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Delaware Economic Analysis for Shoreline Management

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SUMMARY

For decades, the federal and state governments have invested in beach nourishment in Delaware to protect coastal infrastructure and sustain the multiple uses of the beaches by residents and visitors. In recent decades, nourishment projects have been funded wholly by the state or through a cost share agreement between the state and the US Army Corps of Engineers. To ensure the sustainability of this program given increasing costs, budgetary pressures, and more frequent and intense coastal storms, the Delaware Department of Natural Resources and Environmental Control (DNREC) is evaluating the potential for cost-sharing with local partners.

DNREC engaged Industrial Economics, Inc. (IEc) and Woods Hole Group (WHG) to conduct an economic benefits analysis and develop recommendations for equitable cost share ratios for specified beach nourishment projects. From an economics perspective, "equitable" cost share ratios allocate the costs of a project among stakeholders in proportion to the distribution of benefits. Thus, the cost share recommendations described throughout this report simply report the findings regarding how the benefits of the project are distributed across local, county, and state populations. The purpose is to ensure that the financial burden of the projects is shared among those who benefit. This reduces the risk of redistributive effects, which occur, for example, when costs of a project are borne broadly by all state taxpayers although the project benefits are concentrated within a specific subpopulation or geographic area.

Figure S-1. This study assesses the benefits of beach nourishment at eight project sites along the Delaware Bay coast and three project sites along the Atlantic coast

This study is focused on beaches in Delaware that meet the following criteria:

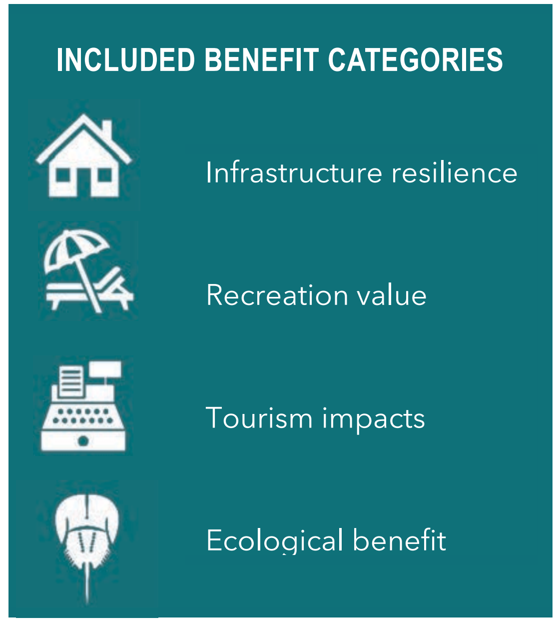
- have historically been nourished,
- provide public recreation access, and
- support built infrastructure.

This results in eight project sites along the Delaware Bay shore and three project sites along the Atlantic coast (Figure S-1). Most of these sites have been the subject of previous benefits analyses. However, this study is the first to apply consistent methodology, including rigorous, site-specific engineering analysis of the influence of beach nourishment on coastal processes, across Bay and Atlantic Coast beaches. While we generally adopt Cape Henlopen as the breakpoint between bay and ocean beaches, we classify

Lewes as an ocean beach despite its location because its characteristics (built infrastructure and recreation profile) more closely resemble those beaches than the remaining set of bay beaches.

Past economic analyses generally focused on the benefits that were expected to be the greatest and that were readily quantifiable (i.e., protection of coastal infrastructure and beach recreation). However, for cost share ratios to be equitable, it is necessary to incorporate all significant benefits. We engaged with subject matter experts and local community representatives through a series of Workgroup Meetings to gain insight on potential benefits of beach nourishment projects in Delaware. Feedback received during these meetings led to the inclusion of two additional benefit categories:

- contributions to the tourism economy associated with maintaining beach recreation, and
- ecological benefits resulting from the nourishment activities.



Our approach to the benefits analysis is organized into three key stages. First, we determine how the nourishment projects influence coastal processes, such as flooding, wave energy, and coastal erosion patterns. Next, we evaluate how these physical changes translate into relevant economic and ecosystem service benefit categories: infrastructure resilience, recreation value, tourism impacts, and ecological benefits. The final stage involves identifying the specific populations that receive these economic and ecosystem service benefits, including both direct beneficiaries (e.g., local residents and businesses), and more indirect beneficiaries (e.g., state and county residents and businesses), to provide a comprehensive understanding of beach nourishment's societal impacts.

The benefits analysis results in a mixture of economic and ecological metrics that cannot be readily combined, and the results necessarily rest on reasoned assumptions and imperfect data. Given these constraints, we developed an approach for aggregating results of the benefits analysis into cost share recommendations that can accommodate mixed metrics and ensures that small changes in numbers (e.g., those driven by imperfect assumptions and/or data) do not disproportionately influence outcomes. The approach we developed borrows from established frameworks for synthesizing diverse information to inform management decisions, allowing for more confident decision-making despite complexities and uncertainties. Described in detail within the report, we compare the quantified (or qualitatively described) benefits against appropriate standards to determine the relative level of each benefit at each project site.

Table S-1 presents the equitable cost share recommendation for each project site. For this summary we focus on the recommended cost share distribution between the State of Delaware, the relevant county (Kent or Sussex, depending on the project location), and local (i.e., sub-county) entities. Further breakdown of local cost shares between public (e.g., municipal) and private (e.g., residents and businesses) entities are provided in the project-specific results chapters (Chapters 4 through 14). In cases where the local benefits span multiple local jurisdictions (i.e., municipalities or unincorporated communities), the project-specific chapters include cost shares with that additional level of detail. Of note, many of the nourishment projects are partially funded by the federal government. The recommended cost shares apply to the remaining (non-federal) portion of total project costs.

Table S-1. Recommended share of non-federal portion of nourishment costs based on distribution of benefits

Project Site	Bay/Ocean	State	County	Local
Pickering	Bay	33%	-	67%
Kitts Hummock	Bay	27%	-	73%
Bowers	Bay	46%	-	54%
South Bowers	Bay	44%	-	56%
Slaughter	Bay	48%	-	52%
Broadkill	Bay	35%	-	65%
Lewes*	Ocean*	19%	16%	65%
Cape Shores	Bay	25%	-	75%
Rehoboth-Dewey	Ocean	16%	31%	53%
Bethany-South Bethany	Ocean	11%	18%	71%
Fenwick Island	Ocean	15%	18%	68%
Range: All projects	-	11-48%	0-31%	52-75%
Range: Delaware Bay projects	Bay	25-48%	0%	52-75%
Range: Atlantic coast projects	Ocean	11-19%	16-31%	53-71%

*We classify Lewes as an ocean beach because its characteristics (development and recreation profiles) are more closely aligned with those beaches than other bay beaches.

Following are the key findings from this analysis:

- **At all sites, the majority of benefits are experienced locally.** At all project sites, we find that the local residents, businesses, and municipal governments experience the majority of the benefits. Specifically, benefits to local entities are between 52 and 75 percent across the project sites. This is because the effects of the nourishment projects in mitigating flooding, erosion, and wave energy are localized around the project sites, resulting in benefits being concentrated on local property owners. Additionally, local recreators generally receive a larger share of the recreation value benefits than non-local state residents, since they tend to visit the beaches at a higher rate.

- **Ocean beach nourishment projects include a county-level cost share element due to the benefits on the tourism economy.** The ocean beaches (including Lewes) are more developed and support significantly higher levels of recreation compared to the bay beaches. As a result, ocean beaches are a driver of the tourism economy in Sussex County, resulting in a county-level cost share for ocean projects of between 16 and 31 percent. This range is driven by differences in the level of non-local recreation across ocean beaches. In contrast, non-local recreation across all bay beaches has a negligible effect on the tourism economy.
- **The state cost share recommendation is higher for the bay beach projects than the ocean beach projects.** The state fraction of the cost share recommendation is driven by the ecological benefits of the nourishment projects and the recreational benefits to in-state, non-local visitors. For the bay beach sites, the recommendation for the state share accounts for all of these non-local benefits (25 to 48 percent). For the ocean beaches (including Lewes), the state share is generally lower (between 11 and 19 percent) due to the additional influence of county-level tourism benefits on the cost share distribution at these sites.
- **At most ocean beach sites, sand spreading results in benefits to adjacent (typically unincorporated) communities.** These benefits account for between 11 and 35 percent of total project benefits, depending on the size of the adjacent communities, their location (e.g., between two nourishment projects or at the end of one project), and the extent of alongshore sand spreading. On the bay, sand spreading does not result in benefits to adjacent communities because bay communities tend to be isolated and sand spreading is more limited.
- **All projects include some level of state cost share driven by the potential contribution of beach nourishment toward coastal ecosystem protection.** While Delaware's coastal ecosystems are highly valuable, the effect of beach nourishment on these ecosystems over the timeframe of our analysis is uncertain and likely modest. Nonetheless, we assign a uniform level of ecological benefit to ocean beaches, and a higher uniform level of ecological benefit to bay beaches due to the additional importance of many bay beaches as horseshoe crab spawning habitat.
- **The equitable cost share recommendations are not sensitive to the design of the nourishment project.** We analyzed the benefits associated with up to four different nourishment designs per project site. We generally find that the cost share recommendations are not sensitive to the alternative project designs.[1] That is, while the total costs of nourishment and the magnitude of benefits may vary by project alternative, the relative distribution of benefits across state, local, and county entities does not. Thus, the cost share recommendations in this chapter are relevant across alternative nourishment project designs.

[1] In nearly all cases, the distribution of benefits varies by less than one percent.

Finally, we performed a social vulnerability assessment. Social vulnerability refers to the susceptibility of human populations to harm or adverse effects from external stresses, such as climate change and coastal storm events or economic disruptions. It may be influenced by factors such as income, health, race, age, education level, and access to services. The goal of the assessment is to characterize, for each of the beach communities that may be expected to share in the costs of future beach nourishment projects, factors influencing their social vulnerability to experiencing adverse effects of coastal storms and the cost burden of storm protection efforts.

We find that the resident populations of the beach communities in this analysis experience social vulnerability primarily due to the predominance of the population that is 65 and older. The beach nourishment projects benefit the vulnerable populations of these beach communities by reducing potential costs of storm-related infrastructure damage and reducing the likelihood of displacement due to storm events or coastal erosion. The population is not disproportionately characterized by low-income status. While the financial aspect of vulnerability is not pronounced in these populations, the populations are characterized by heightened vulnerability due to age, including experiencing increased social isolation and health deficits; reduced access to social support, healthcare facilities, and other services; and relatively limited ability to respond to (e.g., evacuate) or recover from environmental hazards.

CHAPTER 1 | Introduction

1.1 Purpose

For decades, the federal and state governments have invested in beach nourishment in Delaware to protect coastal infrastructure and sustain the multiple uses of the beaches by residents and visitors. In recent decades, nourishment projects have been funded wholly by the state or through a cost share agreement between the state and the US Army Corps of Engineers. To ensure the sustainability of this program given increasing costs, budgetary pressures, and more frequent and intense coastal storms, the Delaware Department of Natural Resources and Environmental Control (DNREC) is evaluating the potential for cost-sharing with local partners.

DNREC engaged Industrial Economics, Inc. (IEc) and Woods Hole Group (WHG) to conduct an economic benefits analysis and develop recommendations for equitable cost share ratios for specified beach nourishment projects (Table 1-1). From an economics perspective, **"equitable" cost share ratios** allocate the costs of a project among stakeholders in proportion to the distribution of benefits. The purpose is to ensure that the financial burden of the projects is shared among those who benefit. This reduces the risk of redistributive effects, which occur, for example, when costs of a project are borne broadly by all state taxpayers although the project benefits are concentrated within a specific subpopulation or geographic area.

Table 1-1. Nourishment project sites included in this study

Delaware Bay		Atlantic Coast
• Pickering • Kitts Hummock • Bowers • South Bowers	• Slaughter • Broadkill • Lewes • Cape Shores	• Rehoboth and Dewey • Bethany and South Bethany • Fenwick Island

A number of previous studies have assessed the benefits of beach nourishment in Delaware. These studies have primarily focused on a subset of the benefits provided by the nourishment projects, specifically infrastructure protection and recreation. The objective of this study is to build upon previous research by 1) providing a more comprehensive evaluation of the diverse and site-specific benefits that beach nourishment projects provide to people and communities in Delaware; and 2) examining how different population groups (e.g., local residents, business owners, municipal governments) experience and gain from beach nourishment.

In addition, we present information on social vulnerabilities of the communities benefitting from the nourishment projects to be considered alongside the equitable cost share recommendations. **Social vulnerability** refers to the degree to which populations are susceptible to harm based on socioeconomic and demographic factors. This is an important consideration to ensure that any cost share policy is just and effective. Our analysis focuses specifically on evaluating the socioeconomic and demographic factors that influence each community's sensitivity to the effects of climate change and coastal storms, and their ability to bear costs of protection efforts, such as beach nourishment.

1.1 History of beach nourishment in Delaware

The first recorded beach nourishment project in the United States was at Coney Island, NY in 1923.[2] Since then, nourishment has become a common approach to protecting developed, multi-use shorelines. In this section, we describe beach nourishment activities in Delaware, including volumes of sand replenished over time, cost trends, and the origins of cost sharing discussions.

1.1.1 Rising nourishment volume and cost

The first recorded beach nourishment in Delaware was at Lewes Beach in 1953. By 1962, nearly all of the beaches in our analysis had been nourished at least once. The one exception is Cape Shores, which was first nourished in 2000. Healthy beaches and dunes can reduce the damaging effects of coastal storms on coastal infrastructure. At the same time, coastal storms generally exacerbate sand loss at the beaches, driving the need for renourishment. As a result, the frequency and sand volumes needed for beach nourishment are variable over time and across beaches. Memorable storms that affected the Delaware coast include the following:

- 1962 "Ash Wednesday" Northeaster: especially destructive due to the deteriorated condition of the dunes at the time and the duration of the storm.
- January 4, 1992 Northeaster: produced large waves and storm surge along the ocean coast and across Route 1.
- January 25 and February 5, 1998 Northeasters: two major storms occurred one week apart, producing large waves and storm surge along the ocean coast and across Route 1.
- May 8-9, 2008 ("Mother's Day Storm"): produced major flooding and erosion at Delaware Bay beaches north of Broadkill.
- January 2016 (Winter Storm Jonas): produced widespread flooding at Rehoboth, Lewes, and Slaughter.

Against the backdrop of these storms and others, over 22 million cubic yards of sand have been placed on the beaches included in this study through 2023. Over the past decade, nourishment activity has increased. From 2010 to 2020, for example, the ten-year rolling average annual fill volume across all beaches in our study increased by over 500 percent (Figure 1-1).[3]

[2] National Beach Nourishment Database (American Shore and Beach Preservation Association): https://gim2.aptim.com/ASBPANationwideRenourishment/

[3] A rolling (or moving) average is useful for identifying trends in data that are highly variable by year.

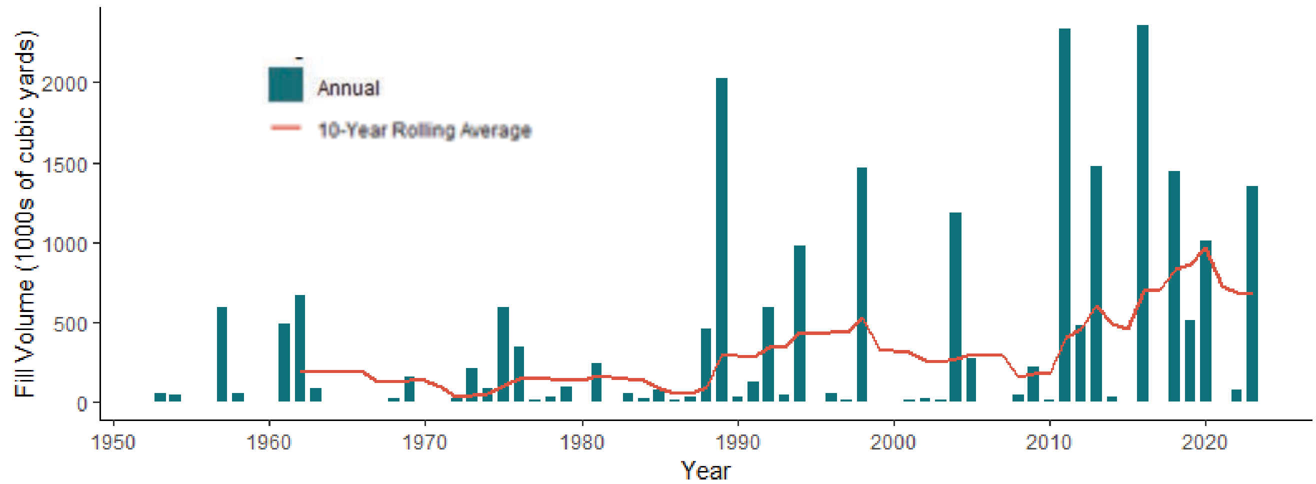


Figure 1-1. Total annual nourishment volumes across all Delaware beaches included in this study

Comparing project costs across beaches and over time is complicated by differences in nourishment methods (e.g., trucking versus offshore dredge), utilization of in-house labor (i.e., state employees), and other factors. Overall, however, the cost of implementing nourishment projects is increasing in real terms (i.e., at a rate that exceeds general inflation). For example, the five ocean beaches in our analysis (Rehoboth, Dewey, Bethany, South Bethany, Fenwick Island) were all nourished in 1998 and in 2023. Total sand volume was similar between the two sets of projects (1,359,500 cubic yards and 1,332,162 cubic yards in 1998 and 2023, respectively), and all projects utilized offshore dredging equipment. However, the total cost of the 2023 projects was more than four times the total cost of the 1998 projects, without adjusting for inflation ($31 million versus $6 million). General inflation over that time period was about 78 percent, accounting for less than one-fifth of the cost difference.[4] The remainder of the increase is likely due to a combination of factors influencing project costs, including reduced sand availability at nearby borrow sites (i.e., the need to transport sand from further distances) and increasing demand for marine construction equipment (e.g., from offshore energy development), among other factors. The simultaneous trends of rising costs and increasing nourishment volume place significant pressure on government budgets.

1.1.2 History and precedent for beach nourishment cost share policies

To date, beach nourishment in Delaware has generally been funded at the federal and state levels. Projects along the Atlantic coast typically include a 65 percent federal cost share, with the remainder paid by the state. Projects along the Delaware Bay are often 100 percent funded by the state. One exception is Cape Shores, a private community that has contributed between 40 and 100 percent of the cost for the relatively small nourishments that beach has received to date.

The localized nature of many benefits of beach nourishment is well-established in the academic literature (e.g., Black, Donnelly, and Settle, 1990; Wakefield and Parsons, 2003; Morgan and

[4] We measure inflation over this period as the percentage change in Consumer Price Index between 1998 (173.4) and 2023 (308.4): Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average (CPILFESL) | FRED | St. Louis Fed (stlouisfed.org).

Hamilton, 2010; Qiu and Gopalakrishnan, 2018). As a result, beach nourishment projects funded at the federal or state level are likely to have redistributive effects. Accordingly, local cost sharing has been considered as a tool for minimizing redistribution and for discouraging new development in high-risk areas (Pompe, 1999; Parsons and Noailly, 2004; Armstrong et al., 2016; Mullin, Smith, and McNamara, 2019). A 1988 report to the Governor of Delaware recommended a local (community) cost share of between 50 and 75 percent of total nourishment project costs, based on the philosophy that "those who benefit financially from beach management projects should bear the costs of such projects in reasonable proportion to the benefits received" (Beaches 2000, 1988, pg. A-5). Following on that report, a number of benefits analyses were conducted for Delaware beaches, as described in the following section.

Policies and programs focused on local cost sharing for beach nourishment are not unique to Delaware. Many other states have already implemented local cost share policies. For example, Florida makes state funds available for nourishment projects that already have local sponsorship and meet certain requirements (e.g., public access for recreation, project area is designated as "critically eroded"). Under this program, local governments (e.g., county, municipal) are responsible for at least 50 percent of the non-federal portion of project costs.[5] Additional examples of states with local cost sharing for nourishment include New Jersey (25 percent of non-federal costs are borne by local governments) and North Carolina (local cost sharing percentage varies by county).[6,7]

Highlights of Previous Studies

- All previous economic analyses quantify avoided storm damage and enhanced recreation; some also quantify various economic impacts.
- At the majority of sites analyzed, avoided storm damage is the primary benefit.
- For avoided flood damage, studies use either depth damage functions or estimate the capitalization of flood risk into property values.
- For recreation, studies estimate the value of changes in trip quantity and/or quality.
- Some of the analyses parse beneficiaries by either in-state and out-of-state residency, or local property owners and state taxpayers (i.e., non-local residents).

[5] Florida Administrative Code (FAC) Chapter 62B-36 "Beach Management Funding Assistance Program."

[6] Information available from the New Jersey Department of Environmental Protection at https://dep.nj.gov/wlm/drec/ce/federal-projects/.

[7] Summary information available from "The Environmental Finance Blog," University of North Carolina at https://efc.web.unc.edu/2020/11/04/regionalization-among-local-governments-a-spotlight-on-beach-nourishment-in-north-carolina/.

1.2 Past analyses of beach nourishment benefits

Several studies have estimated the benefits of beach nourishment at the Delaware beaches considered in this study:

- Johnson, Mirmiran & Thompson. 2014. "Delaware Bayshore Communities Economic Analysis of Options for Shoreline Management." [*referred to in text as JMT 2014*]
- Black, D., Donnelley, L. and R. Settle. 1988. "An Economic Analysis of Beach Renourishment for the State of Delaware." [*referred to in text as Black, Donnelley, and Settle 1998*]
- Jack Faucett Associates, Inc. 1998. "The Economic Effects of a Five Year Nourishment Program for the Ocean Beaches of Delaware." [*referred to in text as JFA 1998*]
- Chrysalis Consulting, Inc. 2007. "The Economic Effects of a Five Year Nourishment Program for the Ocean Beaches of Delaware, Updated." [*referred to in text as Chrysalis 2007*]
- United States Army Corps of Engineers. 1996; 1997; 1998; 2000. "Final Feasibility Report and Environmental Impact Statement." [*referred to generally in text as USACE-EA (with the year included when referencing a particular report*)]

This section summarizes the general findings across studies; additional detail on each study is provided in Appendix C. With the exception of Cape Shores, each beach included in our study has been the subject of at least one benefits analysis. Generally, the ocean beaches have been the subject of more studies, although analysis of the bay beaches is most recent. The analyses consistently focus on two main categories of benefits from beach nourishment: 1) avoided damage to infrastructure from reduced erosion, inundation, and/or wave energy, and 2) enhanced beach recreation. Within the avoided damage category, some studies focus solely on structures and their contents (e.g., JMT 2014) while others include roads and other infrastructure (Army Corps of Engineers Economic Analyses [USACE-EA]).

The existing studies employ two general approaches to quantify avoided damages. One approach relies on empirical "depth damage functions" that describe the relationship between flood depth (relative to the first-floor elevation of a structure) and the percentage of the structure (and its contents) that are damaged. This method, used by JMT 2014 and in the USACE-EA studies, provides a reasonable estimate for the monetary cost of repairing flood damage when flood depths are accurately modeled. Of note, however, repair costs may not represent the full suite of costs of infrastructure damage from flooding (e.g., costs of displacement during reconstruction are not included), leading the depth damage approach to reflect a conservative estimate (i.e., more likely to underestimate than overestimate) the benefits of mitigating storm-related damages.

The studies using depth damage functions can be further distinguished based on their approach to modeling the influence of the nourishment projects on coastal processes. The USACE-EA studies incorporate primary modeling of wave energy (using SBEACH), while JMT 2014 relies on secondary data sources (FEMA Wave Height Analysis for Flood Insurance studies). For base inundation, USACE-EA studies utilize historic ocean stage data, while JMT 2014 relies on a Draft 2011 Storm Surge Study (citation not provided in the original study). All studies rely on historic erosion rates to project coastline changes in the absence of nourishment.

The second approach, employed in Black, Donnelly, and Settle 1988, JFA 1998, and Chrysalis 2007, relies on a simplified relationship between beach width and nearby property values (i.e., it does not involve modeling the influence of nourishment on flooding and wave energy). A form of hedonic valuation, this approach theoretically captures a holistic notion of value to coastal property owners from changes in beach size (e.g., avoided damage, recreation, visual amenity value). However, the individual components of value cannot be disaggregated and its accuracy for valuing avoided damages rests on the accuracy of homeowners' subjective perceptions of flood risk.

Beyond infrastructure protection, beach nourishment projects may also improve beach recreation, through increasing the number of trips and/or increasing the value of trips (i.e., a better beach recreation experience for visitors). Some studies (e.g., Chrysalis 2007) focus on the change in number of trips, some on the change in trip value (e.g., USACE-EA 1998), and some (e.g., JMT 2014) capture both. In all cases, the values are reported in terms of consumer surplus (i.e., the change in beach visitors' "willingness to pay" for the beach recreation experience), a well-accepted economic welfare measure. Per trip consumer surplus values are estimated using one of two nonmarket valuation techniques (contingent valuation or travel cost) from either primary or secondary data on beach recreation. Changes to the number of trips are modeled as a function of beach width, either within a random utility site choice model (e.g., JMT 2014) or using beach capacity and heuristics about tolerance for crowding (e.g., USACE-EA).

The studies generally find that the benefits of infrastructure protection due to beach nourishment exceed the beach recreation benefits. While none of the studies explicitly aggregates the benefits into local and state populations, two of the studies acknowledge the redistributive effect of nourishment projects when there is no local cost share. Specifically, Black, Donnelley, and Settle 1988 conclude that the state portion of the cost share should be small based on the distribution of benefits, while JMT 2014 shows that under the existing federal-state cost share, projects are net-beneficial for local communities but net-negative for state taxpayers.

In addition to avoided damages and recreation, several of the studies acknowledge (and sometimes quantify) additional benefits from beach nourishment projects. The most common is some measure of economic impact associated with nourishment (e.g., sales tax revenues, number of jobs supported by beach recreation and tourism).[8] One study (JMT 2014) also mentions ecological impacts (specifically, habitat improvement). However, the authors concluded from interviews with DNREC, other state agencies, and stakeholders that the ecological effects would be small relative to the primary benefits mentioned above. Therefore, the study did not quantify ecological benefits.

Finally, there is significant variation in the nourishment designs used in the various economic analyses. JMT 2014, for example, use the ten-year nourishment designs contained in DNREC's 2010 Management Plan for the Delaware Bay Beaches. In contrast, Black, Donnelley, and Settle 1988 utilize a hypothetical scenario consisting of enhancing beach width along the Atlantic coastline by 165 feet.

[8] The economic impact associated with nourishment is related to, but distinct from, the recreation benefit described previously. The direct recreation benefit refers to the value of the recreation experience to recreators themselves, whereas the economic impact refers to the effects of spending by recreators in the local economy. See Chapter 2 for additional discussion.

1.3 Focus of the current study

The current study builds on past analyses in several important ways. In this section we outline key parameters of our analysis and describe how they relate to past studies. We conclude with a description of related topics that are not within the scope of this study.

1.3.1 Project sites

Previous studies demonstrate that the magnitude of benefits and their distribution between population groups varies across sites based on differences in physical and ecological features of the beaches, density of development, and popularity for recreation, among other factors. For that reason, we perform our analysis and report results on a site-by-site basis. This study focuses on beaches in Delaware that meet the following criteria:

- have historically been nourished,
- provide public recreation access, and
- support built infrastructure.

This results in eight project sites along the Delaware Bay shore and three project sites along the Atlantic coast (Figure 1-2). Most of these sites have been the subject of previous benefits analyses. However, this study is the first to apply consistent methodology, including rigorous, site-specific engineering analysis of the influence of beach nourishment on coastal processes, across Bay and Atlantic Coast beaches.

Figure 1-2. The current study includes eight project sites along the Delaware Bay coast and three project sites along the Atlantic coast

1.3.2 Benefit categories

As noted, past economic analyses generally focused on the benefits that they expected were the greatest and that were quantifiable (i.e., protection of coastal infrastructure and beach recreation). However, for cost share ratios to be equitable, it is necessary to incorporate all significant benefits. We engaged with subject matter experts and local community representatives through a series of Workgroup Meetings to gain insight on potential benefits of beach nourishment projects in

Delaware. Feedback received during these meetings led to the inclusion of two additional benefit categories:

- contributions to the tourism economy associated with maintaining beach recreation,[9] and
- ecological benefits resulting from the nourishment activities.

INCLUDED BENEFIT CATEGORIES

- Infrastructure resilience
- Recreation value
- Tourism impacts
- Ecological benefit

1.3.3 Timeframe of the analysis

The magnitude and distribution of benefits from beach nourishment are dynamic over time, due to natural spreading of the initial sand placement and the erosion of sediment. The timeframe of past analyses ranges from five to 30 years. We adopt the top of the range (30 years), assuming that beaches are periodically renourished as needed over this period according to individual project design lives (i.e., the expected renourishment interval associated with a design template). Evaluating benefits beyond the 30-year timeframe results in increasingly speculative estimates. For example, over time people and communities are likely to retrofit infrastructure or adopt alternative coastal infrastructure and beach management strategies in ways that affect the magnitude and distribution of the benefits of beach nourishment. Furthermore, the cost estimates and tourism spending estimates that are key inputs to the analysis are less reliable over longer time frames.

We quantify the present value benefits over the 30-year timeframe applying a two percent discount rate.[10] We then annualize the resulting 30-year present values and develop equitable cost share recommendations using the annualized values.

1.3.4 Nourishment design alternatives

Past analyses focused on a single beach nourishment design for each project site. Document review performed for this study revealed that multiple design alternatives exist for many of the sites under consideration. We analyze up to four nourishment design alternatives for each project site and consider the sensitivity of our cost share recommendation to the relevant design alternatives. Nourishment design alternatives are from the following sources (availability varies by site):

- Wetland and Subaqueous Lands Section Permit Application Forms (DNREC, 2022; 2023)

[9] "Regional economic impacts" (e.g., measures of jobs, revenues, or value-added in a given industry or economy) are distinct from "economic values" (i.e., costs and benefits). Economic *impacts* measure distributional effects of a project or activity (i.e., the changes in activity in particular economic sectors or geographic areas). Economic values measure the creation (benefits) or loss (costs) of wealth. The regional economic impacts, while not directly comparable to the economic values, are relevant in the context of this analysis, which focuses on distributional effects.

[10] Two percent discount rate is consistent with current guidance for conducting regulatory analyses for federal agencies (Circular No. A-4, updated November 9, 2023): https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf.

- Delaware Beneficial Use of Dredged Material for the Delaware River: Feasibility Report and Integrated Environmental Assessment (USACE, 2018)
- Beach-specific Integrated Feasibility Report and Environmental Impact Statements (USACE, 1996; 1997; 1998; 2000)
- State of Delaware Bay Beach Design Verification Report (CB&I, 2014)

1.3.5 Scope limitations

This study does not provide recommendations regarding specific policies for enacting the cost share ratios (e.g., by levying taxes broadly or for a targeted population, or imposing user fees). We are focused on identifying the magnitude and distribution of benefits, recognizing that additional factors outside of the scope of our study are important for developing policy. We further recognize that policy mechanisms can introduce complexities, for example in cases where benefits are experienced by unincorporated communities. As previously noted, we do provide information regarding the social vulnerability of affected communities.

We also note that this study is not a benefit-cost analysis of beach nourishment or other shoreline management alternatives. While we provide information on the cost of the nourishment projects as context for understanding the implications of cost-sharing, we do not weigh costs and benefits or conduct a cost-effectiveness analysis to prioritize across project sites or recommend a nourishment design.

1.4 Report roadmap

The remainder of this report is organized as follows. Chapter 2 describes the methodology employed to evaluate the benefits of beach nourishment and aggregate into equitable cost share recommendations. This includes the coastal engineering analysis that explicitly links beach nourishment projects to changes in coastal processes, the economic analysis that converts changes in coastal processes to relevant benefit measures, and the methodology for aggregating benefits into equitable cost share recommendations. Chapter 3 presents the results across all the project sites in the study with a focus on commonalities and drivers of variation. Chapters 4 through 14 present complete findings for each project site. Chapter 15 presents the social vulnerability assessment. Supporting information is organized into three appendices. Appendix A contains answers to common questions about this study. Appendix B presents tables of complete results for each nourishment design alternative at each project site, and Appendix C contains a detailed summary of past economic analyses of the sites in this study.

CHAPTER 2 | Framework and Methods

The objective of this analysis is to evaluate the benefits of beach nourishment projects in Delaware and develop recommendations for equitable cost share ratios, where equitable is defined as paying in proportion to the benefits received. Our approach is organized into three key stages. First, we determine how the nourishment projects influence coastal processes, such as flooding, wave energy, and coastal erosion patterns. Next, we evaluate how these physical changes translate into economic and ecosystem service benefit categories, including property protection, recreation and tourism, and ecological benefits. The final stage involves identifying the specific populations that receive these economic and ecosystem service benefits, including both direct beneficiaries (e.g., local residents and businesses), and more indirect beneficiaries (e.g., state and county residents and businesses), to provide a comprehensive understanding of beach nourishment's societal impacts. Figure 2-1 provides a conceptual model of this approach.

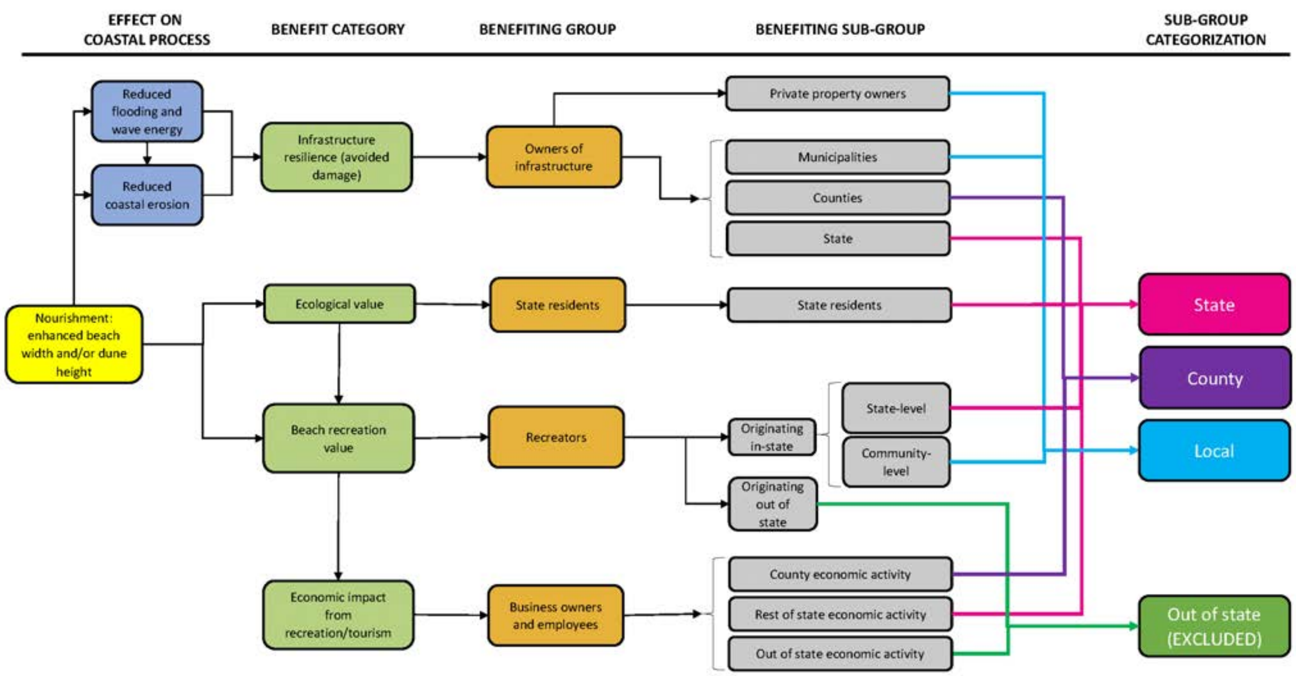


Figure 2-1. Conceptual model linking beach nourishment to specific benefit categories and groups receiving each benefit

Note: Recreation value accruing to out-of-state visitors is excluded from development of the cost share recommendations, which apply to the non-federal portion of nourishment costs. The tourism impacts (i.e., economic impact from recreation/tourism) associated with out of state beach visitation, however, are included.

Nourishment projects generally consist of placing sand in a way that enhances the width of the beach and/or the height of the dune (Figure 2-1 yellow box). This activity provides both direct and indirect benefits (Figure 2-1 green boxes). Wider beaches have positive ecological value (e.g., habitat for horseshoe crab spawning) and recreation value (i.e., space for more recreators and/or less crowded conditions). Additionally, nourishment influences coastal processes (e.g., storm-induced flooding and wave energy, coastal erosion) which in turn provide infrastructure resilience benefits (i.e., avoided damage to coastal infrastructure). More indirectly, by enhancing recreational opportunities, nourishment supports economic activity (i.e., spending by non-local recreators in the local economy). We identified the four general benefit categories in Figure 2-1 based on review of past economic analyses of beach nourishment in Delaware, additional peer-reviewed and grey literature, and consultation with the project Workgroup.

Most benefiting groups are further disaggregated into sub-groups. For example, infrastructure owners include private citizens (e.g., owners of homes and businesses) and public entities (e.g., owners of public buildings or other infrastructure, such as roadways). For each beach, we provide information on benefits at this sub-group level. We also aggregate the cost share ratios into four general categories: state, county, local, and out-of-state. The cost share ratios we develop apply to the non-federal portion of nourishment costs. Therefore, we exclude benefits accruing to out-of-state groups from further analysis.

Our analysis has two distinct but linked modeling components: coastal process modeling followed by economic modeling. The coastal process modeling (the engineering analysis) describes each project site in terms of several physical parameters over the 30-year analysis timeframe with and without the nourishment project in place (e.g., shoreline position/beach width over time, storm-induced flood extent, flood depth, and wave energy). Outputs from the coastal modeling are inputs for the economic modeling, which translates the physical changes to the beach and coastal processes into the relevant benefit categories (e.g., wave energy influences the extent of infrastructure damages and beach width influences recreation value). The benefits of a nourishment project are calculated as the difference between two alternative futures: with and without the beach nourishment projects.

2.1 Coastal processes modeling

The combined effects of coastal processes in the nearshore zone interact with the beach to create an evolving coastal landform. The dominant driving forces, which include winds, waves, tides and currents, storms, and sea-level rise interact in a complex fashion to cause movement of sediment. In many coastal regions, Delaware included, this sediment movement results in both localized and large-scale areas of erosion and/or accretion. To manage the shoreline effectively, it is necessary to understand the primary coastal processes and their ability to move sand along the coastline, as well as how these physical processes can cause damage and produce other economic impacts.

Site-specific coastal processes modeling assessments were conducted at each of the nourishment project sites along the Delaware Bay coastline and the Atlantic Ocean coastline with the goal of determining changes that occur to key physical processes (waves, flooding, shoreline position, nourishment spreading, etc.) with and without the nourishment projects in place. The coastal modeling and assessment consisted of combinations of hydrodynamic, wave transformation, and cross-shore and alongshore sediment transport approaches. Input data for the models were gathered from existing data sources, including project-specific nourishment baseline data provided by the State of Delaware and the United States Army Corps of Engineers.

Physical processes were evaluated over the 30-year analysis timeframe from an ongoing coastal evolution standpoint (normal conditions), as well as assessing impacts associated with episodic storm events ranging in intensity from 20 percent annual exceedance probability (AEP) to two percent AEP.[11] This approach allows for assessment of the potential effectiveness of the nourishment projects on reducing potential flood risk, erosion, and/or damage over a range of physical conditions. As such, modeling the performance of the projects will consist of more than just a single storm scenario. A distribution (or range) of storm scenarios can then identify the varying level(s) of influence on the physical processes, and subsequently, the effect on economic benefits. This assessment over a range of storm conditions is critically important to determine the overall performance of the nourishment projects and alternatives. For example, a specific nourishment alternative may have minimal benefit for a larger, less frequent event; however, it may have substantial benefit for a smaller, more commonly occurring event. If only a single storm or AEP was used to assess the benefits, it is likely there would be some mis-accounting of the physical factors impacting flooding, which could translate to the economic benefits.

Results from the coastal processes modeling include site-specific, comprehensive data on shoreline position, shoreline erosion during storm events, extent and depth of flooding during coastal storm events, wave energy along the shoreline and in overland flood areas, and detailed beach nourishment parameters (beach width, nourishment spreading along the beach, and beach nourishment performance). These coastal processes results provide quantitative data that feed into the economic analyses allowing for improved assessments of benefits of the various nourishment projects and provide more robust physical processes data than were used in some of the previous economic analyses. This section provides an overview of the coastal processes evaluated and provided as inputs into the economic modeling.

We additionally considered whether nourishment would lower the risk of dune breaches. Nourishment would only meaningfully influence this risk in areas where nourishment adds significant width to an otherwise narrow beach. More modest additions to beach width are unlikely to mitigate the surge and wave energy associated with storms capable of producing a breach. While the cumulative effects of continued nourishment over time do reduce breach risk at certain sites, we did not identify this as a benefit of the nourishment projects at the specific beach sites evaluated in this analysis.

2.1.1 Shoreline position

The shoreline position metric is a measure of shoreline retreat over time (in this case a 30-year analysis period). It considers the longer-term average influence of day-to-day conditions, as well as storm events where the beach may temporarily erode but also naturally recover. This parameter is determined for a scenario where nourishment projects are no longer continued. In this case, the shoreline would be expected to continue to advance landward over time due to the continued natural movement of coastal sediment, the erosion occurring during higher energy events and coastal storms, and the increased mean sea level expected to occur under changing climate conditions. As such, the shoreline position at each nourishment project site was determined over the 30-year analysis time horizon for a scenario where all nourishment projects were halted. The results are presented as a spatial shoreline position that would be expected in 30 years from the present-day shoreline position.

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[11] Annual exceedance probability (AEP) refers to the likelihood of a specific storm event intensity being equaled or exceeded in any given year. Events with lower AEP have higher intensity and are more rare.

These projected, future spatial positions are based on documented, historic shoreline change rates from a variety of sources (DNREC, 2023; USACE, 2018; USACE, 1996; USACE, 2000; USACE, 1999; USACE, 1997) and presented with and without the influence of sea level rise (SLR) considerations. The SLR projections are consistent with the State of Delaware application of SLR estimates and are based on the National Oceanic and Atmospheric Administration (NOAA) Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al., 2022) for the Intermediate-High RCP projection. The positions of these future (without nourishment project) shorelines are computed for each site-specific location by assuming the historic long-term erosion rate would continue over a 30-year time period, with and without the incorporation of sea level rise influence. Figure 2-2 provides an example of the geospatial representation of these shoreline positions for a section of Rehoboth Beach. The blue line shows the approximate position of the present-day mean high water shoreline, while the yellow and red lines show the approximate position of the future mean high water shoreline in 30 years with and without the influence of projected sea level rise, respectively. We display both to demonstrate the incremental contribution of sea level rise to shoreline change over this period.

Figure 2-2. Shoreline position example for a section of Rehoboth Beach

Note: The blue line is the position of the present-day mean high water shoreline, and the red and yellow lines show the projected mean high water shoreline position in 30 years with and without sea level rise for a scenario where nourishments have stopped.

This metric of shoreline position can have a direct impact on infrastructure as the beach migrates landward, eventually damaging structures, and also influences recreational access and enjoyment as the beach width is reduced. This factor was evaluated at each of the nourishment project sites and the exact influence is site-specific; however, in general, this process is a critical factor for the Delaware Bay beaches that generally have narrower starting beach widths and would be directly impacted by this longer-term erosion trend without the ongoing nourishment program. For the Atlantic Ocean beaches, this is slightly less important as a direct impact due to the wider starting beach widths. However, it remains a key factor when taken in concert with episodic storm events (e.g., the starting conditions and width of the beach are important relative to the influence of a specific storm).

2.1.2 Episodic erosion

While the longer-term shoreline position is a measure of the health of the beach over the 30-year time horizon of the analysis, episodic erosion considers the short-term erosional effects and damage associated with coastal storm events. Coastal storm events, typically consisting of higher than normal water levels and increased wave energy, will result in greater erosional impacts that can cause direct impacts to infrastructure and overall dune and beach health. The beach also will tend to naturally recover after these episodic events to a certain extent by transporting sand back onshore following the removal of sediment during the storm event. The influence of episodic erosion was evaluated for a range of storm events (2, 10, and 20 percent AEP) to assess the response of the beach and dune system. The modeling simulations were completed for existing conditions (without nourishment in place) and for the various beach nourishment design alternatives.

Figure 2-3. Example of episodic erosion modeling results showing the location of the eroded shoreline for storms of different magnitude along a section of Rehoboth Beach without (left) and with (right) nourishment.

To assess the impacts of episodic erosion, a numerical model that simulates waves and erosion effects in the cross-shore direction was utilized. The numerical model used for this assessment was XBeach (Deltareds, 2015). XBeach is a numerical sediment transport model developed to simulate wave, hydrodynamic, and morphological processes. It has been developed with support from various agencies and includes both hydrodynamic and morphologic processes. Results of the episodic erosion consist of beach profile changes (i.e., the condition of the beach and dune system following the storm event) and the position of the shoreline (alongshore) following the passage of the storm event. The shoreline location is presented with and without the various proposed beach nourishment projects in place. Figure 2-3 presents an example of the episodic erosion results for a segment of Rehoboth Beach. The panel on the left shows the results for a beach with no nourishment project, while the panel on the right shows the results with a nourishment project. Results are shown for AEP storm events with the yellow, orange, and red lines corresponding to the 20, 10, and 2 percent AEP, respectively. Additionally, when the episodic erosion results in enough loss to reach infrastructure, wave heights that interact with the buildings and other built features are also provided by the XBeach modeling.

The results of the episodic erosion vary for each project site, nourishment alternative, and storm level. The alongshore and cross-shore impact on the overall beach and dune system also varies.

However, in general, the episodic erosion at the Atlantic Ocean beaches is a critical factor relative to direct impact and damage to the infrastructure in the project areas due to the larger waves, energetic storm events, and deeper erosional impacts. On the other hand, the episodic erosion on the Delaware Bay beaches is not as significant due to relatively smaller waves and storm energy. This does not mean that storms are not important at the bay beaches, as water levels occurring during storms result in significant flooding from both the back marshes and the shoreline itself. Rather, the erosion that occurs during a single storm event is not as significant as on the Atlantic Ocean beaches.

2.1.3 Wave energy

The impact of waves in the nearshore environment, specifically on highly populated shorelines that serve significant recreational and/or economic benefits, is one of the key reasons to understand wave propagation and transformation for site-specific areas. Impacts to nearshore processes and shoreline changes are highly dependent on the offshore wave climate and the transformation of waves from deep water to the shoreline. Subsequently, as waves interact with the coastline, wave-induced currents play a role in sediment transport and shoreline change.

Episodic erosion is caused by elevated water levels and wave energy that occurs during coastal storm events. However, during those coastal storms, waves also can result in increased damage to infrastructure that resides along the shoreline. Waves that encroach into developed areas were considered in the assessment of coastal processes for all project sites. The transformation and propagation of waves in the project areas were simulated for the same set of AEP storm events and included cases with and without the nourishment projects in place. These results were then used to assess the benefit of wave energy reduction that was caused by the beach nourishment project.

The coastline of Delaware represents a complex coastal setting where the offshore bathymetry, sand bars, tidal shoals, and shoreline orientation influence wave heights and directions at the beaches. Wave modeling is required to simulate refraction, diffraction, shoaling, and breaking of waves. Wave refraction and diffraction produce an uneven distribution of wave energy along the coast. Wave modeling allows for quantitative predictions of these processes. Therefore, in order to assess the wave transformations occurring at each project site, a wave transformation model SWAN (Simulating Waves Nearshore) was applied. SWAN is a third-generation spectral wave model developed for the purpose of simulating wave transformation, refraction, and diffraction due to interactions with complex bathymetry, as well as wave interaction with structures (Delft University of Technology, 2000). SWAN is used to obtain realistic estimates of wave parameters in coastal areas, lakes, and estuaries from given wind, bottom, and current conditions. The model is based on the wave action balance equation (or energy balance in the absence of currents) with sources and sinks.

Model simulations provided wave heights with and without the nourishment projects in place at each site, and for each AEP storm event. This included spatial variation in wave height and energy throughout the region at each project location. Maps of wave heights were produced for each storm case. The results were provided as input to the economic assessment to determine avoided damages to buildings, roads, and other coastal infrastructure.

2.1.4 Flooding extent and depth

Flooding during coastal storm events results in direct damage to coastal infrastructure as elevated water levels encroach upon areas that normally are not wet. In order to determine flooding extent and depth during coastal storms, a combination of hydrodynamic and wave modeling was used to identify the flooded areas at each project site with and without the nourishment in place. This modeling was completed for the same AEP storm events (2, 10, and 20 percent). Maximum flood extent and depths were extracted from each model simulation and mapped across the upland areas providing quantifiable flood information for the economic assessment. Results for the Delaware Bay beaches indicate that flooding occurs from both the back bay and the seaward-facing shoreline during coastal storm events. Both types of flood pathways were identified and simulated in the model. In most cases, flooding from the back bay pathway was a significant contributor to the coastal flooding, and the beach nourishment projects do not significantly mitigate that flood process, as the coastal storm surge water simply advances/flanks the nourishment project and propagates into higher elevations through the marsh system. For the Atlantic Ocean beaches, flooding is more directly due to ocean-based flood pathways during larger coastal storm events that produce large waves and deeper coastal erosion impacts.

2.1.5 Beach nourishment performance

The behavior of the beach nourishment projects once they have been constructed is an important aspect of determining the overall performance and benefits, both physical and economical, of a beach nourishment project. For example, placement of a perturbation on a beach that has reached an equilibrium state results in the natural spreading of the placed material along the shoreline. Therefore, beach nourishment projects not only directly benefit the area where nourishment material is placed, but also adjacent shorelines that receive material that migrates as the beach tries to re-equilibrate over time. The beach nourishment performance modeling completed for this evaluation focused on three elements:

1. The overall longevity of the proposed nourishment projects, evaluated through the migration of nourishment sediment beyond the template where it was initially placed. This element was assessed based on the time-dependent change in volume within the initial nourishment placement area. This informed the service life of each proposed nourishment project and the approximate re-nourishment interval to maintain the desired protection benefits.
2. The temporal evolution of the beach width along the shoreline, both within the nourishment area and in the areas where the nourishment would be expected to spread. This beach width provides inputs related to benefits of both protective and recreational values.
3. The spreading of the nourishment into areas outside of the initial placement template. This analysis provides information on potential avoided damages to areas along the shoreline and other communities or areas outside of the initial placement area.

The model used to assess the evolution of the beach nourishment combines the conservation of sediment equation with the linearized transport equation. This formulation, called the Pelnard-Considére (1956) equation, is used to obtain theoretical results of the performance of beach nourishment projects. For example, nourishment projects are typically placed as approximately an idealized, rectangular nourishment. Over time, the waves and coastal processes result in a temporal planform evolution. This model provides quantified information on the changes in volume and beach width over time and also identifies where the nourishment material diffuses onto the adjacent shorelines.

Beach Service Life

Since the material spreads over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. Subsequently, nourishment alternatives can be compared to one another based on longevity. The service life of the beach nourishment can be based upon the percent of initial beach nourishment left within the boundary of the initial fill template. The percentage remaining will decrease with time, but material is not necessarily lost from the system; it has just spread to regions outside of the original nourishment template. Sediment may have been transported offshore or along the beach, and although the sediment no longer falls within the initial nourishment template, it has not disappeared from the system. The model results provide the volume of material remaining in the initial placement area and therefore a reasonable estimate of the length of the protective value and when renourishment is required.

Figure 2-4 provides an example of the nourishment performance for the various nourishment alternatives at Pickering Beach over the 30-year analysis timeframe. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, for various nourishment templates/alternatives that have been considered at Pickering Beach. The percent of initial material remaining is presented along vertical axis, while the time in years is presented along the horizontal axis. For example, for alternative template four, after five years, approximately 50,000 cubic yards of the initial fill volume of 180,000 cubic yards is remaining in the initial placement area. The vertical jumps in volume represent re-nourishment cycles to restore the nourishment template to the full amount. For example, design alternative 1/2 is nourished every four years (approximately). These data provide information on the cost of nourishment material over the 30-year analysis period.

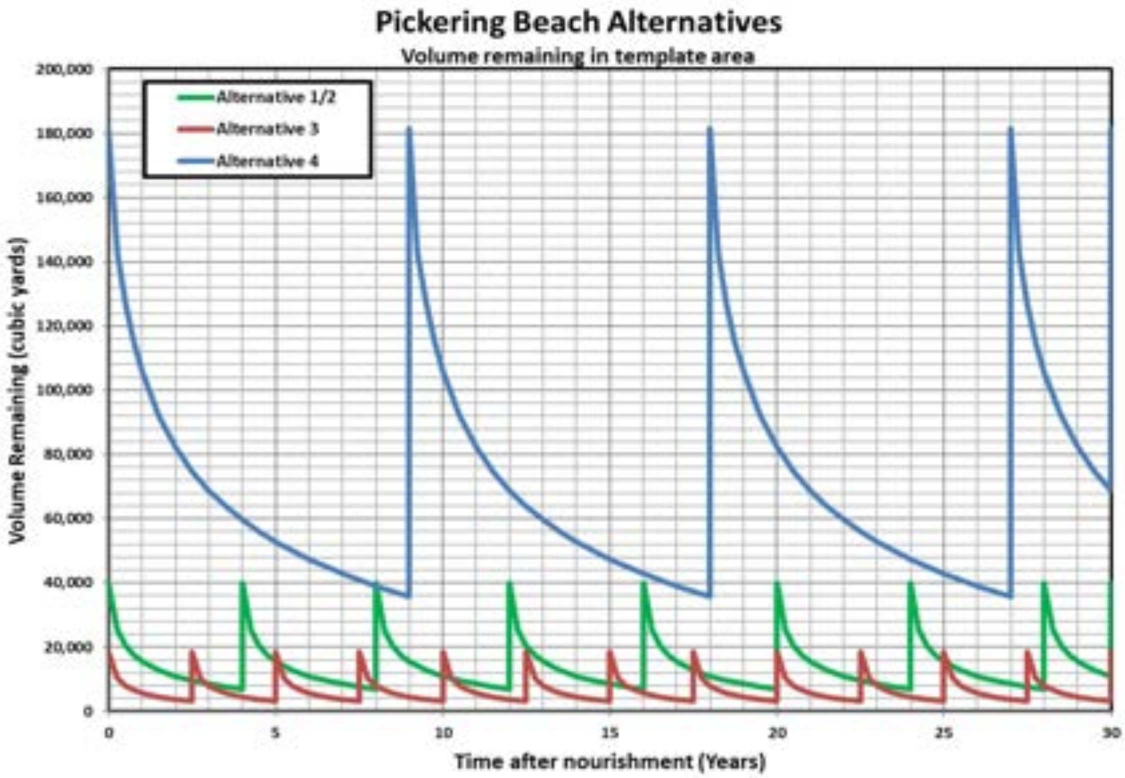

Figure 2-4. Example of volumetric nourishment performance at Pickering Beach

Beach Width and Nourishment Spreading

The second modeling assessment of the beach nourishment alternatives consisted of the evolution of the beach width and alongshore spreading of the nourishment. Figure 2-5 shows an example of these results for a nourishment template at Rehoboth and Dewey beaches, where the nourishment at each beach location interacts with the other and also spreads into adjacent shoreline areas, providing additional benefits over time. The vertical axis in the figure shows beach width in feet extended seaward from the existing (pre-nourishment) beach width, while the horizontal axis represents distance alongshore (in feet). The blue line represents the approximate beach width increase after the placement of nourishment at both Rehoboth and Dewey beach. Subsequent colored lines indicate the expected dispersion of the nourishment material as a function of time (years following the periodic nourishment) and show the changes in beach width and spreading in the alongshore direction.

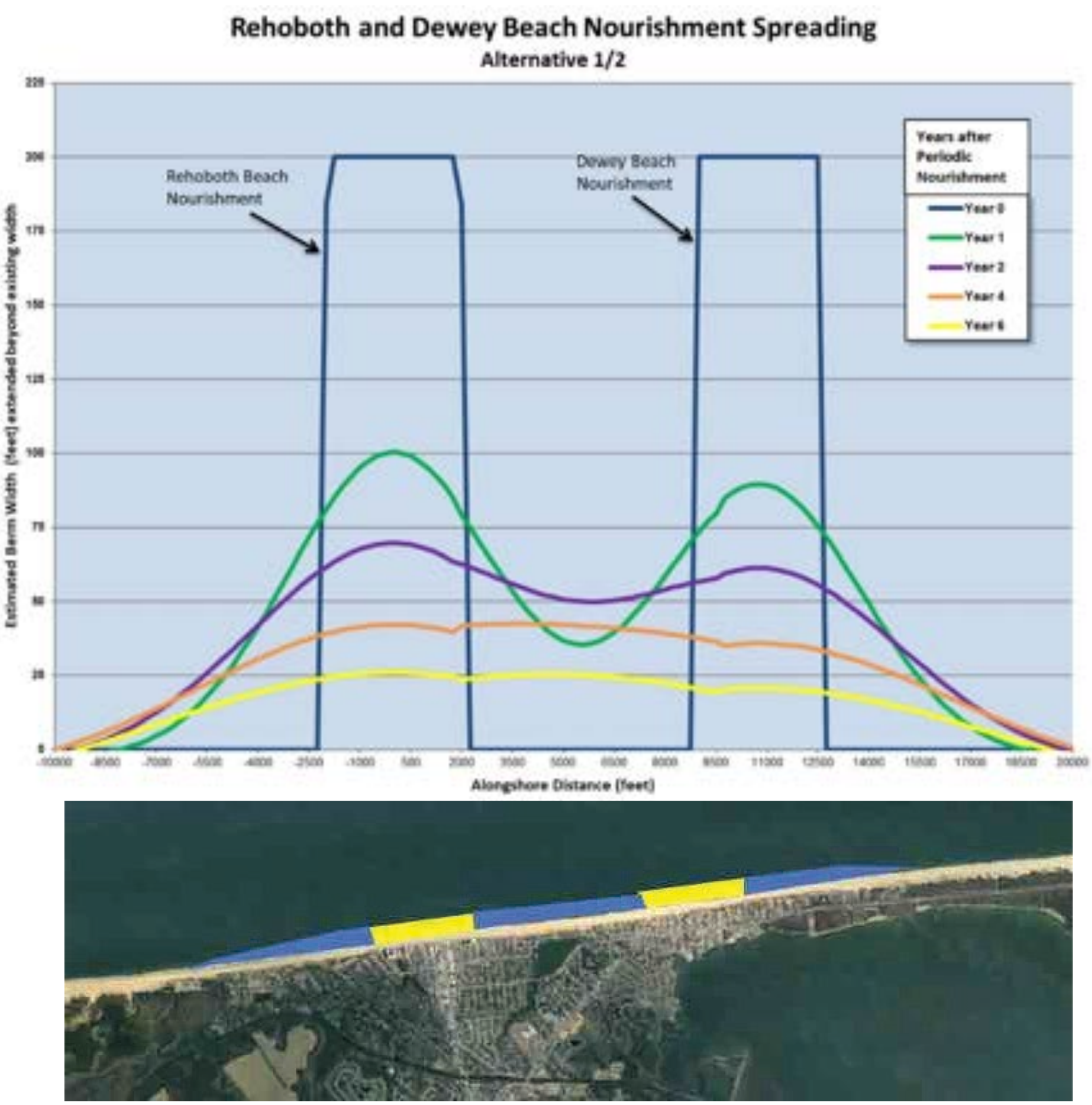

Figure 2-5. Example of beach nourishment evolution showing changes in beach width and spreading of material over time

The bottom panel in the figure shows a representation of the spreading of material spatially, where the yellow areas indicate the initial placement locations and the blue areas indicate locations where the material spreads into but was not initially placed. In other words, the yellow areas have direct benefits from the nourishment placement, and the blue areas have indirect benefits from the nourishment placement resulting from spreading of the material. These results provide information on recreational benefits associated with beach width, protective storm damage reduction benefits, and the benefits associated with nourishment material spreading to other locations along the shoreline.

2.2 Economic modeling of benefits

Outputs from the coastal process modeling are inputs for the economic models we apply to quantify the benefits of beach nourishment. In this section, we describe our approach to modeling infrastructure resilience, recreation value, and tourism impacts, as well as a qualitative assessment of ecological value.

2.2.1 Infrastructure resilience

Infrastructure resilience captures the benefit of beach nourishment to public and private owners of infrastructure in terms of the reduction in expected damages from coastal storm events, expressed in dollars. We start by identifying the at-risk infrastructure in the project area. For buildings (e.g., residences, stores/restaurants, public buildings), we primarily use the National Structure Inventory (NSI), developed and maintained by the U.S. Army Corps of Engineers.[12] The NSI combines multiple data sources to provide spatially explicit parcel-level information relevant to our analysis: structure type, square footage, foundation height, and replacement cost. We supplement NSI with two additional datasets: (1) U.S. Geological Service (USGS) National Structures Dataset,[13] which contains additional critical infrastructure such as water treatment facilities and electricity substations; and (2) U.S. Census TIGER/Lines Shapefiles to identify roadways.[14] Finally, we visually inspect aerial imagery of each project site to identify any additional infrastructure at risk not captured in those datasets (e.g., boardwalks).

Beach nourishment projects reduce the risk of damage to infrastructure from flooding, wave energy, and erosion. We outline the methodology for quantifying avoided damages associated with each of these coastal processes below.

Flooding and Wave Energy

To estimate avoided damages to buildings, roads, and any other infrastructure associated with flooding and wave energy, we perform the following analysis:

1. Calculate the total water level (flood depth plus wave height) experienced by each piece of infrastructure for each modeled storm event based on flood depth and wave height outputs from coastal modeling.
2. Subtract the foundation height (for buildings) as estimated in the NSI to obtain the "effective flood depth" for each building (i.e., the depth of water above first floor elevation).
3. Quantify the damage to buildings and their contents, as well as to roadways, based on effective flood depths.

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[12] United States Army Corps of Engineers. 2022. "National Structure Inventory." Available at: https://nsi.sec.usace.army.mil/downloads/

[13] United States Geological Survey, National Geospatial Technical Operations Center. 2023. "USGS National Structures Dataset." Available at: https://www.sciencebase.gov/catalog/item/4f70b240e4b058caae3f8e1b

[14] United States Census Bureau. 2023. "TIGER/Line Shapefiles: Roads – Primary, Secondary and All Roads." Available at: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html

a. Identify the total replacement value of each piece of infrastructure. For buildings, this is provided in the NSI. For roadways, we rely on average replacement costs per lane mile from the U.S. Department of Transportation.[15]

b. Identify the appropriate depth-damage function (DDF) for the affected infrastructure. DDFs translate water depths to damages, expressed as a percentage of the total cost to replace the building (or roadway, etc.). For buildings and their contents, we select appropriate DDFs (one for the building, one for its contents) based on structure type (e.g., residential, commercial, public) and characteristics (e.g., number of stories, presence of basement, located in a FEMA Special Flood Hazard Area).[16]

   For roadways, we select the appropriate DDF based on road type (e.g., primary, secondary, tertiary) and characteristics (e.g., raised, presence of electronic equipment).[17] Figure 2-6 depicts one example of a DDF intended specifically for application to two-story residential buildings with no basement. We use the DDFs to calculate the percentage of total replacement cost associated with the effective flood depths identified in Step 2.

c. Monetize damages by multiplying the total replacement values (Step 3a) by the percentages identified in Step 3b.

4. Quantify the present value of avoided damages across affected infrastructure. We convert the damage estimates, which are associated with a particular storm event, to expected annual damages (see "Calculating Annual Expected Damages" below). We sum expected annual damages over the 30-year analysis timeframe using a two percent discount rate. A benefit occurs whenever nourishment reduces the total effective flood depth, either by reducing flood depth, wave height, or both.

[15] U.S. Department of Transportation, Federal Highway Administration and Federal Transit Administration, Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report to Congress, 25th Edition (Washington, DC: 2024). https://doi.org/10.21949/1521626.

[16] Federal Emergency Management Agency (FEMA). 2022. "Hazus Flood Technical Manual: Hazus 5.1."

[17] Van Ginkel, K. C., Dottori, F., Alfieri, L., Feyen, L., & Koks, E. E. 2021. Flood risk assessment of the European road network. *Natural Hazards and Earth System Sciences, 21*(3), 1011-1027.

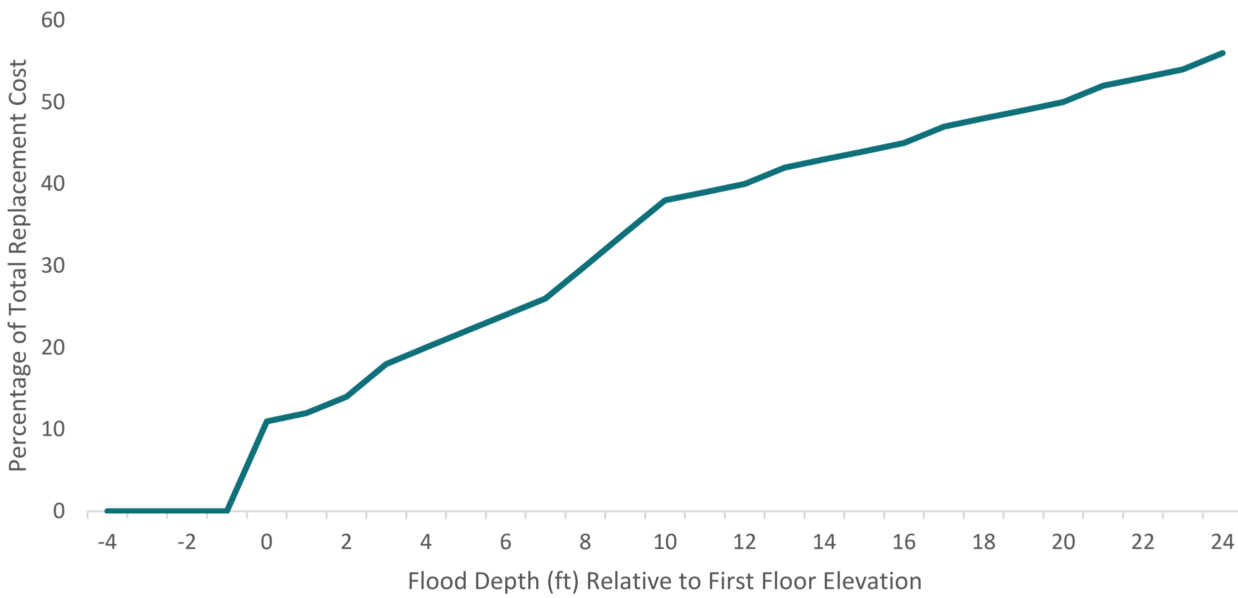

Figure 2-6. Depth-damage function for a two-story residential structure with no basement
Note: Derived from "Hazus Flood Technical Manual: Hazus 5.1" (FEMA, 2022)

To estimate avoided damage to infrastructure driven by erosion, we apply one of two methods depending on whether coastal modeling identifies long-term coastal erosion or episodic (event-driven) erosion as the primary threat to infrastructure at a project site.

Long-Term Coastal Erosion

When the primary threat to infrastructure over the 30-year analysis timeframe is landward migration of the shoreline, we perform the following analysis:

1. Measure the distance from the seaward edge of each piece of infrastructure to the present-day shoreline position.
2. Identify the year that the shoreline would reach the infrastructure assuming a constant annual rate of change between present-day shoreline and the 30-year projected shoreline position (incorporating sea level rise).
3. Quantify the damage to the infrastructure expected to lose its value due to coastal erosion. This step assumes the full market value of the structure is lost when the shoreline reaches the infrastructure footprint (Parsons 2012), using recent market value estimates obtained.[18]
4. Quantify the present value of avoided damages across affected infrastructure. We discount the loss from the year it is expected to occur using a two percent discount rate. A benefit occurs whenever nourishment prevents or delays losses to infrastructure over the 30-year timeframe.

[18] Zillow Zestimate®. https://zillow.com/de/ Last accessed: July 12, 2024.

Episodic Erosion

Unlike shoreline change driven by long-term coastal erosion, episodic erosion is characterized by sudden loss followed by the eventual return of sand. Damages result from the sudden and violent reshaping of sand around the base of the structure. When episodic erosion is the primary threat to infrastructure over the 30-year analysis timeframe, we perform the following analysis:

1. Quantify the total replacement cost of infrastructure that is most vulnerable to episodic erosion (i.e., the first row of infrastructure), including all buildings, roads, and other structures.
2. Split the first row of infrastructure into "segments" based on common distance to the current shoreline.
3. Where episodic erosion extends landward of the segment, we quantify damages as the full replacement cost of all infrastructure in the segment. Where episodic erosion extends through a fraction of the segment, we quantify damages assuming a direct relationship between the fraction of infrastructure exposed to erosion and the fraction of replacement costs incurred (i.e., if the erosion line extends halfway through the segment, damages are equal to half of the full replacement cost of that segment – see Figure 2-4).
4. Quantify the present value of avoided damages across affected segments. We convert the damage estimates, which are associated with a particular storm event, to expected annual damages (see "Calculating Annual Expected Damages" below). We sum expected annual damages over the 30-year analysis timeframe using a two percent discount rate. A benefit occurs whenever nourishment reduces the landward extent of episodic erosion.

Calculating Expected Annual Damages

For integration with other results, it is necessary to convert event-driven infrastructure damages (i.e., damages from flooding/wave energy and episodic erosion associated with storms of varying magnitudes) to an annual measure of *expected* damages based on the probability of experiencing each event in a given year. We then calculate the annual benefit of nourishment as the difference between expected annual damage (EAD) at a site with and without the nourishment project in place, and sum over the 30-year analysis timeframe using a two percent discount rate to obtain the present value benefit.

For each storm event, the contribution to EAD is represented by the following:

$$EAD_s = D_s * P(S)$$

Where EAD_s is the expected annual damage associated with storm event s; D_s is the monetized damage from storm event s; and $P(S)$ is the annual probability of storm s. The modeled storms are characterized by an annual exceedance probability (AEP). We calculate the probability that each storm will occur in a year, subtracting out the probability of all storms with higher depths occurring in that year to avoid double counting (in other words, convert a cumulative density function to a probability density function). To calculate the annual probability $P(S)$ given the other storms included, we subtract the exceedance probability of the storm with the lower probability and higher intensity:

$$P(S_i) = E(S_i) - E(S_{i+1})$$

Where $P(S_i)$ is the annual probability of storm i; $E(S_i)$ is the exceedance probability of storm i; and $E(S_{i+1})$ is the exceedance probability of the next storm with higher intensity and lower probability. For example, the annual probability of a storm with a ten percent AEP, given we also estimate the annual probability of a two percent AEP event, is eight percent (ten percent minus two percent). For the last storm in the series, the annual probability is the same as the exceedance probability.

Given that adjustment to $P(S)$, storm-specific expected annual damages (EAD_s) are additive. Summing across storms yields total EAD.

$$EAD = \sum EAD_s$$

2.2.2 Recreation value

Recreation value captures the enjoyment that recreators derive directly from going to the beach. Estimating the recreation value of beaches with and without nourishment over the next 30 years involves estimating the baseline recreation value of the beach, then calculating how the value changes with and without nourishment over the 30-year analysis timeframe as the beach widens or narrows. To do so we perform the following analysis for each beach:

Table 2-1. Consumer surplus value per recreational beach trip

Study	Value per day (day trips)	Value per day (overnight trips)
Parsons et al., 2013 (Delaware Bay beaches)	$43.69	$48.70
Toussaint 2016 (Atlantic coast beaches)	$67.33	$107.34

1. Estimate the annual baseline (present-day) recreational value of the beach. This is simply the number of annual beach trips multiplied by the value per trip (Table 2-1). Baseline annual trip counts used in this analysis are adjusted to more accurately reflect current visitation (Table 2-2).
   a. Estimate number of annual beach trips. We obtained estimates for the annual number of trips taken to each beach from two published studies: Parsons et al. (2013) for bay beaches, and Parsons and Firestone (2018) for ocean beaches.[19,20] To account for increased visitation since the data were collected, we scale the number of out-of-state trips using tourism growth over the relevant period,[21] and

[19] Parsons (2013) estimates annual visitation to the Bay beaches from a sample of onsite counts conducted throughout an entire calendar year. Parsons and Firestone (2018) estimate annual visitation to the ocean beaches from a mail survey administered to a representative sample of eastern U.S. residents.

[20] Given these data were collected in 2011 and 2015, respectively, we worked with local government officials and chambers of commerce to identify alternative sources of information on recent visitation levels. Though we were unable to identify any more recent, comprehensive visitation data for the beaches in our analysis, anecdotal evidence suggests increased visitation in recent years. Subsequent examination of time series data on state park visitation and local beach parking permit sales suggested that beach visitation among locals has been relatively constant, while visitation by non-locals has followed an upward trend. We accordingly scaled the dated visitation estimates by indicators of growth in population and tourism, respectively.

[21] Rockport Analytics. 2023. "2021 Delaware Tourism Satellite Account." https://onsite.d3corp.com/media/markets/so-del/2021-value-of-tourism-rockport-report.pdf

the number of trips by non-local Delaware residents using the statewide population growth rate over the relevant period (2011 to 2023 for Bay beaches; 2015 to 2023 for Atlantic coast beaches).[22]

b. Estimate appropriate values per trip. We quantify economic values in terms of changes in consumer surplus, a well-accepted monetary measure of the well-being associated with each trip.[23] Consumer surplus estimates for trips to Delaware beaches are a focus of the published economics literature. Parsons et al. (2013) used a travel cost model to estimate the value of day and overnight trips to Delaware Bay beaches. Toussaint et al. (2016) use a contingent behavior model to estimate the value of day and overnight trips to Atlantic coast beaches.[24] Table 2-1 presents the per trip values (adjusted to constant 2023 USD). On average, recreators place more value on overnight trips compared to day trips, and on trips to Atlantic coast beaches compared to Bay beach trips.[25]

c. Multiply the number of recreation days associated with each type of

Table 2-2. Estimated baseline (2023) annual trip (days) to each beach

Beach	Baseline Annual Trips (days)
Pickering	1,507
Kitts Hummock	1,361
Bowers	7,579
South Bowers	2,895
Slaughter	12,079
Broadkill	23,930
Lewes	472,723
Cape Shores	5,459
Rehoboth	4,810,760
Dewey	1,055,032
Bethany	3,350,861
South Bethany	489,870
Fenwick Island	1,183,247

Note: These estimates are derived from Parsons et al. (2013) and Parsons and Firestone (2018), adjusted to account for growth in visitation since data were collected.

[22] U.S. Census Bureau. "DP05 ACS Demographic and Housing Estimates: ACS 1-Year Estimates Data Profiles." https://data.census.gov/table?q=DP05

[23] Consumer surplus is the difference between what consumers are willing to pay for a good or service and what they actually pay. It represents the additional benefit or value consumers receive from participating in an activity at a cost that is less than their maximum willingness to pay. Thus, the consumer surplus values do not reflect spending in the local economy (the economic impact associated tourism spending is a distinct benefit described in Section 2.2.3).

[24] Though the nonmarket valuation method differs between studies, both provide estimates in terms of consumer surplus, a consistent welfare measure.

[25] The age of these data is not a concern because research suggests that values for recreational experiences are reasonably stable over time (Ji et al., 2020).

trip (day or overnight) with the appropriate value per trip to obtain the baseline recreational value of each beach.

2. Estimate the present value of beach recreation over the 30-year analysis period with and without the nourishment projects in place.

    a. Estimate the functional relationship between beach width and consumer surplus. Research consistently demonstrates that recreators value recreational experiences at wider beaches more highly than at narrower beaches (e.g., Whitehead et al., 2008; Parsons et al., 2013; Landry et al., 2020). Specifically, Parsons et al. (2013) found that recreation value for Delaware Bay beach recreators would increase by 7.9% with a doubling of current beach width, and decrease by 14.4% if current beach width was reduced by 75%. For ocean beaches, we utilize the results of Whitehead et al. (2008), which found that recreational value for recreators at Atlantic coast beaches in North Carolina would increase by about 7.3% with an approximate doubling of current beach width. Following the methodology utilized in JMT (2014), we assume that recreational value is completely lost when width is zero. We then use these reference points to derive a piecewise linear functional relationship between beach width and recreation value (relative to baseline width and value) (Figure 2-7). For beach width increases, the relationship is nearly identical between bay and ocean beaches. For width decreases, however, value declines more rapidly at ocean beaches compared to bay beaches due to crowding issues.

    b. Incorporate relevant values into the function for each year of the analysis. Coastal modeling results provide estimated current (baseline) beach width as well as modeled beach width over time with and without nourishment. From these inputs, the function returns the percentage change to baseline value (estimated in Step 1).

    c. Sum across the 30-year analysis timeframe using a two percent discount rate to obtain the present value of beach recreation with and without nourishment projects. The difference comprises the recreation value benefit attributable to nourishment.

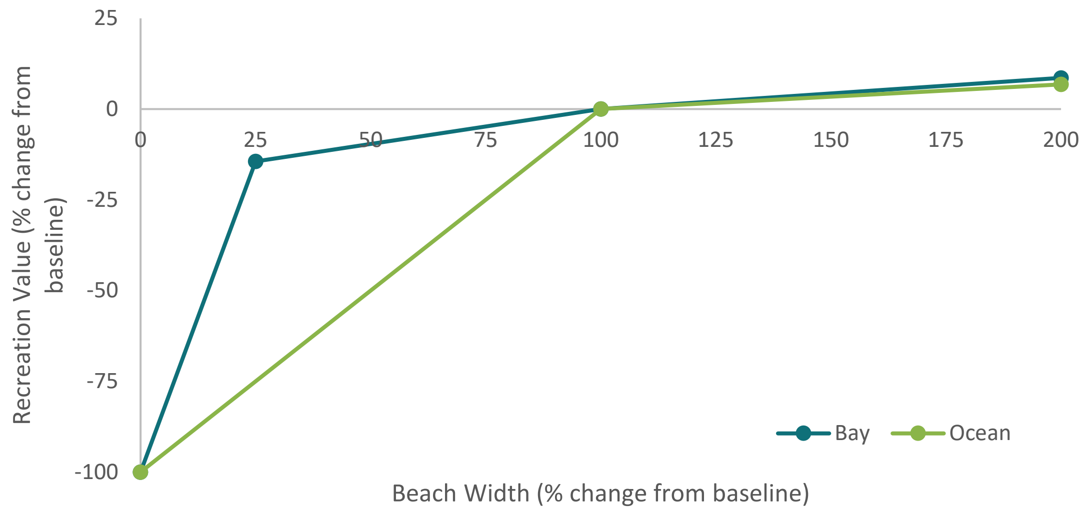

Figure 2-7. Functional relationship between recreation value and beach width

2.2.3 Tourism impacts

When tourists participate in beach recreation, they typically spend money at local businesses. Tourism impacts capture the effects of that spending on the broader economy for trips that originate outside of the local area.[26] To estimate the tourism impacts of beach nourishment, we perform the following analysis:

1. Estimate the number of non-local beach trips that are supported by nourishment. This requires converting the change in recreation values estimated above to changes in the numbers of beach trips associated with nourishment using the per trip values in Table 2-1.

2. Develop an expenditure profile that represents beach visitor spending per day across categories for an "average" beach trip to Delaware (Table 2-3). The expenditure profile is based on responses to the 2012 National Ocean Recreation Expenditure Survey conducted by NOAA (adjusted to 2023 USD). We include survey responses which meet the following criteria: Sussex County or Kent County is the reported destination, and reported activities include one or more activity associated with beach recreation (e.g., beachcombing, swimming, sunbathing).[27]

[26] We do not include local recreators in the tourism impact analysis.

[27] Actual spending by individual recreators is varies according to trip type (e.g., day versus overnight), activities, and individual preferences. Lacking detailed information about individual recreators, however, we derive an "average" profile that we apply uniformly. For this reason, some values in Table 2-3 may appear detached from market rates. For example, daily expenditure on lodging ($75.68) is below market lodging rates but represents the fact that not all beach trips include an overnight stay.

3. Quantify total annual direct spending within each sector as a result of beach nourishment using the number of beach trips (Step 1) and the average expenditure profile (Step 2).

4. Quantify the regional economic impacts associated with this spending using the regional input-output model IMPLAN. This includes the "direct" impacts to local businesses (spending by the beach visitors), the "indirect" impacts triggered by increased demand for goods and services in interrelated economic sectors, and the "induced" impacts stemming from changes in household consumption due to increased employment and income in the regional economy. The indirect and induced impacts together reflect the "multiplier" or "ripple" effects that added spending in the region has on the broader flows of dollars through the economy. We ran IMPLAN as a multi-region model, which captures the direct and multiplier impacts within the county where the spending occurs (the county where the beach is located), as well as the broader multiplier impacts across the rest of the state (i.e., the remaining two counties). IMPLAN reports these impacts in terms of multiple metrics for economic activity (e.g., jobs, revenues, income, and value-added). For this analysis we focus on "value-added," which reflects the total value of all output (or production) minus the costs of intermediate outputs. This metric is comparable to regional gross domestic product (GDP), a commonly used macroeconomic indicator of economic activity. Finally, we sum value-added over the 30-year analysis period using a two percent discount rate to derive the net present value of tourism impacts supported by beach nourishment.

Table 2-3. Expenditure profile for an "average" Delaware beach trip developed for this analysis

Expenditure Category	Daily Expenditures (2023 USD)
Auto fuel	$24.03
Bus, taxi, etc.	$0.52
Parking and site access	$1.16
Lodging	$75.68
Food (restaurants, bars, etc.)	$23.91
Food (grocery, convenience stores)	$9.77
Rented equipment (for example, gear for activities)	$0.17
TOTAL	$135.24

Derived from National Ocean Recreation Expenditure Survey (NOAA 2012).

2.2.4 Ecological benefit

The beaches in this study are integral components of broader coastal ecosystems of Delaware that provide immense ecological value, including supporting biodiversity and regulating water quality and climate. The entire Delaware coastal zone, for example, is designated as an Important Bird Area by the National Audubon Society.[28] Delaware beaches are within the designated range of several species listed under the Endangered Species Act, including red knot, piping plover,

[28] "Explore Important Bird Areas." National Audubon Society. https://www.audubon.org/important-bird-areas

tricolored bat, little brown bat, monarch butterfly, Hirst Brother's panicgrass, and seaside alder.[29] The Delaware coast is also an important stop-over for migratory shorebirds that rely on the beaches, mudflats, and marshes for food and habitat during spring migrations (Burger et al., 1997; Burger et al., 2018). In addition to red knot, these include ruddy turnstone, semipalmated sandpiper, sanderling, and dunlin.[30]

Additionally, Delaware Bay is home to the largest population of horseshoe crabs in North America, with beaches along the Bay coast providing important spawning habitat (Smith et al., 2002). Horseshoe crabs have significant economic value as a baitfish and to the biomedical industry (Krisfalusi-Gannon et al., 2018). They are also an important historical and cultural symbol for many Delaware residents, becoming formally recognized as the Official State Marine Animal in 2002.[31] Indigenous Peoples and early European settlers relied on horseshoe crabs for food, tools, and fertilizer (Kreamer and Michels, 2009). Their importance to current generations is on display during the annual Delaware Bay Horseshoe Crab Survey, a popular citizen-science effort that relies on volunteer labor to track the spawning population during full and new moons each spring.[32] Horseshoe crabs are considered a keystone species within the Delaware Bay coastal ecosystem; in particular, horseshoe crab eggs are a critical food source for migratory shorebirds, including red knots (Karpanty et al., 2006; McGowan et al., 2011).

Beyond providing habitat for sensitive and protected species, coastal wetlands in Delaware are ecologically and economically valuable for several reasons. Ecologically, they act as natural buffers, absorbing storm surges and reducing coastal erosion, which helps protect inland communities from flooding and damage during extreme weather events. Wetlands also play a crucial role in filtering pollutants and improving water quality. Economically, these wetlands support key industries such as fishing and tourism, which rely on the wetlands for maintaining healthy fisheries and attracting eco-tourism and outdoor recreation. Their role in flood control and carbon sequestration also provides long-term economic benefits by mitigating the impacts of climate change.

While coastal ecosystems and the species they support are highly valuable and require long-term protection, the contribution of the beach nourishment projects analyzed in this analysis is likely modest over the 30-year timeframe of our analysis. One reason is that beach nourishment projects designed to safeguard coastal infrastructure may not be the most effective means of enhancing the ecological value of these beaches. The ongoing nourishment efforts are primarily targeted at protecting infrastructure, and as a result, the specific sites and the timing of these projects are designed for that purpose. Rather than implement these particular nourishment projects, the state may elect to implement alternative, more targeted shoreline management strategies to protect

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[29] "Species Ranges." United States Environmental Protection Agency, Office of Pesticide Programs. https://www.arcgis.com/home/item.html?id=2c0a74713eb04ae5921fca27c854a331

[30] "Delaware Bay Ecology." Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife. https://dnrec.delaware.gov/fish-wildlife/conservation/shorebirds/bay-ecology/

[31] 73 Del. Laws, c. 326, §1: https://delcode.delaware.gov/title29/c003/index.html

[32] "Delaware Bay Horseshoe Crab Survey." https://www.delawarebayhscsurvey.org/

species, reflecting a different set of priorities aimed at preserving and enhancing the natural coastal environment. For example, shorebird conservation in Delaware generally focuses on limiting interactions between the birds and beach recreators. Even in the case of horseshoe crab conservation, for which beach nourishment is important, optimizing benefits to horseshoe crabs would influence both the locations and timing of nourishment activities (i.e., the nourishment project would not be designed around protection of infrastructure, as is the status quo).

Additionally, the full suite of ecological effects associated with beach nourishment is not well understood. For example, while some nourishment projects have demonstrated a positive effect on local horseshoe crab abundance, researchers cannot rule out a spatial redistribution rather than an increase in population-level abundance (Jackson et al., 2006; Smith et al., 2020). There may also be some negative ecological effects from beach nourishment, including to benthic organisms at both the project site and the borrow site (e.g., Speybroeck et al., 2006; Saengsupavanich et al., 2023).

Nonetheless, the beach nourishment projects do benefit some species by supplementing sand in the system and mitigating habitat loss. Based on communication with subject matter experts in Delaware, we focus on the following key indicators of ecological benefit:

- presence of horseshoe crabs,
- shorebird habitat, and
- presence of wetland ecosystems within the area of influence of the beach nourishment project over the 30-year timeframe.

We use these indicators to assess the level of ecological benefits from beach nourishment relative to other benefit categories at Bay and Atlantic Coast beaches. Atlantic Coast beaches are generally crowded, resulting in avoidance by most protected species during beach season. However, they are used by bird as stop-overs along migratory routes and during less crowded seasons. In contrast, Delaware Bay beaches are generally less crowded, support shorebird habitat, and many are designated as Horseshoe Crab Sanctuaries.

The nourishment projects we consider in this study adopt practices to avoid harm to birds and other wildlife. However, avoiding harm is different than providing direct benefits. In the long run, adding more sand to the system to limit beach erosion benefits coastal species, including horseshoe crabs and shorebirds. However, over the 30-year timeframe of our analysis, it is unlikely that the beach erosion at these sites would lead to population-level changes in abundance.

Overall, while coastal ecosystems serve critical ecological functions, the immediate economic benefits of these specific beach nourishment projects—protecting infrastructure, property, and recreation—often take precedence in decision-making regarding the project design. This leads to a lower level of ecological benefits of the nourishment projects relative to the targeted economic benefits. This reflects the focus of these projects on safeguarding economic assets and sustaining local economies.

2.3 Developing equitable cost share recommendations

As described through Section 2.2, our analysis results in mixed measures of benefits. For example, infrastructure resilience is measured in terms of avoided economic damages, recreation value is measured in terms of consumer surplus, contribution to the tourism economy is measured in terms of value added, and ecological values are described qualitatively. At the same time, there is inherent uncertainty in each of our estimates. Our modeled results necessarily rest on reasoned assumptions and imperfect data.

Our goal is to implement a methodology for aggregating the benefits into equitable cost share recommendations that is (1) capable of integrating mixed metrics, and (2) ensures that small changes in numbers do not disproportionately influence outcomes. This framework provides results that appropriately reflect the distribution of benefits, allowing for more confident decision-making despite the complexities and uncertainties involved. The approach we developed borrows from established frameworks for synthesizing diverse information to inform management decisions.

Our approach can be described in four basic steps:

STEP 1: Establish standards and criteria.

STEP 2: Compare modeled benefits against criteria.

STEP 3: Allocate benefits.

STEP 4: Aggregate across benefits.

Each of these steps is described in detail subsequently. The text box on this page describes the benefits from a hypothetical nourishment project. We will refer to this hypothetical project as an example to demonstrate the process of aggregating modeled nourishment benefits into an equitable cost share recommendation.

HYPOTHETICAL COST SHARE RECOMMENDATION EXAMPLE

Consider a hypothetical nourishment project along the Atlantic Ocean coastline that provides the following benefits according to the coastal processes and economic modeling described in Sections 2.2 and 2.3:

- Infrastructure resilience: Absent nourishment, infrastructure at the project site experiences $20 million in expected annual damages from erosion, flooding, and wave energy. The project reduces these expected damages by $8 million annually ($4 million at residential and commercial properties; $2 million at state roads and recreational facilities; $2 million at a boardwalk owned by the town).
- Recreation value: Nourishment at the project site generates $9.2 million of recreation value annually ($920,000 to local recreators; $3.7 million to non-local Delaware recreators; $4.6 million to out-of-state recreators).
- Tourism impacts: Non-local recreation, including recreators visiting from out of state, generates $43 million in value added, a GDP-equivalent measure of economic activity ($32 million within Sussex County; $11 million elsewhere in the state).
- Ecological benefit: The project adds sand to an ocean beach while minimizing adverse effects on shorebirds.

2.3.1 Establish standards and criteria

Establishing criteria is necessary to compare and aggregate across benefits that are not all expressed in like terms (e.g., dollars). Essentially, this allows us to convert a qualitative or quantitative modeled project outcome (i.e., benefit) into a standardized (zero to three point) indicator of the level of that benefit at a particular project site. We do so by comparing the benefit against an appropriate standard (Table 2-4).

Table 2-4. Comparison standards used for each benefit category

Infrastructure resilience	Recreation value	Tourism impacts	Ecological benefit
Expected annual damage to infrastructure absent nourishment (site-specific)	Annual recreation value of substitute sites: • $1.4 million (bay beaches) • $307 million (ocean beaches)	Value-added to the regional economy from recreation and tourism across all beaches in the study: $1.1 billion	Qualitative

To develop appropriate standards, we take the perspective of the groups receiving the benefit. The standards used for each benefit category are described below.

- **Infrastructure resilience:** The benefit of nourishment is expressed in terms of avoided damages (economic value). We compare the avoided damages resulting from the nourishment project to the total infrastructure damage experienced at that project site and neighboring communities absent nourishment. This assumes that from the owners' perspective, infrastructure benefitting at a particular project site is not substitutable with infrastructure elsewhere in the state.
- **Recreation value:** The benefit of nourishment to recreational experience is expressed in terms of consumer surplus (economic value). For bay (or ocean) beaches, we compare the enhanced recreation value associated with a nourishment project to the total value of bay (or ocean) beach recreation.[33] This assumes that recreators are willing to substitute recreation at one bay (or ocean) beach for recreation at a different bay (or ocean) beach. However, we do not assume substitution between bay and ocean beaches given the differences in setting and recreational experiences between bay and ocean beaches.
- **Tourism impacts:** The benefit of nourishment to the tourism economy is expressed in terms of impact on regional value-added (economic impact, a distinct measure from economic value that cannot be directly compared). We compare the value-added (a GDP-equivalent metric, see Section 2.2.3) associated with recreation and tourism from a beach nourishment project to the total value-added from beach-driven recreation and tourism across all beaches in the analysis. Here we consider statewide value-added from beach recreation

[33] More specifically, we compare the enhanced recreation value accruing to Delaware residents as a result of nourishment to the total recreational value of bay or ocean beaches to Delaware residents. As described elsewhere, benefits accruing to out-of-state recreators do not enter the cost share recommendation (though trips by out-of-state recreators do contribute to our estimation of tourism impacts).

and tourism, given the economy of the county and broader state benefits regardless of whether the tourism spending is at a bay or ocean beach.

- **Ecological benefit:** Ecological benefits of the nourishment projects are assessed qualitatively and separately for bay and ocean beaches. Each individual beach reflects a relatively small fraction of coastal habitat in Delaware; however, the beaches in the analysis combined represent a significant fraction of the Delaware coastal zone. The ecological benefits based on the qualitative criteria are linked directly to points (see Table 2-6).

The first three benefits are measured in quantitative terms, so the comparison against a standard yields a percentage (0-100 percent, e.g., infrastructure resilience benefits reflect an X% reduction in expected storm-related damages). For these benefits we establish percentage-based criteria which translate percentages into the relative level of the benefit (Table 2-5). If the project benefit registers less than one percent, it is considered negligible and assigned zero points. Generally, changes of less than one percent are considered insignificant. For example, a one percent change in annual ocean beach recreation may occur as a result of normal weather fluctuations. At the other end of the spectrum, the project benefit is considered high and assigned three points if it amounts to greater than ten percent. Staying with the recreation example, if a nourishment project protects one out of every ten ocean beach trips (i.e., ten percent), we would consider recreation a relatively high-level benefit of that project. Between negligible benefits (zero points) and high benefits (three points), we define two additional levels: low benefits (one point) for one to five percent and medium benefits (two points) for five to ten percent.

Table 2-5. Criteria for determining level of benefit at each project site for quantitative benefits assessments

Benefit Category	Negligible (0 points)	Low (1 point)	Medium (2 points)	High (3 points)
Infrastructure resilience	<1% reduction in expected damages	1-5% reduction in expected damages	5-10% reduction in expected damages	>10% reduction in expected damages
Recreation value	<1% contribution to recreational value of bay (ocean) beaches	1-5% contribution to recreational value of bay (ocean) beaches	5-10% contribution to recreational value of bay (ocean) beaches	>10% contribution to recreational value of bay (ocean) beaches
Tourism impacts	<1% contribution to value-added (GDP equivalent) from beach recreation	1-5% contribution to value-added (GDP equivalent) from beach recreation	5-10% contribution to value-added (GDP equivalent) from beach recreation	>10% contribution to value-added (GDP equivalent) from beach recreation

The ecological benefit of beach nourishment projects is described qualitatively. As a result, conversion to a percentage is not possible. In this case we establish qualitative criteria that are directly linked to points indicating the level of benefit. The criteria for ecological value outlined in Table 2-6 were developed with input from DNREC biologists. These criteria reflect the discussion in Section 2.2.4 that describes the ecological importance of these beach ecosystems but the relatively limited ecological benefits of the nourishment activity.

The benefit level of "low" for bay beaches recognizes the importance of supplementing sand into the bay ecosystem for horseshoe crabs and, by extension, red knots. However, it recognizes that horseshoe crabs are abundant across the bay shoreline, including outside of the beaches in this analysis, and that the nourishment projects are not designed or prioritized based on horseshoe crab conservation. This determination additionally reflects our analysis of how the nourishment projects influence wetlands over the period of analysis. Specifically, we consider whether the reduced erosion, flooding, and wave energy resulting from the nourishment projects overlap with surrounding wetland habitat, generally finding this is not the case.

We identify more limited ecological benefits of beach nourishment for ocean beaches relative to the bay beaches. This is due to the high level of human use and development of these beaches, which limits their relative habitat value. The shorebirds that do rely on the ocean beaches are generally more likely to inhabit ocean beach sites with fewer people. Additionally, for the ocean sites, we do not find that the nourishment projects influence erosion, flooding, or wave energy within surrounding wetland habitat over the timeframe of this analysis. Nonetheless, we identify the ecological benefits are not negligible given they contribute to the long-term sustainability of the coastal beaches.

Table 2-6. Criteria for determining level of ecological benefits at each project site

Benefit Category	Negligible (0 points)	Limited (0.5 points)	Low (1 point)
Ecological benefit	Project does not adopt measures to minimize potential adverse effects on species (e.g., horseshoe crabs or shorebirds) and does not influence wetland extent over the analysis timeframe	Project adds sand to ocean beaches and adopts species conservation measures to avoid adverse effects on shorebirds Project does not influence wetland extent over the analysis period	Project adds sand to bay system and adopts species conservation measures to avoid adverse effects on horseshoe crabs and shorebirds Project has limited effect on wetland extent over the analysis period

2.3.2 Compare modeled benefits against criteria

For each benefit category, we compare the modeled project outcomes against the established criteria to determine the importance of each benefit, expressed in points (0-3). For example, consider the hypothetical beach nourishment project developed above (Table 2-7).

Table 2-7. Quantified value and associated level of each benefit for the hypothetical nourishment project on the Atlantic coast

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$8 million	$20 million	40%	High
Recreation value	$4.6 million	$310 million	1.5%	Low
Tourism impacts	$43 million	$1.1 billion	3.9%	Low
Ecological	-	-	-	Limited

The hypothetical project:

- reduces expected damage to infrastructure by 40 percent,
- avoids loss of 1.5 percent of Atlantic beach recreation,
- contributes 3.9 percent to statewide value-added from beach tourism, and
- adds sand to an ocean beach while minimizing potential adverse effects on shorebirds.

According to the criteria (Table 2-5 and Table 2-6), this project would be scored as follows:

- High level (3 points) infrastructure resilience,
- Low level (1 points) recreation value,
- Low level (1 point) tourism impacts, and
- Limited level (0.5 points) ecological benefit.

The overall benefits are therefore the aggregate 5.5 points, with infrastructure resilience reflecting 55 percent of this point value (3/5.5), recreation and tourism constituting another 18 percent (1/5.5) each, and ecological benefits accounting for a low fraction of the total benefits relative to the first three categories.

2.3.3 Allocate benefits

Once points are assigned to each benefit, we allocate the points across benefiting groups according to how the benefit is distributed between those groups based on our modeled results (Table 2-8). We demonstrate this step continuing with the hypothetical example.

Table 2-8. Assignment of benefit subcategories to benefiting groups

State	County	Local	
		Municipal	Private
• Avoided damages to state-owned infrastructure • Recreation value to non-local instate recreators • Tourism impacts (value-added) outside of the primary county • Ecological benefit	• Avoided damages to county-owned infrastructure • Tourism impacts (value-added) in the primary county	• Avoided damages to municipal-owned infrastructure	• Avoided damages to privately-owned infrastructure* • Recreation value to local recreators**

* In some cases, sand spreading results in protection of privately-owned infrastructure in adjacent communities. In these cases, we report the distribution of this sub-benefit between local jurisdictions.

** Due to data availability, the definition of local recreators differs on Bay and Atlantic coast beaches. For Bay beaches, local recreation captures activity by shorefront property owners. For Atlantic coast beaches, local recreation captures activity by anyone residing within five miles of an Atlantic coast beach.

For infrastructure resilience, we base the allocation of the high level (3 points) of benefits on ownership of the affected infrastructure. In the hypothetical example, 50 percent of avoided infrastructure damages are to residential and commercial properties, 25 percent of the avoided infrastructure damages are to state roads and a state recreational facility, and 25 percent of the avoided infrastructure damages are to a boardwalk owned by the town. Therefore, the three points for infrastructure resilience would be allocated as follows:

- 1.5 points to local private property owners (3x50%),
- 0.75 points to the state (3x25%), and
- 0.75 points to the town (3x25%).

For recreation value, we base the allocation on recreators' point of origin. Granularity of the data allows us to allocate recreational value between local residents, non-local instate residents, and out-of-staters. Since the goal is to develop equitable state-county-local cost shares, benefits that accrue out of state are excluded from our analysis. Staying with the hypothetical example, 50 percent of beach trips are taken by out-of-staters, 40 percent of beach trips are taken by non-local instate residents, and 10 percent of beach trips are taken by local residents. The one point for recreation value, therefore, would be allocated as follows (note the extra step to exclude out-of-staters):

- 0.8 points to non-local instate residents (1x[40%/(40+10%)]=1x80%), and
- 0.2 points to local residents (1x[10%/(40+10%)]=1x20%).

For tourism impacts, the allocation is based on the IMPLAN model output, which treats counties as the unit of analysis. In the hypothetical example, 75 percent of value-added accrues to the county where the beach is located (i.e., Sussex County for Atlantic beaches) and the remaining 25 percent accrues elsewhere in the state. Therefore, the one point for tourism impacts would be allocated as follows:

- 0.75 points to Sussex County (2x75%), and
- 0.25 points to the state (2x25%).

Finally, ecological benefit is always allocated 100 percent to the state, which serves as steward of the natural resources in the coastal zone. In the hypothetical example, therefore, the 0.5 points for ecological benefit is assigned to the state.

2.3.4 Aggregate across benefits

Once points have been allocated to benefiting groups, we sum the points across benefit categories, within benefiting groups. Table 2-9 demonstrates this process using the hypothetical example developed throughout this section. In this example, approximately 42 percent of project benefits accrue to the state, 14 percent to the county, and 45 percent to private and public local entities. This distribution is the basis of our equitable cost share recommendation based on the principle that the distribution of the financial burden of nourishment should reasonably match the distribution of benefits.

Table 2-9. Hypothetical example summing points within benefiting groups to determine distribution of total benefits

	State	County	Local		Total
			Municipal	Private	
Infrastructure resilience	0.75		0.75	1.5	3
Recreation value	0.8			0.2	1
Tourism impacts	0.25	0.75			1
Ecological benefit	0.5				0.5
Total points	2.3	0.75	0.75	1.7	5.5
Distribution of total points	**42%**	**14%**	**14%**	**31%**	**100%**

Our study provides these cost share recommendations, outlining an equitable distribution of costs among the stakeholders benefitting. However, we do not prescribe specific policy mechanisms for implementing these recommendations, leaving the choice of policy tools to decision-makers.

2.4 Nourishment project costs

Cost estimates for nourishment project alternatives provide perspective by allowing the cost share ratios to be translated into dollars. For example, if the hypothetical nourishment project described in the previous section has an annualized cost of $1 million, the expected annual contributions based on the distribution of benefits would be as follows (note that due to rounding, the individual contributions do not sum to $1 million):

- State: $480,000 ($1 million x 48%)
- County: $120,000 ($1 million x 12%)
- Local Municipal: $120,000 ($1 million x 12%)
- Local Private: $290,000 ($1 million x 29%)

In collaboration with DNREC, we developed a reduced form model of total nourishment costs over 30 years for each nourishment project:

$$Cost_{PV} = \alpha \cdot StructureCost + \sum_{t=0}^{30} \frac{Volume_t \cdot UnitCost_t + Mobilization}{(1+r)^t}$$

The equation estimates the cost of a particular nourishment design alternative at a particular project site over thirty years in present value terms. Individual model components are as follows:

- α is a variable that indicates the number of new terminal structures (e.g., groins) associated with the nourishment design alternative (typically zero). Note that the model assumes any such structures would only be built once over 30 years (at the beginning of the analysis period).
- *StructureCost* is the approximate cost of building each terminal structure ($1 million).
- *t* is an index indicating the time period (i.e., year from the start of our analysis).
- $Volume_t$ is the volume of sand (in cubic yards) that is placed on the beach in time period *t*. Volume is determined by the size of the nourishment template. Timing is determined by the expected design life of the nourishment. Both are direct outputs from coastal modeling.
- $UnitCost_t$ is the cost of sand per cubic yard, which differs for smaller projects that rely on trucked sand ($25 per cubic yard) and larger projects that rely on offshore dredging equipment ($15 per cubic yard). The *t* subscript indicates that these costs vary over time. We escalate unit sand costs over time to account for expected continued growth in the real cost of sand.[34]
- *Mobilization* captures remaining costs. For offshore dredge projects, this is primarily a fixed mobilization/demobilization cost ($1.5 million). For trucked projects, additional costs are linked directly to nourishment volume, representing a 25% multiplier on total sand cost for the project.
- *r* is the discount rate (2 percent).

[34] We escalate sand cost at a rate of 2.3% annually, which represents the difference in annual growth rates over the last decade between two price indices: Producer Price Index by Commodity: Nonmetallic Mineral Products: Construction Sand, Gravel, and Crushed Stone (a proxy for sand) and Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average (a standard measure for general inflation). We obtain both series from FRED (Federal Reserve Economic Data): https://fred.stlouisfed.org/.

We calculate the 30-year present value of nourishment costs for each alternative, but also convert to an annualized value for consistency with the presentation of benefits.

2.5 Social vulnerability assessment

The goal of the social vulnerability assessment is to characterize, for each of the beach communities that may be expected to share in the costs of future beach nourishment projects, factors influencing their social vulnerability to:

- experiencing adverse effects of coastal storms, and
- the cost burden of storm protection efforts (i.e., nourishment).

The social vulnerability of a community is related to the community's exposure to a stressor, sensitivity to that stressor, and capacity to respond to stressor-induced changes. Examples of community-wide stressors include natural hazards and public health crises, among others (CDC 2024, FEMA 2024a). The nature and extent of a community's sensitivity to a given stressor and that community's resilience in the face of stress may depend on various population characteristics, including demographics (population size, age, race, and ethnicity); health disparities (e.g., prevalence of disabilities or chronic illnesses); and socioeconomics (e.g., income, educational attainment, and public benefits). These characteristics may interact with other community characteristics, such as structural vulnerability (e.g., the vulnerability of buildings or roads to hazard impacts due to building materials, structure grades, etc.) and physical vulnerability (e.g., how a population's location may influence the risk of exposure to potential threats) (NCCOS 2023).

This analysis examines, for each beachfront community of interest, relevant demographic, health/healthcare, socioeconomic, and housing characteristics, relying primarily on recent data from the U.S. Census Bureau, including the 2020 decennial census and American Community Survey (ACS) five-year estimates. The analysis also considers several indices that seek to measure social vulnerability, resilience, and environmental risks. In additional to quantitative metrics related to social vulnerability and resilience, qualitative information is considered where appropriate to account for the unique histories of individual beaches and communities and cultural meanings associated with specific places.

CHAPTER 3 | Summary of Key Findings and Equitable Cost Share Recommendations

This chapter summarizes our cost share recommendations (Table 3-1) and discusses drivers of variation between project sites. While we generally adopt Cape Henlopen as the breakpoint between bay and ocean beaches, we classify Lewes as an ocean beach in spite of its location because its characteristics (built infrastructure and recreation profile) more closely resemble those beaches than the remaining set of bay beaches.

For this summary we focus on the recommended cost share distribution between the State of Delaware, the relevant county (Kent or Sussex, depending on the project location), and local (i.e., sub-county) entities. Further breakdown of local cost shares between public (e.g., municipal) and private (e.g., residents and businesses) entities are provided in the project-specific results reported subsequently (Chapters 4 through 14). In cases where the local benefits span multiple local jurisdictions (i.e., municipalities or unincorporated communities), the project-specific chapters include cost shares with that additional level of detail. Of note, many of the nourishment projects are partially funded by the federal government. The recommended cost shares apply to the remaining (non-federal) portion of total project costs.

Following are the key findings from the benefits analysis. Table 3-1 provides the detailed cost share ratios by project.

- **At all sites, the majority of benefits are experienced locally.** At all project sites, we find that the local residents, businesses, and municipal governments experience the majority of the benefits (Table 3-1). Specifically, benefits to local entities are between 52 and 75 percent across the project sites. This is because the effects of the nourishment projects in mitigating flooding, erosion, and wave energy are localized around the project sites, resulting in benefits being concentrated on local property owners. Additionally, local recreators generally receive a larger share of the recreation value benefits than non-local state residents, since they tend to visit the beaches at a higher rate.
- **Ocean beach nourishment projects include a county-level cost share element due to the benefits on the tourism economy.** The ocean beaches (including Lewes) are more developed and support significantly higher levels of recreation compared to the bay beaches. As a result, ocean beaches are a driver of the tourism economy in Sussex County, resulting in a county-level cost share for ocean projects of between 16 and 31 percent. This range is driven by differences in the level of non-local recreation across ocean beaches. In contrast, non-local recreation across all bay beaches has a negligible effect on the tourism economy.
- **The state cost share recommendation is higher for the bay beach projects than the ocean beach projects.** The state fraction of the cost share recommendation is driven by the ecological benefits of the nourishment projects and the recreational benefits to in-state, non-local visitors. For the bay beach sites, the recommendation for the state share accounts for all of these non-local benefits (25 to 48 percent). For the ocean beaches (including Lewes), the state share is generally lower (between 11 and 19 percent) due to the additional influence of county-level tourism benefits on the cost share distribution at these sites.

- **At most ocean beach sites, sand spreading results in benefits to adjacent (typically unincorporated) communities.** These benefits account for between 11 and 35 percent of total project benefits, depending on the size of the adjacent communities, their location (e.g., between two nourishment projects or at the end of one project), and the extent of alongshore sand spreading. On the bay, sand spreading does not result in benefits to adjacent communities because bay communities tend to be isolated and sand spreading is more limited.
- **All projects include some level of state cost share driven by the potential contribution of beach nourishment toward coastal ecosystem protection.** While Delaware's coastal ecosystems are highly valuable, the effect of beach nourishment on these ecosystems over the timeframe of our analysis is uncertain and likely modest. Nonetheless, we assign a uniform level of ecological benefit to ocean beaches, and a higher uniform level of ecological benefit to bay beaches due to the additional importance of bay beaches as horseshoe crab spawning habitat.
- **The equitable cost share recommendations are not sensitive to the design of the nourishment project.** As described in Section 1.3.4, we analyze the benefits associated with up to four different nourishment designs per beach. We generally find that the cost share recommendations are not sensitive to the alternative project designs.[35] That is, while the total costs of nourishment and the magnitude of benefits may vary by project alternative, the relative distribution of benefits across state, local, and county entities does not. Thus, the cost share recommendations in this chapter are relevant across alternative nourishment project designs.

The remainder of this chapter provides a more detailed description of the findings for bay and ocean projects, including discussion of the primary drivers of project-by-project variation. As described in Chapter 2, the cost share recommendations are driven by: (1) the relative level of each benefit category; and (2) the distribution of the benefit between state, county, and local stakeholders. Variation, therefore, arises from differences in one or both of those factors.

[35] In nearly all cases, the distribution of benefits varies by less than one percent.

Table 3-1. Recommended share of non-federal portion of nourishment costs based on distribution of benefits

Project Site	Bay/Ocean	State	County	Local
Pickering	Bay	33%	-	67%
Kitts Hummock	Bay	27%	-	73%
Bowers	Bay	46%	-	54%
South Bowers	Bay	44%	-	56%
Slaughter	Bay	48%	-	52%
Broadkill	Bay	35%	-	65%
Lewes*	Ocean*	19%	16%	65%
Cape Shores	Bay	25%	-	75%
Rehoboth-Dewey	Ocean	16%	31%	53%
Bethany-South Bethany	Ocean	11%	18%	71%
Fenwick Island	Ocean	15%	18%	68%
Range: All projects	-	11-48%	0-31%	52-75%
Range: Delaware Bay projects	Bay	25-48%	0%	52-75%
Range: Atlantic coast projects	Ocean	11-19%	16-31%	53-71%

*We classify Lewes as an ocean beach because its characteristics (development and recreation profiles) are more closely aligned with those beaches than other bay beaches.

3.1 Delaware Bay project sites

Generally speaking, communities along Delaware Bay are small and relatively isolated. Infrastructure is almost exclusively residential single-family homes (a mix of primary residences and seasonal homes), and development is typically limited to within a few blocks of the coastline (in some cases, a single row of homes along the coast). The communities are generally buffered along the coast by undeveloped coastline and inland by large swaths of marshland. These factors, combined with limited public parking, contribute to Bay beaches supporting more limited recreation than beaches on the Atlantic coast. We estimate the total annual recreational value of bay beaches in this study to be $1.4 million (approximately 55,000 annual visits).

Recommended cost shares for projects on Delaware Bay are between 52 and 75 percent for local entities and between 25 and 48 percent for the state. Local entities in this context refer almost exclusively to the residential property owners in these communities who benefit from infrastructure resilience and the recreational opportunities of these beaches.[36] Our analysis does consider potential benefits to county infrastructure and revenues to county businesses generated by the nourishment projects; however, we did not identify these county-level benefits as an outcome of nourishment projects at the bay project sites.

Figure 3-1 depicts the level of each benefit at each project site. Ecological benefit is not a driver of variation in cost shares for these projects because both the level and distribution of this benefit are consistent across projects. All of the projects add sand to the bay system while minimizing adverse effects on horseshoe crabs and shorebirds and may have a limited effect on wetland ecosystems over the 30-year analysis timeframe. Ecological benefit contributes only to the state cost share.

	Infrastructure Resilience	Recreation Value	Tourism Impacts	Ecological Benefit
Pickering	High	Low	Negligible	Low
Kitts Hummock	High	Low	Negligible	Low
Bowers	Medium	High	Negligible	Low
South Bowers	Medium	Low	Negligible	Low
Slaughter	Medium	High	Negligible	Low
Broadkill	High	High	Negligible	Low
Cape Shores	High	Negligible	Negligible	Low

Figure 3-1. Level of each benefit category at Delaware Bay project sites

Note: While some of the nourishment projects support a significant portion of Delaware Bay beach recreation (leading to high recreation value), the overall level of non-local recreation at bay beaches is not a driver of the broader tourism economy. Therefore, tourism impacts are not a benefit at these beaches.

Infrastructure resilience is inherently a local benefit (with some exceptions), whereas the recreational value of the nourishment projects is split between local and non-local recreators (the latter contributing to the state cost share). Accordingly, projects providing greater infrastructure resilience relative to recreation value generate a cost share weighed more heavily toward local

[36] The sole exception is a commercial property at Bowers which receives some protection.

entities. Pickering, Kitts Hummock, and Cape Shores have the three highest local cost shares recommended among bay projects (67, 73, and 75 percent, respectively), reflecting the more limited recreation at these sites. Additionally, Broadkill has a relatively high local cost share (65 percent), reflecting similar levels of infrastructure resilience and recreation value benefits.

Bowers and Slaughter have lower local cost shares (54 and 52 percent, respectively) due to lesser infrastructure resilience benefits but high levels of recreational value. This is compounded by a relatively high fraction of recreational value being associated with non-local visitors and therefore contributing further to the state cost share recommendation. The more modest infrastructure resilience benefits at these sites arise because a relatively significant portion of storm-induced damages are due to storm-related issues, such as back bay flooding, that are not mitigated by the nourishment projects. The same is true at South Bowers, which has a local cost share recommendation of 56 percent.

3.2 Atlantic Ocean project sites

The ocean beaches in our analysis are highly developed relative to the bay. The density of development is variable but is generally a mix of residential properties (e.g., single family, multi-family, primary, and seasonal residences) and commercial properties (e.g., hotels, restaurants, shops). Delaware's ocean beaches are popular among locals and tourists alike, generating an estimated $1.1 billion in recreation value annually (over 11 million annual visits). The ocean beaches are a key driver of tourism economic activity in Delaware, which was not a benefit for the bay beaches.

Tourism impacts reflect visitor spending at local businesses and the broader multiplier effects of this spending across the regional economy. We find that the majority of the economic activity generated by the beach tourism activities benefits businesses within Sussex County. We therefore include a county cost share recommendation for these beaches. Another differentiating feature of ocean nourishment projects is that they may interact with nourishment projects at adjacent beaches as a result of natural alongshore sand spreading. In these cases (i.e., Rehoboth and Dewey; Bethany and South Bethany), we present aggregate results in this summary chapter, with further breakdown of the results presented in subsequent project-specific Chapters 11 and 12.

Recommended cost shares for ocean projects are between 53 and 71 percent for local entities and between 11 and 19 percent for the state. Local entities include owners of residential and commercial properties, owners of public infrastructure (e.g., municipalities), and recreators living within five miles of a beach.[37] The county share, driven by tourism impacts, ranges from 16 to 31 percent.

Figure 3-2 depicts the level of each benefit at each ocean project site. Within these project sites, Rehoboth-Dewey is an outlier. The recommended local cost share at this site is the lowest among ocean projects (53 percent) as a result of the significantly higher recreation value of this site, which

[37] Natural alongshore sand spreading leads to some local benefits accruing outside the jurisdiction where sand is originally placed. In subsequent project-specific chapters we report further breakdown of the local share accounting for these benefits to adjacent communities.

also magnifies the tourism benefits and contributes to the county and state cost share recommendations.[38]

	Infrastructure Resilience	Recreation Value	Tourism Impacts	Ecological Benefit
Lewes	High	Low	Low	Low
Rehoboth - Dewey	High	High	High	Limited
Bethany - South Bethany	High	Low	Low	Limited
Fenwick Island	High	Low	Low	Limited

Figure 3-2. Level of each benefit category at Atlantic Ocean project sites

The remaining ocean project sites (Lewes, Bethany-South Bethany, and Fenwick Island) have relatively similar local cost shares (65, 71, and 68 percent, respectively) and county cost shares (16, 18, and 18 percent, respectively). At Lewes, the state share is a bit higher (19 percent) than the other ocean sites, reflecting the ecological benefits of Lewes's status as a bay beach, including adding sand to the bay system and potentially supporting horseshoe crab spawning habitat.[39]

3.3 Consideration of social vulnerability of affected populations

Social vulnerability refers to the susceptibility of human populations to harm or adverse effects from external stresses, such as climate change and coastal storm events or economic disruptions. Social vulnerability may be influenced by factors such as income, health, race, age, education level, and access to services. In essence, social vulnerability highlights how existing social inequities can amplify the impact of stressors on certain populations.

As described in Chapter 15 and Appendix C, the resident populations of the beach communities in this analysis experience social vulnerability due to the predominance of the population that is 65 and older. In particular, in Slaughter Beach, Lewes, Bethany Beach, South Bethany, and Fenwick Island, more than half of residents are aged 65 and over. For these older populations, social vulnerability can be experienced in multiple and compounding ways, including the following:

- Increased social isolation and health deficits;
- Reduced access to social support, healthcare facilities, and other services; and

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[38] The fact that recreation at Rehoboth is much greater than recreation at Dewey is reflected in the further breakdown of the local share, reported in the project-specific results Chapter 11.

[39] As a bay beach, Lewes is the only site in this set of beaches that provides spawning habitat for horseshoe crabs and otherwise reflects the ecological benefits of nourishment for bay beaches.

- Limited ability to respond to (e.g., evacuate) or recover from environmental hazards.

Other historically overburdened and underserved populations in the beach communities – including people of color and populations with low incomes – are generally proportional to the state as a whole. That is, these are generally not factors that disproportionately contribute to social vulnerability of the beach community populations. However, potentially vulnerable populations of color are present in the communities of interest, most notably in Lewes. Additionally, Dewey Beach and Slaughter Beach have slightly higher rates of potentially vulnerable low-income residents compared to the broader state population. High rates of housing vacancy in the study communities limit insight into the potential social vulnerability of non-occupant property owners.

The beach nourishment projects benefit the vulnerable populations of these beach communities by reducing potential costs of storm-related infrastructure damage and reducing the likelihood of displacement due to storm events or coastal erosion. The population is not disproportionately characterized by low-income status. While the financial aspect of vulnerability is not pronounced in these populations, the age-related challenges still make the population socially vulnerable in emergencies.

CHAPTER 4 | Pickering

Horseshoe crabs on Pickering Beach. Image credit: Delawarebayshorebyway.org

Pickering Beach is the northernmost bay beach in our analysis. The surrounding community is comprised of about two dozen beachfront properties on Sandpiper Drive and North Sandpiper Drive. The owners of these properties are responsible for a significant portion of the limited number of total beach trips. Other beach goers use a small parking lot to access the beach. The beach is a designated Horseshoe Crab Sanctuary.

4.1 Cost Share Overview for Pickering

The nourishment projects at Pickering Beach result in a high level of infrastructure resilience benefits and a low level of recreation value benefits (Figure 4-1). Due to the limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

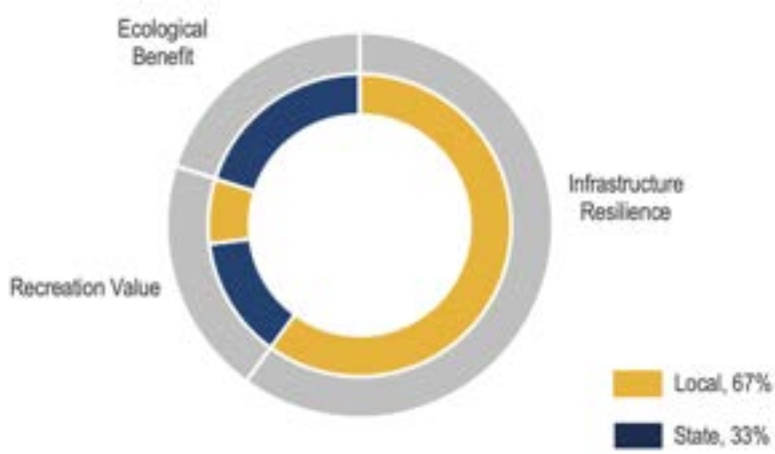


Figure 4-1. Relative levels and distribution of each relevant benefit category at Pickering

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 4-1), we recommend a local cost share of about two thirds (67%) of the non-federal cost of the nourishment projects, with the remaining 33% covered by the state.

Table 4-1. Description of local and state benefits from nourishment activities at Pickering

Local (67%)	State (33%)
• Protection of infrastructure, specifically residential properties on Sandpiper Drive and N Sandpiper Drive • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

4.2 Coastal Process Modeling Results for Pickering

In the absence of nourishment, the residential properties on Pickering Beach face significant threats from long-term shoreline change, characterized by landward migration of the coastline due to erosion and sea level rise (Figure 4-3). Due to the limited beach width (25 feet) and high erosion rate (approximately 5.2 feet/year, including projected sea level rise), the beach would likely be displaced after five years absent nourishment. The nourishment projects effectively eliminate the effects of long-term shoreline change within the nourishment footprint (Figure 4-2). Additionally, nourishment reduces wave energy (proxied by peak height) by about two inches during the modeled two percent AEP storm event and marginally during smaller modeled storms.

Figure 4-2. Sand spreads outside of the initial placement area over time

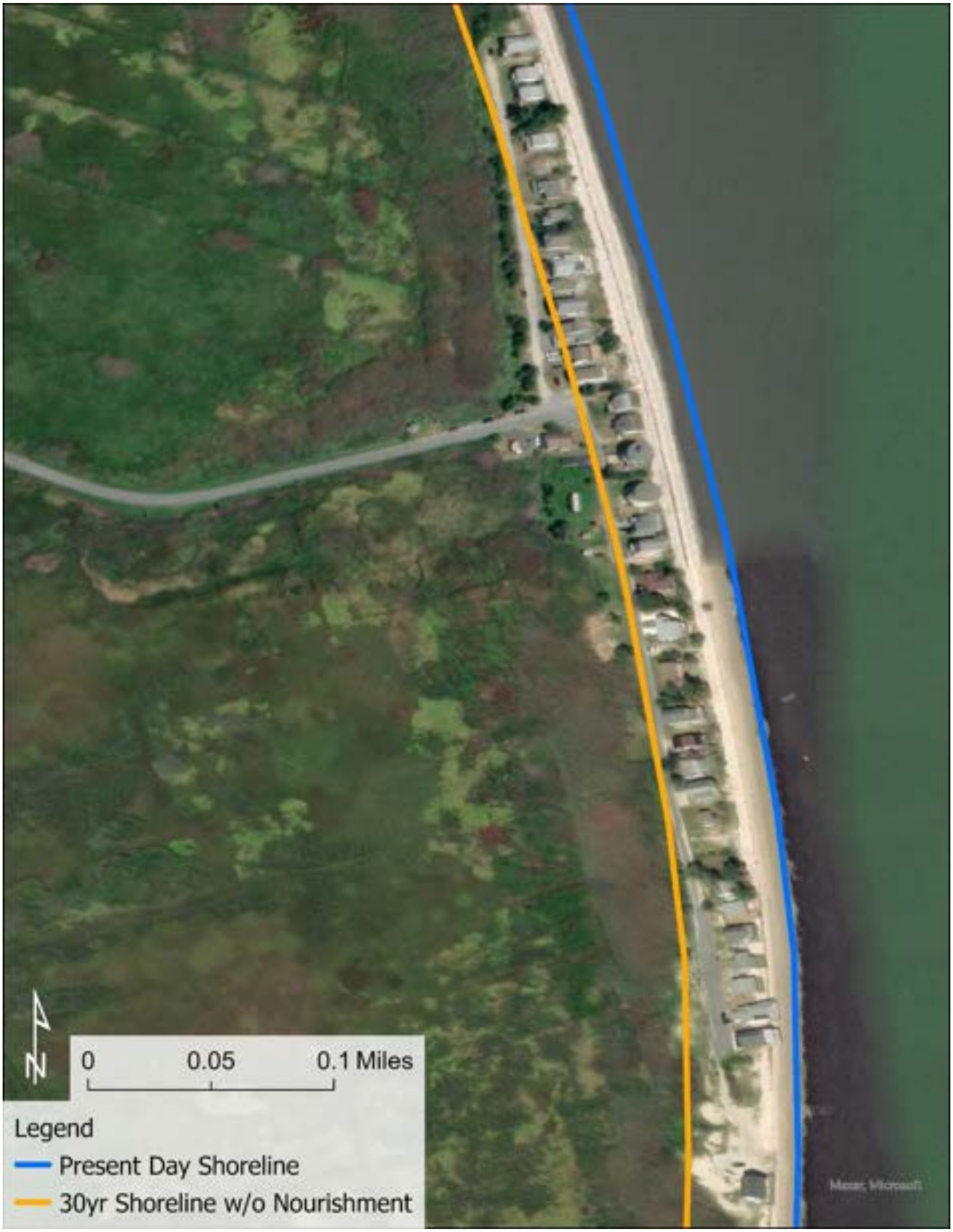


Figure 4-3. Current and future projected shoreline position at Pickering

4.3 Economic Modeling Results for Pickering

The changes to long-term shoreline change, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides a low level of ecological benefit by contributing to the preservation of coastal habitat (Table 4-2).

Table 4-2. Quantified value and associated level of each benefit at Pickering

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$340,000	$400,000	84%	High
Recreation value	$41,000	$1.4 million	2.9%	Low
Tourism impacts	$100,000	$1.1 billion	0.01%	Negligible
Ecological	-	-	-	Low

4.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Pickering is protection from long-term shoreline change. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion and waves is approximately $400,000. Nourishment avoids about 84 percent of those damages, leading to a high level of infrastructure resilience benefits. These benefits are exclusively experienced by local residential property owners (Figure 4-4).

Absent nourishment, the vulnerable properties on Pickering are expected to lose their value due to shoreline change in as few as five years. With nourishment, nearly all properties are completely protected from shoreline change.

Figure 4-4. The local benefits at this site are experienced exclusively within the community of Pickering

4.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Pickering attracts about 1,500 annual beach visits. Almost one third of these visits (30 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Pickering provides $41,000 in annual recreation value to Delaware residents. This represents about three percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as low.[40] Overall, local residents (defined as beach visitors that are community property owners) receive 35 percent ($14,000) of the recreation value benefits. The remaining 65 percent ($27,000) is experienced by non-local Delaware residents (Figure 4-5).

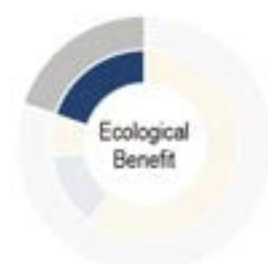
[40] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

Figure 4-5. Breakdown of the recreation value benefits at Pickering

4.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at Pickering Beach (about 1,100 visits annually), the value-added in the tourism economy associated with those visits ($100,00 annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[41] Accordingly, we classify the level of tourism impacts as negligible.

4.3.4 Ecological benefit



To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Pickering Beach ecosystem is a horseshoe crab sanctuary and provides habitat for multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along the Delaware Bay coast, it is unlikely that the beach erosion at Pickering would result in measurable population-level effects on coastal species.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that wetlands around Pickering Beach are unlikely to benefit from nourishment due to the limited project footprint and nourishment volume.

All considered, the beach nourishment activities at Pickering are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we

[41] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

characterize the level of ecological benefits at Pickering as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

4.4 Design Alternatives and Cost Estimates for Pickering

We identified three total nourishment design alternatives for Pickering (Table 4-3). The results above are based on the first nourishment alternative, which roughly covers the area in front of the shorefront properties. The second is a much smaller nourishment along the southern part of the beach that includes a groin. Finally, the third alternative covers a much larger area alongshore, extending well beyond the northernmost and southernmost shorefront properties.

The results presented in this chapter are based on Alternative 1 in the table below. Full results for all nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are significant (particularly for Alternative 3), but do not influence the cost share results. This is primarily because all nourishment alternatives avoid at least 10 percent of infrastructure damages, thereby generating a high level of infrastructure resilience benefits.

Table 4-3. Nourishment alternatives at Pickering

Nourishment alternative	Renourishment volume (cubic yards)	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	33,000	4	$8.6 million	$390,000
2	15,000	2.5	$7.6 million	$340,000
3	150,000	9	$14 million	$620,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. Despite different fill volumes and renourishment intervals, Alternatives 1 and 2 require similar amounts of sand per year and therefore have similar costs. Alternative 3 is significantly more costly because it requires substantially more sand and has higher fixed costs (the project involves offshore dredging, which imposes additional costs compared to the alternatives completed by trucking sand from inland sources).

CHAPTER 5 | Kitts Hummock

Kitts Hummock Beach in February 2024. Image credit: IEc

Kitts Hummock Beach is about two miles south of Pickering Beach and similar in character. The surrounding community is comprised of properties on either side of North Bay Drive, South Bay Drive, and Kitts Hummock Road. The owners of these properties are responsible for a significant portion of the limited number of total beach trips. As they do at Pickering, other beach goers use a small parking lot to access the beach. The beach is a designated Horseshoe Crab Sanctuary.

5.1 Cost Share Overview for Kitts Hummock

The nourishment projects at Kitts Hummock Beach result in a high level of infrastructure resilience benefits and a low level of recreation value benefits (Figure 5-1). Due to the limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

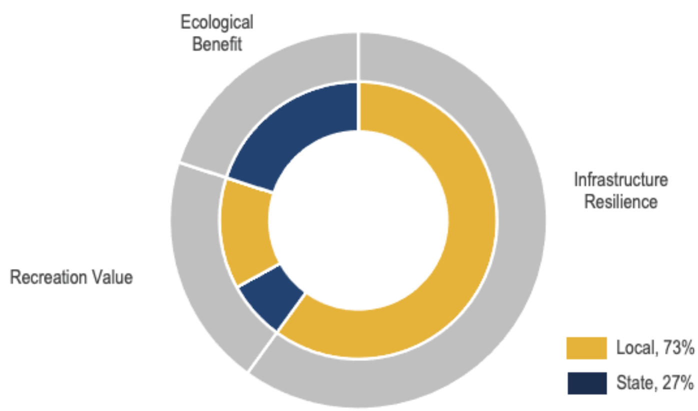


Figure 5-1. Relative levels and distribution of each relevant benefit category at Kitts Hummock

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 5-1), we recommend a local cost share of about three quarters (73%) of the non-federal cost of the nourishment projects, with the remaining 27% covered by the state.

Table 5-1. Description of local and state benefits from nourishment activities at Kitts Hummock

Local (73%)	State (27%)
• Protection of infrastructure, specifically residential properties on N Bay Drive and S Bay Drive • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

5.2 Coastal Process Modeling Results for Kitts Hummock

In the absence of nourishment, the residential properties on Kitts Hummock Beach face significant threats from long-term shoreline change, characterized by landward migration of the coastline due to erosion and sea level rise (Figure 5-3). Due to the limited beach width (50 feet) and high erosion rate (approximately 5.2 feet/year, including projected sea level rise), the beach would likely be displaced after about 10 years absent nourishment. The nourishment projects effectively eliminate the effects of long-term shoreline change within the nourishment footprint (Figure 5-2). Additionally, nourishment reduces wave energy (proxied by peak height) by about three inches during the modeled two percent AEP storm event and marginally during smaller modeled storms.

Figure 5-2. Sand spreads outside of the initial placement area over time

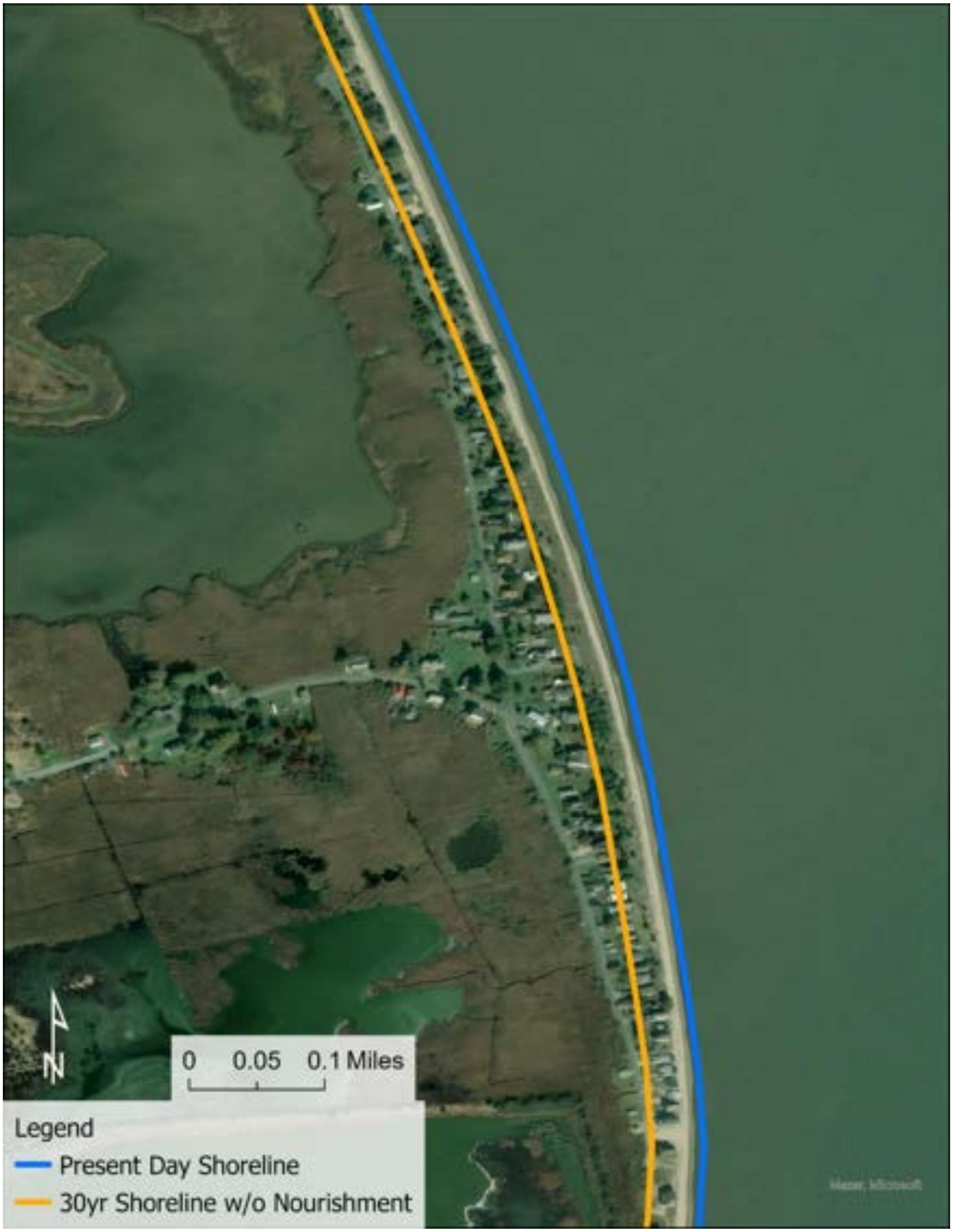


Figure 5-3. Current and future projected shoreline position at Kitts Hummock

5.3 Economic Modeling Results for Kitts Hummock

The changes to long-term shoreline change, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides a low level of ecological benefit by contributing to the preservation of coastal habitat (Table 5-2).

Table 5-2. Quantified value and associated level of each benefit at Kitts Hummock

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$450,000	$810,000	55%	High
Recreation value	$26,000	$1.4 million	1.8%	Low
Tourism impacts	$58,000	$1.1 billion	0.01%	Negligible
Ecological	-	-	-	Low

5.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Kitts Hummock is protection from long-term shoreline change. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion and waves is approximately $810,000. Nourishment avoids about 55 percent of those damages, leading to a high level of infrastructure resilience benefits. These benefits are exclusively experienced by local residential property owners (Figure 5-4).

Figure 5-4. The local benefits at this site are experienced exclusively within the community of Kitts Hummock

Absent nourishment, the vulnerable properties on Kitts Hummock are expected to lose their value due to shoreline change in as few as 10 years. With nourishment, all properties are completely protected from shoreline change.

5.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Kitts Hummock attracts about 1,400 annual beach visits. Over one-third of these visits (37 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Kitts Hummock provides $26,000 in annual recreation value to Delaware residents. This represents about two percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as low.[42] Overall, local residents (defined as beach visitors that are community property owners) receive 65 percent ($17,000) of the recreation value benefits. The remaining 35 percent ($9,000) is experienced by non-local Delaware residents (Figure 5-5).

Figure 5-5. Breakdown of the recreation value benefits at Kitts Hummock

[42] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

5.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at Kitts Hummock Beach (about 540 visits annually), the value-added in the tourism economy associated with those visits ($58,000 annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[43] Accordingly, we classify the level of tourism impacts as negligible.

5.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Kitts Hummock Beach ecosystem is a horseshoe crab sanctuary and provides habitat for multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Kitts Hummock) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that wetlands around Kitts Hummock Beach are unlikely to benefit from nourishment due to the limited project footprint and nourishment volume.

All considered, the beach nourishment activities at Kitts Hummock are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at Kitts Hummock as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

5.4 Design Alternatives and Cost Estimates for Kitts Hummock

We identified three total nourishment design alternatives for Kitts Hummock (Table 5-3). The results above are based on the first nourishment alternative, which roughly covers the area in front

[43] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

of the shorefront properties. The second is a much smaller nourishment along the southern part of the beach that includes a nine-foot elevation dune. Finally, the third alternative covers a much larger area alongshore, extending well beyond the northernmost and southernmost shorefront properties.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. Despite similar fill volumes, Alternatives 1 and 2 have different costs due to different renourishment intervals. Alternative 3 is significantly more costly because it requires substantially more sand and has higher fixed costs (the project involves offshore dredging, which imposes additional costs compared to the alternatives completed by trucking sand from inland sources).

Table 5-3. Nourishment alternatives at Kitts Hummock

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	10,000	5	$2.5 million	$110,000
2	13,000	2.5	$7.7 million	$340,000
3	150,000	9	$15 million	$660,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1, 2, and 3 are 15,000 cu yds, 17,000 cu yds, and 200,000 cu yds, respectively.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for all nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are significant, but do not influence the cost share results. This is primarily because all nourishment alternatives avoid at least 10 percent of infrastructure damages, thereby generating a high level of infrastructure resilience benefits.

CHAPTER 6 | Bowers

Properties on Bowers Beach. Image credit: Delawarebayshorebyway.org

Bowers Beach is located just south of the St. Jones River. The surrounding community includes several streets with dense residential development. The owners of these properties are responsible for a significant portion of total beach trips. Other beach goers access the beach using the Bowers Beach Parking Lot, which has capacity for over 200 vehicles. The beach provides important shorebird habitat and is a known spawning site for horseshoe crabs.

6.1 Cost Share Overview for Bowers

The nourishment projects at Bowers Beach result in a medium level of infrastructure resilience benefits and a high level of recreation value benefits (Figure 6-1). Due to the limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

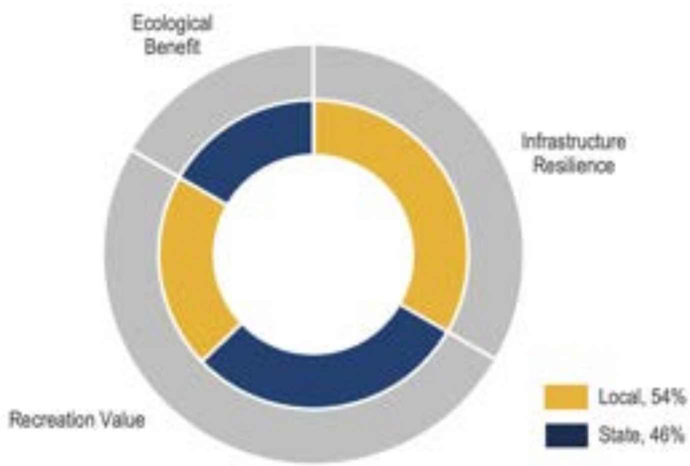


Figure 6-1. Relative level and distribution of each relevant benefit category at Bowers

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 6-1), we recommend a local cost share of about half (54%) of the non-federal cost of the nourishment projects, with the remaining 46% covered by the state.

Table 6-1. Description of local and state benefits from nourishment activities at Bowers

Local (54%)	State (46%)
• Protection of infrastructure, primarily residential properties around Bowers • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

6.2 Coastal Process Modeling Results for Bowers

The residential properties on Bowers Beach face significant threats from 1) storm-related damages and 2) long-term shoreline change, characterized by landward migration of the coastline due to erosion and sea level rise (Figure 6-3). Due in part to the density of development, properties near Bowers Beach would incur substantial storm-related damages absent nourishment. Nourishment reduces wave energy (proxied by peak height) by about two inches during the modeled two percent AEP storm event and marginally during smaller modeled storms. In addition, due to the limited beach width (25 feet) and high erosion rate (approximately 2.8 feet/year, including projected sea level rise), the beach would likely be displaced after nine years absent nourishment. The nourishment projects effectively eliminate long-term shoreline change within the nourishment footprint (Figure 6-2), but have a limited effect on storm-related damages from flooding and wave energy.

Figure 6-2. Alongshore spreading is limited at this project site by the presence of terminal structures

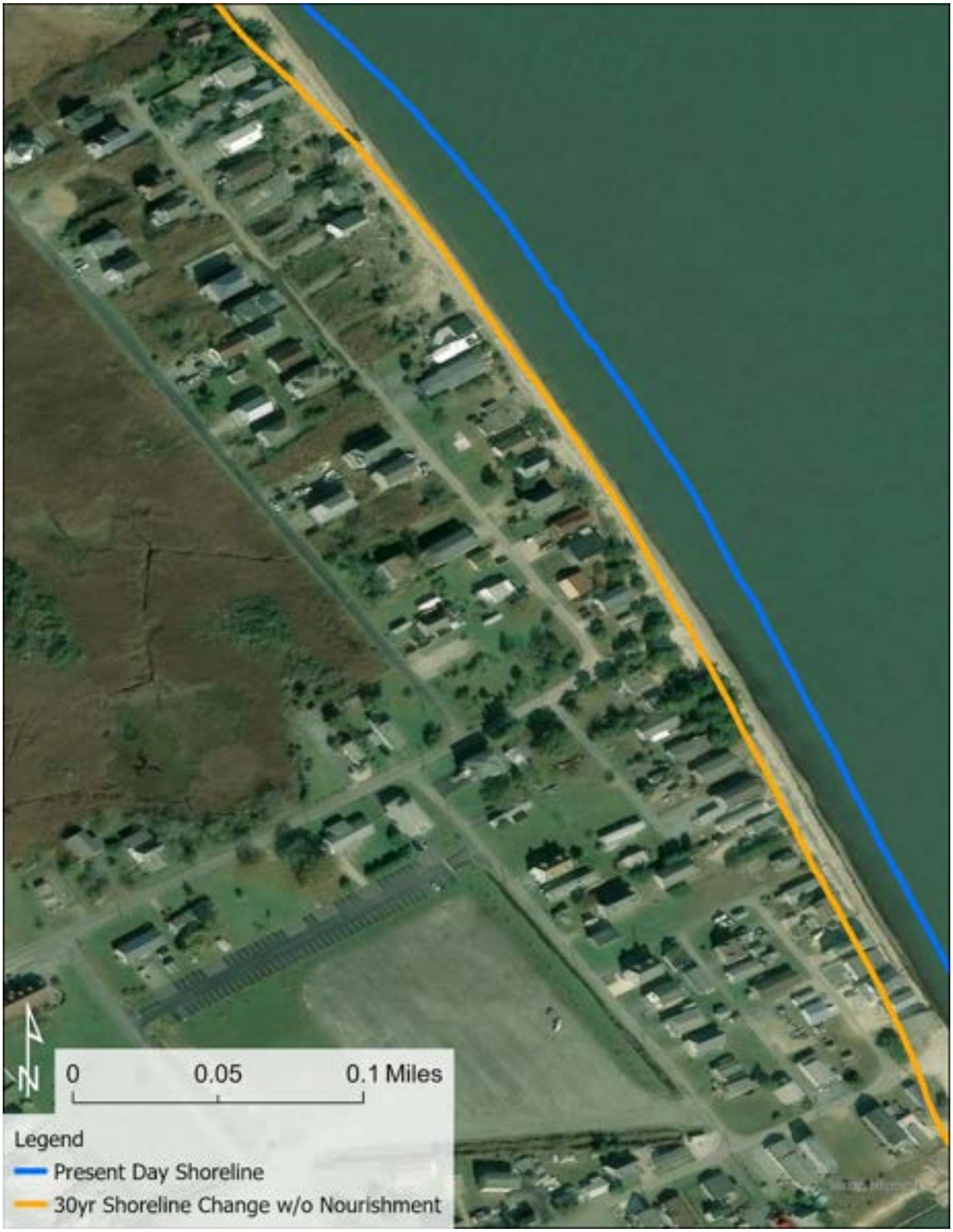


Figure 6-3. Current and future projected shoreline position at Bowers

6.3 Economic Modeling Results for Bowers

The changes to long-term shoreline change, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat.

Table 6-2. Quantified value and associated level of each benefit at Bowers

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$84,000	$860,000	9.8%	Medium
Recreation value	$200,000	$1.4 million	14%	High
Tourism impacts	$410,000	$1.1 billion	0.04%	Negligible
Ecological	-	-	-	Low

6.3.1 Infrastructure resilience

In the absence of nourishment, expected annual damage to infrastructure from erosion is $70,000, and expected annual damage from flooding and waves is approximately $780,000. Nourishment completely protects infrastructure from long-term shoreline change, but only marginally reduces the more substantial storm-induced damages. In total, nourishment avoids just under 10 percent of infrastructure damages, leading to a medium level of infrastructure resilience benefits. These benefits are exclusively experienced by local property owners (Figure 6-4).

Nourishment at Bowers Beach effectively prevents erosion-related damages to infrastructure. However, the projects provide only a medium level of infrastructure resilience benefits because storm-induced flooding and wave damages (including from the back bay, which is not affected by nourishment) account for the majority of baseline damages.

Figure 6-4. The local benefits at this site are experienced exclusively within Bowers

6.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Bowers attracts about 7,600 annual beach visits. Almost one-quarter of these visits (23 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Bowers provides $200,000 in annual recreation value to Delaware residents. This represents about 14 percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as high.[44] Overall, local residents (defined as beach visitors that are community property owners) receive 41 percent ($81,000) of the recreation value benefits. The remaining 59 percent ($120,000) is experienced by non-local Delaware residents (Figure 6-5).

Figure 6-5. Breakdown of the recreation value benefits at Bowers

6.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at Bowers Beach (about 4,500 visits annually), the value-added in the tourism economy associated with those visits ($410,000 annually) represents less than one percent of the

[44] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

total annual value-added associated with recreation at all Delaware Bay beaches in our study.[45] Accordingly, we classify the level of tourism impacts as negligible.

6.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Bowers Beach ecosystem provides habitat for horseshoe crabs and multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Bowers) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that wetlands around Bowers Beach are unlikely to benefit from nourishment given that the beach is located between the Murderkill and Saint Jones Rivers.

All considered, the beach nourishment activities at Bowers are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at Bowers as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

6.4 Design Alternatives and Cost Estimates for Bowers

We identified two total nourishment design alternatives for Bowers (Table 6-3). The results above are based on the first nourishment alternative, which roughly covers the area in front of the shorefront properties. The second alternative is wider and entails larger, less-frequent placements of sand.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. Alternative 2 is significantly more costly than Alternative 1 because it requires substantially more sand per year on average and

[45] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

has higher fixed costs (the project involves offshore dredging, which imposes additional costs compared to the alternatives completed by trucking sand from inland sources).

Table 6-3. Nourishment alternatives at Bowers

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	52,000	8	$8.3 million	$370,000
2	110,000	12	$11 million	$480,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1 and 2 are 70,000 cu yds and 180,000 cu yds, respectively.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the other alternatives are not significant and do not influence the cost share results.

CHAPTER 7 | South Bowers

South Bowers, looking south from near the Murderkill River.
Image credit: delmarvabackroads.blogspot.com

South Bowers Beach is separated from Bowers Beach by the Murderkill River. The surrounding community is comprised of a row of beachfront properties on South Bowers Road. The owners of these properties are responsible for a small portion of total beach trips. The beach provides important shorebird habitat and is a known spawning site for horseshoe crabs.

7.1 Cost Share Overview for South Bowers

The nourishment projects at South Bowers Beach result in a medium level of infrastructure resilience benefits and a low level of recreation value benefits (Figure 7-1). Due to the limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 7-1), we recommend a local cost share of about half (56%) of the non-federal cost of the nourishment projects, with the remaining 44% covered by the state.

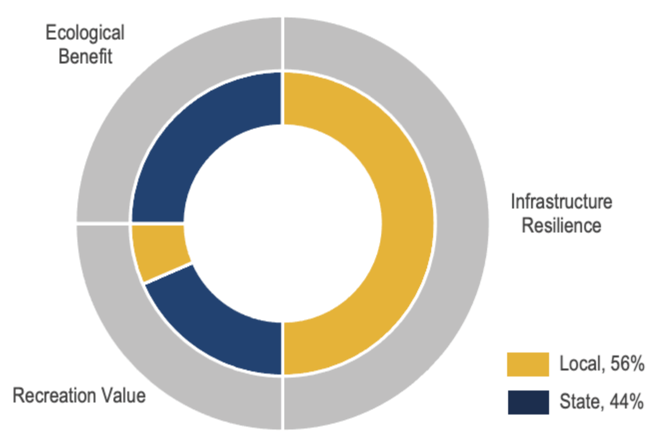


Figure 7-1. Relative level and distribution of each relevant benefit at South Bowers

Table 7-1. Description of local and state benefits from nourishment activities at South Bowers

Local (56%)	State (44%)
• Protection of infrastructure, specifically residential properties on South Bowers Rd • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

7.2 Coastal Process Modeling Results for South Bowers

The residential properties on South Bowers Beach face threats from 1) storm-related damages and 2) long-term shoreline change, characterized by landward migration of the coastline due to erosion and sea level rise (Figure 7-3). Nourishment reduces wave energy (proxied by peak height) by about three inches during the modeled two percent AEP storm event and marginally during smaller modeled storms. In addition, due to the limited beach width (45 feet) and high erosion rate (approximately 3.9 feet/year, including projected sea level rise), the beach would likely be displaced after 12 years absent nourishment. The nourishment projects effectively eliminate long-term shoreline change within the nourishment footprint (Figure 7-2), but have a limited effect on storm-related damages from flooding and wave energy.

Figure 7-2. Sand spreads outside of the initial placement area over time

Figure 7-3. Current and future projected shoreline position at South Bowers

7.3 Economic Modeling Results for South Bowers

The changes to long-term shoreline change, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat (Table 7-2).

Table 7-2. Quantified value and associated level of each benefit at South Bowers

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$20,000	$270,000	7%	Medium
Recreation value	$43,000	$1.4 million	3.1%	Low
Tourism impacts	$160,000	$1.1 billion	0.01%	Negligible
Ecological	-	-	-	Low

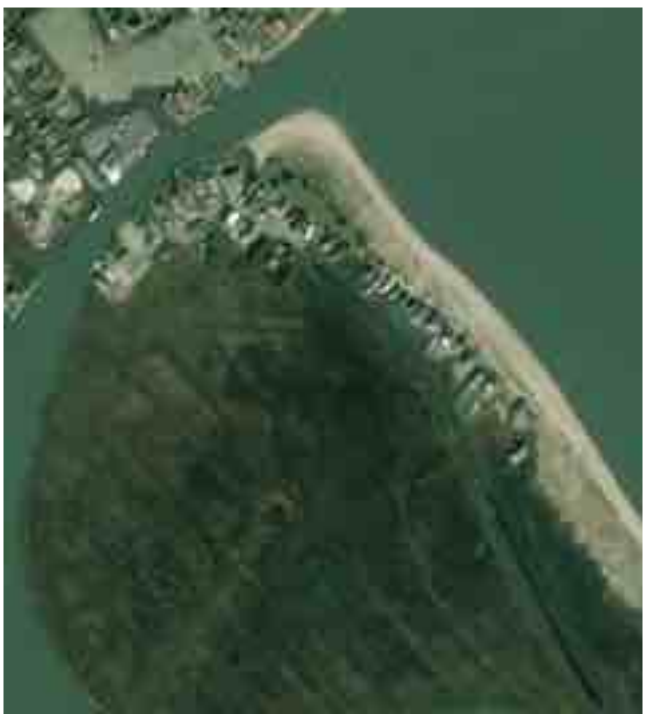


Figure 7-4. The local benefits at this site are experienced exclusively within South Bowers

7.3.1 Infrastructure resilience

In the absence of nourishment, expected annual damage to infrastructure from erosion is $20,000, and expected annual damage from flooding and waves is approximately $250,000. Nourishment completely protects infrastructure from the effects of long-term shoreline change, but only marginally reduces the more substantial storm-induced damages. In total, nourishment avoids about seven percent of infrastructure damages, leading to a medium level of infrastructure resilience benefits. These benefits are exclusively experienced by local property owners (Figure 7-4).

Nourishment at South Bowers Beach effectively prevents erosion-related damages to infrastructure. However, the projects provide only a medium level of infrastructure resilience benefits because storm-induced flooding and wave damages (including from the back bay, which is not affected by nourishment) account for the majority of baseline damages.

7.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. South Bowers attracts about 2,900 annual beach visits. Almost one quarter of these visits (23 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at South Bowers provides $43,000 in annual recreation value to Delaware residents. This represents about three percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as low.[46] Overall, local residents (defined as beach visitors that are community property owners) receive 26 percent ($11,000) of the recreation value benefits. The remaining 74 percent ($32,000) is experienced by non-local Delaware residents (Figure 7-5).

Figure 7-5. Breakdown of the recreation value benefits at South Bowers

7.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at South Bowers Beach (about 1,800 visits annually), the value-added in the tourism economy associated with those visits ($160,000 annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[47] Accordingly, we classify the level of tourism impacts as negligible.

[46] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

[47] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

7.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The South Bowers Beach ecosystem provides habitat for horseshoe crabs and multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at South Bowers) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that coastal wetlands up to 4,000 feet south of the developed part of South Bowers Beach may experience minor benefits from nourishment due to spreading.

All considered, the beach nourishment activities at South Bowers are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at South Bowers as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

7.4 Design Alternatives and Cost Estimates for South Bowers

We identified three total nourishment design alternatives for South Bowers (Table 7-3). The results above are based on the first nourishment alternative, which roughly covers the area in front of the shorefront properties. The second and third nourishment alternatives cover a similar length of beach as the first but involve more substantial additions to beach width.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. Despite similar renourishment intervals, Alternative 2 requires more sand per year than Alternative 1 and is therefore more costly. Alternative 3 is significantly more costly than either of the others because it requires substantially more sand per year and has higher fixed costs (the project involves offshore dredging, which imposes additional costs compared to the alternatives completed by trucking sand from inland sources).

Table 7-3. Nourishment alternatives at South Bowers

Nourishment alternative	Fill volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	23,000	5	$5.5 million	$240,000
2	29,000	4	$7.8 million	$350,000
3	100,000	6	$16.8 million	$750,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1, 2, and 3 are 28,000 cu yds, 35,000 cu yds, and 120,000 cu yds, respectively.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for all nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the other alternatives are not significant and do not influence the cost share results.

CHAPTER 8 | Slaughter

Families visit Slaughter Beach in June 2022. Image credit: Baltimoresun.com

Slaughter Beach is located just south of the Mispillion River. The surrounding community is comprised of more than 100 properties on Bay Avenue and adjoining streets. Slaughter is the second most popular beach for recreation among bay beaches in this study. The beach is a designated Horseshoe Crab Sanctuary.

8.1 Cost Share Overview for Slaughter

The nourishment projects at Slaughter Beach result in a medium level of infrastructure resilience benefits and a high level of recreation value benefits (Figure 8-1). Due to the relatively limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

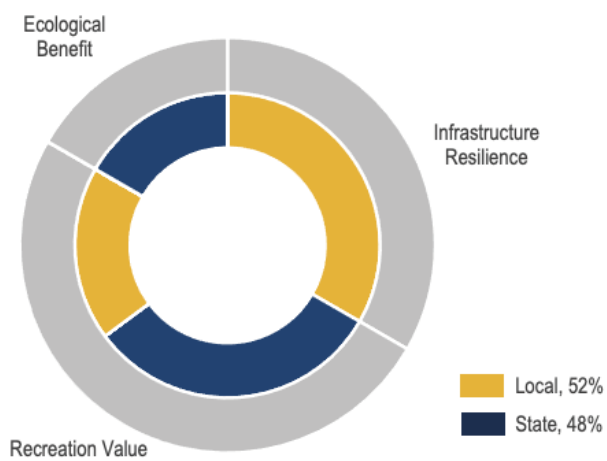


Figure 8-1. Relative level and distribution of each relevant benefit at Slaughter

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 8-1), we recommend a local cost share of about half (52%) of the non-federal cost of the nourishment projects, with the remaining 48% covered by the state.

Table 8-1. Description of local and state benefits from nourishment activities at Slaughter

Local (52%)	State (48%)
• Protection of infrastructure, primarily residential properties on Bay Avenue and adjoining streets • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

8.2 Coastal Process Modeling Results for Slaughter

The properties on Slaughter Beach face significant threats from storm-related damages and some risk from long-term shoreline change, characterized by landward migration of the coastline due to erosion and sea level rise (Figure 8-3). Absent nourishment, properties near Slaughter would incur substantial storm-related damages due to flooding and wave impacts. Nourishment reduces wave energy (proxied by peak height) by about one inch during the modeled two percent AEP storm event and marginally during smaller modeled storms. In addition, due to the limited beach width (20 feet) and high erosion rate (approximately 3.0 feet/year, including projected sea level rise), the beach would likely be displaced after seven years absent nourishment. The nourishment projects effectively eliminate long-term shoreline change within the nourishment footprint (Figure 8-2) but have a limited effect on storm-related damages from flooding and wave energy.

Figure 8-2. Sand spreads outside of the initial placement area over time

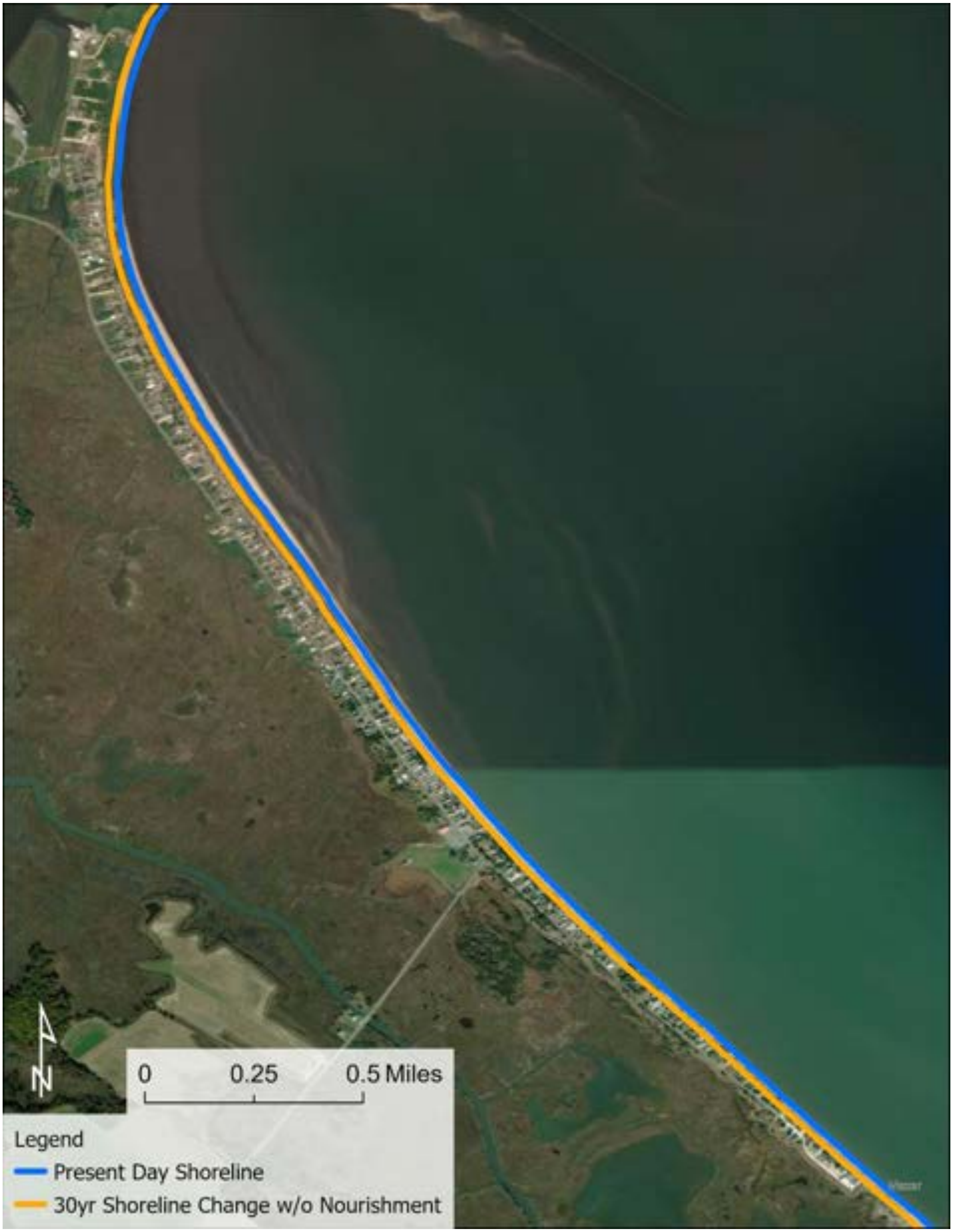


Figure 8-3. Current and future projected shoreline position at Slaughter

8.3 Economic Modeling Results for Slaughter

The changes to long-term shoreline change, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat (Table 8-2).

Table 8-2. Quantified value and associated level of each benefit at Slaughter

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$260,000	$2.7 million	9.5%	Medium
Recreation value	$250,000	$1.4 million	18%	High
Tourism impacts	$650,000	$1.1 billion	0.06%	Negligible
Ecological	-	-	-	Low

8.3.1 Infrastructure resilience

In the absence of nourishment, expected annual damage to infrastructure from erosion is $240,000, and expected annual damage from flooding and waves is approximately $2.5 million. Nourishment completely protects infrastructure from the effects of long-term shoreline change, but only marginally reduces the more substantial storm-induced damages. In total, nourishment avoids about nine percent of infrastructure damages, leading to a medium level of infrastructure resilience benefits. These benefits are exclusively experienced by local property owners (Figure 8-4).

Nourishment at Slaughter Beach effectively prevents erosion-related damages to infrastructure. However, the projects provide only a medium level of infrastructure resilience benefits because storm-induced flooding and wave damages (including from the back bay, which is not affected by nourishment) account for the majority of baseline damages.

Figure 8-4. The local benefits at this site are experienced exclusively at Slaughter

8.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Slaughter attracts about 12,000 annual beach visits. More than one third of these visits (35 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Slaughter provides $250,000 in annual recreation value to Delaware residents. This represents about 18 percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as high.[48] Overall, local residents (defined as beach visitors that are community property owners) receive 37 percent ($93,000) of the recreation value benefits. The remaining 63 percent ($160,000) is experienced by non-local Delaware residents (Figure 8-5).

Figure 8-5. Breakdown of the recreation value benefits at Slaughter

8.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at Slaughter Beach (about 7,100 visits annually), the value-added in the tourism

[48] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

economy associated with those visits ($650,000 annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[49] Accordingly, we classify the level of tourism impacts as negligible.

8.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Slaughter Beach ecosystem is a horseshoe crab sanctuary and provides habitat for multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Slaughter) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that coastal wetlands up to 2,200 feet north of Delaware Bay Launch Services and 3,500 feet south of the developed part of Slaughter Beach may experience minor benefits from nourishment due to spreading.

All considered, the beach nourishment activities at Slaughter are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at Slaughter as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

8.4 Design Alternatives and Cost Estimates for Slaughter

We identified three total nourishment design alternatives for Slaughter (Table 8-3).[50] The results above are based on the first nourishment alternative, which roughly covers the length of beach from Slaughter Beach Road to the southernmost beachfront property. The second alternative is

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[49] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

[50] We considered one additional dune-only project that nourished the dune from about 325 feet north of Virginia Avenue to about 500 feet south of Simpson Avenue. Because this project does not involve adding sand to the beach itself, we consider it a different type of project and do not report the results.

significantly larger than the first, spanning from Bridgeham Avenue to about 1,350 feet south of Simpson Avenue. Finally, the third alternative covers the entire developed area.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. The range in project costs arises from differences across all of these dimensions. Alternatives 2 and 3 are larger projects which involve offshore dredging, imposing additional costs compared to Alternative 1, which is completed by trucking sand from inland sources.

Table 8-3. Nourishment alternatives at Slaughter

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	36,000	4	$9.5 million	$420,000
2	240,000	6	$30 million	$1.4 million
3	180,000	10	$17 million	$760,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1, 2, and 3 are 40,000 cu yds, 300,000 cu yds, and 260,000 cu yds, respectively.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for all nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are significant (particularly for Alternative 3). For Alternative 3, we recommend a slightly higher local cost share of 59% of the non-federal cost of the nourishment projects, with the remaining 41% covered by the state. This is because Alternative 3 generates a higher level of infrastructure resilience benefits, shifting project benefits more toward local property owners.

CHAPTER 9 | Broadkill

Recreators on Broadkill Beach. Image credit: Beaches-searcher.com

Broadkill Beach is located just north of Lewes Beach. The surrounding community is comprised of a few hundred properties on North and South Bayshore Drives and adjoining streets. Broadkill Beach is the most popular beach for recreators among bay beaches in this study. The beach is a designated Horseshoe Crab Sanctuary.

9.1 Cost Share Overview for Broadkill

The nourishment projects at Broadkill Beach result in a high level of infrastructure resilience benefits and a high level of recreation value benefits (Figure 9-1). Due to the limited nature of non-local recreation at this beach, nourishment results in negligible tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

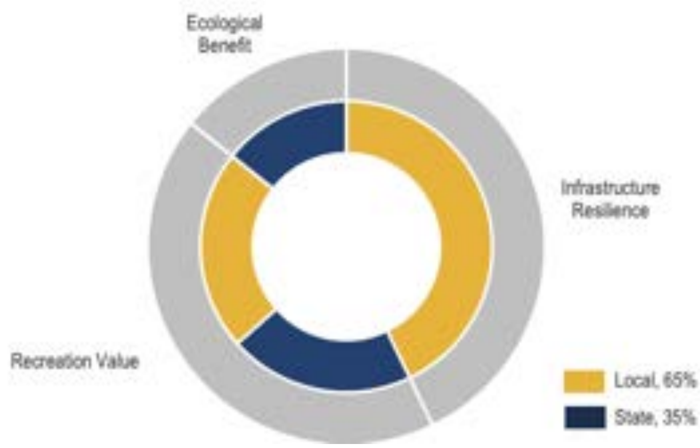


Figure 9-1. Relative level and distribution of each relevant benefit at Broadkill

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 9-1), we recommend a local cost share of about two thirds (65%) of the non-federal cost of the nourishment projects, with the remaining 35% covered by the state.

Table 9-1. Description of local and state benefits from nourishment activities at Broadkill

Local (65%)	State (35%)
• Protection of infrastructure, specifically residential properties on North and South Bayshore Drives and adjoining streets • Recreation by local residents (defined for bay beaches as community property owners)	• Recreation by non-local state residents • Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

9.2 Coastal Process Modeling Results for Broadkill

In the absence of nourishment, the developed coastline at Broadkill faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar (Figure 9-3). Much of the sand eventually migrates back to the beach during calmer periods. The nourishment projects reduce episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads (Figure 9-2). Additionally, nourishment reduces or eliminates wave energy (proxied by peak height) by as much as two inches.

Despite an initial beach width of approximately 55 feet and relatively fast average annual shoreline change rate (approximately 4.3 feet/year, including projected sea level rise), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. This is because beachfront properties on Broadkill are typically positioned several yards landward of the dune crest. Average beach width increases by as much as 115 feet immediately following the nourishment, then decreases over time as alongshore spreading and background erosion occur.

Figure 9-2. Sand spreads outside of the initial placement area over time

Figure 9-3. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Broadkill

9.3 Economic Modeling Results for Broadkill

The changes to episodic erosion risk, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure and enhance recreational value. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat (Table 9-2).

Table 9-2. Quantified value and associated level of each benefit at Broadkill

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$5 million	$8 million	63%	High
Recreation value	$330,000	$1.4 million	24%	High
Tourism impacts	$1.2 million	$1.1 billion	0.1%	Negligible
Ecological	-	-	-	Low

9.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Broadkill is protection from episodic erosion damage during coastal storm events. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion is $5 million and expected annual damage from flooding and waves is approximately $3 million. Nourishment avoids about 63 percent of those damages, leading to a high level of infrastructure resilience benefits. These benefits are exclusively experienced by local residential property owners (Figure 9-4).

Figure 9-4. The local benefits at this site are experienced exclusively within Broadkill

9.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Broadkill attracts about 24,000 annual beach visits. More than half of these visits (53 percent) are by non-Delaware residents. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Broadkill provides $330,000 in annual recreation value to Delaware residents. This represents about 24 percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits at this site as high.[51] Overall, local residents (defined as beach visitors that are community property owners) receive 52 percent ($170,000) of the recreation value benefits. The remaining 48 percent ($160,000) is experienced by non-local Delaware residents (Figure 9-5).

[51] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

Figure 9-5. Breakdown of the recreation value benefits at Broadkill

9.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. While nourishment does sustain some non-local visitation at Slaughter Beach (approximately 13,000 visits annually), the value-added in the tourism economy associated with those visits ($1.2 million annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[52] Accordingly, we classify the level of tourism impacts as negligible.

9.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Broadkill Beach ecosystem is a horseshoe crab sanctuary and provides habitat for multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Broadkill) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that coastal wetlands

[52] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

from Green Street to Roosevelt Inlet may experience minor benefits from nourishment due to spreading.

All considered, the beach nourishment activities at Broadkill are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at Broadkill as low relative to the infrastructure resilience and recreation benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

9.4 Design Alternatives and Cost Estimates for Broadkill

We identified two total nourishment design alternatives for Broadkill (Table 9-3). The results above are based on the first nourishment alternative, which extends from the cul-de-sac to the south end of South Bayshore Drive to 900 feet north of California Avenue. The second alternative covers the same stretch of beach but is wider and requires more sand.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. Both alternatives have high fixed costs (the projects involve offshore dredging, which imposes additional costs compared to trucking sand from inland sources). However, Alternative 2 is significantly more costly than Alternative 1 because it requires substantially more sand per year despite a less frequent renourishment interval.

Table 9-3. Nourishment alternatives at Broadkill

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	270,000	6	$34 million	$1.5 million
2	950,000	7	$86 million	$3.8 million

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1 and 2 are 390,000 cu yds and 1.3 million cu yds, respectively.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are subtle and do not influence the cost share results.

CHAPTER 10 | Lewes

Families enjoy Lewes Beach in the summer. Image credit: Tripadvisor.com

Lewes Beach is located just north of Cape Shores and Cape Henlopen. The surrounding community is highly developed. The beach is popular among both locals and tourists, supporting an estimated 470,000 beach visits annually. Though Lewes Beach is a bay beach by our geographic definition (east of Cape Henlopen), we find that it more closely resembles ocean beaches in terms of visitation levels and the level of surrounding development.[53]

10.1 Cost Share Overview for Lewes

The nourishment projects at Lewes result in high levels of benefits to infrastructure resilience and low levels of benefits to recreation value and tourism impacts (Figure 10-1). The nourishment projects also provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

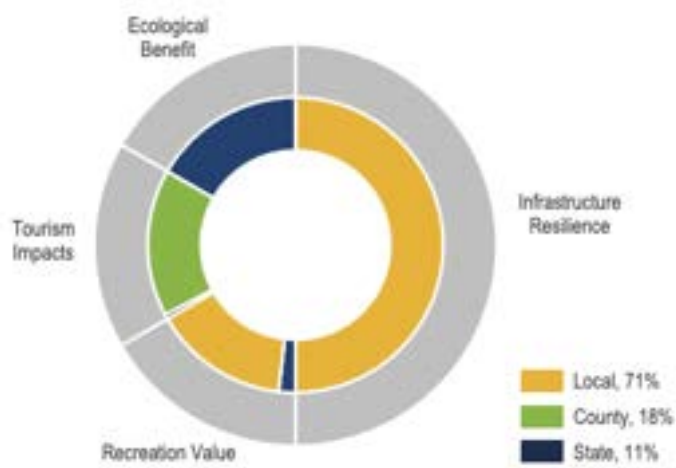


Figure 10-1. Relative level and distribution of each relevant benefit at Lewes

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table

[53] This distinction is pertinent to the recreation value analysis, which considers the role of nourishment at each site in sustaining ocean (or bay) beach recreation overall.

10-1), we recommend a local cost share of about two thirds (65%) of the non-federal cost of the nourishment projects. We additionally recommend that Sussex County contribute another 16%, with the remaining 19% covered by the state.

Table 10-1. Description of local, county, and state benefits from nourishment activities at Lewes

Local (65%)	County (16%)	State (19%)
• Protection of infrastructure, including residential and commercial properties • Recreation by local residents (defined for ocean beaches as people who live within five miles of the beaches)	• Tourism impacts that accrue in Sussex County	• Recreation by non-local state residents • Tourism impacts accruing outside Sussex County • Ecological benefit from supporting shorebird habitat

10.2 Coastal Process Modeling Results for Lewes

The developed coastline at Lewes faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar (Figure 10-3). Much of the sand eventually migrates back to the beach during calmer periods. The nourishment projects reduce this episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads. Additionally, nourishment reduces or eliminates wave energy (proxied by peak height) by as much as 2.8 feet, measured at the landward edge of the dune.

Despite an initial beach width of approximately 25 feet and relatively fast average annual shoreline change rate (approximately 3.5 feet/year, including projected sea level rise), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. This is because beachfront properties on Lewes are generally positioned several yards landward of the dune crest. Average beach width increases by as much as 125 feet immediately following the sand placement, then decreases over time as alongshore spreading and background erosion occur (Figure 10-2).

Figure 10-2. Sand spreads outside of the initial placement area over time

Figure 10-3. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Lewes

10.3 Economic Modeling Results for Lewes

The changes to episodic erosion risk, wave energy, and beach width protect vulnerable infrastructure and enhance recreational value, which in turn contribute to the broader regional tourism economy. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat (Table 10-2).

Table 10-2. Quantified value and associated level of each benefit at Lewes

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$2.6 million	$4 million	66%	High
Recreation value	$4.5 million	$310 million	1.5%	Low
Tourism impacts	$16 million	$1.1 billion	1.4%	Low
Ecological	-	-	-	Low

10.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Lewes is protection from episodic erosion damage during coastal storm events. In the absence of nourishment, expected annual damage to infrastructure from erosion and waves is approximately $4 million. Nourishment avoids about 66 percent of those damages, leading to a high level of infrastructure resilience benefits at this project site.

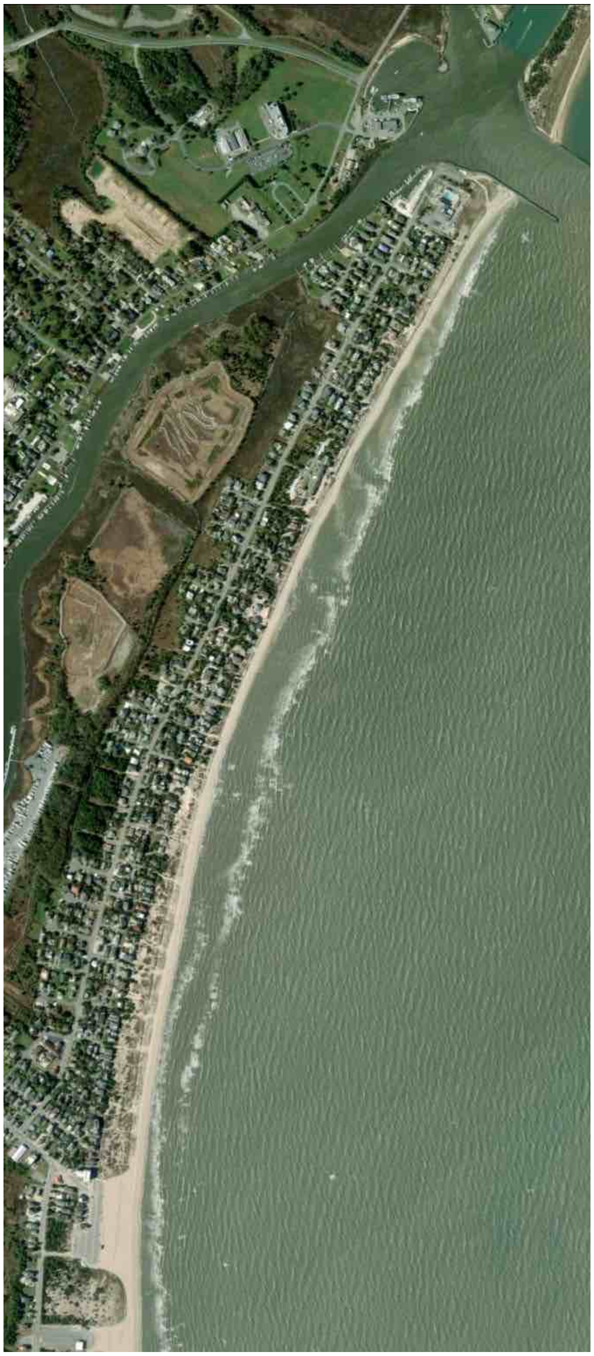


Figure 10-4. Lewes is located on the bay, but its development and visitor profile are more closely aligned with the ocean beaches in this study

10.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Lewes attracts approximately 470,000 annual visits. We estimate that a significant portion of these visits (77 percent) are by non-Delaware residents. Visits by out-of-state tourists contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Lewes provides over $4.5 million in recreation value to Delaware residents. This represents about 1.5 percent of the total recreation value of Atlantic coast beaches to residents of Delaware, leading to a low level of recreation benefits at this site (Figure 10-4).[54] Overall, local residents (defined as beach visitors that reside within five miles of the beach) receive 89 percent ($4.0 million) of the recreation benefits. The remaining 11 percent ($480,000) is experienced by non-local Delaware residents (Figure 10-5).

[54] Atlantic coast beaches in our analysis provide about $307 million of recreation value to Delaware residents.

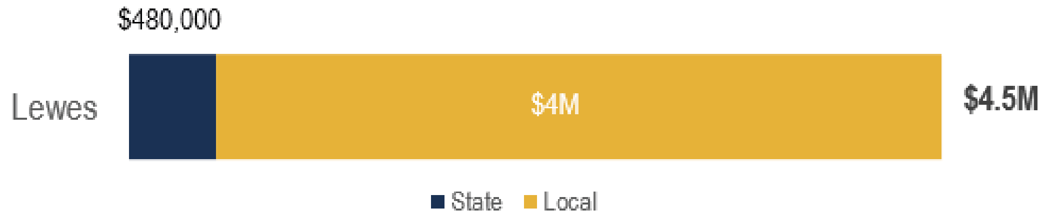
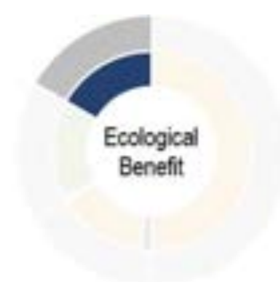


Figure 10-5. Breakdown of the recreation value benefits at Lewes

10.3.3 Tourism impacts

As described in the previous section, nourishment supports significant non-local recreation at Lewes, especially from out-of-state visitors. In total, the beach nourishment provides opportunity for approximately 166,000 annual visits to Lewes by non-local recreators relative to the no nourishment scenario. Spending in the local economy from these visitor and tourist trips generates business activity within Sussex County and throughout the state more broadly. Total value-added in the tourism economy from nourishment at Lewes ($15.6 million) represents about 1.5 percent of total value-added from recreation at all Delaware beaches in our study.[55] We therefore classify the level of tourism impact benefits as high at this project site. A relatively small share (three percent) of value-added accrues to businesses outside of Sussex County, suggesting that the interrelated businesses benefiting from the tourism spending at this beach are primarily located within Sussex County.

10.3.4 Ecological benefit



To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Lewes Beach ecosystem provides habitat for horseshoe crabs and multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in

[55] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Lewes) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that nourishment at Lewes Beach is unlikely to benefit wetlands.

All considered, the beach nourishment activities at Lewes are not expected to harm ecological resources but are not designed to specifically benefit horseshoe crabs, birds, and other wildlife species. While there is likely some contribution to the long-run objective of maintaining coastal habitats, we characterize the level of benefits to birds, wildlife, and wetlands of the nourishment activities at Lewes as low. As described in Chapter 2, this benefit is wholly attributed to the state.

10.4 Design Alternatives and Cost Estimates for Lewes

We identified two potential nourishment alternatives for Lewes (Table 10-3). The results above are based on the first nourishment alternative, which extends from Roosevelt Inlet to 1400 feet to the East. The second alternative extends from the Roosevelt Inlet to the parking lot at Savannah Beach.

Alternative 1 is significantly more costly than Alternative 2 because it requires substantially more sand per year due to a more frequent renourishment interval.

The results presented in this chapter are based on Alternative 1 in the table below. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are substantial but do not influence the cost share results.

Table 10-3. Nourishment alternatives at Lewes

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	170,000	4	$30 million	$1.4 million
2	130,000	6	$20 million	$900,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1 and 2 are 170,000 cu yds and 190,000 cu yds, respectively.

CHAPTER 11 | Cape Shores

Properties on Cape Shores Beach. Image credit: Silicatodevelopment.com

Cape Shores Beach is the southernmost bay beach in our analysis. The surrounding residential properties (primarily condominiums) comprise two neighboring private communities—Cape Shores and Port Lewes. While the beach is technically open to the public, we find that limited parking and accessibility lead recreation to be largely confined to members of the community, their guests, and renters (including short-term). The beach is also a seasonal host for horseshoe crabs and migratory bird species.

11.1 Cost Share Overview for Cape Shores

The nourishment projects at Cape Shores Beach result in a high level of infrastructure resilience benefits (Figure 11-1). Due to a low rate of projected shoreline change in the absence of nourishment, projects at this site provide negligible recreation value and tourism impacts. The nourishment projects do provide a low level of ecological benefits, primarily by maintaining horseshoe crab and shorebird habitat.

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 11-1), we recommend a local cost share of three quarters (75%) of the non-federal cost of the nourishment projects, with the remaining 25% covered by the state.

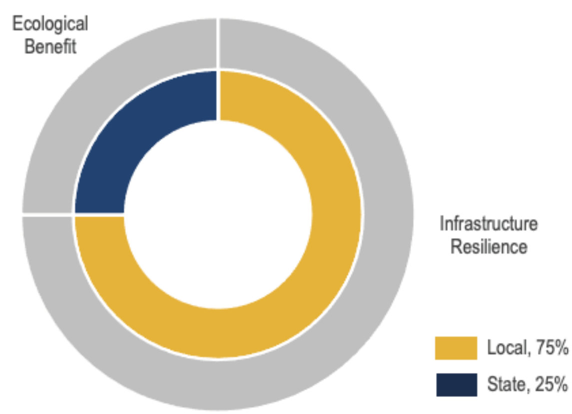


Figure 11-1. Relative level and distribution of each relevant benefit at Cape Shores

Table 11-1. Description of local and state benefits from nourishment activities at Cape Shores

Local (75%)	State (25%)
• Protection of infrastructure, specifically residential properties	• Ecological benefit from supporting horseshoe crab and shorebird habitat

Notes: Nourishment at this project site does not protect county-owned infrastructure or result in impacts to the county-level tourism economy. As a result, cost share is limited to state and local stakeholders.

The infrastructure resilience benefits are experienced at residential properties located in two communities (Cape Shores and Port Lewes). Table 11-2 presents a detailed breakdown of the distribution of benefits across these communities. These benefits are experienced exclusively by the owners of the benefiting residential properties.

Table 11-2. Detailed breakdown of the local share of benefits (75 percent of total project benefits) from nourishment at Cape Shores

Location	Private Benefit Share
Cape Shores	65%
Port Lewes	10%

Note: Numbers in the table represent raw shares, not redistribution of the local share. For example, private entities within the community of Cape Shores receive 65 percent of total project benefits. Due to rounding, portions in the table may not sum to the total local share exactly.

11.2 Coastal Process Modeling Results for Cape Shores

The developed coastline at Cape Shores faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar, with much of the sand eventually migrating back to the beach during calmer periods (Figure 11-3). The nourishment projects reduce this episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads. Additionally, nourishment reduces or eliminates wave energy (proxied by peak height) by as much as 0.5 feet, measured at the landward edge of the dune.

Table 11-3. Quantified value and associated level of each benefit at Cape Shores

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$3.5 million	$4.9 million	71%	High
Recreation value	$9,400	$1.4 million	0.67%	Negligible
Tourism impacts	$23,000	$1.1 billion	0.002%	Negligible
Ecological	-	-	-	Low

Due to the initial beach width of approximately 25 feet and low average annual projected shoreline change rate (approximately 0.1 feet/year, including projected sea level rise), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. Average beach width increases by as much as 65 feet immediately following the sand placement, then decreases over time as alongshore spreading and background erosion occur.

Figure 11-2. Sand spreads outside of the initial placement area over time

Figure 11-3. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Cape Shores

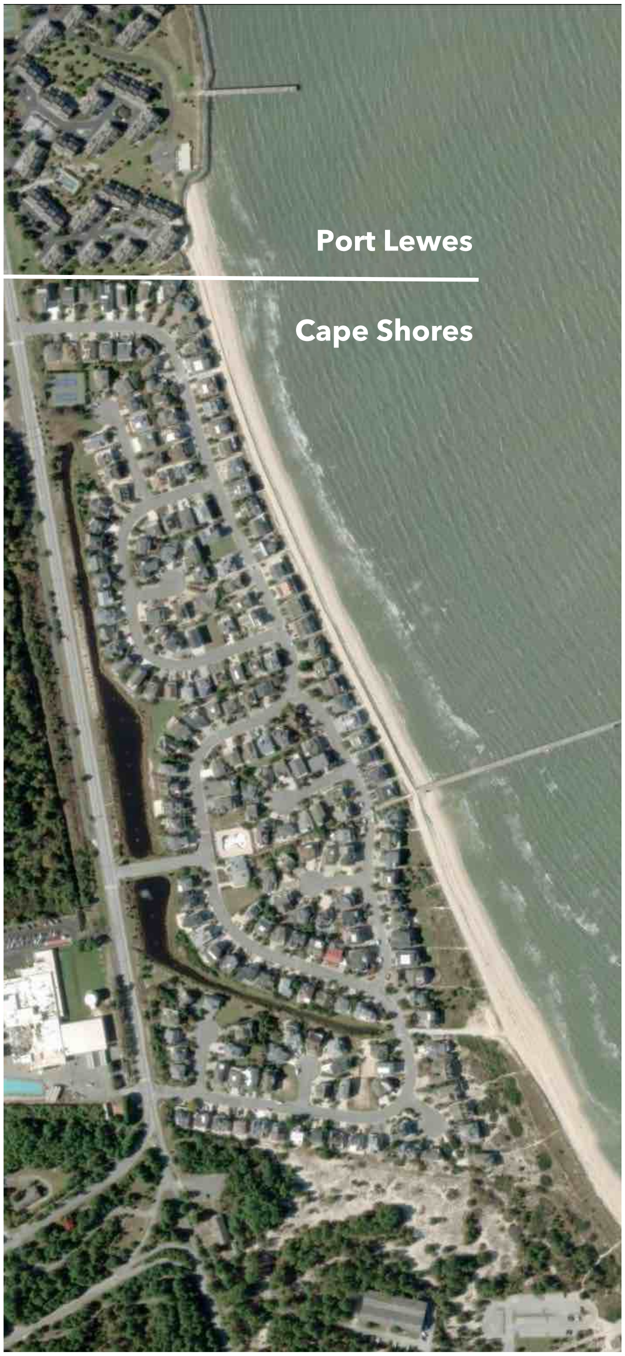


Figure 11-4. Nourishment at this project site provides infrastructure resilience to properties in two communities

11.3 Economic Modeling Results for Cape Shores

The changes to episodic erosion risk, wave energy, and beach width induced by beach nourishment projects protect vulnerable infrastructure. In addition, nourishment provides low levels of ecological benefits by contributing to the preservation of coastal habitat (Table 11-3).

11.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Cape Shores is protection from episodic erosion damage during coastal storm events. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion is approximately $4.5 million, and expected annual damage from flooding and waves is approximately $290,000. Nourishment avoids about 71 percent of those damages (Table 11-4), leading to a high level of infrastructure resilience benefits. These benefits are exclusively experienced by local residential property owners, split between the communities of Cape Shores and Port Lewes (Figure 11-4).

Table 11-4. Annualized expected avoided damage to infrastructure by community resulting from beach nourishment at Cape Shores

Location	Avoided damages
Cape Shores	$3.0 million
Port Lewes	$450,000
Total	**$3.5 million**

Values are reported in 2023 USD and rounded to two significant figures. As a result, values may not sum to the total.

11.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. We estimate about 5,500 annual beach visits at Cape Shores, with about half of these visits (53 percent) made by non-Delaware residents, presumably owners or renters of seasonal homes in one of the communities. Visits by out-of-state tourists can potentially contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

Despite the non-negligible level of baseline beach visits, we find that beach nourishment at Cape Shores provides just $9,000 in annual recreation value to Delaware residents due to the low projected annual shoreline change rate at this site. The recreation value of nourishment projects at Cape Shores represents less than one percent of the total annual recreation value of bay beaches to residents of Delaware, leading us to classify the level of recreation value benefits as negligible.[56]

11.3.3 Tourism impacts

As described in Chapter 2, tourism impacts capture the benefit to the broader regional economy associated with spending by non-local beach visitors. Nourishment sustains a small amount of non-local visitation at Cape Shores Beach (approximately 240 visits annually) due to the low projected shoreline change rate. The value-added in the tourism economy associated with those visits ($23,000 annually) represents less than one percent of the total annual value-added associated with recreation at all Delaware Bay beaches in our study.[57] Accordingly, we classify the level of tourism impacts as negligible.

[56] Bay beaches in our analysis provide about $1.4 million of recreation value to Delaware residents annually.

[57] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

11.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of horseshoe crabs, shorebirds, and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Cape Shores Beach ecosystem provides habitat for horseshoe crabs and multiple shorebird species, including red knot. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife (e.g., timing to avoid horseshoe crab spawning season). However, avoiding harm to horseshoe crabs and birds is different than benefitting them. In the long run, adding more sand to the bay system to limit beach erosion benefits coastal species. However, over the 30-year timeframe of our analysis and given the presence of additional sandy habitat along Delaware Bay, it is unlikely that the beach erosion at this site would result in measurable population-level effects on coastal species. Over longer time periods, continued efforts to maintain coastal habitats (not necessarily at Cape Shores) will be important.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. Because Cape Shores is located directly between Lewes Beach and Cape Henlopen, which has a surplus of sand, we find that nourishment at Cape Shores is unlikely to benefit wetlands.

All considered, the beach nourishment activities at Cape Shores are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining Delaware Bay coastal habitats, we characterize the level of ecological benefits at Cape Shores as low relative to the infrastructure resilience benefits at this site. As described in Chapter 2, this benefit is wholly attributed to the state.

11.4 Design Alternatives and Cost Estimates for Cape Shores

We identified three nourishment design alternatives for Cape Shores (Table 11-5). The results above are based on the first nourishment alternative, which roughly covers the area in front of the shorefront properties. The second and third alternatives cover a similar stretch of beach, but have different widths and volumes. Alternative 2 is slightly less wide and uses almost twice as much sand to increase the elevation of the beach. Alternative 3 is very similar to Alternative 1 but is slightly less wide and requires slightly less sand.

Project costs are a function of the volume of sand required for each nourishment, the frequency of renourishment, and the fixed costs required to mobilize equipment. The fixed costs are the same across all alternatives because each project involves trucking sand from inland sources. Since renourishment intervals are also identical across projects, differences are driven by the volume of sand required for nourishment. Accordingly, Alternatives 1 and 3 have similar costs, while Alternative 2 is significantly more costly.

Table 11-5. Nourishment alternatives at Cape Shores

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	22,000	5	$5.4 million	$230,000
2	40,000	5	$9.2 million	$410,000
3	22,000	5	$5.0 million	$220,000

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for each alternative are identical to the renourishment volume at this site.

The results presented in this chapter are based on Alternative 1 in the table above. Full results for all nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are modest and do not influence the cost share results. This is primarily because all nourishment alternatives avoid at least 10 percent of infrastructure damages, thereby generating a high level of infrastructure resilience benefits.

CHAPTER 12 | Rehoboth and Dewey

Rehoboth Beach Boardwalk looking south toward Dewey Beach. Image credit: Delaware.gov

Rehoboth and Dewey are the two northernmost Atlantic coast beaches in our analysis. Both have highly developed coastlines, including the Rehoboth Beach Boardwalk. The beaches are popular among both locals and tourists, supporting nearly six million beach visits annually combined. Rehoboth Beach alone accounts for over 40 percent of the total recreation at Atlantic beaches in our analysis.

12.1 Cost Share Overview for Rehoboth and Dewey

The nourishment projects at Rehoboth and Dewey result in high levels of benefits to infrastructure resilience, recreation value, and tourism impacts (Figure 12-1). However, the nourishment projects provide limited ecological benefits at these beaches.

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 12-1), we recommend a local cost share of slightly more than half (53%) of the non-federal cost of the nourishment projects. We additionally recommend that Sussex County contribute another 31%, with the remaining 16% covered by the state.

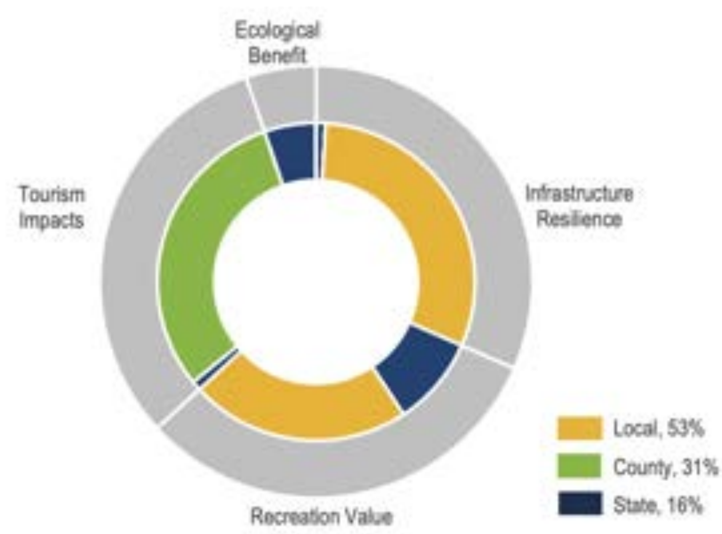


Figure 12-1. Relative level and distribution of each relevant benefit at Rehoboth and Dewey

Table 12-1. Description of local, county, and state benefits from nourishment activities at Rehoboth and Dewey

Local (53%)	County (31%)	State (16%)
• Protection of infrastructure, including residential properties, commercial properties, and the Rehoboth Beach Boardwalk • Recreation by local residents (defined for ocean beaches as people who live within five miles of the beaches)	• Tourism impacts that accrue in Sussex County	• Protection of small roadway sections and a state park building • Recreation by non-local state residents • Tourism impacts accruing outside Sussex County • Ecological benefit from supporting shorebird habitat

Due to alongshore sand spreading following nourishment, the local benefits are not confined to Rehoboth Beach and Dewey Beach. Table 12-2 presents a detailed breakdown of the distribution of benefits across local jurisdictions. As described in Table 12-1, local benefits include infrastructure resilience and recreation value. These benefits are primarily experienced by private entities, though protection of the Rehoboth Beach Boardwalk constitutes a municipal benefit.

Table 12-2. Detailed breakdown of the local share of benefits (53 percent of total project benefits) from nourishment at Rehoboth and Dewey

Location	Municipal Benefit Share	Private Benefit Share
North Shores, Henlopen Acres		4%
Rehoboth Beach	2%	23%
Silver Lake		2%
Dewey Beach		18%
Indian Beach, The Chancellery		4%

Note: Numbers in the table represent raw shares, not redistribution of the local share. For example, private entities within the City of Rehoboth Beach receive 23 percent of total project benefits. Due to rounding, portions in the table may not sum to the total local share exactly.

12.2 Coastal Process Modeling Results for Rehoboth and Dewey

In the absence of nourishment, the developed coastline at Rehoboth and Dewey faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar (Figure 12-2). Much of the sand eventually migrates back to the beach during calmer periods. The nourishment projects reduce this episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads (Figure 12-3). Additionally, nourishment reduces or eliminates wave energy (proxied by peak height) by as much as 2.7 feet, measured at the landward edge of the dune.

Due to the wide initial beach width (approximately 150 feet) relative to the average annual shoreline change rate (approximately 4.6 feet/year eroded), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. Average beach width increases by as much as 200 feet immediately following the sand placement, then decreases over time as alongshore spreading and background erosion occur.

Figure 12-2. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Rehoboth-Dewey

Figure 12-3. Sand spreads outside of the initial placement areas over time

12.3 Economic Modeling Results for Rehoboth and Dewey

The changes to episodic erosion risk, wave energy, and beach width protect vulnerable infrastructure and enhance recreational value, which in turn contribute to the broader regional tourism economy. In addition, nourishment provides limited ecological benefits by contributing to the preservation of coastal habitat (Table 12-3).

Table 12-3. Quantified value and associated level of each benefit at Rehoboth and Dewey

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$17 million	$17 million	96%	High
Recreation value	$110 million	$310 million	36%	High
Tourism impacts	$190 million	$1.1 billion	18%	High
Ecological	-	-	-	Limited

12.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Rehoboth and Dewey is protection from episodic erosion damage during coastal storm events. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion and waves is approximately $17 million. Nourishment avoids about 96 percent of those damages (Table 12-4), leading to a high level of infrastructure resilience benefits at this project site. These benefits are primarily (97 percent) experienced locally, though a small portion of avoided damages (three percent) is experienced by state-owned infrastructure.

Due to sand spreading over time, the benefits are not confined to infrastructure within the municipal boundaries of Rehoboth Beach and Dewey Beach. Infrastructure protection extends to the communities of Henlopen Acres and North Shores to the north of the nourished area, and Indian Beach and The Chancellery to the south. In addition, shorefront residential properties between Rehoboth and Dewey in the community of Silver Lake benefit from the nourishment projects.

Figure 12-4. Nourishment at Rehoboth and Dewey provides benefits to neighboring communities as well

Table 12-4. Annualized expected avoided damage to infrastructure by community resulting from beach nourishment at Rehoboth and Dewey

Location	Avoided damages
Henlopen Acres, North Shores	$2.5 million
Rehoboth Beach	$3.4 million
Silver Lake	$880,000
Dewey Beach	$7.8 million
Indian Beach, The Chancellery	$2.0 million
Total	**$17 million**

Values are reported in 2023 USD and rounded to two significant figures. As a result, values may not sum to the total.

Generally, the vulnerable infrastructure at Rehoboth is located closer to the existing shoreline than the vulnerable infrastructure at Dewey (Figure 12-4). However, avoided damages are two to three times greater at Dewey due to presence of the Rehoboth Boardwalk, which is expected to limit erosion damage to landward infrastructure. In Dewey, the first row of infrastructure is generally residential and commercial buildings, which have higher repair and replacement costs relative to the boardwalk. Additionally, nourishment prevents some damage to residential and commercial structures at Rehoboth landward of the boardwalk from waves; however, those damages are more modest (as a percentage of replacement cost) than the erosion damage experienced by residential and commercial structures at Dewey.

12.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Rehoboth and Dewey are both popular beaches, attracting 4.8 million and 1.1 million annual visitors, respectively. A significant portion of these visits (56 percent at Rehoboth, 75 percent at Dewey) are by non-Delaware residents. Visits by out-of-state tourists contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Rehoboth and Dewey provides over $110 million in recreation value to Delaware residents (Figure 12-5). This represents about 36 percent of the total recreation value of Atlantic coast beaches to residents of Delaware, leading to a high level of recreation benefits at these sites.[58]

Figure 12-5. Breakdown of the recreation value benefits at Rehoboth and Dewey

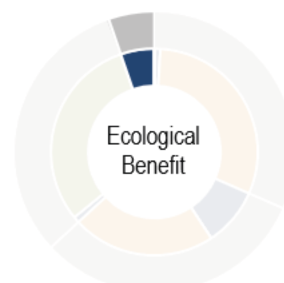
Overall, local residents (defined as beach visitors that reside within five miles of the beach) receive 71 percent ($78 million) of the recreation benefits. The remaining 29 percent ($32 million) is experienced by non-local Delaware residents. As expected, Rehoboth is the main contributor, with 88 percent ($98 million) of the beach recreation value resulting from the nourishment projects associated with Rehoboth Beach (Figure 12-5). The smaller recreational value of nourishment at Dewey is a result of lower total visitation compared to Rehoboth as well as a higher proportion of out-of-state visitors.

[58] Atlantic coast beaches in our analysis provide about $307 million of recreation value to Delaware residents.

12.3.3 Tourism impacts

As described in the previous section, nourishment supports significant non-local recreation at Rehoboth and Dewey, especially from out-of-state visitors. In total, the beach nourishment provides opportunity for approximately 1.8 million annual visits to Rehoboth and 430,000 annual visits to Dewey by non-local recreators relative to the no nourishment scenario. Spending in the local economy from these visitor and tourist trips generates business activity within Sussex County and throughout the state more broadly. Total value-added in the tourism economy from nourishment at Rehoboth and Dewey ($192 million) represents almost 18 percent of total value-added from recreation at all Delaware beaches in our study.[59] We therefore classify the level of tourism impact benefits as high at these project sites. A relatively small share (three percent) of value-added accrues to businesses outside of Sussex County, suggesting that the interrelated businesses benefiting from the tourism spending at these beaches are primarily located within Sussex County.

12.3.4 Ecological benefit



To evaluate the ecological benefits of the project, we first consider the presence of shorebirds and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

Rehoboth and Dewey beach ecosystems are habitat for multiple shorebird species. While the beaches are generally crowded, resulting in avoidance by most protected species during beach season, they are used by birds as stopovers along migratory routes and during less crowded seasons. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife. However, avoiding harm to birds is different than benefitting them. In the long run, adding more sand to the system to limit beach erosion benefits coastal species, including shorebirds. However, over the 30-year timeframe of our analysis, it is unlikely that the beach erosion at this site would preclude its ability to support shorebirds. While over longer time periods, continued efforts to maintain coastal shorebird habitats (not necessarily at Rehoboth and Dewey) will be important, shorebird conservation efforts along the Atlantic coast are currently more focused on avoiding human-shorebird interactions.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We find that wetlands at Cape Henlopen to the north are buffered by significant beach width that is likely to continue to grow

[59] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

even absent nourishment at Rehoboth and Dewey. We did not identify vulnerable wetland area on the seaward side of the barrier beach to the south.

All considered, the beach nourishment activities at Rehoboth and Dewey are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining coastal habitats, we characterize the level of ecological benefits from the nourishment activities at Rehoboth and Dewey as limited relative to the infrastructure resilience, recreation value, and tourism impact benefits. As described in Chapter 2, the ecological benefit is wholly attributed to the state.

12.4 Design Alternatives and Cost Estimates for Rehoboth and Dewey

We identified two potential nourishment alternatives for Rehoboth and Dewey (Table 12-5). The first includes two separate sand placement sites (one at Rehoboth, one at Dewey) separated by a roughly 6,500-foot alongshore gap; we find that the gap is filled within one year of nourishment due to natural sand spreading. The second alternative is a single sand placement that approximately spans both smaller projects.

Despite large differences in the volume of sand required for each nourishment, total present value cost of the two smaller projects over 30 years is just 10 percent lower than the larger project due to the need for more frequent renourishment.

Table 12-5. Nourishment alternatives at Rehoboth and Dewey

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1 (Rehoboth)	160,000	5	$26 million	$1.1 million
1 (Dewey)	160,000	4	$30 million	$1.3 million
2 (Rehoboth-Dewey)	1,200,000	12	$62 million	$2.8 million

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1 (Rehoboth), 1 (Dewey), and 2 are 200,000 cu yds, 190,000 cu yds, and 1,400,000 cu yds, respectively.

The results presented in this chapter are based on the alternative consisting of two smaller nourishment sites. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are relatively minor and do not influence the cost share results. This is primarily because average beach width over the 30-year analysis timeframe is similar, despite significant year-to-year variation in beach width between alternatives.

CHAPTER 13 | Bethany and South Bethany

Bethany and South Bethany Beaches are located between the Delaware Seashore State Park and Fenwick Island. Both have highly developed coastlines, including the Bethany Beach Boardwalk. The beaches are popular among both locals and tourists, supporting nearly three million beach visits annually combined. Bethany Beach alone accounts for about 30 percent of the total recreation at Atlantic beaches in our analysis.

13.1 Cost Share Overview for Bethany and South Bethany

The nourishment projects at Bethany and South Bethany result in high levels of benefits to infrastructure resilience and low levels of benefits to recreation value and tourism impacts (Figure 13-1). The nourishment projects also provide limited ecological benefits, primarily by maintaining shorebird habitat.

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 13-1), we recommend a local cost share of slightly more than two thirds (71%) of the non-federal cost of the nourishment projects. We additionally recommend that Sussex County contribute another 18%, with the remaining 11% covered by the state.

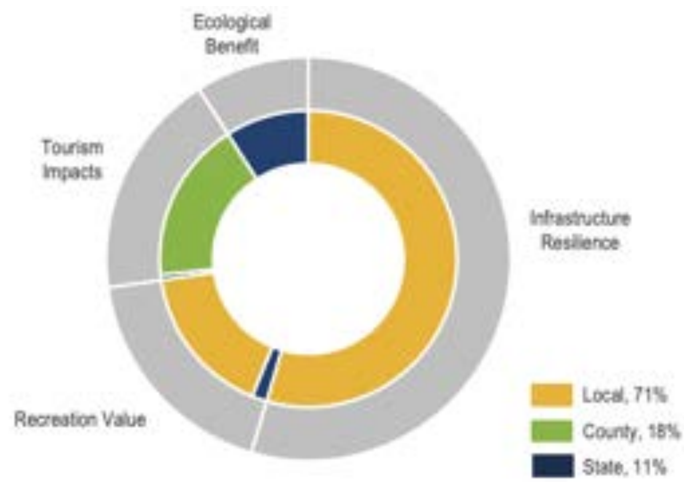


Figure 13-1. Relative level and distribution of each relevant benefit at Bethany and South Bethany

Table 13-1. Description of local, county, and state benefits from nourishment activities at Bethany and South Bethany

Local (71%)	County (18%)	State (11%)
• Protection of infrastructure, including residential properties, commercial properties, and the Bethany Beach Boardwalk • Recreation by local residents (defined for these beaches as people who live within five miles of the beaches)	• Tourism impacts that accrue in Sussex County	• Recreation by non-local state residents • Tourism impacts accruing outside Sussex County • Ecological benefit from supporting shorebird habitat

Due to alongshore sand spreading following nourishment, the local benefits are not confined to Bethany Beach and South Bethany Beach. Table 13-2 presents a detailed breakdown of the distribution of benefits across local jurisdictions. As described in Table 13-1, local benefits include infrastructure resilience and recreation value. These benefits are primarily experienced by private entities, though protection of the Bethany Beach Boardwalk constitutes a municipal benefit.

Table 13-2. Detailed breakdown of the local share of benefits (71 percent of total project benefits) from nourishment at Bethany and South Bethany

Location	Municipal Benefit Share	Private Benefit Share
Bethany	6%	17%
Sea Colony, Middlesex Beach		25%
South Bethany		23%

Note: Numbers in the table represent raw shares, not redistribution of the local share. For example, private entities within Bethany receive 17 percent of total project benefits. Due to rounding, portions in the table may not sum to the total local share exactly.

13.2 Coastal Process Modeling Results for Bethany and South Bethany

The developed coastline at Bethany and South Bethany faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar (Figure 13-3). Much of the sand eventually migrates back to the beach during calmer periods. The nourishment projects reduce this episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads (Figure 13-2). Additionally, nourishment reduces or eliminates wave energy (proxied by peak height) by as much as 3.4 feet, measured at the landward edge of the dune.

Due to the wide initial beach width (approximately 155 feet) relative to the average annual shoreline change rate (approximately 1.1 feet/year eroded at Bethany and 4.1 feet/year eroded at South Bethany), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. Average beach width increases by as much as 150 feet immediately following the sand placement, then decreases over time as alongshore spreading and background erosion occur.

Figure 13-2. Sand spreads outside of the initial placement areas over time

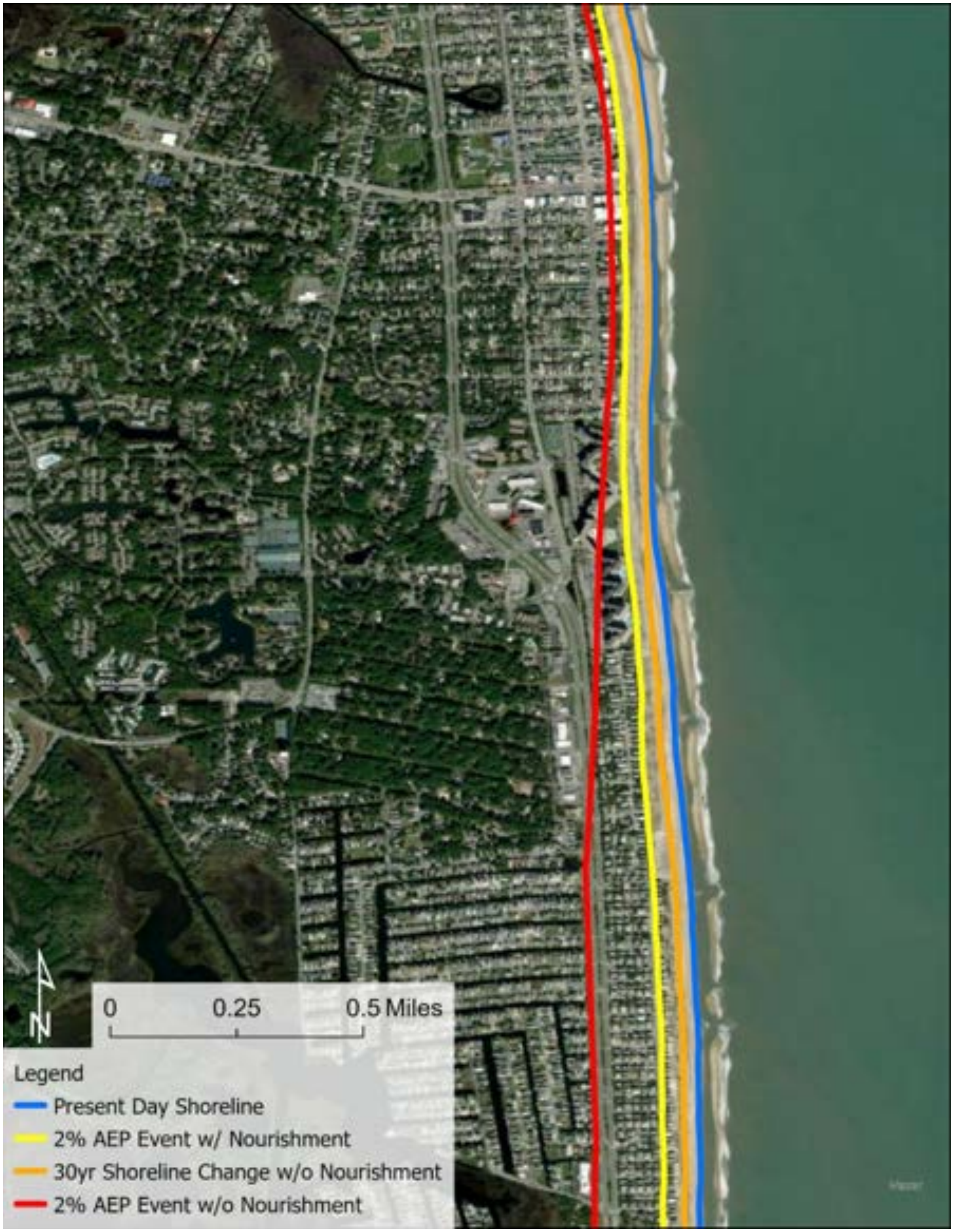


Figure 13-3. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Bethany-South Bethany

13.3 Economic Modeling Results for Bethany and South Bethany

The changes to episodic erosion risk, wave energy, and beach width protect vulnerable infrastructure and enhance recreational value, which in turn contribute to the broader regional tourism economy. In addition, nourishment provides limited ecological benefits by contributing to the preservation of coastal habitat (Table 13-3).

Table 13-3. Quantified value and associated level of each benefit at Bethany and South Bethany

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$4.7 million	$11 million	42%	High
Recreation value	$5 million	$310 million	1.6%	Low
Tourism impacts	$44 million	$1.1 billion	4.1%	Low
Ecological	-	-	-	Limited

13.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Bethany and South Bethany is protection from episodic erosion damage during coastal storm events. The nourishment projects additionally reduce infrastructure damages from wave energy, but these benefits are relatively minor. In the absence of nourishment, expected annual damage to infrastructure from erosion and waves is approximately $11 million. Nourishment avoids about 42 percent of those damages (Table 13-4), leading to a high level of infrastructure resilience benefits at this project site.

Due to sand spreading over time, the benefits are not confined to infrastructure within the municipal boundaries of Bethany Beach and South Bethany Beach. Shorefront properties between Bethany and South Bethany in the communities of Sea Colony and Middlesex Beach also receive a sizeable portion of expected avoided damages from the nourishment projects (Table 13-4). Some spreading to the north of Bethany Beach does occur, but infrastructure in communities such as Sussex Shores, Vista del Mar, and Seabreak are located further from the present-day coastline and therefore face much lower risk of damage from episodic erosion in the absence of nourishment. To the south of the nourishment projects there is no infrastructure at risk.

Figure 13-4. Nourishment at Bethany and South Bethany provides benefits to neighboring communities as well

Table 13-4. Annualized expected avoided damage to infrastructure by community resulting from beach nourishment at Bethany and South Bethany

Location	Avoided damages
Bethany	$750,000
Sea Colony and Middlesex Beach	$2.2 million
South Bethany	$1.8 million
Total	**$4.7 million**

Values are reported in 2023 USD and rounded to two significant figures. As a result, values may not sum to the total.

Generally, episodic erosion risk increases south of Bethany Beach. Additionally, the presence of the Bethany Beach Boardwalk is expected to limit damages to landward infrastructure within that municipality. The boardwalk itself receives a significant protection benefit, but its replacement costs are lower than the infrastructure to the south. Sea Colony and Middlesex Beach receive the highest portion of expected avoided damages due to the higher replacement cost of infrastructure within those communities relative to South Bethany.

13.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to these beaches. Bethany and South Bethany are both popular beaches, attracting 3.3 million and 490,000 annual visitors, respectively. A significant portion of these visits (91 percent at Bethany, 90 percent at South Bethany) are by non-Delaware residents. Visits by out-of-state tourists contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

Despite high baseline visitation at these beaches, the relatively low projected annual shoreline change rate at these sites suggests that many of these visits would not be lost in the absence of nourishment over the 30-year analysis timeframe. Nonetheless, we find that beach nourishment at Bethany and South Bethany provides over $5 million in recreation value to Delaware residents. This represents about 1.6 percent of the total recreation value of Atlantic coast beaches to residents of Delaware, leading to a low level of recreation benefits at these sites.[60]

Figure 13-5. Breakdown of the recreation value benefits at Bethany and South Bethany

Overall, local residents (defined as beach visitors that reside within five miles of the beach) receive 91 percent ($4.6 million) of the recreation benefits. The remaining nine percent ($430,000) is experienced by non-local Delaware residents. As expected, Bethany is the main contributor, with 86 percent ($4.3 million) of the beach recreation value resulting from the nourishment projects associated with Bethany Beach (Figure 13-5). The smaller recreational value of nourishment at South Bethany is a result of lower total visitation compared to Bethany.

13.3.3 Tourism impacts

As described in the previous section, nourishment supports significant non-local recreation at Bethany and South Bethany, especially from out-of-state visitors. In total, the beach nourishment provides opportunity for approximately 440,000 annual visits to Bethany and 62,000 annual visits to South Bethany by non-local recreators relative to the no nourishment scenario.[61] Spending in the local economy from these visitor and tourist trips generates business activity within Sussex County and throughout the state more broadly. Total value-added in the tourism economy from nourishment at Bethany and South Bethany ($44 million) represents about four percent of total

[60] Atlantic coast beaches in our analysis provide about $307 million of recreation value to Delaware residents.

[61] As described, the relatively low contribution of nourishment to visitation at these beaches arises from the wide initial beach width and low projected annual shoreline change rate.

value-added from recreation at all Delaware beaches in our study.[62] We therefore classify the level of tourism impact benefits as high at these project sites. A relatively small share (three percent) of value-added accrues to businesses outside of Sussex County, suggesting that the interrelated businesses benefiting from the tourism spending at these beaches are primarily located within Sussex County.

13.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of shorebirds and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

Bethany and South Bethany beach ecosystems are habitat for multiple shorebird species. While the beaches are generally crowded resulting in avoidance by most protected species during beach season, they are used by birds as stopovers along migratory routes and during less crowded seasons. The nourishment projects generally adopt practices to avoid harm to birds and other wildlife. However, avoiding harm to birds is different than benefitting them. In the long run, adding more sand to the system to limit beach erosion benefits coastal species, including shorebirds. However, over the 30-year timeframe of our analysis, it is unlikely that the beach erosion at this site would preclude its ability to support shorebirds. While over longer time periods, continued efforts to maintain coastal shorebird habitats (not necessarily at Bethany and South Bethany) will be important, shorebird conservation efforts along the Atlantic coast are currently more focused on avoiding human-shorebird interactions.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We did not identify vulnerable wetland area within the project's area of influence.

All considered, the beach nourishment activities at Bethany and South Bethany are not expected to harm ecological resources but are not designed to specifically benefit birds and other wildlife species. While there is likely some contribution to the long-run objective of maintaining coastal habitats, we characterize the level of benefits to birds, wildlife, and wetlands of the nourishment activities at Bethany and South Bethany as limited. As described in Chapter 2, this benefit is wholly attributed to the state.

13.4 Design Alternatives and Cost Estimates for Bethany and South Bethany

We identified two potential nourishment alternatives for Bethany and South Bethany (Table 13-5). The first includes two separate sand placement sites (one at Bethany, one at South Bethany) separated by a roughly 5,500-foot alongshore gap; we find that the gap is filled within one year of

[62] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

nourishment due to natural sand spreading. The second alternative has only a 1,750-foot gap and extends beyond the northern and southern reach of both smaller projects.

The total combined present value cost of the two smaller projects over 30 years is lower than the present value cost of the larger project due to greater total sand volume.

Table 13-5. Nourishment alternatives at Bethany and South Bethany

Nourishment alternative	Renourishment volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1 (Bethany)	310,000	5	$39 million	$1.8 million
1 (South Bethany)	290,000	5	$40 million	$1.8 million
2 (Bethany/South Bethany)	2,200,000	12	$130 million	$5.7 million

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*The initial fill volume for Alternative 2 is 3,500,000 cu yds. Initial fill volumes for Alternative 1 at both sites does not differ from renourishment volumes.

The results presented in this chapter are based on the alternative consisting of two smaller nourishment sites. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are modest and do not influence the cost share results. This is primarily because average beach width over the 30-year analysis timeframe is similar, despite significant year-to-year variation in beach width between alternatives.

CHAPTER 14 | Fenwick Island

Fenwick Island looking south. Image credit: Expedia.com

Fenwick Island is the southernmost Atlantic coast beach in our analysis. The beachfront is highly developed, as shown in the image above. Though it attracts locals and tourists alike, Fenwick Island accounts for far fewer beach trips than Rehoboth and Bethany. It supports just five percent of the total recreation at Atlantic beaches in our analysis.

14.1 Cost Share Overview for Fenwick Island

The nourishment projects at Fenwick Island result in high levels of benefits to infrastructure resilience and low levels of benefits to recreation value and tourism impacts (Figure 14-1). The nourishment projects also provide limited ecological benefits, primarily by maintaining shorebird habitat.

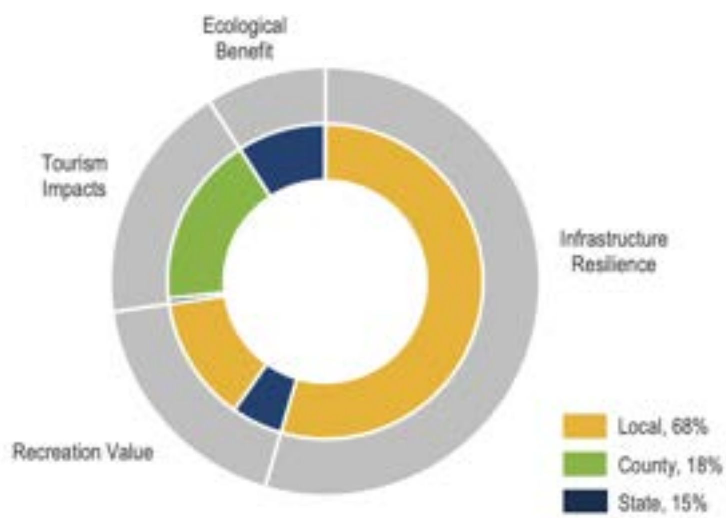


Figure 14-1. Relative level and distribution of each relevant benefit at Fenwick Island

Consistent with the types and magnitudes of economic and ecosystem service benefits resulting from the nourishment activity (Table 14-1), we recommend a local cost share of about two thirds (68%) of the non-federal cost of the nourishment projects. We additionally recommend that Sussex County contribute another 18%, with the remaining 15% covered by the state.

Table 14-1. Description of local, county, and state benefits from nourishment activities at Fenwick Island

Local (68%)	County (18%)	State (15%)
• Protection of residential properties • Recreation by local residents (defined for ocean beaches as people who live within five miles of the beaches)	• Tourism impacts that accrue in Sussex County	• Recreation by non-local state residents • Tourism impacts accruing outside Sussex County • Ecological benefit from supporting shorebird habitat

Due to alongshore sand spreading following nourishment, the local benefits are not confined to Fenwick Island. Table 14-2 presents a detailed breakdown of the distribution of benefits across local jurisdictions. As described in Table 14-1, local benefits include infrastructure resilience and recreation value. These benefits are experienced by private entities.

Table 14-2. Detailed breakdown of the local share of benefits (68 percent of total project benefits) from nourishment at Fenwick Island

Location	Private Benefit Share
Fenwick Island	32%
Community to the South	35%

Note: Numbers in the table represent raw shares, not redistribution of the local share. For example, private entities within Fenwick Island receive 32 percent of total project benefits. Due to rounding, portions in the table may not sum to the total local share exactly.

14.2 Coastal Process Modeling Results for Fenwick Island

The developed coastline at Fenwick Island faces significant threats from episodic erosion driven by large waves pulling sand offshore during storm events to create a sandbar (Figure 14-3). Much of the sand eventually migrates back to the beach during calmer periods. The nourishment projects reduce this episodic erosion, but the extent of reduction varies along the shoreline and over time as the sand spreads (Figure 14-2).

Due to the wide initial beach width (approximately 160 feet) relative to the average annual shoreline change rate (approximately 1.2 feet/year eroded), longer-term shoreline change is not expected to result in the erosion of built infrastructure during the 30-year timeframe of our analysis, even in the absence of nourishment. Average beach width increases by as much as 100 feet immediately following the sand placement, then decreases over time as alongshore spreading and background erosion occur.

Figure 14-2. Sand spreads outside of the initial placement area over time

Figure 14-3. Current and future projected shoreline position, as well as shoreline position following a two percent AEP storm event with and without nourishment at Fenwick Island

14.3 Economic Modeling Results for Fenwick Island

The changes to episodic erosion risk and beach width protect vulnerable infrastructure and enhance recreational value, which in turn contribute to the broader regional tourism economy. In addition, nourishment provides limited ecological benefits by contributing to the preservation of coastal habitat (Table 14-3).

Table 14-3. Quantified value and associated level of each benefit at Fenwick Island

Benefit	Quantified value	Comparison value	Percentage	Level
Infrastructure resilience	$730,000	$730,000	100%	High
Recreation value	$3.1 million	$1.4 million	1%	Low
Tourism impacts	$13 million	$1.1 billion	1.1%	Low
Ecological	-	-	-	Limited

14.3.1 Infrastructure resilience

The primary infrastructure resilience benefit of the nourishment projects at Fenwick Island is protection from episodic erosion damage during coastal storm events. In the absence of nourishment, expected annual damage to infrastructure from erosion is approximately $730,000. Nourishment avoids all of those damages (Table 14-4), leading to a high level of infrastructure resilience benefits at this project site. These benefits are experienced locally.

Due to sand spreading over time, the benefits are not confined to infrastructure within the municipal boundaries of Fenwick Island. Infrastructure protection extends to an unincorporated community to the south of the nourished area. (Figure 14-4). Avoided damages at Fenwick Island account for slightly less than half of the total avoided damages due to slightly lower total replacement value of the infrastructure and slightly wider initial beach width. To the north of Fenwick island, there is no infrastructure at risk from episodic erosion damages over the 30-year analysis timeframe.

Figure 14-4. Due to sand spreading, nourishment at Fenwick Island results in infrastructure benefits to a community to the south

Table 14-4. Annualized expected avoided damage to infrastructure by community resulting from beach nourishment at Fenwick Island

Location	Avoided damages
Fenwick Island	$350,000
Unincorporated Community	$380,000
Total	**$730,000**

Values are reported in 2023 USD and rounded to two significant figures. As a result, values may not sum to the total.

14.3.2 Recreation value

Recreation value captures the value accruing to Delaware residents from taking trips to Fenwick Island. The beach attracts 1.2 million annual visitors. A significant portion of these visits (81 percent) are by non-Delaware residents. Visits by out-of-state tourists contribute to the tourism economy (see next subsection) but are not included in the recreation value calculation, as described in Chapter 2.

We find that beach nourishment at Fenwick Island provides over $3.1 million in recreation value to Delaware residents. This represents about one percent of the total recreation value of Atlantic coast beaches to residents of Delaware, leading to a low level of recreation benefits at this site.[63] Overall, local residents (defined as beach visitors that reside within five miles of the beach) receive 71 percent ($2.2 million) of the recreation benefits. The remaining 29 percent ($880,000) is experienced by non-local Delaware residents (Figure 14-5).

[63] Atlantic coast beaches in our analysis provide about $307 million of recreation value to Delaware residents.

Figure 14-5. Breakdown of the recreation value benefits at Fenwick Island

14.3.3 Tourism impacts

As described in the previous section, nourishment supports significant non-local recreation at Fenwick Island, especially from out-of-state visitors. In total, the beach nourishment provides opportunity for approximately 140,000 annual visits by non-local recreators relative to the no nourishment scenario. Spending in the local economy from these visitor and tourist trips generates business activity within Sussex County and throughout the state more broadly. Total value-added in the tourism economy from nourishment at Fenwick Island ($12.5 million) represents about one percent of total value-added from recreation at all Delaware beaches in our study.[64] We therefore classify the level of tourism impact benefits at this project site as low. A relatively small share (three percent) of value-added accrues to businesses outside of Sussex County, suggesting that the interrelated businesses benefiting from the tourism spending at these beaches are primarily located within Sussex County.

14.3.4 Ecological benefit

To evaluate the ecological benefits of the project, we first consider the presence of shorebirds and other wildlife species that are vulnerable to beach loss. We additionally consider whether wetland ecosystems are located within the area of influence of the beach nourishment project; specifically, we consider whether the nourishment activity is likely to avoid wetland loss or degradation within the 30-year timeframe of our analysis.

The Fenwick Island beach ecosystem is habitat for multiple shorebird species. While the beach is generally crowded, resulting in avoidance by most protected species during beach season, it is used by birds as stopovers along migratory routes and during less crowded seasons. The nourishment project generally adopts practices to avoid harm to birds and other wildlife. However, avoiding harm to birds is different than benefitting them. In the long run, adding more sand to the system to limit beach erosion benefits coastal species, including shorebirds. However, over the 30-year timeframe of our analysis, it is unlikely that the beach erosion at this site would preclude its ability to support shorebirds. While over

[64] All beaches in our analysis contribute about $1.1 billion in value-added to the tourism economy.

longer time periods, continued efforts to maintain coastal shorebird habitats (not necessarily at Fenwick Island) will be important, shorebird conservation efforts along the Atlantic coast are currently more focused on avoiding human-shorebird interactions.

We additionally considered the potential for the nourishment projects to avoid the loss or degradation of wetlands, including consideration of sand spreading. We did not identify vulnerable wetland area within the project's area of influence.

All considered, the beach nourishment activities at Fenwick Island are not expected to harm ecological resources; however, the benefits are uncertain, as described in Section 2.3. While there is likely some contribution to the long-run objective of maintaining coastal habitats, we characterize the level of ecological benefits from the nourishment activities at Fenwick Island as limited relative to the infrastructure resilience, recreation value, and tourism impact benefits. As described in Chapter 2, the ecological benefit is wholly attributed to the state.

14.4 Design Alternatives and Cost Estimates for Fenwick Island

We identified two potential nourishment alternatives for Fenwick Island (Table 14-5). The first alternative spans roughly 5,500 feet from King Street in the north to the Delaware/Maryland state border. The second alternative spans 6,500 feet and spans from the Bethany-Fenwick Area Chamber of Commerce in the north to 146th Street.

Alternative 2 is significantly more costly than Alternative 1 because it requires substantially more sand per year despite a less frequent renourishment interval.

The results presented in this chapter are based on the alternative consisting of two smaller nourishment sites. Full results for both nourishment alternatives are available in Appendix B. Differences in the magnitude of benefits provided by the different alternatives are modest and do not influence the cost share results. This is primarily because average beach width over the 30-year analysis timeframe is similar, despite year-to-year variation in beach width between alternatives.

Table 14-5. Nourishment alternatives at Fenwick Island

Nourishment alternative	Fill volume (cubic yards)*	Renourishment interval (years)	Cost (30-year present value)	Cost (annualized)
1	240,000	5	$36 million	$1.6 million
2	440,000	6	$50 million	$2.2 million

Present value is derived by aggregating costs over the 30-year analysis timeframe using a 2 percent discount rate. We annualize the present value, again using a 2 percent rate. This is necessary because the costs occur at irregular intervals over the 30-year analysis timeframe. All numbers are rounded to two significant figures.

*Initial fill volumes for Alternatives 1 and 2 are 300,000 cu yds and 600,000 cu yds, respectively.

CHAPTER 15 | Social Vulnerability Assessment

Social vulnerability refers to the susceptibility of human populations to harm or adverse effects from external stresses, such as climate change and coastal storm events or economic disruptions. Social vulnerability may be influenced by factors such as poverty, health, race, age, education level, and access to services. In essence, social vulnerability highlights how existing social inequalities can amplify the impact of stressors on certain populations.

The goal of this social vulnerability assessment is to characterize, for each of the beach communities that may be expected to share in the costs of future beach nourishment projects, factors influencing their social vulnerability to:

- experiencing adverse effects of coastal storms, and
- the cost burden of storm protection efforts.

This chapter provides our findings regarding the factors that contribute to social vulnerability. The detailed data referenced for this analysis are provided in Appendix C. The data and analyses presented in this chapter and Appendix C are intended for consideration by decisionmakers alongside the economic benefits assessment and resulting equitable cost share recommendations.

15.1 Summary of Findings

For the beach communities included in this analysis, available data suggest that social vulnerability is most significantly driven or amplified by the relative predominance of residents over 65. In the aggregate, the population age structure of these communities is markedly skewed towards older cohorts compared to county- and state-wide populations, with some variability across communities. In particular, in Slaughter Beach, Lewes, Bethany Beach, South Bethany, and Fenwick Island, more than half of residents are aged 65 and over.

Age-related vulnerability measures conventionally focus on populations aged 65 years and older – the age at which Social Security contributions have historically been distributed, along with federal healthcare benefits and private pensions. In our study populations, there are also substantial relative populations of individuals aged 55 to 64 years who are likely to age in place (i.e., remain in their home and/or community as they age) which may lead to increasing social vulnerability over time. Populations in these communities are also more likely to experience health conditions such as disability, cancer, and heart disease. These rates are likely correlated with the presence of relatively larger populations of older individuals.

Other factors that contribute to population-level social vulnerability include historically overburdened and underserved populations, such as people of color and low-income populations. We do not find that these are factors that disproportionately contribute to social vulnerability of the beach community populations, as a whole, in our analysis. However, potentially vulnerable populations of color are present in the communities of interest, most notably in Lewes. Additionally, Dewey Beach and Slaughter Beach have slightly higher rates of potentially vulnerable low-income residents compared to the broader state population.

The beach nourishment projects reduce storm-related infrastructure damage and the likelihood of displacement due to storm events or coastal erosion. As noted, the beach communities are not disproportionately characterized by low-income status, meaning that in the aggregate, residents are not particularly likely to have insufficient resources to contribute to a cost share for the beach nourishment projects. While the financial aspect of vulnerability is not pronounced in these populations, the age-related challenges still make the population socially vulnerable in emergencies. The ability to pay a cost share mitigates some risks but does not entirely remove their heightened vulnerability due to age.

15.2 Overview and Approach

The social vulnerability of a community is related to the community's exposure to a stressor, sensitivity to that stressor, and capacity to respond to stressor-induced changes. Examples of community-wide stressors include natural hazards and public health crises, among others (CDC 2024, FEMA 2024a). The nature and extent of a community's sensitivity to a given stressor and that community's resilience in the face of stress may depend on various population characteristics, including demographics (population size, age, race, and ethnicity); health disparities (e.g., prevalence of disabilities or chronic illnesses); and socioeconomics (e.g., income, educational attainment, and public benefits). These characteristics may interact with other community characteristics, such as structural vulnerability (e.g., the vulnerability of buildings or roads to hazard impacts due to building materials, structure grades, etc.) and physical vulnerability (e.g., how a population's location may influence the risk of exposure to potential threats (NCCOS 2023).

This analysis examines, for each beachfront community of interest, relevant demographic, health/healthcare, socioeconomic, and housing characteristics, relying primarily on recent data from the U.S. Census Bureau, including the 2020 decennial census and American Community Survey (ACS) five-year estimates. The analysis also considers several indices that seek to measure social vulnerability, resilience, and environmental risks (see Table 15-1 below). In addition to quantitative metrics related to social vulnerability and resilience, qualitative information is considered where appropriate to account for the unique histories of individual beaches and communities and cultural meanings associated with specific places.

Table 15-1. Community Characteristics Considered in the Social Vulnerability Analysis

Category	Characteristic	Data Source
Demographic	Total population	2020 Decennial Census
	Population of color (i.e., Hispanic and/or non-white)	2020 Decennial Census
	Population 65 or older	2022 ACS 5-Year Estimates (2018-2022)
Health and Access to Healthcare Facilities	Percentage of population 65 or older with one or more disabilities	DE-PLANs
	Health conditions percentiles	US EPA 2015
	Distance to nearest hospital, urgent care, and EMS/paramedic station	Google Earth
Socioeconomic	Population with annual income below federal poverty level	2022 ACS 5-Year Estimates
	Households receiving social security income	2022 ACS 5-Year Estimates
	Population with Medicare, Medicaid, or means-tested public health insurance coverage	2022 ACS 5-Year Estimates
	Population with less than high school diploma or equivalent	2022 ACS 5-Year Estimates
Housing	Total households	2020 Decennial Census
	Vacant households	2020 Decennial Census
Vulnerability Indices	Social Vulnerability Index	CDC/ATSDR
	National Risk Index	FEMA

15.3 Community-Level Assessment

This section describes key factors related to social vulnerability of the affected populations, including population demographics, health and healthcare access, socioeconomic characteristics, and housing occupancy. Detailed community profiles are included in Appendix C.

15.3.1 Demographic Characteristics

As summarized in Table 15-2, cross all communities, a large proportion of the population consists of individuals aged 65 years or over. While about 19.6 percent of the population is at least 65 years old across Delaware as a whole, the proportion is at least double that in every community of interest other than Dewey Beach, which is only slightly lower at 36.8 percent. Proportionally, the largest populations of individuals aged 65 and over are found in the southernmost communities, South Bethany (62.7 percent) and Fenwick Island (66.4 percent) (2022 ACS 5-Year Estimates).

Though less pronounced, the five communities on the Atlantic Coast – Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany, and Fenwick Island – also exhibit larger populations over 65, particularly in the latter three communities, which are nearest to the Maryland border. The northernmost communities, Pickering Beach and Kitts Hummock, were the only two communities with a lower proportion of elderly residents than the state (5-Year ACS 2022). These patterns might be explained by data limitations, at least in part; these communities exist within a geographically large census tract (Tract 432.02) that also includes several inland communities near Dover, which is the second most populous city in Delaware and thus has an outsized impact on average state demographics.

Older populations (i.e., age 60 years and up) generally experience increased social vulnerability due to a variety of compounding factors (Andrew et al. 2008, Abeliansky et al. 2021). These factors include increases in social isolation and health deficits as people age. Increased social vulnerability may amplify the impacts of environmental hazards for older populations. In the immediate aftermath of a hazardous event, the social vulnerability of older populations may reduce their ability to move to safer locations, obtain assistance, or access emergency care. In the longer term, social vulnerability may contribute to reduced access to healthcare, disrupted social connections, and the physical and cognitive challenges of extended displacement or damage to housing and infrastructure.

Compared to the rest of the state, the 13 communities have notably small populations of color (i.e., individuals *other* than those identified in census data as White Alone, not Hispanic or Latino). In the communities of interest, the share of residents who identify as persons of color range from 2.4 to 22.2 percent, while the statewide proportion is 41.4 percent. However, potentially vulnerable populations of color are present within the beachfront communities, with Lewes (365 individuals) having the largest of these populations.

The skew towards White Alone, non-Hispanic or Latino residents is concentrated among communities along the Atlantic Coast; though the bay communities also tended to have fewer Hispanic and/or non-white residents than the state, the populations of color in Atlantic Coast communities never hit above seven percent of the total population. Slaughter Beach, where residents of color make up only five percent of total residents, was the only Cape Region community with a percentage below seven percent. Cape Shores, a luxury housing development in Lewes, had an exceptionally low percentage of residents of color, falling somewhere between 1.1 and 2.4 percent.

Table 15-2. Demographic Characteristics

Community	Total population	Population of color	Population 65 or older
Pickering Beach	29	6 (20.7%)	206 (16.6%)**
Kitts Hummock	275	61 (22.2%)	206 (16.6%)**
Bowers	278	40 (14.4%)	144 (42.9%)
South Bowers	39	4 (10.3%)	180 (34.6%)**
Slaughter Beach	218	11 (5.0%)	633 (54.2%)
Broadkill Beach	392	44 (11.1%)	n/a
Lewes	3,303	365 (11.1%)	1,886 (56.5%)
Cape Shores	94–207	1–5 (1.1–2.4%)	n/a
Rehoboth Beach	1,108	77 (6.9%)	633 (46.6%)
Dewey Beach	353	22 (6.2%)	132 (36.8%)
Bethany Beach	954	59 (6.2%)	592 (55.6%)
South Bethany	451	11 (2.4%)	307 (62.7%)
Fenwick Island	343	22 (6.4%)	232 (66.3%)
Communities of Interest Total	*7,743*	*722 (9.3%)*	*4,945 (63.9%)*
Delaware	*989,948*	*410,097 (41.4%)*	*195,016 (19.6%)*

* Data only available at census tract level
** Data only available at census block group level

15.3.2 Health/Healthcare Characteristics

Overall, the communities of interest tend to have higher concentrations of individuals with health-related risk factors than the state overall (Table 15-3). Whereas only 5.5 percent of Delaware's population is 65 or older with one or more disabilities, the census tracts containing the communities examined in this study had percentages ranging from 15.51 percent (Fenwick Island) to 29.87 percent (Pickering Beach, Kitts Hummock, Bowers, and South Bowers). To some extent, this trend is expected to reflect the generally high proportion of elderly population in these communities. However, for certain communities, the number of residents aged 65 and up with at least one disability is disproportionately high relative to the total number of residents in the same age group (i.e., regardless of disability status). Pickering Beach and Kitts Hummock, for example, have a relatively low percentage of elderly residents at 16.6 percent, but have the highest percentile of individuals with disabilities (72nd percentile nationally) compared to all other communities examined. This indicates that a comparatively large number of elderly individuals may also have at least one disability, amplifying their social vulnerability.

The communities of interest also consistently have a higher proportion of individuals with health conditions such as heart disease and cancer than the U.S. as a whole. This trend may primarily reflect the concentrations of older individuals in these communities, given that these conditions are far more prevalent among individuals aged 65 and over (CDC/NCHS 2023). Cancer risk is particularly high in these populations, among which all except Pickering Beach and Kitts Hummock are above the 90th percentile nationally.

Asthma rates are not particularly high in these beach communities except for Bowers and South Bowers, where asthma rates are in the 84th percentile nationally. There may be other environmental stressors in these communities, since asthma prevalence in adults does not increase with age (CDC/NCES 2023). Populations in most of the analyzed communities generally do not experience low life expectancy, with two exceptions: Pickering Beach and Kitts Hummock are in the 85th percentile nationally for low life expectancy.

Table 15-3. Health/Healthcare Characteristics

Community	Percentage of population 65 or older with one or more disabilities*	Health conditions percentiles**	Driving distance to nearest... (miles)		
			Hospital	Urgent Care	EMS/ Paramedic Station
Pickering Beach	29.87%	Low life expectancy (85th), heart disease (86th), cancer (67th), individuals with disabilities (72nd)	10.9	8.6	9.0
Kitts Hummock			9.6	8.2	7.2
Bowers	29.87%	Low life expectancy (85th), heart disease (86th), asthma (84th), cancer (67th), individuals with disabilities (72nd)	14.2	12.5	11.9
South Bowers			22.0	19.1	19.7
Slaughter Beach	27.75%	Heart disease (74th), cancer (92nd), individuals with disabilities (68th)	7.1	10.1	8.6
Broadkill Beach	18.38%	Heart disease (64th), cancer (93rd)	13.4	11.3	6.2
Lewes	20.38%	Heart disease (82nd), cancer (97th), individuals with disabilities (62nd)	0.3	2.0	11.5
Cape Shores	n/a	n/a	0.3	2.0	11.5
Rehoboth Beach	15.48%	Heart disease (86th), cancer (99th)	7.2	6.2	5.0
Dewey Beach	18.15%	Heart disease (74th), cancer (97th), individuals with disabilities (64th)	7.5	6.6	5.2
Bethany Beach	23.93%	Heart disease (95th), cancer (99th), individuals with disabilities (63rd)	18.5	5.6	3.2
South Bethany	17.63%	Heart disease (97th), cancer (99th), individuals with disabilities (70th)	20.0	3.7	3.6
Fenwick Island	15.51%	Heart disease (95th), cancer (99th), individuals with disabilities (64th)	17.0	7.4	4.8
Delaware	*5.54%*	*n/a*	*n/a*	*n/a*	*n/a*

* Data only available at census tract level
** Data only available at census block group level

15.3.3 Socioeconomic Characteristics

Residents in the communities of interest are generally less likely to have low incomes (i.e., below the federal poverty line) or rely on means-tested public healthcare plans such as Medicare or Medicaid than the population of Delaware as a whole. Only Dewey Beach (13.1 percent of the total population) and Slaughter Beach (12.2 percent) have higher rates of low-income residents than the state (11.1 percent). Those communities with the smallest proportions of low-income residents are along the Atlantic Coast, including South Bethany (5.3 percent), Rehoboth Beach (4.6 percent), Bethany Beach (2.6 percent), and Fenwick Island (1.1 percent). However, income data are not available for the communities with the fewest residents; these are Pickering Beach, Kitts Hummock, South Bowers, and Cape Shores.

Bowers and Broadkill Beach both have a higher percentage of residents receiving means-tested public health insurance coverage than the state (37.7 and 23.0 percent, respectively, compared to 21.1 percent for the state).

All the communities of interest have higher educational attainment (i.e., proportion of population with at least a high school diploma or equivalent) than the state. In Delaware as a whole, 8.8 percent of the population has not attained a high school diploma or equivalent, compared to Bowers (7.3 percent), Lewes (6.3 percent), and Broadkill Beach (5.7 percent); the other communities range from 0.3 to 4.5 percent. Again, these statistics are not available for Pickering Beach, Kitts Hummock, South Bowers, or Cape Shores.

Between 43.3 and 70.6 percent of residents in each beach community receive Social Security income, representing universally higher proportions than the state (35.9 percent). The largest of these are in Fenwick Island (70.6 percent), Bethany Beach (69.5 percent), South Bethany (68.9 percent), and Lewes (65.9 percent).

Table 15-4. Socioeconomic Characteristics

Community	Population with annual income below federal poverty level	Households receiving social security income	Population with Medicare, Medicaid, or means-tested public health insurance coverage	Population with less than high school diploma or equivalent
Pickering Beach	n/a	220 (44.4%)**	n/a	n/a
Kitts Hummock	n/a	220 (44.4%)**	n/a	n/a
Bowers	34 (10.1%)	76 (55.9%)	57 (37.7%)	21 (7.3%)
South Bowers	n/a	107 (45.9%)**	n/a	n/a
Slaughter Beach	48 (12.2%)	100 (43.3%)	24 (14.1%)	13 (3.9%)
Broadkill Beach	223 (5.9%)	839 (48.8%)	461 (23.0%)	171 (5.7%)
Lewes	184 (5.8%)	1,049 (65.9%)	181 (14.7%)	193 (6.3%)
Cape Shores	n/a	n/a	n/a	n/a
Rehoboth Beach	62 (4.6%)	379 (49.5%)	76 (11.9%)	4 (0.3%)
Dewey Beach	47 (13.1%)	100 (51.5%)	31 (15.0%)	13 (4.0%)
Bethany Beach	28 (2.6%)	363 (69.5%)	52 (12.1%)	16 (1.7%)
South Bethany	26 (5.3%)	208 (68.9%)	9 (5.0%)	2 (0.4%)
Fenwick Island	4 (1.1%)	139 (70.6%)	6 (5.8%)	15 (4.5%)
Delaware	*107,790 (11.1%)*	*139,461 (35.9%)*	*119,654 (21.1%)*	*61,344 (8.8%)*

* Data only available at census tract level
** Data only available at census block group level

15.3.4 Housing Occupancy

A housing unit is categorized as "vacant" by the U.S. Census Bureau when it has "no one living in it at the time of the interview, unless its occupants are only temporarily absent" or when it "is entirely occupied by persons who have a usual residence elsewhere" (U.S. Census Bureau 2024). Vacancy statistics may reflect several situations, including the use of housing units as second homes, housing that is for sale, or short-term rental properties (STRs).

Nearly all of the beach communities have high rates of vacancy (Table 15-5). The vacancy rate for Delaware (14 percent) is significantly lower than most of these communities, which have a median vacancy rate of about 74 percent. Communities in the Atlantic Coast region have a particularly high vacancy rate; in Dewey Beach and Bethany Beach, over 80 percent of housing units are classified as vacant. A notable exception to this pattern is Kitts Hummock, where only 26 of 163 housing units (16 percent) are vacant.

Table 15-5. Housing Characteristics

Community	Total housing units	Vacant housing units
Pickering Beach	38	18 (47%)
Kitts Hummock	163	26 (16%)
Bowers	231	100 (43%)
South Bowers	44	26 (59%)
Slaughter Beach	261	139 (53%)
Broadkill Beach	685	512 (75%)
Lewes	3,085	1,413 (46%)
Cape Shores	145–502	103–387 (71–77%)
Rehoboth Beach	3,081	2,457 (80%)
Dewey Beach	1,468	1,286 (88%)
Bethany Beach	2,564	2,044 (80%)
South Bethany	1,258	1,012 (80%)
Fenwick Island	715	536 (75%)
Delaware	*448,735*	*62,360 (14%)*

* Data only available at census tract level
** Data only available at census block group level

15.4 Vulnerability Indices

Vulnerability indices combine multiple statistics measures to provide additional insight into vulnerability conditions surrounding the beach communities, although these measures are not specific to individual communities. The Social Vulnerability Index (SVI), produced by the Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR), measures overall social vulnerability at the census tract level (Figure 15-1). Public health officials and local planners use the place-based indices, database, and maps to prepare for and reduce human suffering, economic loss, and health inequities associated with community-wide crises (ATSDR/CDC 2024). As shown in Figure 15-1 below, this measure combines variables in four categories: socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation; it thus reflects characteristics such as poverty, educational attainment, age, disability status, race, ethnicity, among others. The SVI Index can be interpreted as a percentile; for example, a census tract with an SVI of 0.75 is more socially vulnerable than 75 percent of census tracts in the state (ATSDR/CDC 2024).

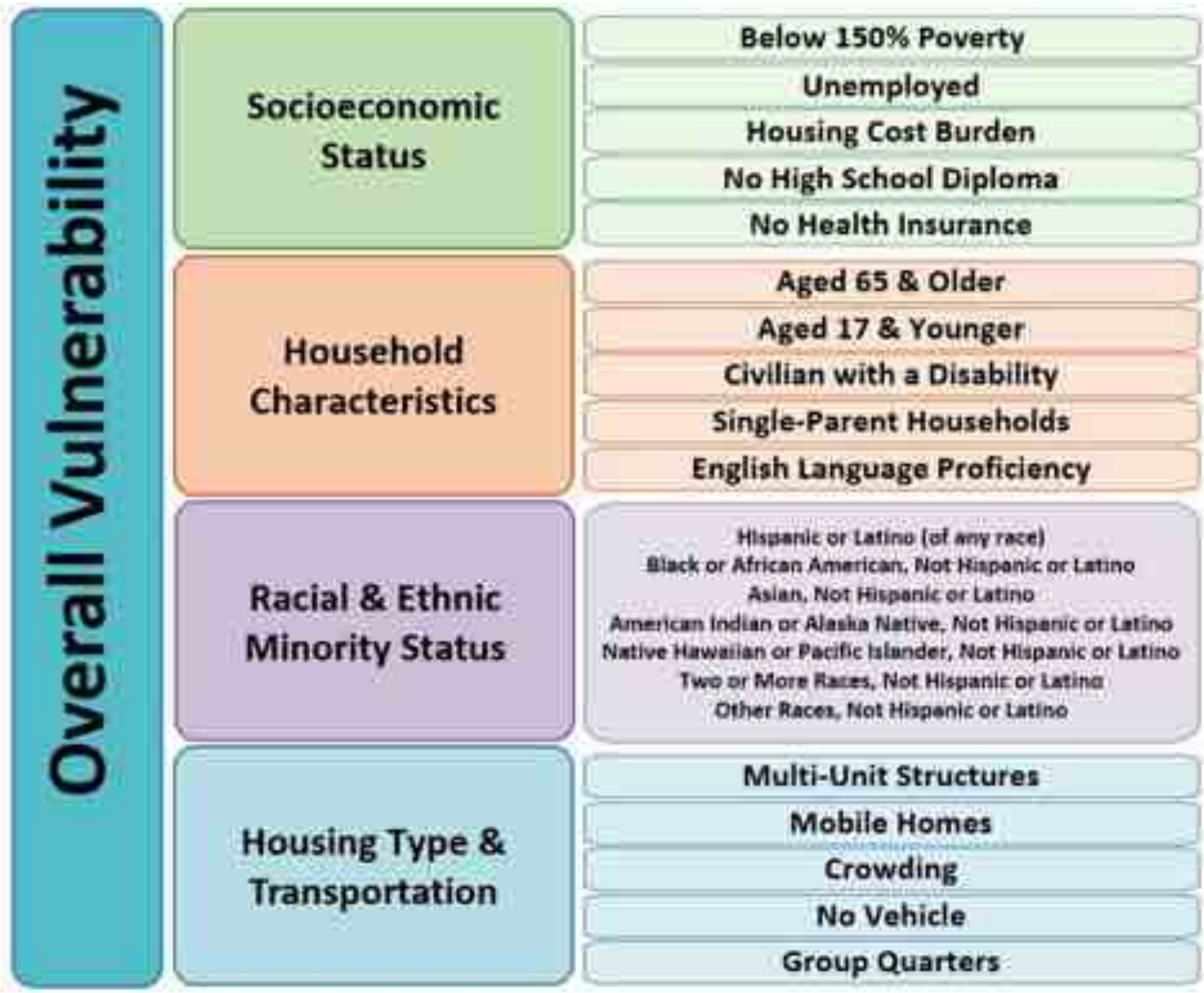


Figure 15-1. Social Vulnerability Index Variables (ATSDR/CDC 2024)

The National Risk Index (NRI), maintained by the Federal Emergency Management Agency (FEMA), measures a population's exposure to risk from various natural hazards relative to the United States as a whole. The NRI considers SVI scores, resilience indicators, and expected annual losses due to natural hazards (FEMA 2024b).

Both SVI and NRI measures tend to indicate increasing vulnerability moving from south to north along the coast (Table 15-6). The northernmost communities – Pickering Beach, Kitts Hummock, Bowers, and South Bowers – are within a tract with an SVI score of 0.5176, the highest relative to the other communities and higher than Delaware as a whole. It should be noted that bay communities like Pickering Beach and South Bowers are extremely small and are represented by a census tract that also encompasses many other communities, including some nearer to Dover. Fenwick Island stands out among the southern Atlantic Coast communities for being in an area with relatively high SVI (0.2196) and NRI (14.17) scores.

Table 15-6. Vulnerability Indices

Community	Social Vulnerability Index*	National Risk Index*
Pickering Beach†	0.5176	47.48
Kitts Hummock†		
Bowers†		
South Bowers†		
Slaughter Beach	0.4118	41.46
Broadkill Beach	0.2379	31.51
Lewes	0.3041	26.35
Cape Shores	n/a	n/a
Rehoboth Beach	0.1777	12.89
Dewey Beach	0.2062	11.53
Bethany Beach	0.0704	5.11
South Bethany	0.0941	8.31
Fenwick Island	0.2196	14.17
Delaware	*0.5000*	*50.00*

* Data only available at census tract level.

† Pickering Beach, Kitts Hummock, Bowers, and South Bowers are located within the same census tract.

We also considered the DNREC Environmental Justice (EJ) Area Viewer tool, which provides data on several measures of demographic, social, and environmental factors that may influence social vulnerability.[65] These measures include Justice40 Tracts, EJScreen indices, DelDOT Equity Focus Areas, and Limited English Neighborhoods. In general, the measures presented by the EJ Area Viewer tool generally do not highlight increased social vulnerability within the beachfront communities of interest.

The EJ Area Viewer tool indicates that none of the tracts containing the beachfront communities of interest is identified as disadvantaged according to Justice40 Initiative criteria. At the block group level, none of the block groups containing the beachfront communities exceed EJScreen's primary or supplemental EJ indices. Bowers Beach is within a larger neighborhood group identified as a moderate-level Equity Focus Area, due to a population with low median incomes compared to the state as a whole. However, this Equity Focus Area encompasses multiple communities, and the incomes of Bowers Beach residents cannot be distinguished from those of other residents in the Equity Focus Area. Finally, Limited English Neighborhoods are defined based on the percentage of residents who speak a primary language other than English at home. Within the beachfront

[65] The DNREC EJ Area Viewer tool is available at: https://dnrec.delaware.gov/environmental-justice/data/

communities, only an inland portion of Bethany Beach in which 16.5 per cent of the population speaks a non-English language at home is identified as a Limited English Neighborhood. In summary, the measures presented by the EJ Area Viewer tool generally do not highlight increased social vulnerability within the beachfront communities of interest.

APPENDIX A | Answers to Common Questions

What was the impetus for this analysis to be completed?

DNREC is authorized by the legislature to administer the shoreline management program. The shoreline management program saw this as a potential research question to inform future funding options given rising costs. Cost share is only one potential avenue for future funding, and other cost reduction measures have already been and will continue to be considered and integrated. DNREC will also continue to ask for the state funding needed to complete nourishment projects.

Will this study affect current nourishment projects?

No, this study will be completed in parallel with currently planned nourishment projects.

Who will be expected to pay?

This study is not the only information to be considered in developing a future policy. The study provides relevant insight regarding who benefits from the beach nourishment projects and to what extent. This study identifies the benefiting groups and quantifies the share of nourishment benefits they receive, but does not make recommendations regarding specific payment or funding mechanisms. We recognize that there are other factors that require consideration in the development of a cost share policy.

How would this cost share be implemented?

This study does not examine how a cost share policy or program may be implemented. The cost share recommendations included in this report reflect the distribution of beach nourishment benefits across benefitting populations.

How does this affect federal and non-federal cost shares?

This study does not affect federal contributions to beach nourishment project costs in Delaware. Any cost sharing policy developed from the results of this study would apply only to non-federal cost shares (currently borne by the state). It is not a novel concept that local populations and municipalities contribute to the costs of beach nourishment projects. Historically, beach nourishment efforts have often been funded through a combination of federal, state, and local resources, with local governments and communities contributing. This shared responsibility reflects the significant local benefits of these projects. For example, New Jersey cost shares the non-federal portion 75% state and 25% sub-state, and Maryland's non-federal costs are shared 50% state, 25% county, 25% city. Florida additionally includes a local cost share in funding beach nourishment projects.

How would this affect current easements and public access to beaches?

As funding is still (and will continue to be) provided by federal and state sources, public access will still be required on all beaches nourished with public funding. If a cost share is ultimately recommended for implementation, existing easements and other policies and agreements will require consideration.

Why is only beach nourishment being examined as an option for sustainable shorelines?

The study focuses on sites where beach nourishment has traditionally been used as a means of shoreline management. The analysis considers historical and potential future beach nourishment plans and designs at these sites. Some formally proposed alternatives that do include terminal groins are being examined as options. However, the focus of this particular study was not to optimize shoreline protection or identify alternative engineering approaches or managed retreat options. Many DNREC staff and others continue to address all aspects of coastal resilience as separate efforts outside of this study.

Does this analysis include costs to coastal communities of maintaining the beaches?

We recognize towns already do a lot to manage and maintain these beaches and recreational sites, including providing staffing and maintaining parking. The focus of the study is on evaluating how different groups (including coastal towns) benefit from the beach nourishment projects over the 30-year timeframe of the study.

Does this analysis address other coastal resiliency issues facing communities, such as flooding from the back bays?

This analysis is focused exclusively on the benefits of beach nourishment as a means to isolate the specific benefits associated with those projects. The study results do reflect that back bay flooding contributes to the level of flooding experienced by some structures during storm events. The coastal process modeling generally found, however, that beach nourishment has a negligible effect on flooding that occurs through this pathway. DNREC will continue to work with communities to address other coastal resiliency issues such as back bay flooding.

Why does the analysis use a 30-year timeframe? What are the implications for identifying benefits of beach nourishment?

The benefits of nourishment projects are dynamic over time as the placed sand establishes equilibrium and reacts to episodic events. As a result, focusing on a single year could produce biased results. In addition, our analysis considers various nourishment alternatives with differing design lives. To compare across alternative designs, it is necessary to consider a period comprised of multiple nourishment cycles. Our choice to bound the analysis 30 years into the future reflects an acknowledgement of increasing uncertainty over time. The benefits of beach nourishment depend on both natural and economic factors that become increasingly difficult to forecast, such as the timing and intensity of future storms, projected sea level rise, the extent of coastal development, preferences for beach recreation, and tourist spending patterns. For example, coastal communities may undertake adaptive measures (e.g., raising more properties) that would influence the magnitude of infrastructure resilience benefits.

The 30-year timeframe represents a reasonable balance between the competing factors described above, but it potentially precludes some benefits that may accrue over longer time periods. For example, over longer periods nourishment may have a more significant effect on wetland protection by reducing the likelihood of dune breaches on Delaware Bay, it may become more important for supporting coastal habitats, and it can reduce the required volume of future nourishment projects by enhancing the overall sediment budget. At the same time, we do not expect that including these types of benefits would have a meaningful impact on results due to the magnitude of the primary benefits and the effect of discounting on future benefits.

Does this analysis incorporate sea level rise?

Yes. The 30-year projected shoreline position accounts for expected sea level rise over this period. The sea level rise projections are consistent with those commonly used in other state and federal analyses. See Section 2.1.1 for more details.

Does this analysis consider that areas outside of where the sand is placed (for example, neighboring communities) receive some of the benefits from nourishment?

Yes. The coastal process modeling, which informs the benefits analysis, accounts for expected alongshore sand spreading over time. This transport of material into other adjacent areas can result in avoided storm damage and recreational benefits in neighboring communities. Generally speaking, the analysis finds that sand spreading does not result in significant benefits outside the original placement area for projects on the Delaware Bay beaches due to the relatively low nourishment volumes for those projects and the isolated nature of the communities. For projects on the Atlantic coast, however, we find that alongshore sand spreading does generate benefits to adjacent communities. In these cases, we indicate the portion of local benefits accruing to each jurisdiction within the project-specific results chapters of this report.

More complex sediment transport dynamics that may occur over greater timeframes and spatial scales requires more detailed assessment of multiple nourishment cycles and more advanced coastal processes modeling, which is beyond the scope of this analysis. For example, DNREC is developing a comprehensive sediment budget to better understand the accretion that has been observed at Cape Henlopen. While it is likely that past (and future) nourishments along the Atlantic coast contribute sediment, it is not clear that Cape Henlopen would be eroding in the absence of these nourishment projects. It is most likely that Cape Henlopen would continue to accrete even absent the nourishment projects due to the dominant net south to north transport along this stretch of the Atlantic Delaware coastline. As such, there are diminishing benefits associated with additional sediment delivered to beaches that are growing over time regardless. As a result, the nourishment projects are unlikely to provide a meaningful benefit to Cape Henlopen in spite of its popularity among recreators. Nourishment is most likely to produce benefits along portions of the coastline that are sand limited and vulnerable to erosion, such as communities adjacent to Rehoboth, Dewey, Bethany, South Bethany, and Fenwick Island beaches.

Does this analysis consider protection of public infrastructure, such as roads and wastewater treatment plants?

The analysis considers all types or infrastructure, both public and private, and is not limited to residential and commercial buildings. The results of the coastal process modeling identify the area over which nourishment has an effect on long-term shoreline change, episodic erosion, flooding, and wave energy. The benefits analysis subsequently identifies all infrastructure within the affected area, including public infrastructure.

Does this analysis consider impacts to agriculture, such as saltwater intrusion?

We considered whether agricultural land or buildings may benefit from the nourishment projects. However, the analysis finds that the area over which the nourishment projects reduce flooding, wave energy, and erosion does not overlap with agricultural land or assets.

Delaware faces a real threat from saltwater intrusion onto agricultural lands and into groundwater aquifers; however, the nourishment projects we evaluated are not expected to have a meaningful effect on mitigating this threat of salinity intrusion into freshwater aquifers. A recent study estimated that 3,824 hectares (approximately 9,500 acres) of agricultural land in Delaware converted to marsh between 2011 and 2017, and an additional 55,511 hectares (approximately 140,000 acres) may be at risk (Mondal et al., 2023). As described in the study, saltwater intrusion is driven by a combination of factors: natural sea-level variability, sea-level rise, land subsidence, drought, storm surge, connectivity of the landscape, and groundwater extraction. While beach nourishment has the potential to influence one such factor (storm surge), the projects we evaluated are not likely to provide a meaningful reduction in risk of flooding of agricultural land.

Does this analysis consider impacts to property values?

Property values reflect the present value of a flow of services that the property is expected to provide over time. Reducing the risk of damage from coastal storms and enhancing the recreational value of a coastal property has a positive influence on these services which are theoretically reflected in the value of these properties. This analysis specifically models the influence of the beach nourishment projects on these types of benefits individually. Accordingly, separately quantifying the potential effect on property values would risk double counting. Some prior studies have used property value effects as a proxy for decreasing the risk of damage from coastal storms and enhancing recreational value. In this study we opted for the more direct and disaggregated measure in order to better answer the question regarding the distribution of benefits.

If shorefront properties are lost to erosion, there would be lost property tax revenue to the county or municipality. Should avoiding lost property tax revenue be considered a benefit of nourishment?

Property tax effects were considered but ultimately not determined to influence the cost share recommendations. While it is true that the relevant town or county would no longer collect property taxes on a shorefront property that is lost to shoreline change, it is unlikely to result in a significant net loss to the relevant jurisdiction.

The loss of property tax revenue is not likely to be a significant long-term economic effect primarily because of redevelopment and other mitigating factors. When properties are lost to erosion, other areas are developed further inland, which offsets potential declines in property tax revenue. Additionally, if the owner of a lost property relocates to a different jurisdiction, the original jurisdiction loses tax revenue but also the need to provide services to the property. In either case, the original taxing jurisdiction does not experience a net gain or loss.

The real estate market in Sussex County provides revenue to state and county governments via the real estate transfer tax. Should that tax revenue be included as a benefit of these nourishment projects?

Proximity to the coast is undoubtedly a driver of demand for residential housing in Delaware and beyond. In the continental United States, coastal counties comprise less than 10 percent of total land area but account for 39 percent of the total population.[66] The presence of sandy beaches is likely an important driver of this trend in Delaware; however, the contribution of nourishment projects over the 30-year analysis timeframe is uncertain but unlikely to significantly affect the results of the analysis with respect to the distribution of benefits. If the Atlantic coast beaches were allowed to degrade to a point where they could no longer support recreation, some potential buyers may exit the local market. However, our analysis found that the Atlantic coast beaches would not disappear within the analysis timeframe even if all nourishment activity ceased.

Are reductions in flood insurance premiums a benefit that should be included?

Actuarily fair annual insurance premiums should reflect annual expected damages. However, the effects of coastal resilience projects on flood insurance premiums are complex and not always direct. While projects such as beach nourishment can reduce flood risk and erosion in coastal areas, their effect on insurance premiums depends on a variety of factors. Resilience projects may reduce the risk of flooding in some areas, potentially leading to lower premiums if they result in updated flood maps or demonstrate a significant reduction in risk. However, the coastal properties are also affected by back bay flooding and other threats that influence insurance premiums and are not mitigated by the beach nourishment projects. If the nourishment projects do lead to a reduction in flood insurance premiums, there may be an additional benefit to the local property owners.

The recreational visitation data relied on for this study was collected over a decade ago. Has visitation changed since then?

The beach visitation data we utilized in this study come from published research utilizing rigorous and well accepted methods. However, given the timeframe the data were collected, they may not

[66] https://ecowatch.noaa.gov/thematic/coastal-population

reflect current conditions. In the course of this study, we met with multiple stakeholders to identify the best available visitation data for each beach. While we were unable to identify specific monitoring data for beach-by-beach visitation, we obtained additional pieces of information that suggested two trends: local visitation was relatively constant over the past decade, and non-local visitation had increased. As a result, we calibrated non-local visitation to account for growth over this period based on growth in tourism and statewide population.

How can nourishment at a popular Atlantic Coast beach provide "low" recreation value and/or tourism economy benefits?

The "low" level of benefit does not indicate that the beach provides a low level of recreational activity or tourism economy impacts. The "low" level refers to the influence of the beach nourishment projects on the recreational and/or tourism activity. That is, the magnitude of these benefits depends not only on how popular the beach is for recreation, but also on how nourishment alters longer-term shoreline change, which is variable by site. Some of the Atlantic coast beaches, for example, are expected to experience relatively low rates of annual erosion losses even in the absence of nourishment projects. In these cases, the nourishment projects may result in low recreation and tourism benefits in spite of high annual visitation.

How does this analysis compare to the findings contained in the recently updated "Seaside to Statewide: The Economic Contributions of Delaware's Coastal Region" (henceforth, the Coastal Economy Report)?

We reviewed The Coastal Economy Report (Rising and Wilson, 2024) and do not believe the two analyses are contradictory, although they answer different questions. The Coastal Economy Report quantifies the total statewide economic contribution of coastal industries in Delaware (e.g., tourism, real estate, fishing, agriculture, and renewable energy). Our report evaluates how beach nourishment projects at specific beaches within the state benefit people and the economy. With respect to evaluating regional economic contributions, the two reports employ similar methods and models. Both studies consider direct, indirect, and induced economic effects using a Multiregional Input-Output model within IMPLAN. However, the two studies address fundamentally different questions. The Coastal Economy Report found that coastal activities in Delaware contribute $10.4 billion in value added to the statewide economy. Our analysis found that out-of-state visitors (i.e., recreators) to the beaches included in our study contribute $1.1 billion in value added to the statewide economy, a portion of which is supported by nourishment. The larger number in the Coastal Economy Report reflects contributions to the economy of marine- and coastal-dependent industries and activities that we did not find were significantly affected by the nourishment projects (e.g., fishing, agriculture, and renewable energy).

APPENDIX B | Complete Benefit and Cost Share Results

B.1 Pickering

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$0	$339,551	$339,551
	2	Quantified Benefit	$0	$0	$0	$0	$0	$339,551	$339,551
	3	Quantified Benefit	$0	$0	$0	$0	$0	$135,722	$135,722
	4	Quantified Benefit	$0	$0	$0	$0	$0	$367,630	$367,630
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$18,908	$26,674	$0	$0	$0	$14,275	$59,857
	2	Quantified Benefit	$18,908	$26,674	$0	$0	$0	$14,275	$59,857
	3	Quantified Benefit	$16,254	$22,931	$0	$0	$0	$12,272	$51,457
	4	Quantified Benefit	$20,874	$29,448	$0	$0	$0	$15,760	$66,082
	1	Distribution of Benefit	**0.00**	**0.65**	**0.00**	**0.00**	**0.00**	**0.35**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.65**	**0.00**	**0.00**	**0.00**	**0.35**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.65**	**0.00**	**0.00**	**0.00**	**0.35**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.65**	**0.00**	**0.00**	**0.00**	**0.35**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$9,298	$95,041	$0	$0	$0	$104,339
	2	Quantified Benefit	$0	$9,298	$95,041	$0	$0	$0	$104,339
	3	Quantified Benefit	$0	$7,996	$81,742	$0	$0	$0	$89,738
	4	Quantified Benefit	$0	$10,267	$104,955	$0	$0	$0	$115,223
	1	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.65	0.00	0.00	0.00	0.35
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.65	0.00	0.00	0.00	3.35
Cost Share	**1.00**	**0.33**	**0.00**	**0.00**	**0.00**	**0.67**

ALTERNATIVE 2		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.65	0.00	0.00	0.00	0.35
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.65	0.00	0.00	0.00	3.35
Cost Share	**1.00**	**0.33**	**0.00**	**0.00**	**0.00**	**0.67**

ALTERNATIVE 3		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.65	0.00	0.00	0.00	0.35
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.65	0.00	0.00	0.00	3.35
Cost Share	**1.00**	**0.33**	**0.00**	**0.00**	**0.00**	**0.67**

ALTERNATIVE 4		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.0	0.0	0.0	0.0	3.0
Recreation	1	0.7	0.0	0.0	0.0	0.3
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	5.00	1.65	0.00	0.00	0.00	3.35
Cost Share	**1.00**	**0.33**	**0.00**	**0.00**	**0.00**	**0.67**

B.2 Kitts Hummock

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$139	$0	$0	$445,541	$445,681
	2	Quantified Benefit	$0	$0	$139	$0	$0	$445,541	$445,681
	3	Quantified Benefit	$0	$0	$141	$0	$0	$255,909	$256,050
	4	Quantified Benefit	$0	$0	$126	$0	$0	$445,345	$445,471
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$16,851	$9,067	$0	$0	$0	$16,530	$42,448
	2	Quantified Benefit	$16,851	$9,067	$0	$0	$0	$16,530	$42,448
	3	Quantified Benefit	$13,470	$7,248	$0	$0	$0	$13,213	$33,930
	4	Quantified Benefit	$18,149	$9,765	$0	$0	$0	$17,803	$45,717
	1	Distribution of Benefit	**0.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$5,150	$52,640	$0	$0	$0	$57,790
	2	Quantified Benefit	$0	$5,150	$52,640	$0	$0	$0	$57,790
	3	Quantified Benefit	$0	$4,115	$42,061	$0	$0	$0	$46,176
	4	Quantified Benefit	$0	$5,544	$56,667	$0	$0	$0	$62,210
	1	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.35	0.00	0.00	0.00	0.65
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.35	0.00	0.00	0.00	3.64
Cost Share	**1.00**	**0.27**	**0.00**	**0.00**	**0.00**	**0.73**

ALTERNATIVE 2		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.35	0.00	0.00	0.00	0.65
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.35	0.00	0.00	0.00	3.64
Cost Share	**1.00**	**0.27**	**0.00**	**0.00**	**0.00**	**0.73**

ALTERNATIVE 3		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	1	0.35	0.00	0.00	0.00	0.65
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	5.00	1.35	0.00	0.00	0.00	3.64
Cost Share	**1.00**	**0.27**	**0.00**	**0.00**	**0.00**	**0.73**

ALTERNATIVE 4		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.0	0.0	0.0	0.0	3.0
Recreation	1	0.4	0.0	0.0	0.0	0.6
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	5.00	1.35	0.00	0.00	0.00	3.64
Cost Share	**1.00**	**0.27**	**0.00**	**0.00**	**0.00**	**0.73**

B.3 Bowers

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$75	$0	$2,917	$80,952	$83,945
	2	Quantified Benefit	$0	$0	$75	$0	$2,917	$80,952	$83,945
	3	Quantified Benefit	$0	$0	$75	$0	$2,917	$80,952	$83,945
	4	Quantified Benefit	$0	$0	$83	$0	$3,883	$81,431	$85,397
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.96**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.96**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.96**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**	**0.95**	**1.00**
Recreation Value	1	Quantified Benefit	$60,621	$116,582	$0	$0	$0	$80,699	$257,902
	2	Quantified Benefit	$60,621	$116,582	$0	$0	$0	$80,699	$257,902
	3	Quantified Benefit	$60,621	$116,582	$0	$0	$0	$80,699	$257,902
	4	Quantified Benefit	$62,285	$119,781	$0	$0	$0	$82,913	$264,979
	1	Distribution of Benefit	**0.00**	**0.59**	**0.00**	**0.00**	**0.00**	**0.41**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.59**	**0.00**	**0.00**	**0.00**	**0.41**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.59**	**0.00**	**0.00**	**0.00**	**0.41**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.59**	**0.00**	**0.00**	**0.00**	**0.41**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$36,880	$376,992	$0	$0	$0	$413,872
	2	Quantified Benefit	$0	$36,880	$376,992	$0	$0	$0	$413,872
	3	Quantified Benefit	$0	$36,880	$376,992	$0	$0	$0	$413,872
	4	Quantified Benefit	$0	$37,895	$387,372	$0	$0	$0	$425,267
	1	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.07	1.93
Recreation	3	1.77	0.00	0.00	0.00	1.23
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	2.77	0.00	0.00	0.07	3.16
Cost Share	**1.00**	**0.46**	**0.00**	**0.00**	**0.01**	**0.53**

ALTERNATIVE 2			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.07	1.93
Recreation	3	1.77	0.00	0.00	0.00	1.23
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	2.77	0.00	0.00	0.07	3.16
Cost Share	**1.00**	**0.46**	**0.00**	**0.00**	**0.01**	**0.53**

ALTERNATIVE 3			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.07	1.93
Recreation	3	1.77	0.00	0.00	0.00	1.23
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	2.77	0.00	0.00	0.07	3.16
Cost Share	**1.00**	**0.46**	**0.00**	**0.00**	**0.01**	**0.53**

ALTERNATIVE 4			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.0	0.0	0.0	0.1	1.9
Recreation	3	1.8	0.0	0.0	0.0	1.2
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	6.00	2.77	0.00	0.00	0.09	3.13
Cost Share	**1.00**	**0.46**	**0.00**	**0.00**	**0.02**	**0.52**

B.4 South Bowers

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$0	$19,566	$19,566
	2	Quantified Benefit	$0	$0	$0	$0	$0	$19,566	$19,566
	3	Quantified Benefit	$0	$0	$0	$0	$0	$21,603	$21,603
	4	Quantified Benefit	$0	$0	$0	$0	$0	$23,069	$23,069
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$38,994	$32,089	$0	$0	$0	$11,268	$82,351
	2	Quantified Benefit	$38,994	$32,089	$0	$0	$0	$11,268	$82,351
	3	Quantified Benefit	$41,385	$34,056	$0	$0	$0	$11,959	$87,399
	4	Quantified Benefit	$41,185	$33,892	$0	$0	$0	$11,901	$86,978
	1	Distribution of Benefit	**0.00**	**0.74**	**0.00**	**0.00**	**0.00**	**0.26**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.74**	**0.00**	**0.00**	**0.00**	**0.26**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.74**	**0.00**	**0.00**	**0.00**	**0.26**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.74**	**0.00**	**0.00**	**0.00**	**0.26**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$14,432	$147,526	$0	$0	$0	$161,958
	2	Quantified Benefit	$0	$14,432	$147,526	$0	$0	$0	$161,958
	3	Quantified Benefit	$0	$15,320	$156,606	$0	$0	$0	$171,926
	4	Quantified Benefit	$0	$15,246	$155,853	$0	$0	$0	$171,100
	1	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.09**	**0.91**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.00	2.00
Recreation	1	0.74	0.00	0.00	0.00	0.26
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	4.00	1.74	0.00	0.00	0.00	2.26
Cost Share	**1.00**	**0.44**	**0.00**	**0.00**	**0.00**	**0.56**

ALTERNATIVE 2		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.00	2.00
Recreation	1	0.74	0.00	0.00	0.00	0.26
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	4.00	1.74	0.00	0.00	0.00	2.26
Cost Share	**1.00**	**0.44**	**0.00**	**0.00**	**0.00**	**0.56**

ALTERNATIVE 3		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.00	2.00
Recreation	1	0.74	0.00	0.00	0.00	0.26
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	4.00	1.74	0.00	0.00	0.00	2.26
Cost Share	**1.00**	**0.44**	**0.00**	**0.00**	**0.00**	**0.56**

ALTERNATIVE 4		Distribution of Points				
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.0	0.0	0.0	0.0	2.0
Recreation	1	0.7	0.0	0.0	0.0	0.3
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	4.00	1.74	0.00	0.00	0.00	2.26
Cost Share	**1.00**	**0.44**	**0.00**	**0.00**	**0.00**	**0.56**

B.5 Slaughter

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$1,796	$18,794	$20,590
	2	Quantified Benefit	$0	$0	$0	$0	$1,796	$255,520	$257,316
	3	Quantified Benefit	$0	$0	$0	$0	$1,371	$253,832	$255,203
	4	Quantified Benefit	$0	$0	$0	$0	$1,800	$270,273	$272,073
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.09**	**0.91**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.99**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.99**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.99**	**1.00**
Recreation Value	1	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	2	Quantified Benefit	$143,362	$155,555	$0	$0	$0	$92,967	$391,885
	3	Quantified Benefit	$159,486	$173,050	$0	$0	$0	$103,423	$435,959
	4	Quantified Benefit	$184,723	$200,433	$0	$0	$0	$119,789	$504,945
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.63**	**0.00**	**0.00**	**0.00**	**0.37**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.63**	**0.00**	**0.00**	**0.00**	**0.37**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.63**	**0.00**	**0.00**	**0.00**	**0.37**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	2	Quantified Benefit	$0	$20,323	$630,022	$0	$0	$0	$650,346
	3	Quantified Benefit	$0	$22,610	$700,908	$0	$0	$0	$723,518
	4	Quantified Benefit	$0	$26,187	$811,795	$0	$0	$0	$837,982
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	0	0.00	0.00	0.00	0.00	0.00
Recreation	0	0.00	0.00	0.00	0.00	0.00
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	0.00	0.00	0.00	0.00
Cost Share	**1.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**

ALTERNATIVE 2				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.01	1.99
Recreation	3	1.88	0.00	0.00	0.00	1.12
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	2.88	0.00	0.00	0.01	3.11
Cost Share	**1.00**	**0.48**	**0.00**	**0.00**	**0.00**	**0.52**

ALTERNATIVE 3				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	2	0.00	0.00	0.00	0.01	1.99
Recreation	3	1.88	0.00	0.00	0.00	1.12
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	2.88	0.00	0.00	0.01	3.11
Cost Share	**1.00**	**0.48**	**0.00**	**0.00**	**0.00**	**0.52**

ALTERNATIVE 4				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.0	0.0	0.0	0.0	3.0
Recreation	3	1.9	0.0	0.0	0.0	1.1
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	7.00	2.88	0.00	0.00	0.02	4.10
Cost Share	**1.00**	**0.41**	**0.00**	**0.00**	**0.00**	**0.59**

B.6 Broadkill

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	2	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	3	Quantified Benefit	$0	$0	$0	$0	$478	$5,008,164	$5,008,642
	4	Quantified Benefit	$0	$0	$0	$0	$402	$5,007,877	$5,008,279
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	2	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	3	Quantified Benefit	$397,064	$159,441	$0	$0	$0	$173,970	$730,475
	4	Quantified Benefit	$421,256	$169,155	$0	$0	$0	$184,569	$774,981
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	3	Distribution of Benefit	**0.00**	**0.48**	**0.00**	**0.00**	**0.00**	**0.52**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.48**	**0.00**	**0.00**	**0.00**	**0.52**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	2	Quantified Benefit	$0	$0	$0	$0	$0	$0	$0
	3	Quantified Benefit	$0	$36,410	$1,128,705	$0	$0	$0	$1,165,115
	4	Quantified Benefit	$0	$38,626	$1,197,408	$0	$0	$0	$1,236,034
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	0.0	0	0	0	0	0.0
	2	Quantified Benefit	0	0.0	0	0	0	0	0.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	0	0.00	0.00	0.00	0.00	0.00
Recreation	0	0.00	0.00	0.00	0.00	0.00
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	0.0	0.00	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00	0.00	0.00
Cost Share	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

ALTERNATIVE 2				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	0	0.00	0.00	0.00	0.00	0.00
Recreation	0	0.00	0.00	0.00	0.00	0.00
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	0.0	0.00	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00	0.00	0.00
Cost Share	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

ALTERNATIVE 3				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.00	3.00
Recreation	3	1.43	0.00	0.00	0.00	1.57
Value Added	0	0.00	0.00	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	7.00	2.43	0.00	0.00	0.00	4.57
Cost Share	**1.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**

ALTERNATIVE 4				Distribution of Points		
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.0	0.0	0.0	0.0	3.0
Recreation	3	1.4	0.0	0.0	0.0	1.6
Value Added	0	0.0	0.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	7.00	2.43	0.00	0.00	0.00	4.57
Cost Share	**1.00**	**0.35**	**0.00**	**0.00**	**0.00**	**0.65**

B.7 Lewes

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$629,257	$2,005,346	$2,634,603
	2	Quantified Benefit	$0	$0	$0	$0	$629,257	$2,005,346	$2,634,603
	3	Quantified Benefit	$0	$0	$0	$0	$652,915	$2,797,801	$3,450,716
	4	Quantified Benefit	$0	$0	$0	$0	$652,915	$2,797,801	$3,450,716
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.24**	**0.76**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.24**	**0.76**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.19**	**0.81**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.19**	**0.81**	**1.00**
Recreation Value	1	Quantified Benefit	$13,680,920	$483,030	$0	$0	$0	$4,048,505	$18,212,455
	2	Quantified Benefit	$13,680,920	$483,030	$0	$0	$0	$4,048,505	$18,212,455
	3	Quantified Benefit	$28,190,330	$995,311	$0	$0	$0	$8,342,179	$37,527,820
	4	Quantified Benefit	$28,190,330	$995,311	$0	$0	$0	$8,342,179	$37,527,820
	1	Distribution of Benefit	**0.00**	**0.11**	**0.00**	**0.00**	**0.00**	**0.89**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.11**	**0.00**	**0.00**	**0.00**	**0.89**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.11**	**0.00**	**0.00**	**0.00**	**0.89**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.11**	**0.00**	**0.00**	**0.00**	**0.89**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$487,888	$15,124,524	$0	$0	$0	$15,612,412
	2	Quantified Benefit	$0	$487,888	$15,124,524	$0	$0	$0	$15,612,412
	3	Quantified Benefit	$0	$1,005,320	$31,164,928	$0	$0	$0	$32,170,248
	4	Quantified Benefit	$0	$1,005,320	$31,164,928	$0	$0	$0	$32,170,248
	1	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.72	2.28
Recreation	1	0.11	0.00	0.00	0.00	0.89
Value Added	1	0.03	0.97	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	1.14	0.97	0.00	0.72	3.18
Cost Share	**1.00**	**0.19**	**0.16**	**0.00**	**0.12**	**0.53**

ALTERNATIVE 2			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.72	2.28
Recreation	1	0.11	0.00	0.00	0.00	0.89
Value Added	1	0.03	0.97	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	1.14	0.97	0.00	0.72	3.18
Cost Share	**1.00**	**0.19**	**0.16**	**0.00**	**0.12**	**0.53**

ALTERNATIVE 3			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.00	0.00	0.00	0.57	2.43
Recreation	1	0.11	0.00	0.00	0.00	0.89
Value Added	1	0.03	0.97	0.00	0.00	0.00
Ecological	1.0	1.00	0.00	0.00	0.00	0.00
Total	6.00	1.14	0.97	0.00	0.57	3.33
Cost Share	**1.00**	**0.19**	**0.16**	**0.00**	**0.09**	**0.55**

ALTERNATIVE 4			Distribution of Points			
Benefit	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	3	0.0	0.0	0.0	0.6	2.4
Recreation	1	0.1	0.0	0.0	0.0	0.9
Value Added	1	0.0	1.0	0.0	0.0	0.0
Ecological	1.0	1.0	0.0	0.0	0.0	0.0
Total	6.00	1.14	0.97	0.00	0.57	3.33
Cost Share	**1.00**	**0.19**	**0.16**	**0.00**	**0.09**	**0.55**

B.8 Cape Shores

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$0	$3,477,483	$3,477,483
	2	Quantified Benefit	$0	$0	$0	$0	$0	$3,477,483	$3,477,483
	3	Quantified Benefit	$0	$0	$0	$0	$0	$3,205,232	$3,205,232
	4	Quantified Benefit	$0	$0	$0	$0	$0	$3,477,483	$3,477,483
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$11,323	$0	$0	$0	$0	$9,444	$20,767
	2	Quantified Benefit	$11,323	$0	$0	$0	$0	$9,444	$20,767
	3	Quantified Benefit	$8,646	$0	$0	$0	$0	$7,212	$15,858
	4	Quantified Benefit	$7,062	$0	$0	$0	$0	$5,890	$12,952
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$720	$22,316	$0	$0	$0	$23,035
	2	Quantified Benefit	$0	$720	$22,316	$0	$0	$0	$23,035
	3	Quantified Benefit	$0	$549	$17,028	$0	$0	$0	$17,577
	4	Quantified Benefit	$0	$449	$13,908	$0	$0	$0	$14,357
	1	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	1.0	0	0	0	0	1.0
	2	Quantified Benefit	0	1.0	0	0	0	0	1.0
	3	Quantified Benefit	0	1.0	0	0	0	0	1.0
	4	Quantified Benefit	0	1.0	0	0	0	0	1.0
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1			Distribution of Points				
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Cape Shores	3	0.00	0.00	0.00	0.00	2.61
	Port Lewes						0.39
Recreation		0	0.00	0.00	0.00	0.00	0.00
Value Added		0	0.00	0.00	0.00	0.00	0.00
Ecological		1.0	1.00	0.00	0.00	0.00	0.00
Total		4.00	1.00	0.00	0.00	0.00	3.00
Cost Share		**1.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.75**

ALTERNATIVE 2			Distribution of Points				
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Cape Shores	3	0.00	0.00	0.00	0.00	2.61
	Port Lewes						0.39
Recreation		0	0.00	0.00	0.00	0.00	0.00
Value Added		0	0.00	0.00	0.00	0.00	0.00
Ecological		1.0	1.00	0.00	0.00	0.00	0.00
Total		4.00	1.00	0.00	0.00	0.00	3.00
Cost Share		**1.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.75**

ALTERNATIVE 3			Distribution of Points				
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Cape Shores	3	0.00	0.00	0.00	0.00	2.61
	Port Lewes						0.39
Recreation		0	0.00	0.00	0.00	0.00	0.00
Value Added		0	0.00	0.00	0.00	0.00	0.00
Ecological		1.0	1.00	0.00	0.00	0.00	0.00
Total		4.00	1.00	0.00	0.00	0.00	3.00
Cost Share		**1.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.75**

ALTERNATIVE 4			Distribution of Points				
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Cape Shores	3	0.0	0.0	0.0	0.0	2.6
	Port Lewes						0.4
Recreation		0	0.0	0.0	0.0	0.0	0.0
Value Added		0	0.0	0.0	0.0	0.0	0.0
Ecological		1.0	1.0	0.0	0.0	0.0	0.0
Total		4.00	1.00	0.00	0.00	0.00	3.00
Cost Share		**1.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.75**

ALT 1/2/4				
Local share:	**0.75**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Cape Shores	0.00	0.00	0.65	0.65
Port Lewes	0.00	0.00	0.10	0.10
Total	0.00	0.00	0.75	0.75

ALT 3				
Local share:	**0.75**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Cape Shores	0.00	0.00	0.65	0.65
Port Lewes	0.00	0.00	0.10	0.10
Total	0.00	0.00	0.75	0.75

B.9 Rehoboth and Dewey

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$434,786	$0	$1,027,885	$3,059,322	$12,052,632	$16,574,625
	2	Quantified Benefit	$0	$434,786	$0	$1,027,885	$3,059,322	$12,052,632	$16,574,625
	3	Quantified Benefit	$0	$439,179	$0	$1,076,050	$3,187,445	$12,344,965	$17,047,639
	4	Quantified Benefit	$0	$439,179	$0	$1,076,050	$3,187,445	$12,344,965	$17,047,639
	1	Distribution of Benefit	**0.00**	**0.03**	**0.00**	**0.06**	**0.18**	**0.73**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.00**	**0.06**	**0.18**	**0.73**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.00**	**0.06**	**0.19**	**0.72**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.00**	**0.06**	**0.19**	**0.72**	**1.00**
Recreation Value	1	Quantified Benefit	$158,139,862	$31,902,971	$0	$0	$0	$78,334,233	$268,377,067
	2	Quantified Benefit	$158,139,862	$31,902,971	$0	$0	$0	$78,334,233	$268,377,067
	3	Quantified Benefit	$156,492,199	$31,600,204	$0	$0	$0	$77,527,176	$265,619,579
	4	Quantified Benefit	$156,492,199	$31,600,204	$0	$0	$0	$77,527,176	$265,619,579
	1	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$6,008,013	$186,248,394	$0	$0	$0	$192,256,407
	2	Quantified Benefit	$0	$6,008,013	$186,248,394	$0	$0	$0	$192,256,407
	3	Quantified Benefit	$0	$5,945,151	$184,299,690	$0	$0	$0	$190,244,842
	4	Quantified Benefit	$0	$5,945,151	$184,299,690	$0	$0	$0	$190,244,842
	1	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	0.5	0	0	0	0	0.5
	2	Quantified Benefit	0	0.5	0	0	0	0	0.5
	3	Quantified Benefit	0	0.5	0	0	0	0	0.5
	4	Quantified Benefit	0	0.5	0	0	0	0	0.5
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1/2			Distribution of Points					
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Henlopen Acres, North Shores	3				0.04	0.42
	Rehoboth		0.01		0.19	0.13	0.29
	Silver Lake						0.16
	Dewey		0.07		0.00	0.23	1.11
	Indian Beach, The Chancellery					0.15	0.21
Recreation	Henlopen Acres, North Shores	3					
	Rehoboth		0.86				1.79
	Silver Lake						
	Dewey		0.01				0.34
	Indian Beach, The Chancellery						
Value Added	Henlopen Acres, North Shores	3					
	Rehoboth		0.08	2.36			
	Silver Lake						
	Dewey		0.02	0.55			
	Indian Beach, The Chancellery						
Ecological	Henlopen Acres, North Shores	0.5					
	Rehoboth		0.25				
	Silver Lake						
	Dewey		0.25				
	Indian Beach, The Chancellery						
Total		9.50	1.54	2.91	0.19	0.55	4.31
Cost Share		**1.00**	**0.16**	**0.31**	**0.02**	**0.06**	**0.45**

ALTERNATIVE 3/4			Distribution of Points				
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Henlopen Acres, North Shores	3				0.04	0.40
	Rehoboth		0.01		0.19	0.15	0.32
	Silver Lake						0.16
	Dewey		0.07		0.00	0.22	1.09
	Indian Beach, The Chancellery					0.15	0.20
Recreation	Henlopen Acres, North Shores	3					
	Rehoboth		0.86				1.79
	Silver Lake						
	Dewey		0.01				0.34
	Indian Beach, The Chancellery						
Value Added	Henlopen Acres, North Shores	3					
	Rehoboth		0.08	2.36			
	Silver Lake						
	Dewey		0.02	0.55			
	Indian Beach, The Chancellery						
Ecological	Henlopen Acres, North Shores	0.5					
	Rehoboth		0.25				
	Silver Lake						
	Dewey		0.25				
	Indian Beach, The Chancellery						
Total		9.50	1.54	2.91	0.19	0.56	4.30
Cost Share		**1.00**	**0.16**	**0.31**	**0.02**	**0.06**	**0.45**

ALT 1/2				
Local share:	**0.53**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Henlopen Acres, North Shores		0.00	0.04	0.05
Rehoboth	0.02	0.01	0.22	0.25
Silver Lake		0.00	0.02	0.02
Dewey	0.00	0.02	0.15	0.18
Indian Beach, The Chancellery		0.02	0.02	0.04
Total	0.02	0.06	0.45	0.53

ALT 3/4				
Local share:	**0.53**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Henlopen Acres, North Shores		0.00	0.04	0.05
Rehoboth	0.02	0.02	0.22	0.26
Silver Lake		0.00	0.02	0.02
Dewey	0.00	0.02	0.15	0.17
Indian Beach, The Chancellery		0.02	0.02	0.04
Total	0.02	0.06	0.45	0.53

B.10 Bethany and South Bethany

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$518,448	$624,097	$3,578,067	$4,720,612
	2	Quantified Benefit	$0	$0	$0	$518,448	$624,097	$3,578,067	$4,720,612
	3	Quantified Benefit	$0	$0	$0	$535,344	$657,400	$5,240,046	$6,432,790
	4	Quantified Benefit	$0	$0	$0	$535,344	$657,400	$5,240,046	$6,432,790
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.11**	**0.13**	**0.76**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.11**	**0.13**	**0.76**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.08**	**0.10**	**0.81**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.08**	**0.10**	**0.81**	**1.00**
Recreation Value	1	Quantified Benefit	$45,216,091	$429,644	$0	$0	$0	$4,584,171	$50,229,906
	2	Quantified Benefit	$45,216,091	$429,644	$0	$0	$0	$4,584,171	$50,229,906
	3	Quantified Benefit	$52,500,397	$498,859	$0	$0	$0	$5,322,681	$58,321,937
	4	Quantified Benefit	$52,500,397	$498,859	$0	$0	$0	$5,322,681	$58,321,937
	1	Distribution of Benefit	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.91**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.91**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.91**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.91**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$1,388,218	$43,034,750	$0	$0	$0	$44,422,968
	2	Quantified Benefit	$0	$1,388,218	$43,034,750	$0	$0	$0	$44,422,968
	3	Quantified Benefit	$0	$1,611,860	$49,967,653	$0	$0	$0	$51,579,512
	4	Quantified Benefit	$0	$1,611,860	$49,967,653	$0	$0	$0	$51,579,512
	1	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	0.5	0	0	0	0	0.5
	2	Quantified Benefit	0	0.5	0	0	0	0	0.5
	3	Quantified Benefit	0	0.5	0	0	0	0	0.5
	4	Quantified Benefit	0	0.5	0	0	0	0	0.5
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1/2			Distribution of Points					
Benefit	Location	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	Bethany	3			0.33	0.05	0.09
	Sea Colony, Middlesex Beach					0.34	1.06
	South Bethany					0.00	1.12
Recreation	Bethany	1	0.09				0.78
	Sea Colony, Middlesex Beach						
	South Bethany		0.00				0.14
Value Added	Bethany	1	0.03	0.85			
	Sea Colony, Middlesex Beach						
	South Bethany		0.00	0.12			
Ecological	Bethany	0.5	0.25				
	Sea Colony, Middlesex Beach						
	South Bethany		0.25				
Total		5.50	0.62	0.97	0.33	0.40	3.19
Cost Share		**1.00**	**0.11**	**0.18**	**0.06**	**0.07**	**0.58**

ALTERNATIVE 3/4			Distribution of Points				
Benefit	Location	Points	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)
Avoided Damage	Bethany	3			0.25	0.04	0.07
	Sea Colony, Middlesex Beach					0.27	0.80
	South Bethany					0.00	1.58
Recreation	Bethany	1	0.09				0.78
	Sea Colony, Middlesex Beach						
	South Bethany		0.00				0.14
Value Added	Bethany	1	0.03	0.85			
	Sea Colony, Middlesex Beach						
	South Bethany		0.00	0.12			
Ecological	Bethany	0.5	0.25				
	Sea Colony, Middlesex Beach						
	South Bethany		0.25				
Total		5.50	0.62	0.97	0.25	0.31	3.36
Cost Share		**1.00**	**0.11**	**0.18**	**0.05**	**0.06**	**0.61**

ALT 1/2				
Local share:	**0.71**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Bethany	0.06	0.01	0.16	0.23
Sea Colony, Middlesex Beach		0.06	0.19	0.26
South Bethany			0.23	0.23
Total	0.06	0.07	0.58	0.71

ALT 3/4				
Local share:	**0.71**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Bethany	0.05	0.01	0.15	0.21
Sea Colony, Middlesex Beach		0.05	0.15	0.19
South Bethany			0.31	0.31
Total	0.05	0.06	0.61	0.71

B.11 Fenwick Island

Quantified Benefits and Distribution

Benefit	Nourishment Alternative	Metric	Out of state	State	County	Local (Municipal)	Local (Commercial)	Local (Residents)	Total
Infrastructure Resilience	1	Quantified Benefit	$0	$0	$0	$0	$0	$730,006	$730,006
	2	Quantified Benefit	$0	$0	$0	$0	$0	$730,006	$730,006
	3	Quantified Benefit	$0	$0	$0	$0	$0	$730,006	$730,006
	4	Quantified Benefit	$0	$0	$0	$0	$0	$730,006	$730,006
	1	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**1.00**
Recreation Value	1	Quantified Benefit	$9,818,036	$881,548	$0	$0	$0	$2,192,781	$12,892,366
	2	Quantified Benefit	$9,818,036	$881,548	$0	$0	$0	$2,192,781	$12,892,366
	3	Quantified Benefit	$12,540,012	$1,125,951	$0	$0	$0	$2,800,713	$16,466,677
	4	Quantified Benefit	$12,540,012	$1,125,951	$0	$0	$0	$2,800,713	$16,466,677
	1	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.71**	**1.00**
Tourism Impacts	1	Quantified Benefit	$0	$391,058	$12,122,790	$0	$0	$0	$12,513,847
	2	Quantified Benefit	$0	$391,058	$12,122,790	$0	$0	$0	$12,513,847
	3	Quantified Benefit	$0	$499,475	$15,483,722	$0	$0	$0	$15,983,197
	4	Quantified Benefit	$0	$499,475	$15,483,722	$0	$0	$0	$15,983,197
	1	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**0.03**	**0.97**	**0.00**	**0.00**	**0.00**	**1.00**
Ecological Benefit	1	Quantified Benefit	0	0.5	0	0	0	0	0.5
	2	Quantified Benefit	0	0.5	0	0	0	0	0.5
	3	Quantified Benefit	0	0.5	0	0	0	0	0.5
	4	Quantified Benefit	0	0.5	0	0	0	0	0.5
	1	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	2	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	3	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
	4	Distribution of Benefit	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Cost Share Calculations

ALTERNATIVE 1				Distribution of Points			
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Fenwick Island	3	0.00	0.00	0.00	0.00	1.06
	community to south						1.94
Recreation		1	0.29	0.00	0.00	0.00	0.71
Value Added		1	0.03	0.97	0.00	0.00	0.00
Ecological		0.5	0.50	0.00	0.00	0.00	0.00
Total		5.50	0.82	0.97	0.00	0.00	3.71
Cost Share		**1.00**	**0.15**	**0.18**	**0.00**	**0.00**	**0.68**

ALTERNATIVE 2				Distribution of Points			
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Fenwick Island	3	0.00	0.00	0.00	0.00	1.06
	community to south						1.94
Recreation		1	0.29	0.00	0.00	0.00	0.71
Value Added		1	0.03	0.97	0.00	0.00	0.00
Ecological		0.5	0.50	0.00	0.00	0.00	0.00
Total		5.50	0.82	0.97	0.00	0.00	3.71
Cost Share		**1.00**	**0.15**	**0.18**	**0.00**	**0.00**	**0.68**

ALTERNATIVE 3				Distribution of Points			
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Fenwick Island	3	0.00	0.00	0.00	0.00	1.06
	community to south						1.94
Recreation		1	0.29	0.00	0.00	0.00	0.71
Value Added		1	0.03	0.97	0.00	0.00	0.00
Ecological		0.5	0.50	0.00	0.00	0.00	0.00
Total		5.50	0.82	0.97	0.00	0.00	3.71
Cost Share		**1.00**	**0.15**	**0.18**	**0.00**	**0.00**	**0.68**

ALTERNATIVE 4				Distribution of Points			
Benefit	**Location**	**Points**	**State**	**County**	**Local (Municipal)**	**Local (Commercial)**	**Local (Residents)**
Avoided Damage	Fenwick Island	3	0.0	0.0	0.0	0.0	1.1
	community to south						1.9
Recreation		1	0.3	0.0	0.0	0.0	0.7
Value Added		1	0.0	1.0	0.0	0.0	0.0
Ecological		0.5	0.5	0.0	0.0	0.0	0.0
Total		5.50	0.82	0.97	0.00	0.00	3.71
Cost Share		**1.00**	**0.15**	**0.18**	**0.00**	**0.00**	**0.68**

ALT 1/2/4				
Local share:	**0.68**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Fenwick Island	0.00	0.00	0.32	0.32
community to south	0.00	0.00	0.35	0.35
Total	0.00	0.00	0.68	0.68

ALT 3				
Local share:	**0.68**			
Location	**Municipal**	**Commercial**	**Residents**	**Total**
Fenwick Island	0.00	0.00	0.32	0.32
community to south	0.00	0.00	0.35	0.35
Total	0.00	0.00	0.68	0.68

APPENDIX C | Community-Level Social Vulnerability Data

C.1 Pickering Beach

Pickering Beach is a very small unincorporated community located on Delaware Bay approximately six miles east of Dover. The sole access route is via Pickering Beach Road (County Rd. 349).

C.1.1 Data Availability and Limitations

Pickering Beach is represented by a single census block (Block 1070, Block Group 1, Tract 432.02). Census data for total population, race, ethnicity, and certain housing data are available at the block level. Other data to inform the social vulnerability analysis are only available at the block group or tract levels. Pickering Beach falls within a geographically extensive block group that also includes (at least in part) the communities of Woodland Beach, Leipsic, Little Creek, and Kitts Hummock. Consequently, for various data categories, the population of Pickering Beach cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.1.2 Social Vulnerability Indices

CDC/ATSDR SVI for Pickering Beach Census Tract (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Medium-High	**Medium-High**	**Low-Medium**	**Low** *0.1367*	**Medium-High**

FEMA National Risk Index for Pickering Beach Census Tract (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Moderate *47.48**	**Insufficient Data** *36.37*	**Relatively Moderate** *63.23**	**Insufficient Data** *44.40*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.1.3 Demographics

	Pickering Beach	Block group	Kent County	Delaware
Total population	29	1,142	181,851	989,948
Population of color*	6 (20.7%)	289 (25.3%)	77,006 (42.3%)	410,097 (41.4%)
65 years and over	n/a	206 ±113 (16.6%)	32,138 ±n/a (17.6%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.1.4 Housing

	Pickering Beach	Block group	Kent County	Delaware
Housing units[67]	38	569	72,708	448,735
Occupied	20 (53%)	452 (79%)	68,290 (94%)	386,375 (86%)
Vacant	18 (47%)	117 (21%)	4,418 (6%)	62,360 (14%)

C.1.5 Socioeconomic Indicators

	Pickering Beach	Block group	Kent County	Delaware
Annual income below federal poverty level	n/a	n/a	21,850 ±1,745 (12.3%)	107,790 ±3,568 (11.1%)
Households receiving social security income	n/a	220 ±121 (44.4%)	25,466 ±805 (37.1%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	n/a	n/a	26,222 ±3,289 (25.6%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	n/a	n/a	13,654 ±1,031 (11.1%)	61,344 ±2,142 (8.8%)

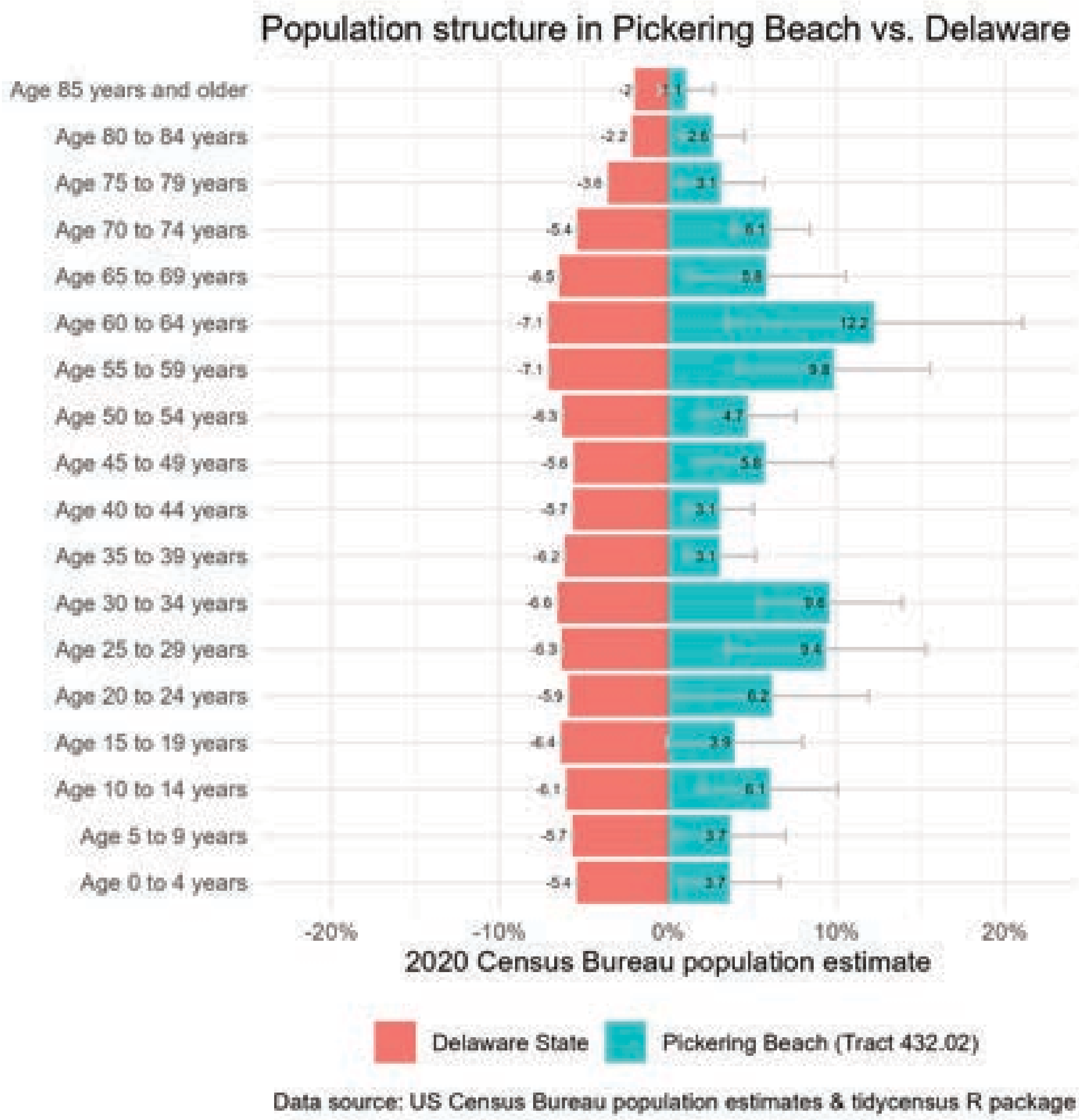
C.1.6 Health Indicators

Within census tract 432.02, an estimated 29.87 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Pickering Beach and nearby communities experience high measures for low life expectancy (85th percentile nationally) and heart disease (86th percentile). These communities are in the 72nd percentile for individuals with disabilities, and the 67th percentile for cancer (US EPA 2015).

C.1.7 Facilities

The nearest hospital and urgent care facilities are in Dover. Kent General Hospital is 10.9 miles from Pickering Beach, MedExpress Urgent Care is 8.6 miles away, and Kent County EMS, at 911 Public Safety Blvd., is nine miles away.

[67] Decennial Census 2020, Table H1


Population structure in Pickering Beach vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-20%
-10%
0%
10%
20%
2020 Census Bureau population estimate
Delaware State
Pickering Beach (Tract 432.02)
Data source: US Census Bureau population estimates & tidycensus R package

C.2 Kitts Hummock

Kitts Hummock is a small unincorporated beach community located on the Delaware Bay. It is approximately 7.6 miles southeast of Dover and is just north of several wildlife reserves, including the Ted Harvey Conservation Area and the Delaware National Estuarine Research Reserve. The sole access route is via Kitts Hummock Road.

C.2.1 Data Availability and Limitations

Kitts Hummock is represented by two block groups (Blocks 1074 and 1084, referred to as the "Kitts Hummock Census Blocks"). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Other data to inform the social vulnerability analysis are only available at the block group or tract levels. Kitts Hummock falls within a geographically extensive census block group and tract (Block Group 1, Tract 432.02) that also includes (at least in part) the communities of Pickering Beach, Woodland Bech, Leipsic, and Little Creek. Consequently, for various data categories, the population of Kitts Hummock cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.2.2 Social Vulnerability Indices

CDC/ATSDR SVI for Kitts Hummock Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Medium-High	**Medium-High**	**Low-Medium**	**Low** *0.1367*	**Medium-High**

FEMA National Risk Index for Kitts Hummock Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Moderate *47.48**	**Insufficient Data** *36.37*	**Relatively Moderate** *63.23**	**Insufficient Data** *44.40*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.2.3 Demographics

	Kitts Hummock	Block group	Kent County	Delaware
Total population	275	1,142	181,851	989,948
Population of color*	61 (22.2%)	289 (25.3%)	77,006 (42.3%)	410,097 (41.4%)
65 years and over	n/a	206 ±113 (16.6%)	32,138 ±n/a (17.6%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.2.4 Housing

	Kitts Hummock	Block group	Kent County	Delaware
Housing units[68]	163	569	72,708	448,735
Occupied	137 (84%)	452 (79%)	68,290 (94%)	386,375 (86%)
Vacant	26 (16%)	117 (21%)	4,418 (6%)	62,360 (14%)

C.2.5 Socioeconomic Indicators

	Kitts Hummock	Block group	Kent County	Delaware
Annual income below federal poverty level	n/a	n/a	21,850 ±1,745 (12.3%)	107,790 ±3,568 (11.1%)
Households receiving social security income	n/a	220 ±121 (44.4%)	25,466 ±805 (37.1%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	n/a	n/a	26,222 ±3,289 (25.6%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	n/a	n/a	13,654 ±1,031 (11.1%)	61,344 ±2,142 (8.8%)

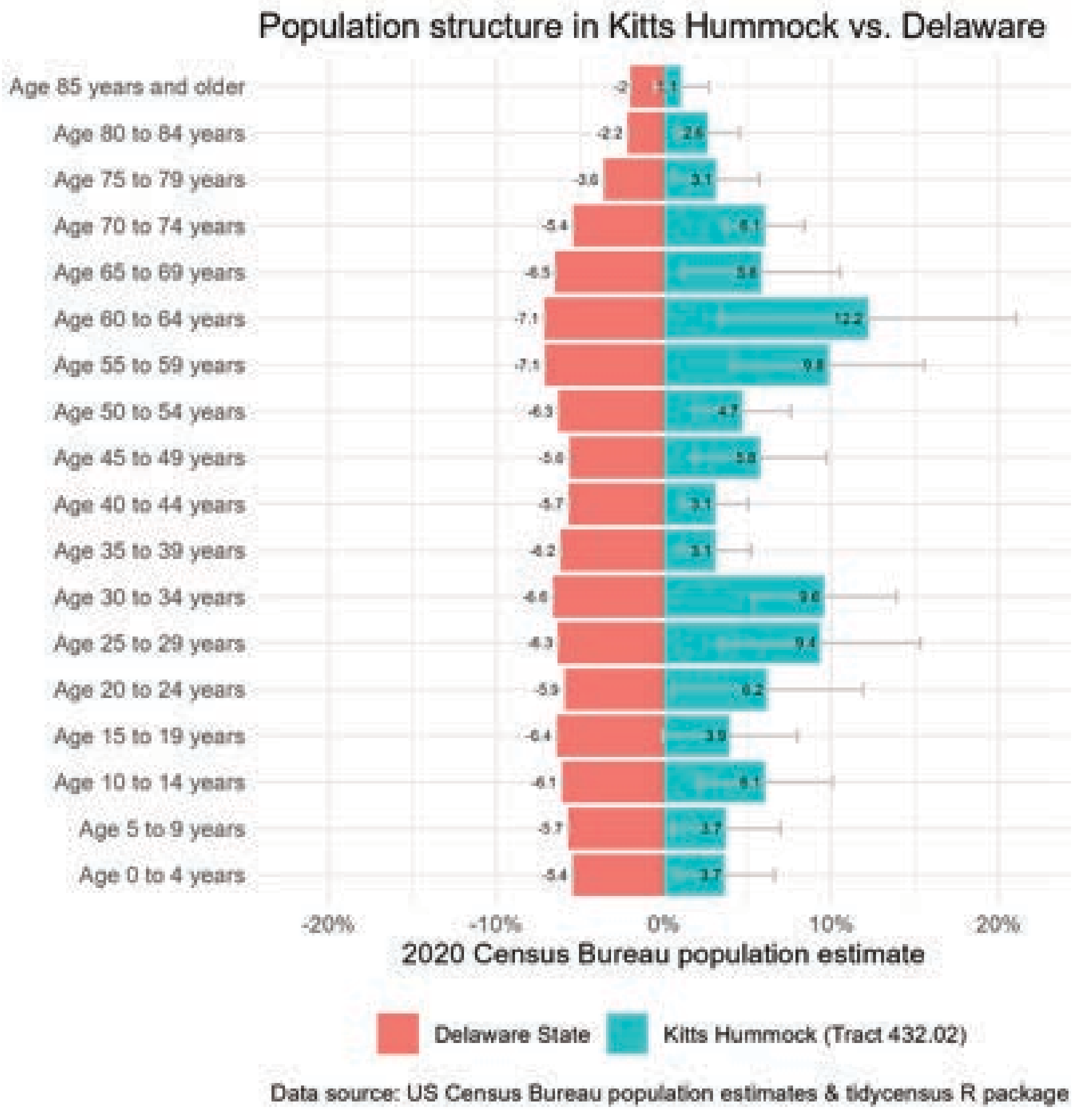
C.2.6 Health Indicators

Within census tract 432.02, an estimated 29.87 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Kitts Hummock and nearby communities experience high measures for low life expectancy (85th percentile nationally) and heart disease (86th percentile). These communities are in the 72nd percentile for individuals with disabilities and the 67th percentile for cancer (US EPA 2015).

[68] Decennial Census 2020, Table H1

C.2.7 Facilities

The nearest hospital and urgent care facilities are in Dover. Bayhealth Hospital is 9.6 miles from Kitts Hummock, MedExpress Urgent Care is 8.2 miles away, and Kent County EMS is 7.2 miles away.



C.3 Bowers

Bowers, located on the Delaware Bay, is part of the Dover Metropolitan Statistical Area. It is bordered on the north side by the Saint Jones River and on the south by the Murderkill River.

C.3.1 Data Availability and Limitations

Bowers is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Bowers falls within a geographically extensive census tract (Tract 432.02) that also includes (at least in part) the communities of Pickering Beach and Kitts Hummock. Consequently, for various data categories, the population of Bowers cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.3.2 Social Vulnerability Indices

CDC/ATSDR SVI for Bowers Census Tract 432.02 (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Medium-High	**Medium-High**	**Low-Medium**	**Low** *0.1367*	**Medium-High**

FEMA National Risk Index for Bowers Census Tract 432.02 (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Moderate *47.48**	**Insufficient Data** *53.70*	**Relatively Moderate** *63.23**	**Insufficient Data** *44.40*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.3.3 Demographics

	Bowers	Kent County	Delaware
Total population	278	181,851	989,948
Population of color*	40 (14.4%)	77,006 (42.3%)	410,097 (41.4%)
65 years and over	144 ±77 (42.9%)	32,138 ±n/a (17.6%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.3.4 Housing

	Bowers	Kent County	Delaware
Housing units[69]	231	72,708	448,735
Occupied	131 (50.6%)	68,290 (94%)	386,375 (86%)
Vacant	100 (49.4%)	4,418 (6%)	62,360 (14%)

C.3.5 Socioeconomic Indicators

	Bowers	Kent County	Delaware
Annual income below federal poverty level	34 ±33 (10.1%)	21,850 ±1,745 (12.3%)	107,790 ±3,568 (11.1%)
Households receiving social security income	76 ±27 (55.9%)	25,466 ±805 (37.1%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	57 ±81 (37.7%)	26,222 ±3,289 (25.6%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	21 ±13 (7.3%)	13,654 ±1,031 (11.1%)	61,344 ±2,142 (8.8%)

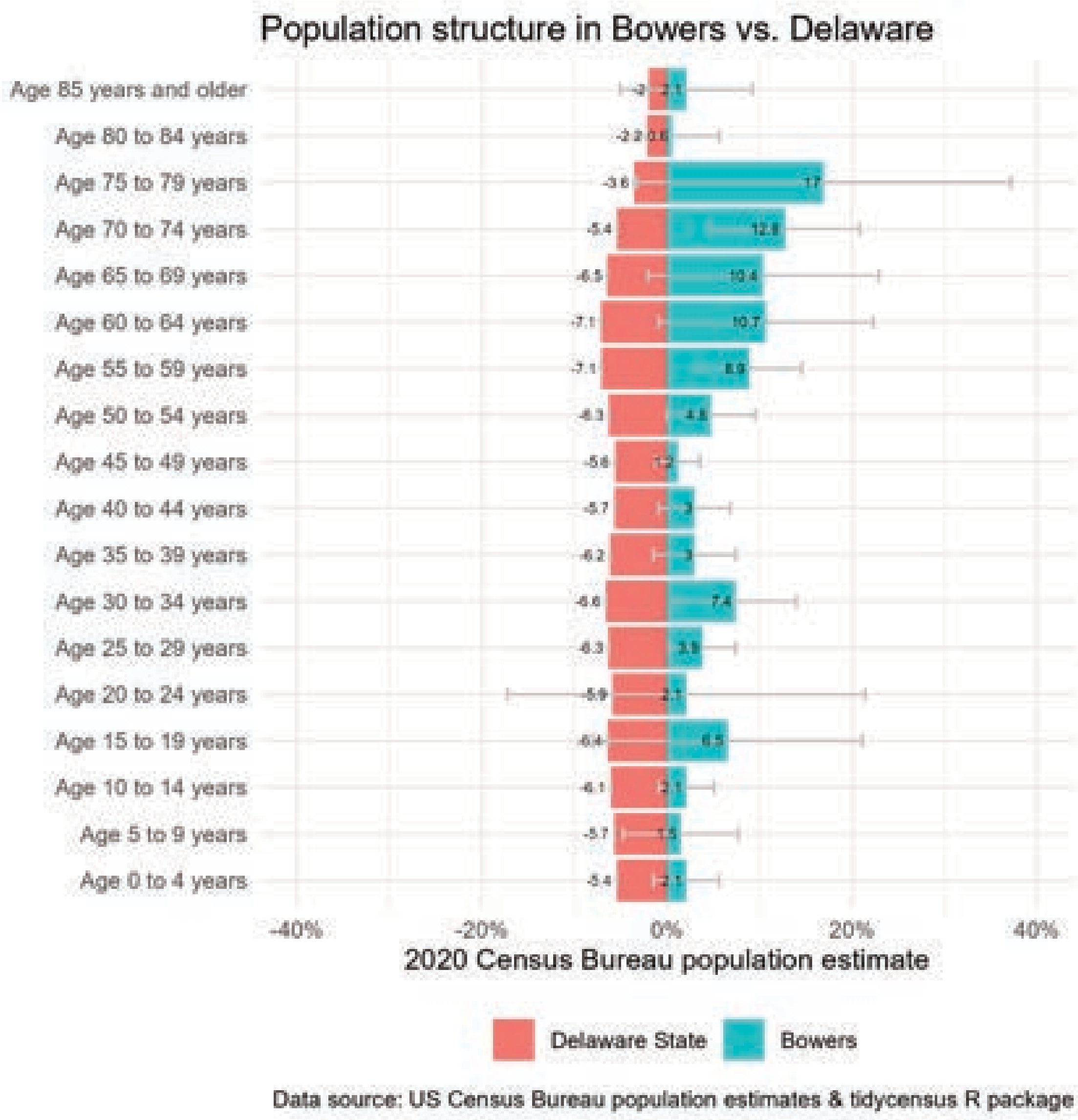
C.3.6 Health Indicators

Within census tract 432.02, an estimated 29.87 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Bowers and nearby communities experience high measures for low life expectancy (85th percentile nationally), heart disease (86th percentile nationally), asthma (84th percentile nationally), cancer (67th percentile nationally), and individuals with disabilities (72nd percentile nationally).

C.3.7 Facilities

The nearest hospital and urgent care facilities are in Dover. Kent General Hospital is 14.2 miles from Bowers, Camden Walk-In Medical Center Urgent Care is 12.5 miles away, and Kent County EMS, is 11.9 miles away.

[69] Decennial Census 2020, Table H1


Population structure in Bowers vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-40%
-20%
0%
20%
40%
2020 Census Bureau population estimate
Delaware State
Bowers
Data source: US Census Bureau population estimates & tidycensus R package

C.4 South Bowers

South Bowers is a small unincorporated beach community located on Delaware Bay. It is just south of the Murderkill River, opposite Bowers.

C.4.1 Data Availability and Limitations

South Bowers is represented by a single census block (Block 2002, Block Group 2, Tract 432.02). Census data for total population, race, ethnicity, and certain housing data are available at the block level. Other data to inform the social vulnerability analysis are only available at the block group or tract levels. South Bowers falls within a geographically extensive block group that includes several small inland communities. Consequently, for various data categories, the population of South Bowers cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.4.2 Social Vulnerability Indices

CDC/ATSDR SVI for South Bowers Census Tract (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Medium-High	**Medium-High**	**Low-Medium**	**Low** *0.1367*	**Medium-High**

FEMA National Risk Index for South Bowers Census Tract (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Moderate *47.48**	**Insufficient Data** *36.37*	**Relatively Moderate** *63.23**	**Insufficient Data** *44.40*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.4.3 Demographics

	South Bowers	Block Group 2	Kent County	Delaware
Total population	39	581	181,851	989,948
Population of color*	4 (10.3%)	100 (17.2%)	77,006 (42.3%)	410,097 (41.4%)
65 years and over	n/a	180 ±82 (34.6%)	32,138 ±n/a (17.6%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.4.4 Housing

	South Bowers	Block Group 2	Kent County	Delaware
Housing units[70]	44	296	72,708	448,735
Occupied	18 (40.9%)	247 (83.4%)	68,290 (94%)	386,375 (86%)
Vacant	26 (59.1%)	49 (16.6%)	4,418 (6%)	62,360 (14%)

C.4.5 Socioeconomic Indicators

	South Bowers	Block Group 2	Kent County	Delaware
Annual income below federal poverty level	n/a	n/a	21,850 ±1,745 (12.3%)	107,790 ±3,568 (11.1%)
Households receiving social security income	n/a	107 ±46 (45.9%)	25,466 ±805 (37.1%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	n/a	n/a	26,222 ±3,289 (25.6%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	n/a	n/a	13,654 ±1,031 (11.1%)	61,344 ±2,142 (8.8%)

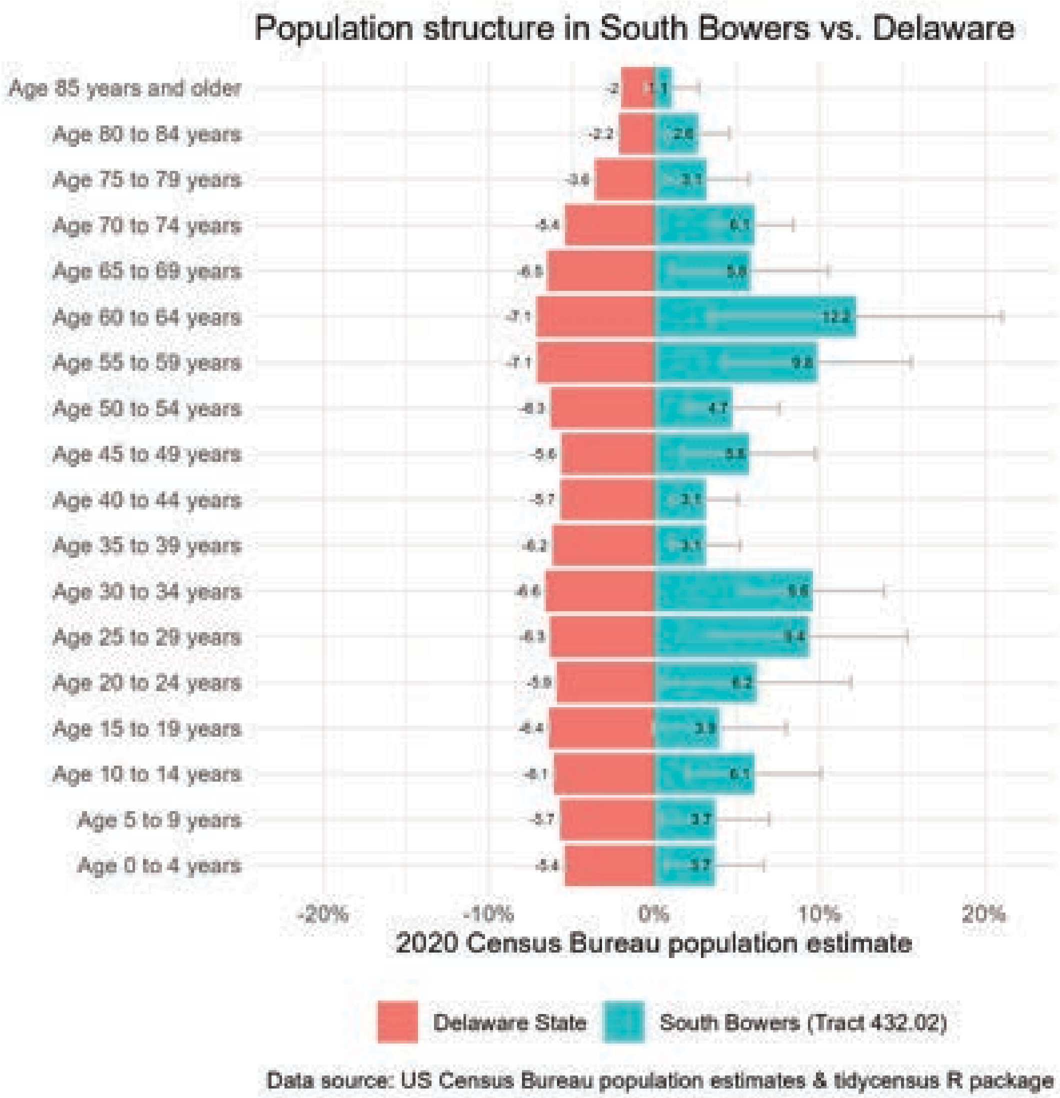
C.4.6 Health Indicators

Within census tract 432.02, an estimated 29.87 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of South Bowers and nearby communities experience high measures for low life expectancy (85th percentile nationally), heart disease (86th percentile nationally), asthma (84th percentile nationally), cancer (67th percentile nationally), and individuals with disabilities (72nd percentile nationally) (US EPA 2015).

C.4.7 Facilities

The nearest hospital and urgent care facilities are in Dover. Kent General Hospital is 22.0 miles from South Bowers, Camden Walk-In Medical Center Urgent Care is 19.1 miles away, and Kent County EMS, is 19.7 miles away.

[70] Decennial Census 2020, Table H1


Population structure in South Bowers vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-20%
-10%
0%
10%
20%
2020 Census Bureau population estimate
Delaware State
South Bowers (Tract 432.02)
Data source: US Census Bureau population estimates & tidycensus R package

C.5 Slaughter Beach

Slaughter Beach is a small beach town located on the southwest shore of the Delaware Bay. It is part of the Salisbury, Maryland-Delaware Metropolitan Statistical Area.

C.5.1 Data Availability and Limitations

Slaughter Beach is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Slaughter Beach is entirely contained within a single census tract (Tract 501.03, see Fig. 1), which includes some other small beachfront communities, including parts of Broadkill Beach. In cases where data are not available at the CDP level, the community is represented by this tract.

C.5.2 Social Vulnerability Indices

CDC/ATSDR SVI for Slaughter Beach Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low-Medium	**Low** *0.1686*	**Medium-High**	**Low** *0.1055*	**Medium-High**

FEMA National Risk Index for Slaughter Beach Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Moderate *41.46**	**Insufficient Data** *45.20*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.5.3 Demographics

	Slaughter Beach	Sussex County	Delaware
Total population	218	237,378	989,948
Population of color*	11 (5.0%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	633 ±84 (54.2%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.5.4 Housing

	Slaughter Beach	Sussex County	Delaware
Housing units[71]	261	142,280	448,735
Occupied	122 (46.7%)	98,514 (69%)	386,375 (86%)
Vacant	139 (53.3%)	43,766 (31%)	62,360 (14%)

C.5.5 Socioeconomic Indicators

	Slaughter Beach	Sussex County	Delaware
Annual income below federal poverty level	48 ±52 (12.2%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	100 ±34 (43.3%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	24 ±70 (14.1%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	13 ±12 (3.9%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

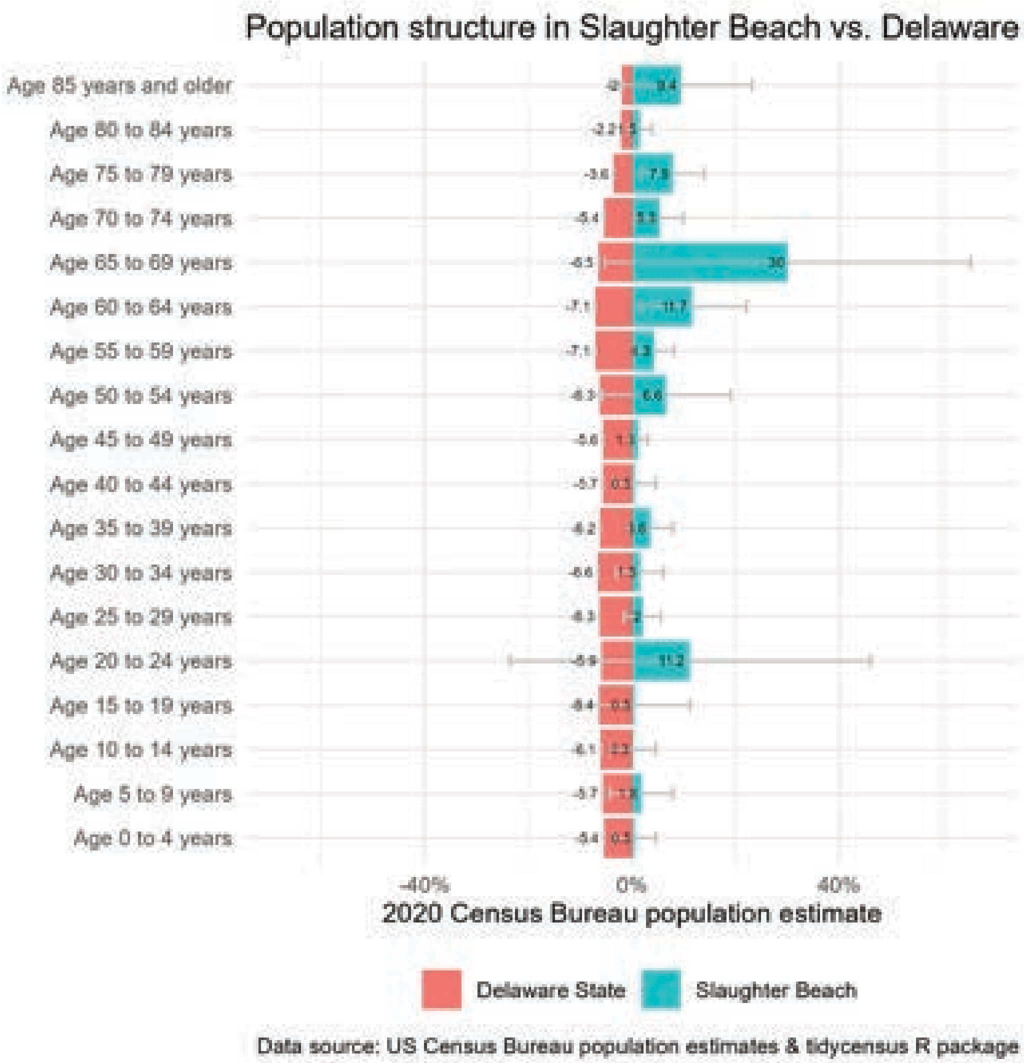
C.5.6 Health Indicators

Within Tract 501.03, an estimated 27.75 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Slaughter Beach and nearby communities experience high measures for heart disease (74th percentile nationally), cancer (92nd percentile nationally), and individuals with disabilities (68th percentile nationally) (US EPA 2015).

C.5.7 Facilities

Slaughter Beach is 7.1 miles from Bayhealth Hospital in Milford and 10.1 miles from CareForceMD Speedy Care Milford urgent care center. Sussex County Paremedic Station 101, located in Lincoln, is 8.6 miles from Slaughter Beach.

[71] Decennial Census 2020, Table H1


Population structure in Slaughter Beach vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-40%
0%
40%
2020 Census Bureau population estimate
Delaware State
Slaughter Beach
Data source: US Census Bureau population estimates & tidycensus R package

C.6 Broadkill Beach

Broadkill Beach is a small unincorporated beach community located on Delaware Bay. It is surrounded by the Atlantic Ocean to the northeast and the Prime Hook National Wildlife Refuge to the southwest. The sole access route is via Broadkill Road.

C.6.1 Data Availability and Limitations

Broadkill Beach is represented by several census blocks (Blocks 4000, 4001, 4002, 4003, 4004, 4010, 4011, 4012, and 4013 in Block Group 4, Tract 509.05; and Blocks 1007, 1008, 1009, 1029, 1030, 1031, and 1032 in Block Group 1, Tract 501.03; referred to as the "Broadkill Beach Census Blocks"). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Other data to inform the social vulnerability analysis are only available at the block group or tract levels. Broadkill Beach falls within geographically extensive census tracts (Tracts 501.03 and 509.05, referred to as the "Broadkill Beach Census Tracts") that also includes (at least in part) the communities of Lewes, Primehook Beach, and Savannah Beach. Consequently, for certain data categories, the population of Broadkill Beach cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.6.2 Social Vulnerability Indices

CDC/ATSDR SVI for Broadkill Beach Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low-Medium	**Low-Medium**	**Low-Medium**	**Low** *0.0651*	**Medium-High**

FEMA National Risk Index for Broadkill Beach Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Low *31.51**	**Insufficient Data** *36.37*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.6.3 Demographics

	Broadkill Beach	Sussex County	Delaware
Total population	392	237,378	989,948
Population of color*	44 (11.1%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	n/a	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.6.4 Housing

	Broadkill Beach	Sussex County	Delaware
Housing units[72]	685	142,280	448,735
Occupied	173 (25.3%)	98,514 (69%)	386,375 (86%)
Vacant	512 (74.7%)	43,766 (31%)	62,360 (14%)

C.6.5 Socioeconomic Indicators

	Broadkill Beach	Sussex County	Delaware
Annual income below federal poverty level	223 ±118 (5.9%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	839 ±211 (48.8%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	461 ±431 (23.0%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	171 ±112 (5.7%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

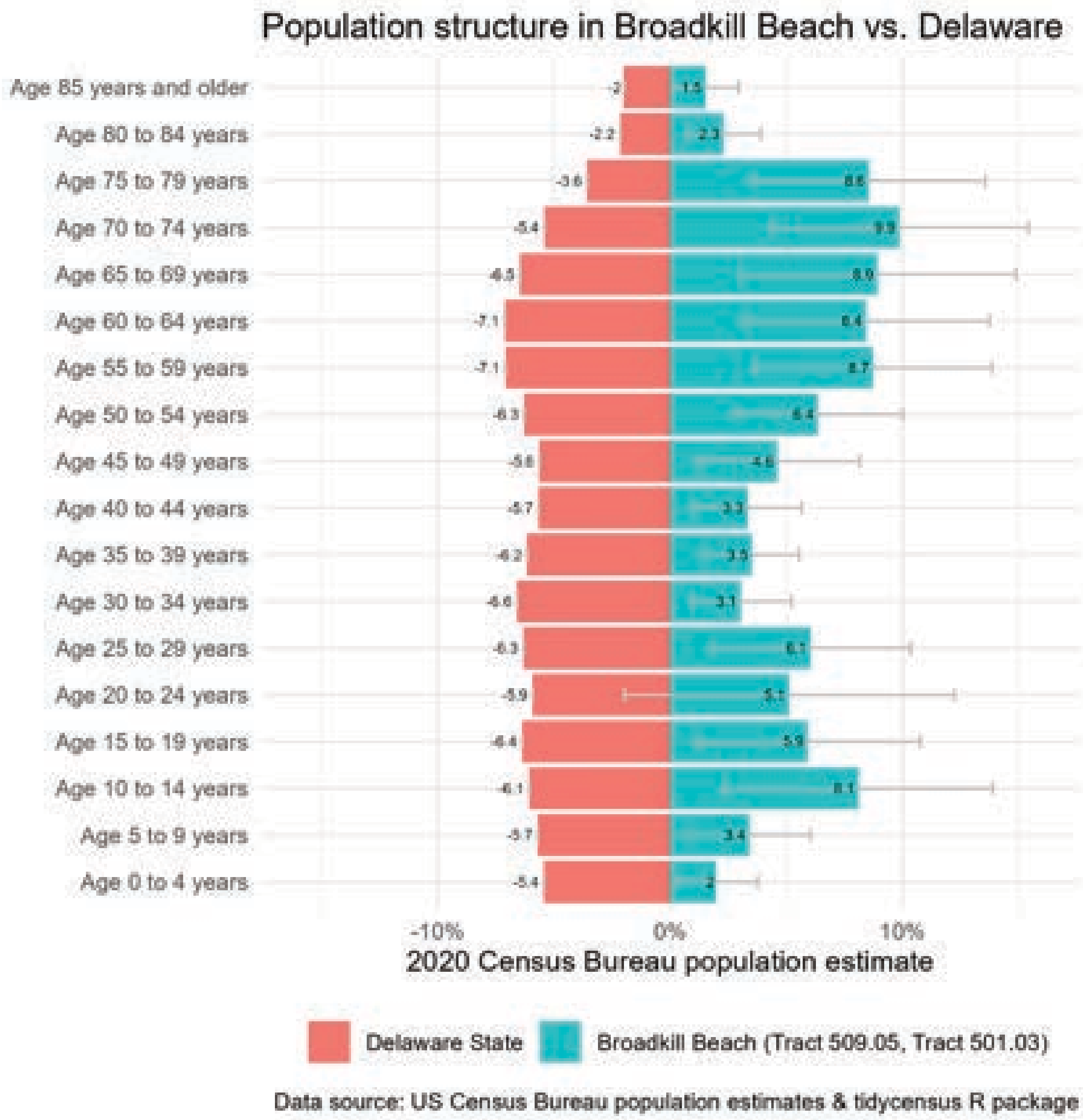
C.6.6 Health Indicators

Within census tract 509.05, an estimated 18.38 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Broadkill Beach and nearby communities experience high measures for heart disease (64th percentile nationally) and cancer (93rd percentile nationally) (US EPA 2015).

[72] Decennial Census 2020, Table H1

C.6.7 Facilities

The nearest hospital and urgent care facilities are in Lewes. Beebe Healthcare is 13.4 miles away, CarePortMD Speedy Care is 11.3 miles away, and Sussex County EMS Paramedic Station 111 is 6.2 miles away.



C.7 Lewes

Lewes is a medium-to-small beach city located on the Delaware Bay in the Cape Region of Delaware. Lewes is home to the University of Delaware's Hugh R. Sharp campus. Lewes also contains the luxury housing development Cape Shores, which is a community of interest in this study.

C.7.1 Data Availability and Limitations

Lewes is an incorporated city and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Lewes is split between several census tracts (Tract 509.03, Tract 509.04, Tract 509.05, Tract 510.09, Tract 9800, referred to as the "Lewes Census Tracts"), which include several smaller communities. In cases where data are not available at the CDP level, the community is represented by the summed Lewes populations of these five tracts.

The community of Cape Shores occupies four entire census blocks (Blocks 1008, 1010, 1015, and 1051) and part of a fifth (Block 1006) near the eastern shoreline of Lewes. Block 1006 is large and spans most of the shoreline of Lewes. Cape Shores data are provided below at the block level, but is given as a range, where the lower number represents census data for the four blocks that are completely contained within Cape Shores and the higher number additionally includes Block 1006. The true demographic statistics for Cape Shores lie somewhere between these two values.

C.7.2 Social Vulnerability Indices

CDC/ATSDR SVI for Lewes Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low-Medium	**Low-Medium**	**Low** *0.2336*	**Low** *0.1280*	**Medium-High**

FEMA National Risk Index for Lewes Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Low *26.35**	**Insufficient Data** *30.69*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.7.3 Demographics

	Lewes	Cape Shores	Sussex County	Delaware
Total population	3,303	94–207	237,378	989,948
Population of color*	365 (11.1%)	1–5	65,637 (27.7%)	410,097 (41.4%)
65 years and over	1,886 ±294 (56.5%)	n/a	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.7.4 Housing

	Lewes	Cape Shores	Sussex County	Delaware
Housing units[73]	3,085	145–502	142,280	448,735
Occupied	1,672 (56.3%)	42–115	98,514 (69%)	386,375 (86%)
Vacant	1,413 (43.7%)	103–387	43,766 (31%)	62,360 (14%)

C.7.5 Socioeconomic Indicators

	Lewes	Cape Shores	Sussex County	Delaware
Annual income below federal poverty level	184 ±117 (5.8%)	n/a	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	1,049 ±182 (65.9%)	n/a	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	181 ±203 (14.7%)	n/a	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	193 ±115 (6.3%)	n/a	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

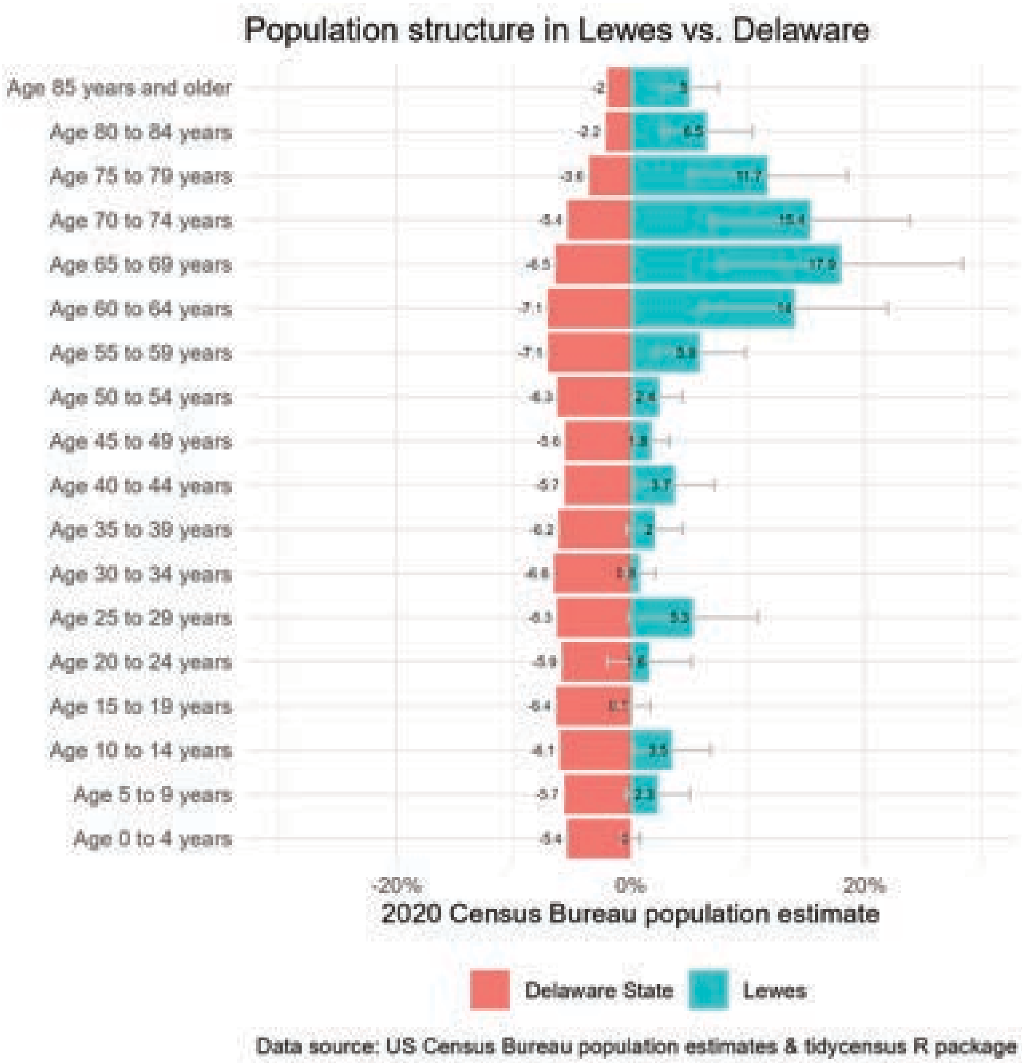
C.7.6 Health Indicators

Within the Lewes Census Tracts, an estimated 20.38 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Lewes and nearby communities experience high measures for heart disease (82nd percentile nationally), cancer (97th percentile nationally), and individuals with disabilities (62nd percentile nationally) (US EPA 2015).

[73] Decennial Census 2020, Table H1

C.7.7 Facilities

There are multiple hospitals in Lewes, including Beebe Healthcare and Bayview Medical Center, which are 0.3 miles and two miles away from the city center, respectively. Sussex County EMS Paramedic Station 111 at Broadkill Road is 11.5 miles away.



C.8 Rehoboth Beach

Rehoboth Beach is a small beach town located on the Atlantic Coast in Delaware.

C.8.1 Data Availability and Limitations

Rehoboth Beach is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Rehoboth Beach is split between two census tracts (Tracts 511.01 and 511.02, referred to as the "Rehoboth Beach Census Tracts"), which includes some small communities outside of Rehoboth Beach. In cases where data are not available at the CDP level, the community is represented by the summed Rehoboth Beach populations of these two tracts.

C.8.2 Social Vulnerability Indices

CDC/ATSDR SVI for Rehoboth Beach Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low	**Low**	**Low**	**Low**	**Low-Medium**
0.1777	*0.1750*	*0.1142*	*0.2213*	

FEMA National Risk Index for Rehoboth Beach Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Very Low	**Insufficient Data**	**Relatively Moderate**	**Insufficient Data**
*12.89**	*16.91*	*43.95**	*28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.8.3 Demographics

	Rehoboth Beach	Sussex County	Delaware
Total population	1,108	237,378	989,948
Population of color*	77 (6.9%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	633 ±84 (46.6%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.8.4 Housing

	Rehoboth Beach	Sussex County	Delaware
Housing units[74]	3,081	142,280	448,735
Occupied	624 (24.2%)	98,514 (69%)	386,375 (86%)
Vacant	2,457 (75.8%)	43,766 (31%)	62,360 (14%)

C.8.5 Socioeconomic Indicators

	Rehoboth Beach	Sussex County	Delaware
Annual income below federal poverty level	62 ±47 (4.6%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	379 ±62 (49.5%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	76 ±91 (11.9%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	4 ±8 (0.3%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

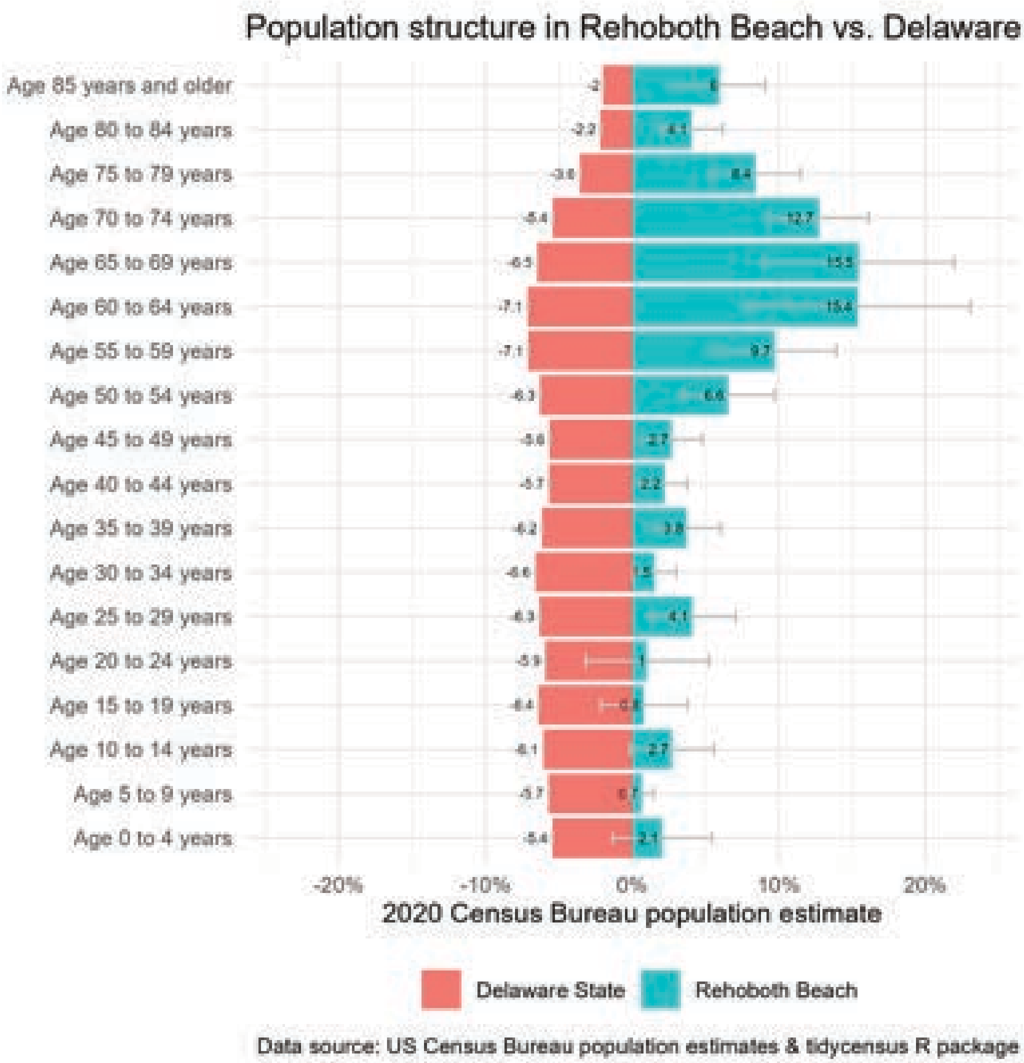
C.8.6 Health Indicators

Within the Rehoboth Beach Census Tracts, an estimated 15.48 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Rehoboth Beach and nearby communities experience high measures for heart disease (86th percentile nationally) and cancer (99th percentile nationally) (US EPA 2015).

C.8.7 Facilities

The nearest hospital and urgent care facilities are in Lewes. Beebe Healthcare and Bayview Medical Center are 7.2 and 6.2 miles from Rehoboth Beach, respectively. Sussex County EMS Paramedic Station 104/100 is located five miles away.

[74] Decennial Census 2020, Table H1


Population structure in Rehoboth Beach vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-20%
-10%
0%
10%
20%
2020 Census Bureau population estimate
Delaware State
Rehoboth Beach
Data source: US Census Bureau population estimates & tidycensus R package

C.9 Dewey Beach

Dewey Beach is a small beach town located in southern Delaware. It is centered around Coastal Highway (Rt. 1) and is surrounded by the Atlantic on the east and Rehoboth Bay to the west.

C.9.1 Data Availability and Limitations

Dewey Beach is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Dewey Beach overlaps with two census tracts (Tract 511.02 and Tract 511.03, referred to as the "Dewey Beach Census Tracts"), which includes several smaller communities. In cases where data are not available at the CDP level, the community is represented by the summed Dewey Beach populations of these two tracts.

C.9.2 Social Vulnerability Indices

CDC/ATSDR SVI for Dewey Beach Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low *0.2062*	**Low** *0.1428*	**Low-Medium**	**Low** *0.0846*	**Low-Medium**

FEMA National Risk Index for Dewey Beach Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Very Low **11.53***	**Insufficient Data** *15.65*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.9.3 Demographics

	Dewey Beach	Sussex County	Delaware
Total population	353	237,378	989,948
Population of color*	22 (6.2%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	132 ± 50 (36.8%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.9.4 Housing

	Dewey Beach	Sussex County	Delaware
Housing units[75]	1,468	142,280	448,735
Occupied	182 (12.9%)	98,514 (69%)	386,375 (86%)
Vacant	1,286 (87.1%)	43,766 (31%)	62,360 (14%)

C.9.5 Socioeconomic Indicators

	Dewey Beach	Sussex County	Delaware
Annual income below federal poverty level	47 ±37 (13.1%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	100 ±36 (51.5%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	31 ±74 (15.0%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	13 ±11 (4.0%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

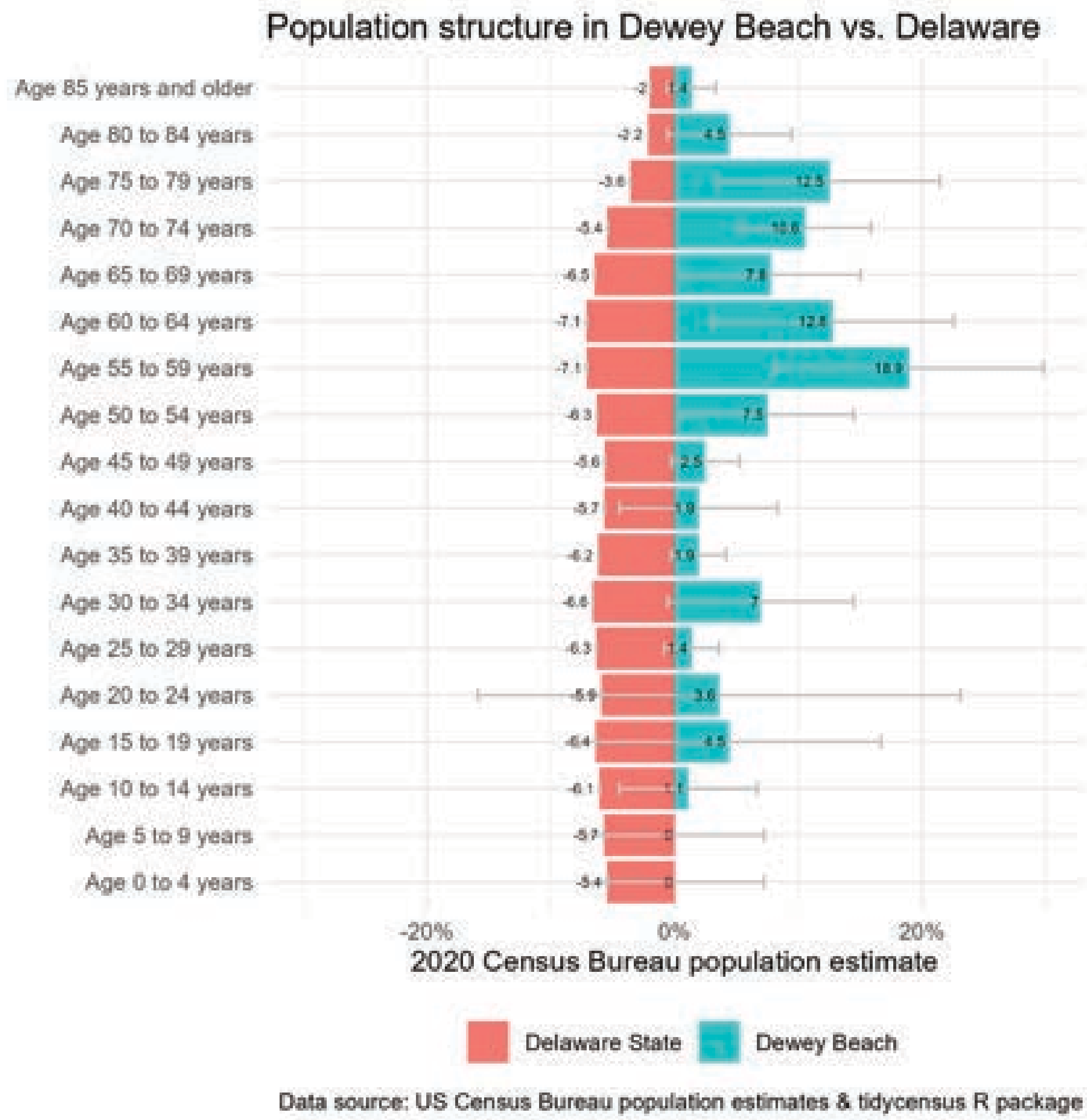
C.9.6 Health Indicators

Within the Dewey Beach Census Tracts, an estimated 18.15 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Dewey Beach and nearby communities experience high measures for heart disease (74th percentile nationally), cancer (97th percentile nationally), and individuals with disabilities (64th percentile) (US EPA 2015).

C.9.7 Facilities

The nearest hospital and urgent care facilities are in Lewes. Beebe Healthcare and Bayview Medical Center are 7.5 and 6.6 miles from Dewey Beach, respectively. Sussex County EMS Paramedic Station 104/100 is located 5.2 miles away. There are some specialized medical facilities, such as the Beebe Healthcare Cardiac Rehabilitation and Outpatient Surgery Centers, about 4.4 miles away.

[75] Decennial Census 2020, Table H1


Population structure in Dewey Beach vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-2
1.4
-2.2
4.5
-3.6
12.5
-5.4
10.6
-6.5
7.8
-7.1
12.8
-7.1
18.9
-6.3
7.5
-5.6
2.5
-5.7
1.9
-6.2
1.9
-6.6
7
-6.3
1.4
-5.9
3.6
-6.4
4.5
-6.1
1.1
-5.7
0
-5.4
0
-20%
0%
20%
2020 Census Bureau population estimate
Delaware State
Dewey Beach
Data source: US Census Bureau population estimates & tidycensus R package

C.10 Bethany Beach

Bethany Beach is a small beach town located in the Cape Region in southern Delaware. It is located between Delaware Seashore State Park to the north and Fenwick Island State Park to the south. It is centered around Coastal Highway (Rt. 1) and Garfield Parkway.

C.10.1 Data Availability and Limitations

Bethany Beach is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Bethany Beach is split between several census tracts (Tract 512.02, Tract 512.03, and Tract 512.04, referred to as the "Bethany Beach Census Tracts"), which includes several smaller communities. In cases where data are not available at the CDP level, the community is represented by the summed Bethany Beach populations of these three tracts.

C.10.2 Social Vulnerability Indices

CDC/ATSDR SVI for Bethany Beach Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low	**Low**	**Low-Medium**	**Low**	**Low**
0.0704	*0.0417*		*0.1015*	*0.1864*

FEMA National Risk Index for Bethany Beach Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Relatively Low	**Insufficient Data**	**Relatively Moderate**	**Insufficient Data**
*28.92**	*34.70*	*43.95**	*28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.10.3 Demographics

	Bethany Beach	Sussex County	Delaware
Total population	954	237,378	989,948
Population of color*	59 (6.2%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	592 ±91 (55.6%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.10.4 Housing

	Bethany Beach	Sussex County	Delaware
Housing units[76]	2,564	142,280	448,735
Occupied	520 (19.6%)	98,514 (69%)	386,375 (86%)
Vacant	2,044 (80.4%)	43,766 (31%)	62,360 (14%)

C.10.5 Socioeconomic Indicators

	Bethany Beach	Sussex County	Delaware
Annual income below federal poverty level	28 ±22 (2.6%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	363 ±57 (69.5%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	52 ±80 (12.1%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	16 ±14 (1.7%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

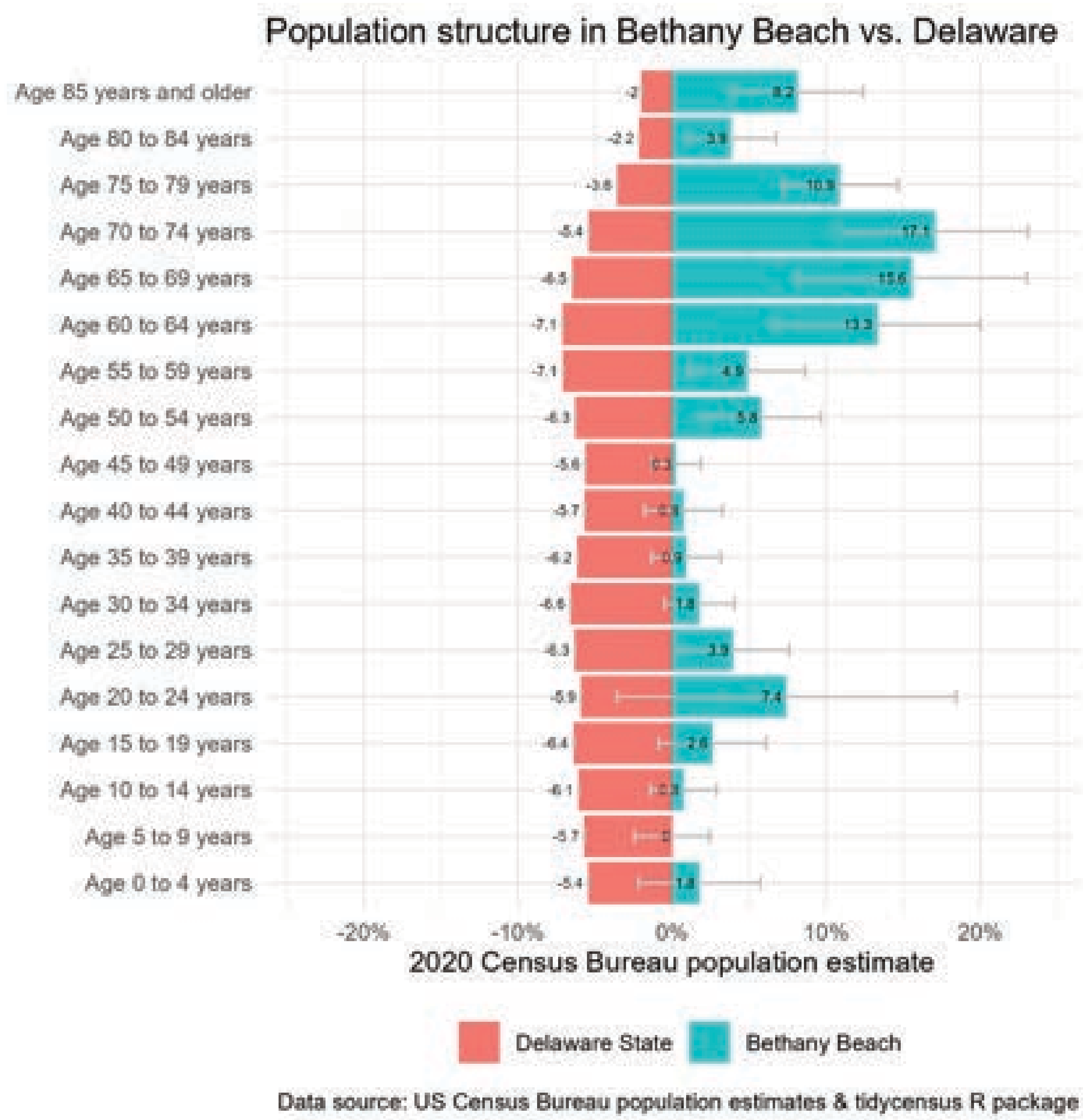
C.10.6 Health Indicators

Within the Bethany Beach Census Tracts, an estimated 23.93 per cent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Bethany Beach and nearby communities experience high measures for heart disease (95th percentile nationally), cancer (99th percentile nationally), and individuals with disabilities (63rd percentile nationally) (US EPA 2015).

[76] Decennial Census 2020, Table H1

C.10.7 Facilities

The nearest hospital and urgent care facilities are in Lewes; Beebe Healthcare is 18.5 miles from Bethany Beach. Beebe Healthcare's South Coastal Emergency Department is closer at 5.6 miles away, and the Sussex County EMS Station 105 on S Coastal Lane is 3.2 miles away.



C.11 South Bethany

South Bethany is a medium-to-small beach city located on the Atlantic Coast of Delaware, somewhat near the Maryland border.

C.11.1 Data Availability and Limitations

South Bethany is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

South Bethany is contained within a single census tract (Tract 512.04), which includes parts of Bethany Beach. In cases where data are not available at the CDP level, the community is represented by the summed Lewes populations of these five tracts.

C.11.2 Social Vulnerability Indices

CDC/ATSDR SVI for South Bethany Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low *0.3279*	**Low** *0.2552*	**Low-Medium**	**Low-Medium**	**Low** *0.6401*

FEMA National Risk Index for South Bethany Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Very Low *8.31**	**Insufficient Data** *10.00*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.11.3 Demographics

	South Bethany	Sussex County	Delaware
Total population	451	237,378	989,948
Population of color*	11 (2.4%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	307 ±98 (62.7%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.11.4 Housing

	South Bethany	Sussex County	Delaware
Housing units[77]	1,258	142,280	448,735
Occupied	246 (23.9%)	98,514 (69%)	386,375 (86%)
Vacant	1,012 (76.1%)	43,766 (31%)	62,360 (14%)

C.11.5 Socioeconomic Indicators

	South Bethany	Sussex County	Delaware
Annual income below federal poverty level	26 ±18 (5.3%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	208 ±91 (68.9%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	9 ±40 (5.0%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	2 ±3 (0.4%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

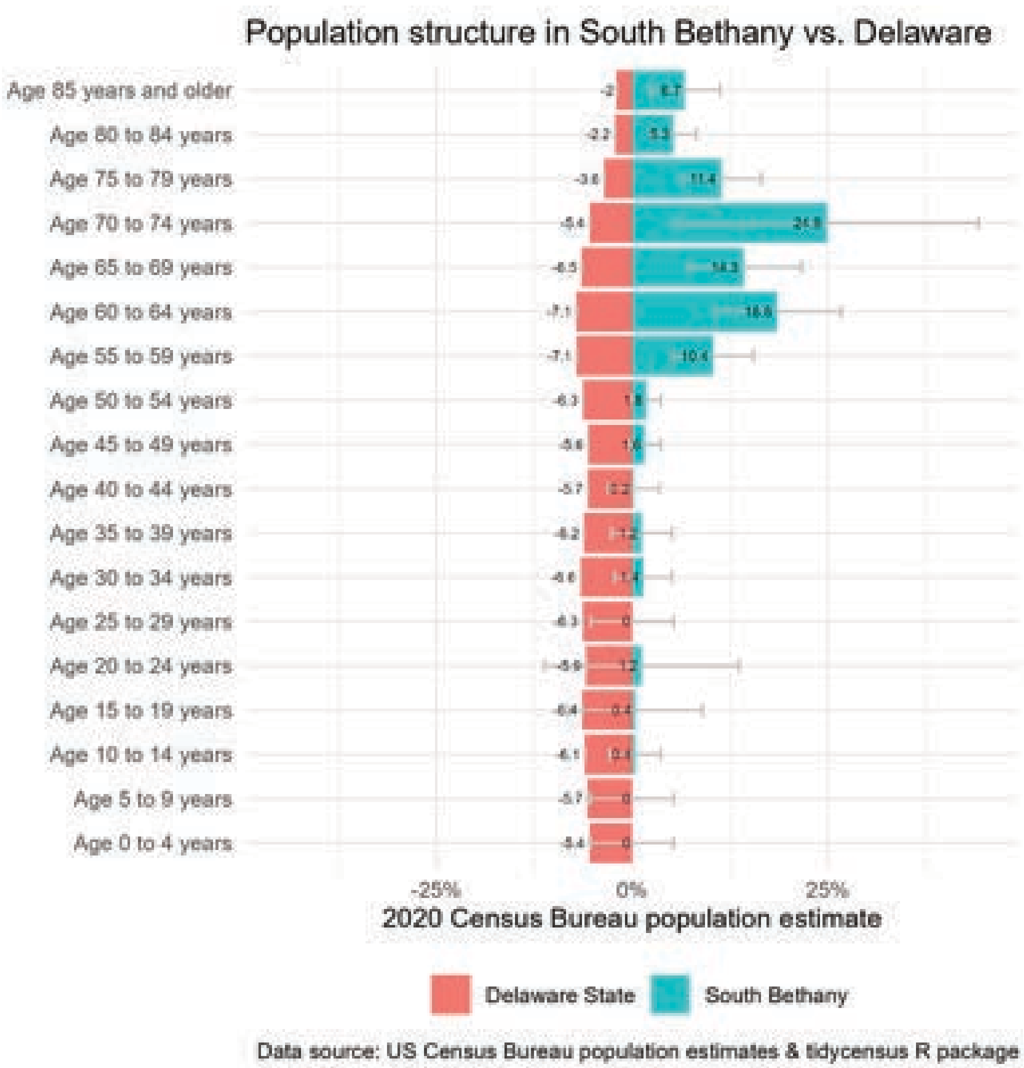
C.11.6 Health Indicators

Within Tract 512.04, an estimated 17.63 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of South Bethany and nearby communities experience high measures for heart disease (97th percentile nationally), cancer (99th percentile nationally), and individuals with disabilities (70th percentile nationally) (US EPA 2015).

C.11.7 Facilities

The nearest hospital and urgent care facilities are in Lewes; Beebe Healthcare is 20 miles from South Bethany. CareForceMD Speedy Care in Milford is 3.7 miles away. Beebe Healthcare's South Coastal Emergency Department is 7.4 miles away, and the Sussex County EMS Station 105 on S Coastal Lane is 3.6 miles away.

[77] Decennial Census 2020, Table H1


Population structure in South Bethany vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-25%
0%
25%
2020 Census Bureau population estimate
Delaware State
South Bethany
Data source: US Census Bureau population estimates & tidycensus R package

C.12 Fenwick Island

Fenwick Island is a coastal resort town located just north of the Maryland-Delaware border on a barrier island. It is bordered by the Atlantic Ocean to the east and the Little Assawoman Bay to the west.

C.12.1 Data Availability and Limitations

Fenwick Island is an incorporated town and is thus represented by a single census designated place (CDP). Census data for demographics, housing, and socioeconomic indicators are available for this geography. Data for the latter two categories, as well as some of the former, are sourced from the American Community Survey (ACS), which examines a representative sample rather than the entire population; thus, these indicators include estimates of error.

Fenwick Island falls within a geographically extensive census tract (Tract 512.05) that also includes several smaller communities outside of the formal boundaries of Fenwick Island. Consequently, for various data categories, the population of Fenwick Island cannot be distinguished from these other populations, limiting more precise evaluation of its particular vulnerabilities.

C.12.2 Social Vulnerability Indices

CDC/ATSDR SVI for Fenwick Island Census Tracts (2020)

Overall	Socioeconomic Status	Household Characteristics	Racial & Ethnic Minority Status	Housing Type & Transportation
Low *0.2196*	**Low** *0.1182*	**Low** *0.1608*	**Low** *0.2383*	**Low-Medium**

FEMA National Risk Index for Fenwick Island Census Tracts (2020)

Relative rankings as determined by FEMA; insufficient data for comparison with state of Delaware.

Social Vulnerability	Social Vulnerability	Community Resilience	Community Resilience
Very Low *14.17**	**Insufficient Data** *20.10*	**Relatively Moderate** *43.95**	**Insufficient Data** *28.60*

*Scores are in comparison to state of Delaware unless otherwise marked; * indicates that score is compared to U.S.*

C.12.3 Demographics

	Fenwick Island	Sussex County	Delaware
Total population	343	237,378	989,948
Population of color*	22 (6.4%)	65,637 (27.7%)	410,097 (41.4%)
65 years and over	232 ±54 (66.3%)	70,195 ±n/a (29.2%)	195,016 ±17 (19.6%)

* Defined as total population minus census respondents identifying race as White alone and ethnicity as not Hispanic or Latino.

C.12.4 Housing

	Fenwick Island	Sussex County	Delaware
Housing units[78]	715	142,280	448,735
Occupied	179 (25.6%)	98,514 (69%)	386,375 (86%)
Vacant	536 (74.4%)	43,766 (31%)	62,360 (14%)

C.12.5 Socioeconomic Indicators

	Fenwick Island	Sussex County	Delaware
Annual income below federal poverty level	4 ±4 (1.1%)	27,585 ±2,071 (11.6%)	107,790 ±3,568 (11.1%)
Households receiving social security income	139 ±35 (70.6%)	46,872 ±830 (46.9%)	139,461 ±1,461 (35.9%)
Population with Medicare, Medicaid, or means-tested public health insurance coverage	6 ±60 (5.8%)	29,858 ±3,343 (24.3%)	119,654 ±7,412 (21.1%)
Population with less than high school diploma or equivalent	15 ±18 (4.5%)	18,020 ±1,125 (9.9%)	61,344 ±2,142 (8.8%)

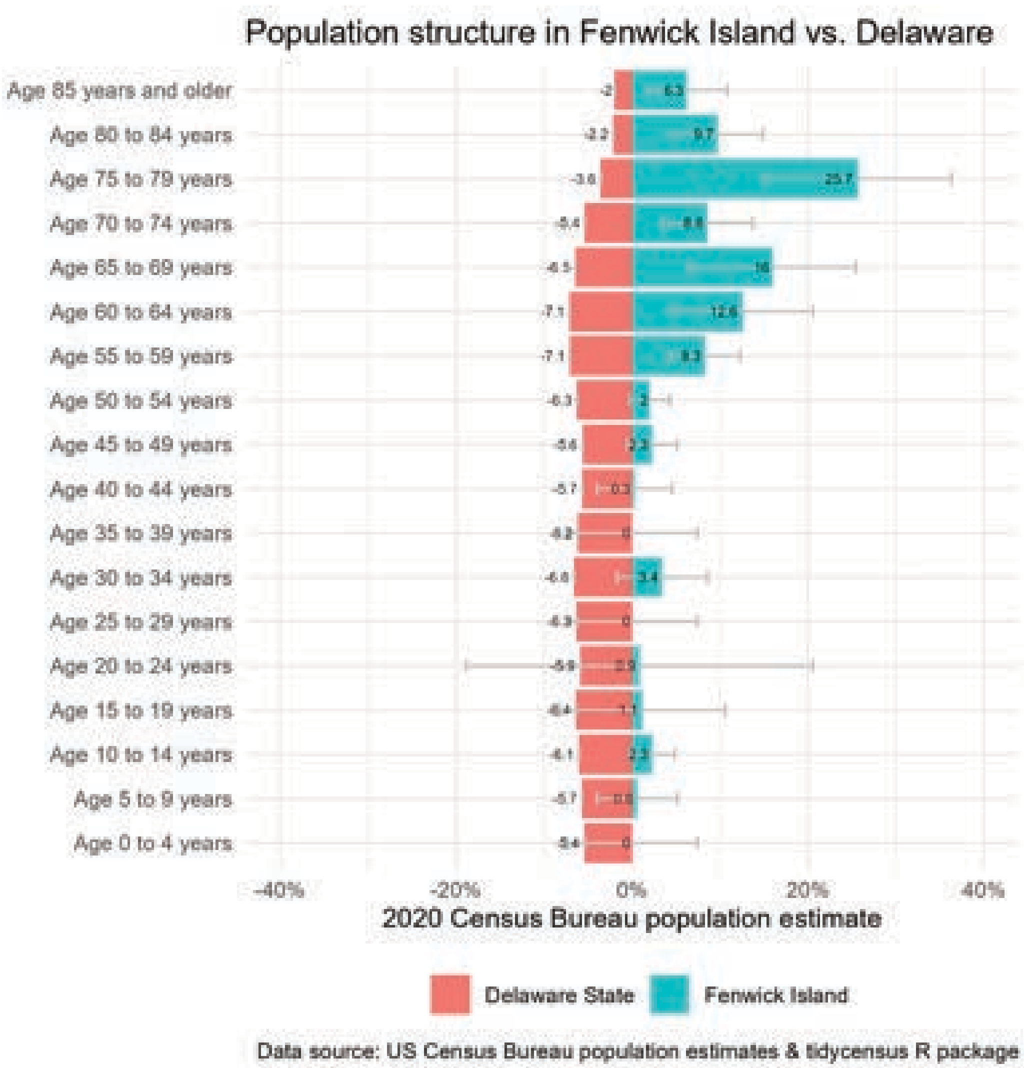
C.12.6 Health Indicators

Within Census Tract 512.05, an estimated 15.51 percent of people are 65 and over with one or more disabilities (DE-PLANs; ACS 2018-2022). At the block group level, residents of Lewes and nearby communities experience high measures for heart disease (95th percentile nationally), cancer (99th percentile nationally), and individuals with disabilities (64th percentile nationally) (US EPA 2015).

C.12.7 Facilities

The nearest hospital to is Atlantic General Hospital, located 17 miles away in Berlin, Maryland. The nearest urgent care facility is Atracare Urgent Care Clinic in Ocean View, Delaware, and is 7.4 miles away. Sussex County EMS Paramedic Station 109 is 4.8 miles away.

[78] Decennial Census 2020, Table H1


Population structure in Fenwick Island vs. Delaware
Age 85 years and older
Age 80 to 84 years
Age 75 to 79 years
Age 70 to 74 years
Age 65 to 69 years
Age 60 to 64 years
Age 55 to 59 years
Age 50 to 54 years
Age 45 to 49 years
Age 40 to 44 years
Age 35 to 39 years
Age 30 to 34 years
Age 25 to 29 years
Age 20 to 24 years
Age 15 to 19 years
Age 10 to 14 years
Age 5 to 9 years
Age 0 to 4 years
-40%
-20%
0%
20%
40%
2020 Census Bureau population estimate
Delaware State
Fenwick Island
Data source: US Census Bureau population estimates & tidycensus R package

APPENDIX D | Detailed review of past economic analyses

For inclusion in this review, we consider economic analysis to be quantification of the benefits and costs of shoreline management activities in Delaware, primarily beach nourishment. Generally, studies that include this type of analysis fall within two categories: (1) standalone economic analyses commissioned by DNREC, and (2) economic analysis performed by USACE as a standard component of feasibility studies.

D.1 Delaware Bayshore Communities Economic Analysis (JMT 2014)

This study, led by Johnson, Mirmiran & Thompson (JMT), is the most recent of the DNREC analyses and the only to focus on bay beaches. It quantifies the benefits and costs associated with several shoreline management alternatives at seven beaches. The study compares beach nourishment (based on 10-year designs from PBS&J 2010), basic managed retreat, and a more aggressive (enhanced) managed retreat scenario, to baseline conditions of no management (i.e., allowing the shoreline to erode according to historic rates). The study quantifies benefits in terms of avoided losses to housing services (from prevented erosion), avoided flood damage to structures and their contents, and enhanced beach recreation. In addition, the study considers changes to property tax revenue, ecosystem services such as habitat protection, and economic activity. However, these benefits are not considered in the final benefits analysis either because they were deemed minor relative to other categories (in the case of ecosystem services), or they are not considered a valid measure of economic benefit in traditional benefit-cost analysis frameworks (in the case of economic activity and tax revenues).

The study found that in present value terms over a 30-year timeframe, all three management alternatives result in an aggregate net loss (i.e., total costs outweigh total benefits), though beach nourishment results in the highest benefit to cost ratio. The study also notes considerable variation across communities. For example, considering each community in isolation, nourishment and basic retreat were found to produce positive net benefits at one beach each (Broadkill and Slaughter, respectively).

Important to the question of equitable cost share development, the study found that across all three management alternatives, net benefits accruing to the local communities were positive while net benefits to State taxpayers were negative. This follows directly from the fact that within the analysis, all costs (sand and fill for nourishment, acquisition and demolition for managed retreat) were assumed to be borne wholly by the State. Because of this cost centralization, benefits accruing to any subgroup (e.g., avoided damage to residential structures, recreation by local residents) are guaranteed to be net positive given they do not share in the cost.

Focusing on the beach nourishment scenario, protection of properties from total loss due to erosion was the primary benefit ($23.7 million), followed by enhanced beach recreation ($20.9 million) and avoided damage to structures and contents ($3.5 million). Figure D-1 summarizes these findings by beach, combining avoided structure losses from erosion with avoided storm damage reduction. Recreational benefits are based on count and survey data collected onsite (Parsons et al., 2013), capturing a variety of beach-based activities throughout the year (e.g., swimming, kayaking, fishing) and parsed by local property owners and non-owners. For two beaches (Bowers and Slaughter), total recreational benefits exceed avoided losses to structures. At the remaining four beaches, avoided losses to structures exceed benefits to recreation. This is particularly true at Pickering and Kitts Hummock, relatively short and narrow beaches where structures are highly susceptible to loss from shoreline erosion.

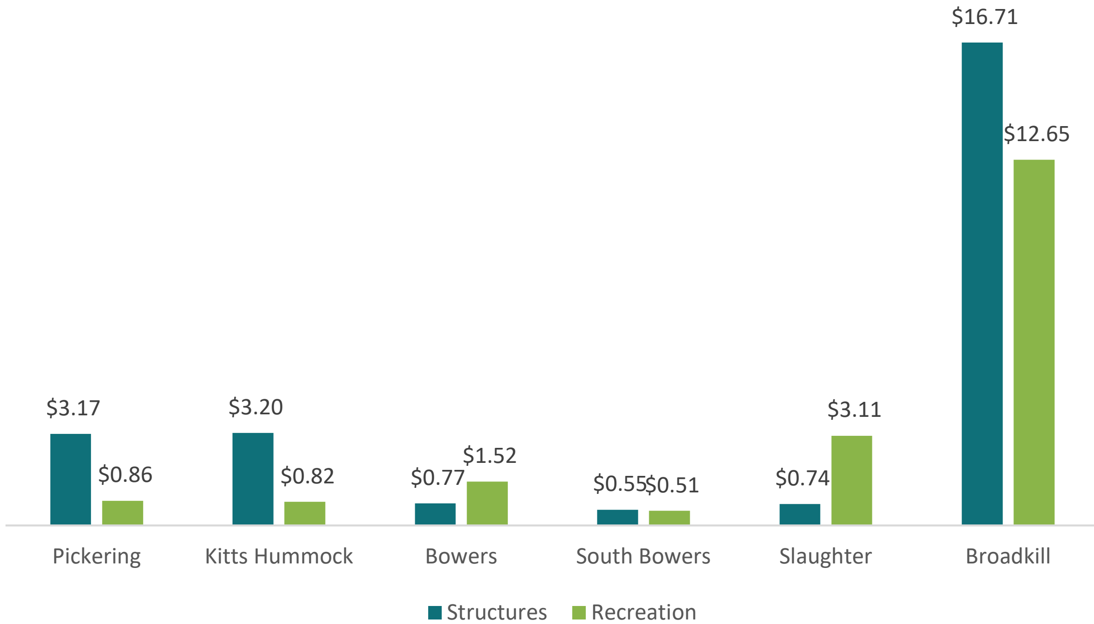


Figure D-1. Distribution of benefits between structures (reduced storm damages and housing services lost due to erosion) and recreation by beach, present value millions of constant 2023 USD (JMT 2014)

D.2 An Economic Analysis of Beach Renourishment for the State of Delaware (Black, Donnelley, and Settle 1988)

This study, conducted by economists at the University of Delaware, is the first in a series of three focused on Atlantic coast beaches. The study focuses specifically on the benefits and costs of a large, proposed beach nourishment project that involves expanding beach width by 165 feet from Bethany Beach south to the Maryland border. The study uses real estate appraisals to estimate increases to private property values associated with nourishment, reflective of enhanced protection from coastal storms and additional amenity values associated with proximity to wider beaches. It also considers benefits to beach recreation from decreased crowding and attempts to quantify the net in-state expenditure impacts (i.e., the change in expenditures originating outside of Delaware).

Over the 11-year analysis timeframe, the study found positive net benefits overall, as well as at each individual project site. However, the authors note significant variation across sites primarily attributable to differing levels of public access (including no public access at the private beaches). The study found that property value benefits ($49.9 million) exceed benefits to beach recreation ($11.2 million) by roughly fivefold. Because economic impacts from expenditures (i.e., employment, income, and taxes, ostensibly a State benefit) are relatively minor in comparison, and household incomes of coastal property owners and beachgoers are relatively high (i.e., the direct beneficiaries have the ability to pay), the authors conclude that the State should bear a small portion of overall costs.

D.3 The Economic Effects of a Five Year Nourishment Program for the Ocean Beaches of Delaware (JFA 1998)

This study, led by Jack Faucett Associates, Inc., is similar to Black, Donnelly, and Settle 1988. Key differences include the geographic scope, the nourishment scenario analyzed, and the methodology used to estimate changes to property values. Geographically, JFA 1998 considers more area along the Atlantic coast (from Rehoboth south to Fenwick Island). The nourishment design, however, is more modest, intended to maintain (but not enhance) beach width. Methodologically, JFA 1998 differs from the earlier study in that it estimates an empirical relationship between beach width and property values rather than relying on expert (realtor/appraiser) judgement.

Over the five-year analysis timeframe, the study estimated the following aggregate benefits of nourishing to maintain the coastline (as it existed at the time), which exceed the estimated cost. The primary benefit is maintenance of coastal property values ($81.7 million), followed by tourism expenditures ($57.0 million) and the value (measured as willingness to pay per trip) of preserving beach recreation trips ($37.9 million). The study then allocates the benefits in those categories to State and out-of-state beneficiary groups using coastal property ownership data and information on the place of residence of recreators. The authors conclude that just eight percent of recreation benefits and 40 percent of all other benefits accrue to Delaware residents.

D.4 The Economic Effects of a Five Year Nourishment Program for the Ocean Beaches of Delaware, Updated (Chrysalis 2007)

This study, led by Chrysalis Consulting, Inc., is an update to JFA 1998. The studies are nearly identical in geographic coverage, shoreline management scenario, and methodology. The primary update is to data. As before, the main benefit is maintenance of coastal property values ($163.2 million), followed by tourism revenue ($134.4 million), and beach recreation ($34.6 million). In addition, this study reaches a similar conclusion regarding the distribution of benefits in and out of Delaware. Coastal properties are owned primarily by out-of-state residents (60 percent), and Delaware residents account for just 10 percent of beach visitors.

One interesting finding from this study is that the observed empirical relationship between coastal property values and beach width in JFA 1998 appears to have diminished completely in subsequent years. The authors suggest that this indicates the housing market has internalized expectations for the state to continue funding nourishment to maintain the coastline. Therefore, they rely on the empirical relationship identified in the prior analysis to estimate the contribution of beach nourishment to coastal property values.

D.5 Army Corps of Engineers Economic Analyses (USACE-EA various years)

USACE performs economic analysis of beach nourishment projects as a component of Feasibility Studies. For this literature review, we considered all available USACE feasibility studies for

Delaware's public beaches: Pickering, Kitts Hummock, Bowers, South Bowers, Slaughter, and Broadkill (combined, USACE-EA 2018); Lewes (USACE-EA 1997); Rehoboth and Dewey (combined, USACE-EA 1996); Bethany and South Bethany (combined, USACE-EA 1998); and Fenwick Island (USACE-EA 2000). Within these studies, USACE uses avoided storm damages (relative to project costs) to select an optimal nourishment design. The feasibility studies also report on other benefits, including recreation. USACE-EA 2018, however, differs in scope from the other studies and does not assess recreation impacts. Therefore, we do not include that study in further review.

Findings from the USACE economic analyses are summarized in Figure D-2. For each beach analyzed, storm damage reductions to residential structures exceed recreational benefits. For one beach (Lewes), USACE concluded that the project would result in a minor reduction to storm damage but would have no impact on recreation. Aside from Lewes, the analysis of Bethany demonstrated the starkest difference between benefit categories, with reduced storm damage exceeding recreational benefits by nearly seven times.

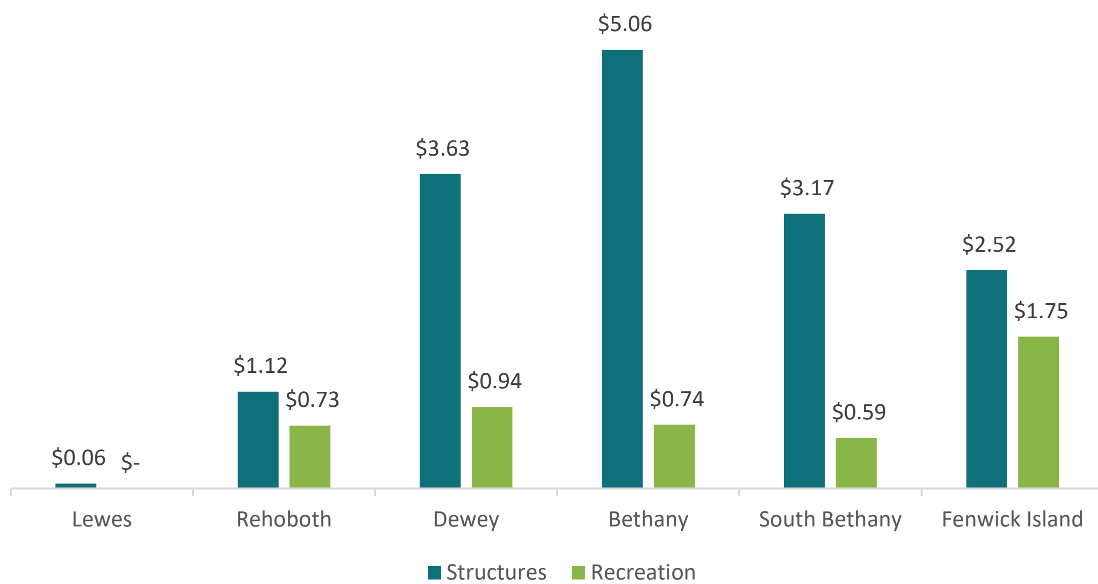


Figure D-2. Distribution of benefits between structures and recreation by beach, annualized millions of constant 2023 USD (USACE Feasibility Studies)

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