address the scarcity of landcover types and the presence of listed or endangered species, but this only affects use values. Unique features often have significant non-use values that should also be incorporated within a BCA. Non-use values are typically estimated through contingent valuation methods which ask survey respondents about their willingness-to-pay to ensure that a site (or species) is protected in perpetuity. Standardized surveys could be developed to help applicants conduct contingent valuation studies, the results of which could be added to the BCA Toolkit.

While the application of contingent valuation methods is sometimes debated, the approach has an extensive record in litigation for environmental damages. Even those who will never visit a site or observe an endangered species may still value them—indeed, this is part of why we have public parks, memorials, and endangered species protections. Contingent valuation is still the most effective means of estimating non-use value and should be included in the BCA framework for project site features and both built and natural capital features protected from natural hazards.

Conclusion

This report has demonstrated that many federal agencies have begun to acknowledge the importance of natural capital and the value of ecosystem services for human wellbeing. Although FEMA is the only agency that has quantified ecosystem services benefits, others still require qualitative reviews of the impact of federal actions on the environment. It is clear that the way the federal government views the environment has shifted and that in response it has taken steps to better understand links between the environment, economy, and community wellbeing. This shift has spurred multiple policy reforms not only within FEMA but other agencies and branches. While FEMA is a leader in incorporating ecosystem services into planning and assessment, there are still ways in which it could be more effective in integrating natural capital into its frameworks.

FEMA's current approach to hazard mitigation indirectly perpetuates grey infrastructure solutions by under-valuing nature-based solutions. Without updating FEMA's BCA Toolkit, grey infrastructure will continue to be favored, ultimately limiting the nation's adaptability and potentially increasing future exposure to natural disasters. We have argued that there are three major opportunities to improve within FEMA's hazard mitigation planning:

1. viewing the environment as critical infrastructure, including natural capital in avoided damages calculations;
2. improving the ecosystem services framework by including regional economic values for every landcover type, integrating best practices for recreation analyses, and incorporate scarcity multipliers to capture regional variations in the importance of landcover benefits, including habitat for listed and endangered species;
3. standardizing contingent valuation methods to enable BCA Toolkit users to quantify non-use values.

These improvements would significantly improve the competitiveness of less-traditional, nature-based hazard mitigation projects such as living shorelines. This paper intends to initiate a critical conversation about how the nation can adopt more sustainable strategies to hazard mitigation planning. To build community resilience, it is critical to acknowledge shared interests across multiple stakeholder groups and remain open to other perspectives. The goal should be a collaborative process focused on generating novel solutions to build the strongest analytical framework for selecting cost-effective hazard mitigation investments.

Drawing on the contents of this report, Earth Economics and Save the Sound with Connecticut Sea Grant, New York Sea Grant, and The Pew Charitable Trusts hosted an invite-only workshop, "Expanding the Benefit-Cost Analysis for Nature-Based Solutions" on June 15, 2023, for professionals from federal and state agencies, municipalities, environmental NGOs, and engineering firms.

For a copy of the workshop summary and video recording please visit savethesound.org.

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Appendix

This appendix shows the input data and resulting BCRs according to FEMA's BCA Toolkit v6.0. The purpose of this exercise was to demonstrate how subtle changes to a project's budget or land cover distribution can impact the final BCR. Each scenario is based on design concepts for the Chittenden Living Shoreline. Therefore, each scenario has a total site extent of 11.08 acres and modeled at a 7 percent discount rate over a 100-year lifetime to be consistent with FEMA's standards (FEMA suggests a 100-year lifetime for projects that will be managed in perpetuity, such as the Chittenden Living Shoreline).

Table 1. Comparison of Scenarios

SCENARIO	COASTAL WETLAND ACRES	BEACH/DUNE ACRES	SHELLFISH REEF ACRES	CONSTRUCTION COST ($2022)	O&M COST PER YEAR ($2022)	BCR
1	8	3.08	0	$ 2,591,054	$ 1,000	5.46
2	8	3.08	0	$ 3,000,000	$ 5,000	4.63
3	5.54	3.324	2.216	$ 3,500,000	$ 10,000	4.13
4	10	1.08	0	$ 3,000,000	$ 5,000	1.92
5	10.78	0	0.3	$ 3,500,000	$ 10,000	0.38
6	10	0	1.08	$ 4,000,000	$ 20,000	0.31

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