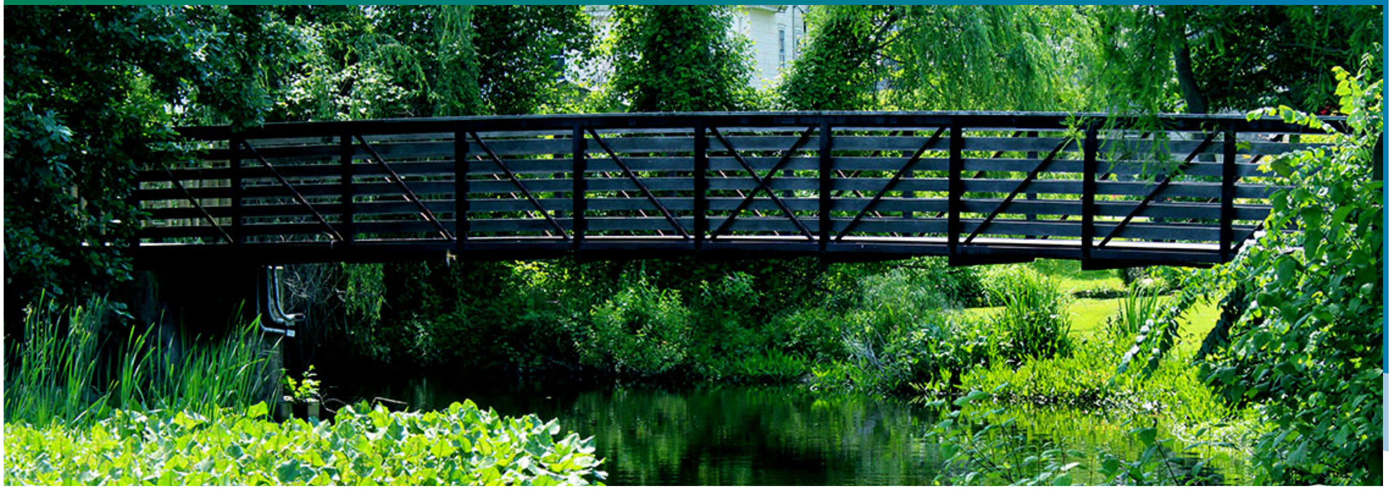

Vulnerability Assessment of the Mispillion and Cedar Creek Watersheds

Final report for

Waterways Infrastructure and Investment Network and National Fish and Wildlife Foundation

Grant ID #: 0318.20.069001

Partnership for the DELAWARE ESTUARY

July 2022 | Report No. 22-04

A publication of the Partnership for the Delaware Estuary—A National Estuary Program

Vulnerability Assessment of the Mispillion and Cedar Creek Watersheds

Final report

The Partnership for the Delaware Estuary (PDE), a 501(c)(3) environmental nonprofit organization, hosts the Delaware Estuary Program, which is one of 28 congressionally designated National Estuary Programs working to improve the environmental health of the nation's estuaries. PDE works to restore the health of the Delaware River and Bay - an environment on which millions of people, wildlife, and plants depend. With an emphasis on science and collaboration, and a focus on the entire Estuary, PDE is uniquely positioned to develop and implement programs that improve the Estuary. Working with and through PDE, concerned individuals, businesses, and governments can amplify their impact on protecting an important natural resource at the center of our region's quality of life.

Authors

Ella Rothermel

Joshua Moody

Kate Hutelmyer

Acknowledgments

The authors are deeply grateful for the generous funding provided for this effort by the National Fish & Wildlife Foundation National Coastal Resilience Fund ID#: 0318.20.069001 The Partnership for the Delaware Estuary would like to thank Danielle Swallow in particular for her invaluable guidance and feedback throughout the vulnerability assessment process. Jennifer Egan of the University of Maryland and John Callahan of the Delaware Geological Survey also provided essential input on project analysis parameters. The authors would like to acknowledge stakeholders including Bob Wood of Slaughter Beach, Brad Dennehy of Milford, and Sara Bloom of Milford, among many others, who supplied information and gave feedback regarding site selection and naming. Finally, previous PDE employee Kaitlin Tucker played a key role in formulating this project and her intellectual contributions helped to make it a success.

Suggested Method for Citing this Report.

Rothermel, E, J. Moody, and K. Hutelmyer. 2022. Vulnerability Assessment of the Mispillion and Cedar Creek Watersheds. Partnership for the Delaware Estuary Final Report for Waterways Infrastructure and Investment Network and Coalition and National Fish and Wildlife Foundation. PDE Report No. 22-04. 39 pages.

Executive Summary

The Mispillion and Cedar Creek Watersheds currently face multiple pressures that threaten the future value and health of nature-based resources and the stability of economically important infrastructure. Located along the Delaware Bayshore, these regions rely on natural assets for both the ecosystem services and ecotourism income they provide. However, many of these resources are currently vulnerable to flooding and may experience an even higher risk of inundation and damage in the future due to climate change. The present document introduces a vulnerability assessment tool that can help stakeholders and community members in the Mispillion and Cedar Creek Watersheds identify areas of relative vulnerability both today and in the future, better understand the interactive factors that may threaten regional nature-based resources, and inform place-based decisions regarding goal-based interventions to address both natural and economic losses. Combined with community feedback and economic evaluation, this tool can be used to conduct an investment analysis and eventually produce a management plan and future investment strategy for the region.

The Mispillion and Cedar Creek Watersheds vulnerability assessment tool can be used to examine risks to community resources in the context of flooding vulnerability, both today and tomorrow, as well as broad measures of social vulnerability so that managers and stakeholders have the ability to factor age, minority, and socioeconomic status into any prioritization decisions. Relative vulnerability is considered with respect to the entire area of both watersheds and to specific community-identified features of interest, and therefore does not represent a comparison to other watersheds in Delaware or beyond. As such, this tool is intended to be used to inform place-based prioritization efforts. Of note, current and future flooding risks were categorized using existing publicly available datasets; therefore, no new modeling or analyses were conducted for this effort. For this assessment, FEMA flood maps were used to represent current flooding risk, while the Delaware-specific coastal inundation map at 1′ and 2′ increments was chosen to approximate future flooding risk. Current and future flooding risk designations were combined to create a composite measure of flooding vulnerability consisting of five categories: Highest, High, Moderate, Low, and Lowest. The final flooding vulnerability tool and associated interactive map was created by layering base social, current flooding, future flooding, and composite flooding vulnerability maps on top of current land use and area of concern maps.

Composite vulnerability results revealed that the majority of land in the Mispillion and Cedar Creek Watersheds lies within the lowest category of current and future flooding risk (72% of the total study area), positioned inland beyond the ocean and the Mispillion River flood zones. However, critical communities such as the towns of Milford and Slaughter Beach are located in close proximity to water bodies, where current and future flooding risks are higher. Although only 6% of the total study area was found to have the highest composite vulnerability score, many of these high-risk regions are near the coast and overlap with valuable wetland habitat and agricultural land. Additionally, 10% of the study area was classified as high composite vulnerability, which indicates elevated future risk of flooding in combination with high current flooding risk.

Highest and high composite vulnerability land was concentrated near the coast, where populations have a relatively higher income and fewer minorities are present compared to the rest of the study area. However, these regions also contain a higher proportion of older (60+ yrs) residents, which may present a concern as coastal flooding and sea level rise continue to threaten these communities at an accelerated rate . High composite vulnerability to flooding also extends inland, up the Mispillion River and Cedar Creek, and intersects with inland areas that contain communities with relatively higher social vulnerability. Though populations in these communities are younger compared to coastal regions, higher proportions of residents are considered to have minority status and lower income. These inland areas may thus present locations for focused attention to ensure that socially-disadvantaged communities are not overlooked in the context of flooding risk assessment.

Roughly one third of the land nominated as areas of concern have at least some level of composite vulnerability risk; the remaining 68% of the area of concern regions was classified as lowest vulnerability. Protected land, parks and recreation assets, water access sites, and certain agricultural easements are among the areas of concern with the highest levels of composite vulnerability. Although most assets were found to have some current or future vulnerability to flooding, schools and hospitals are located entirely within lowest-risk areas.

The vulnerability assessment tool also identified the features with highest risk of combined current and future flooding in the focal communities of Milford and Slaughter Beach. Due to its inland location, no areas of concern in Milford were classified as having the highest vulnerability designation. However, assets closer to the River, including Goat Island and portions of the Mispillion Riverwalk, still contain areas with high vulnerability to current and future flooding. Other features further from the River, such as Marvel Square Park and the Milford museum, were not found to have any risk of flooding, today or tomorrow. In contrast, all areas of concern near Slaughter Beach have some degree of current or future flooding vulnerability. Land located inland of beach dune areas, including the Prime Hook National Wildlife Refuge and multiple agricultural easements, have the highest proportion of area in the highest-risk categories. Meanwhile, areas of concern such as community parks and beach access points that are located closer to the ocean, but along dune features, are composed of moderate- to low-risk land due to their relatively higher elevation.

Although the analyses and maps presented in this report provide useful takeaways regarding social vulnerability and risk of flooding across the Mispillion and Cedar Creek Watersheds, the true value of this product lies in its capacity as an adaptable tool that can be queried and updated over time. Since managers and stakeholders are likely to have their own needs-based approaches for how to prioritize site investments, this vulnerability assessment tool allows users to input multiple filters and search terms to locate desired combinations of land use, social status, and flooding risk. Walk-throughs included herein provide example queries that may prove useful in any eventual investment analysis. Additionally, this living tool can be easily updated as new datasets become available and when modeling forecasts are improved. The Mispillion and Cedar Creek vulnerability assessment tool can therefore help guide nature-based resiliency planning in a way that suits practitioner needs, both now and into the future.

Contents

Introduction

The Mispillion and Cedar Creek Watersheds contain some of the largest remaining tracts of protected land along the Delaware Bayshore. These lands and habitats provide vital natural resources, including one of the most productive horseshoe crab spawning areas in the world. The Mispillion region is also home to many communities, such as the towns of Milford and Slaughter Beach, that rely on environmental assets for both cultural and economic benefit. Stakeholders within these communities are invested in the natural beauty and bounty of their surrounding region and wish to maintain and grow this value for future generations. In order to determine the best strategies for managing resources into the future, the Waterways Infrastructure and Investment Network (WIIN) coalition was formed. WIIN is made up of partners and stakeholders aiming to create an investment strategy for the Mispillion and Cedar Creek Watersheds that enhances opportunities for nature-based investments and eco-tourism while helping communities become more resilient. A recently-completed regional economic study (https://www.derascl.org/_files/ugd/a0ae54_8bb2f43fb4c249858d8cef9180761f7a.pdf) commissioned by the group demonstrated the considerable value of select Mispillion resources; recreational capital afforded by natural assets likely ranges in the millions of dollars.

Despite their immense cultural and economic value, natural assets in the Mispillion and Cedar Creek Watersheds are likely to become increasingly threatened in the near future. Communities in the Mispillion region currently struggle with the impacts of flooding and storm surge, and these events are predicted to increase in frequency and intensity over time due to climate change. Already, sea level has risen 14-16 inches since 1920 in Delaware, and the rate of sea level rise in the area continues to accelerate. Sea level rise brings with it numerous adverse impacts including increased tidal surges, inundation, erosion, saltwater intrusion into septic systems and agricultural lands, and worsened severity of flooding from storm events. Together, these threats will place many valuable habitats and communities at increased risk over time. The Mispillion and Cedar Creek Watersheds are also faced with challenges of impending development and land use changes, which may impose further pressure on nature-based assets that are already vulnerable to flooding and inundation. Additionally, different communities within the watershed may be variably impacted by threats due to their social vulnerability. Economic status, household composition, and minority status of certain residents could amplify the effects of sea level rise and land use changes on these groups and necessitate a higher degree of planning in certain communities.

Considering the combined risks to valuable habitats and communities, there is a clear need for data-driven, resilient planning and investments in the Mispillion and Cedar Creek watersheds. The present report summarizes a geospatial vulnerability assessment tool developed for the Mispillion and Cedar Creek Watersheds, and provides the results of an initial assessment with a focus on specific community-identified features of interest, to inform a prioritization of place-based investments. As prioritization cannot exist independently of goals, and goals can vary among stakeholders, this tool allows users to explore place-based prioritization from multiple goal-based perspectives. The goal of the current assessment is to identify risks associated with current and future flooding scenarios within the context of land use, social vulnerability, and key areas of concern. Although flooding, sea level rise, land use planning, and social vulnerability are complex and dynamic factors, this assessment relies solely upon current and existing data to assess risk. Thus, no new data collection or modeling was conducted. However, this assessment is intended to provide a process for asset risk identification that can be adapted and improved over time by management bodies or communities as new information (i.e., datasets) become available. Ultimately, this vulnerability assessment product is a living tool to provide results to be combined with insights from the previous economic study to create a resource management plan for the region (Figure 1). Through an investment analysis that considers new ecotourism opportunities and stakeholder feedback, this vulnerability assessment can inform how to prioritize sites in the Mispillion and Cedar Creek Watersheds for protection, enhancement, and investment.

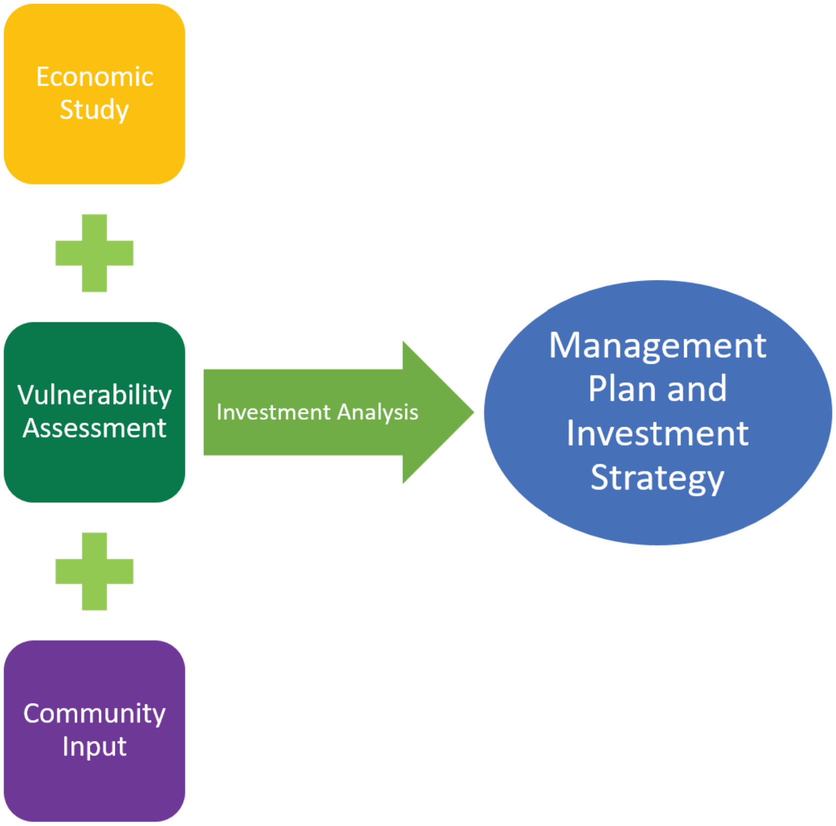

Figure 1. Flow chart of steps leading to a natural asset Management Plan for the Mispillion and Cedar Creek Watersheds. Results of this assessment can be combined with outputs from the University of Maryland Environmental Finance Center economic study through an investment analysis to prioritize key opportunities for investment.

Methods and Data Visualization Products

Data Sources

Datasets were compiled from pre-existing, scientifically validated, sources and are described below. The WIIN coalition and community stakeholders provided guidance regarding asset identification and threshold levels for analysis (e.g., magnitude of inundation considered). Data were obtained in the form of shapefiles and analyzed in ArcGIS version 10.8.1. A catalog of all base layer and analysis shapefiles are included in the map package, "PDE_MispVulnAssessment", associated with this report and are available for use in the next steps of the study.

Base Shapefile Data Compilation and Categorization

The following sections describe data sources and manipulation, an explanation of the attribute table associated with each shapefile, and instruction on how a user can view various attributes.

1. Current Land Use Base Shapefile

In order to summarize the human and natural landscape of the Mispillion region and provide area-wide metrics of vulnerability, a shapefile was developed to depict current land use from Delaware's 2017 classification of Land Use Land Cover (LULC) and a selection of stakeholder-nominated parks and recreation assets. LULC is a product provided by USGS that classifies land use categories based on satellite imagery and are thus general in nature. Details regarding how satellite imagery is classified for LULC analysis can be found at: https://pubs.usgs.gov/pp/0964/report.pdf. Existing classifications were regrouped into the following types (broad) and categories (refined):

a) **Type**: Developed
 Category: Residential, Commercial/Industrial, Critical Infrastructure
b) **Type**: Agriculture
 Category: Agriculture, Rangeland, Other (Ag)
c) **Type**: Habitat
 Category: Forest, Wetland, Sand/Shore
d) **Type**: Recreation
 Category: Parks/Recreation, Marinas/Boat, Historic, Other (Rec)

Each polygon for current land use in the base shapefile is associated with both a land use type and category that can be viewed in the associated attribute table (Table 1). Type and category classifications allow any map package user to display, select, or turn off land uses as desired. Original LULC classification is retained in the attribute table under the column "LULC_CATEG" if greater specificity is needed, and area calculations in acres are also included. Water bodies were clipped from the study area to ensure that acreage accurately reflected currently inhabitable land.

Table 1. Description of Current Land Use base shapefile attribute table features.

Attribute Column Header	Type	Category	LULC_Category	Acres
Description of attribute	Current Land Use general classification	Current Land Use more-specific classification	Original LULC classification	Total area of the Current Land Use polygon, in Acres (US)

A publication of the Partnership for the Delaware Estuary—A National Estuary Program

Current land use in these watersheds is dominated by agricultural land (Figure 2). Recreation assets take up relatively less area in comparison, but this type of classification may underestimate the amount of land that is used for human recreation in practice. Habitat, most of which is wetland, takes up more than a quarter of the land in the study area and provides numerous recreational opportunities to residents and visitors. For the purposes of this land use summary, all forests, nature reserves, and natural undeveloped areas were classified as habitat to underscore their function as natural ecosystems. However, ecosystem services and recreation opportunities provided by these habitats make them valuable to humans both culturally and economically. Lastly, developed land makes up less than a quarter of current land use and it is largely comprised of residential areas (Figure 3).

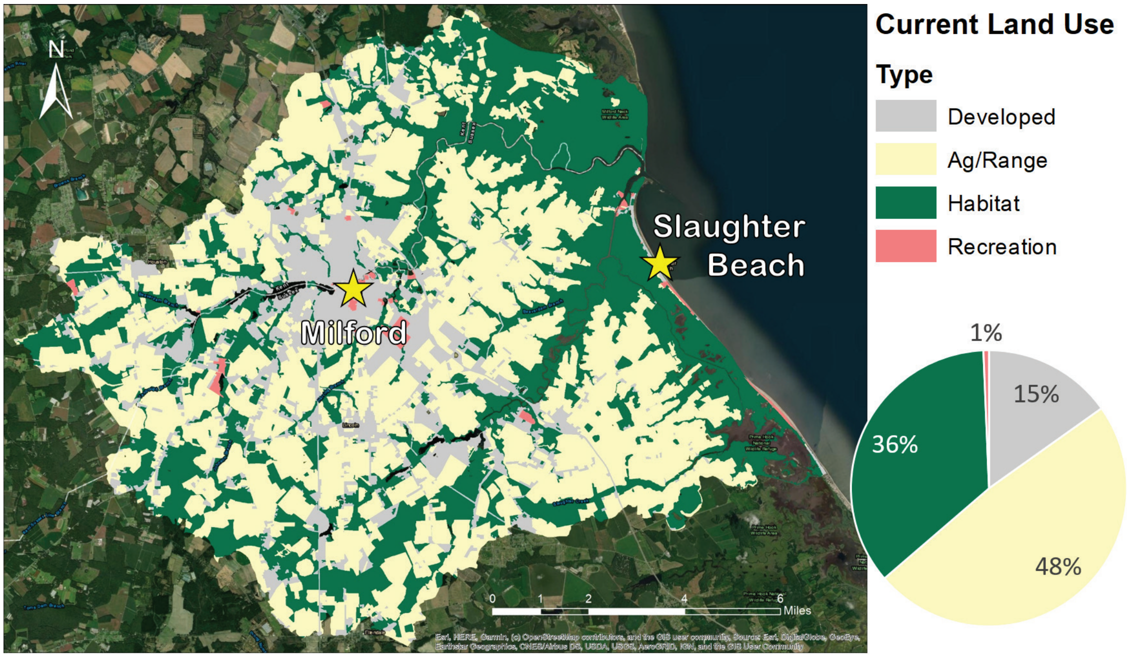

Figure 2. Current Land Use by type. 74,317 Acres makes up the entire study area.

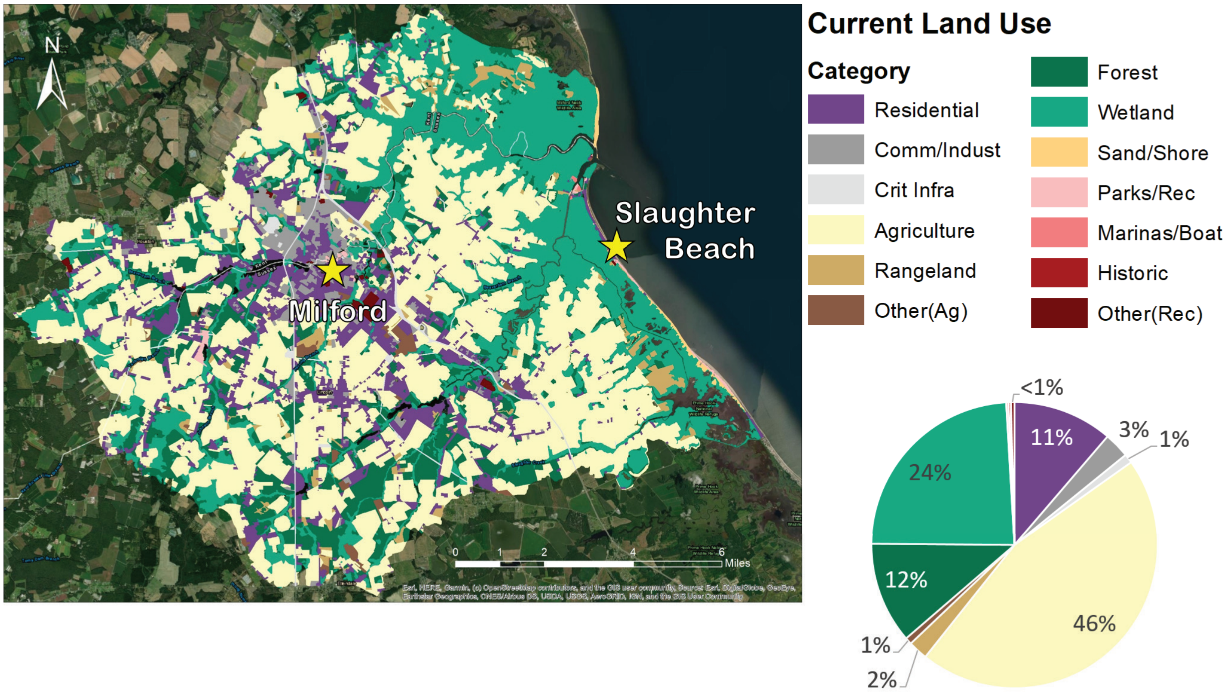

Figure 3. Current Land Use by category. 74,317 Acres makes up the entire study area.

2. Areas of Concern Base Shapefile

The vulnerability of specific types of assets and resources were a key concern for partners and stakeholders. Thus, in addition to watershed-wide land use, individual areas of concern were compiled into a unique shapefile. Data sources varied depending on information type, but all areas of concern were either suggested by project partners or nominated by stakeholders. Sources ranged from state data to individual polygon delineations by community members. Data sources are listed below along with available area of concern type:

a) Delaware State Plane

  Type: Hospitals, Schools, Historic Sites, Roads

b) University of Maryland Environmental Finance Center

  Type: Water Access, Recreation Facilities, Trails

c) 2018 Sussex County Comprehensive Plan

  Type: Protected Land, Existing and Developing Areas, Agricultural Preservation, Wellhead Recharge Areas

d) Stakeholder-delineated polygons

  Type: Historic Sites, Recreation Facilities, Water Access

Historic sites are both registered historic features and historic districts. Water access features are a combination of canoe launches, boat ramps, piers, and marinas. Protected land includes nature preserves, public parks, state forests, and wildlife areas. Trails are both hiking and biking paths. Each data source was examined for quality assurance and control before the appropriate polygons within the clipped feature extent were merged into one shapefile. Water bodies were excluded from areas of concern. Roads, which included both evacuation routes and byways, were isolated into a unique base shapefile to facilitate easier visualization of these critical features. Attributes in the areas of concern base shapefile include "Type" "Detail", and "Acres" (Table 2). Detail provides additional information regarding specific polygon characteristics provided by the nominator. Unique area of concern types can be selected, symbolized, or turned off within the map package, depending on the needs of the user

Table 2. Description of Areas of Concern base shapefile attribute table features.

Attribute Column Header	Type	Detail	Acres
Description of attribute	Area of Concern general classification	Area of Concern specific identifier	Total area of the Area of Concern polygon, in Acres (US)

Many areas of concern are small in extent and concentrated near the towns of Slaughter Beach and Milford (Figure 4). Certain features such as preserved agricultural lands, developing areas, and wellhead recharge areas overlap and take up a greater amount of acreage.

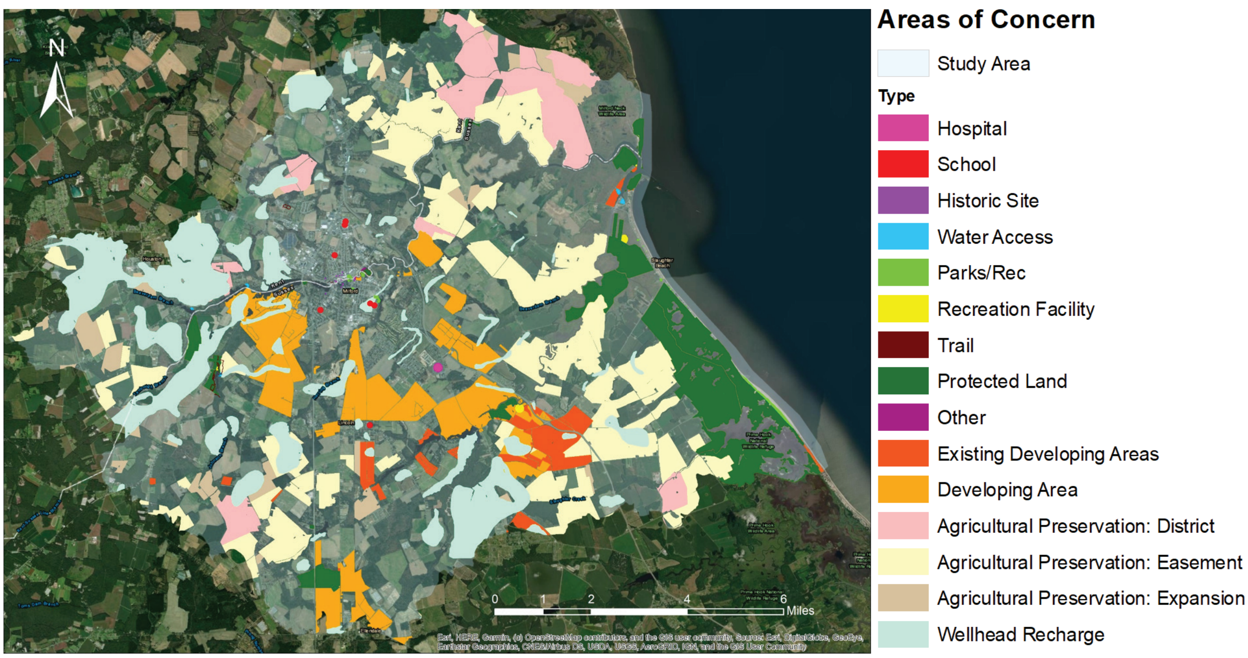

Figure 4. Areas of concern listed by type. Areas of concern comprise 36, 827 Acres of the study area.

3. Social Vulnerability

Due to the likelihood that aspects of social status might influence the vulnerability of groups residing in the Mispillion watershed, social vulnerability was incorporated into the assessment. Base shapefile information was sourced from the 2018 CDC Social Vulnerability Index (SVI) dataset. Spatial resolution was relatively coarse (i.e., census tract) compared to land use and areas of concern. Despite the social vulnerability shapefile only containing 11 large-scale polygons, broad differences in social status between groups provided important, spatially distinct, levels of vulnerability.

To facilitate comparison of vulnerability between census tracts, social indicators were selected and ranked relative to one another within the Mispillion and Cedar Creek Watersheds. Although the CDC SVI dataset includes cumulative indices of vulnerability, these are calculated over the entire national CDC dataset, which smoothed differences at the local scale. Therefore, this analysis focused on key indicators that were relevant to the Mispillion region, local resilience to climate and land use changes, and were classified as either high or low vulnerability. Three representative vulnerability indicators were chosen through guidance from project partners to represent critical SVI summary themes as listed below:

a) Theme: Socioeconomic Status

  Indicator: Per Capita Income Estimate

b) Theme: Household Composition

  Indicator: Estimated Percent Aged 65+

c) Theme: Minority Status

  Indicator: Estimated Percent Minority

Although other aspects of social vulnerability were available, many indicators of vulnerability within each theme were correlated. The chosen indicators were selected due to their likely relevance to stakeholders and product end users. Indicators within each social theme were classified as high or low vulnerability using a natural Jenks breakpoint of census data within the study area. Natural Jenks identified a logical breakpoint between an upper and lower half of each indicator dataset such that each tract could be classified into regionally relative high and low vulnerability bins. All three indices of social vulnerability were calculated within a singular shapefile that was composed of census tracts and used to create the final base social vulnerability shapefile (described in "Social Vulnerability Classification" Section).

Highest socioeconomic vulnerability was centralized in the census tracts surrounding the town of Milford and in the very western edge of the watershed study area (Figure 5). Per capita income was relatively higher in the region containing Slaughter Beach and the tracts immediately west of Milford, indicating that these communities generally have a lower vulnerability in terms of socioeconomic status. In general, household composition vulnerability mirrored these spatial trends and showed higher percentages of the population aged 65+ in the tracts west of Milford and surrounding Slaughter Beach (Figure 6). Household composition was generally younger, and therefore relatively less vulnerable, in the middle census tracts encompassing Milford and areas both north and south. However, the higher household composition vulnerability (older composition) designation takes up a greater overall amount of acreage in the region. Highest vulnerability in terms of minority status was concentrated in only the middle and southern census tracts of the study area (Figure 7). Most spatial area of the two watersheds is comprised of households in the lower minority status vulnerability category.

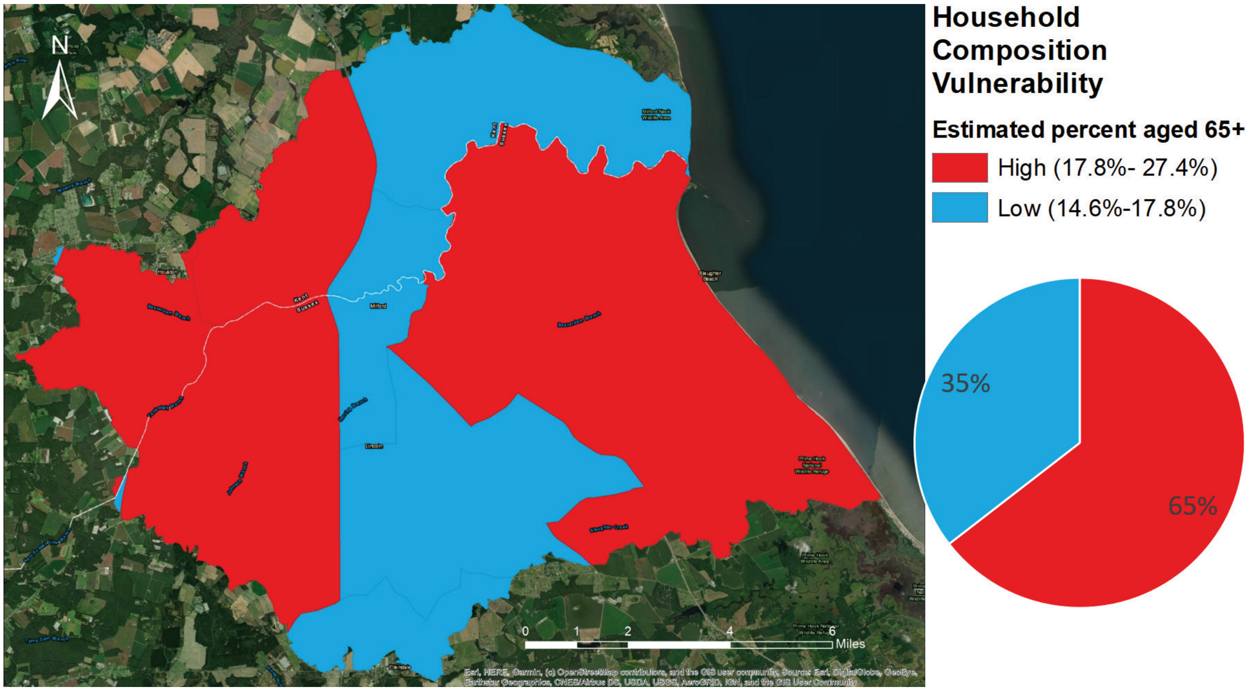

Figure 5. Socioeconomic vulnerability with respect to per capita income estimate. Total area of social vulnerability census tracts is 76,612 Acres.

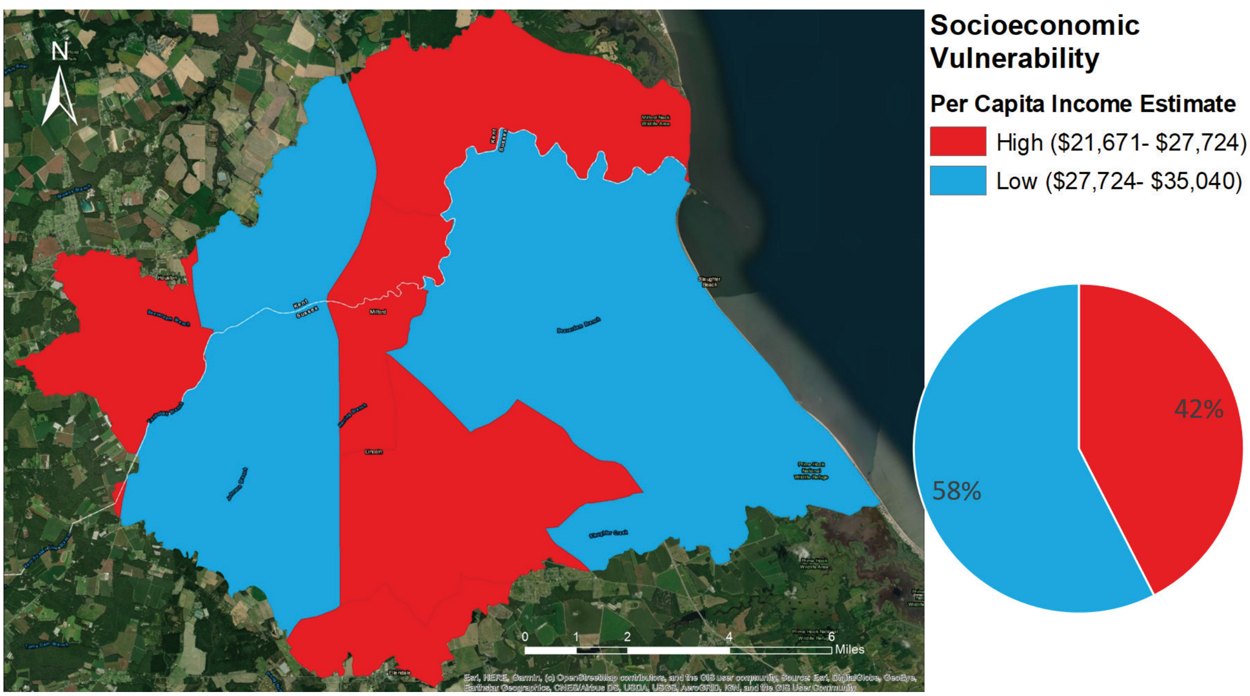

Figure 6. Household composition vulnerability with respect to estimated percent of population aged 65+. Total area of social vulnerability census tracts is 76,612 Acres.

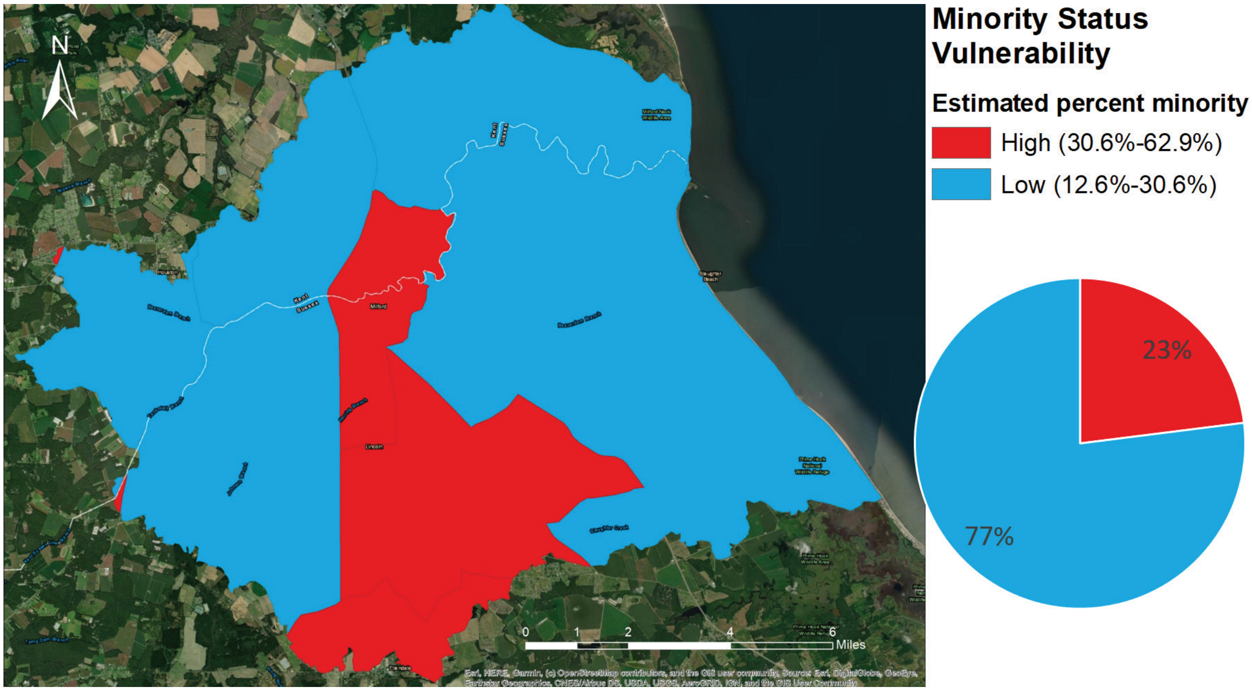

Figure 7. Minority status vulnerability with respect to estimated percent minority. Total area of social vulnerability census tracts is 76,612 Acres.

4. Current Flooding Risk

Following consultation with WIIN project partners and Delaware Geologic Survey representatives, FEMA Flood maps were determined to provide appropriate data for representing current flooding risk in the Mispillion region. Categories of risk for this shapefile were delineated based on zones of the area's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. FIRM maps are calculated based on a yearly 1% chance of flooding as related to 100-year flood information. Risks under 1% annual flooding thus translate to a 26% chance of flooding over the next 30 years. The FIRM also accounts for increased risk from coastal flooding. FEMA flood zones were translated into current risk categories as follows:

a) Zone VE: Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves

Vulnerability: High

b) Zone AE: Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage

Vulnerability: Moderate

c) Zone X: Areas of moderate to minimal flood hazard, usually the area between the limits of the 100-year and 500-year floods

Vulnerability: Low

Current flood risk categories were calculated using attribute table manipulations to associate each FEMA flood zone with the designated level of vulnerability. FEMA Flood zone information and vulnerability level classification are both included in the final base shapefile for current flooding. Flooding data can therefore be visualized or filtered according to either attribute.

Nearly three quarters of the area of interest is classified as having low vulnerability to current flooding (Zone X; Figure 8). High to moderate current flooding vulnerability occurs over a smaller acreage of land (28%) but is most concentrated near the coastline and around the Mispillion River and Cedar Creek, where communities like the towns of Slaughter Beach and Milford are located.

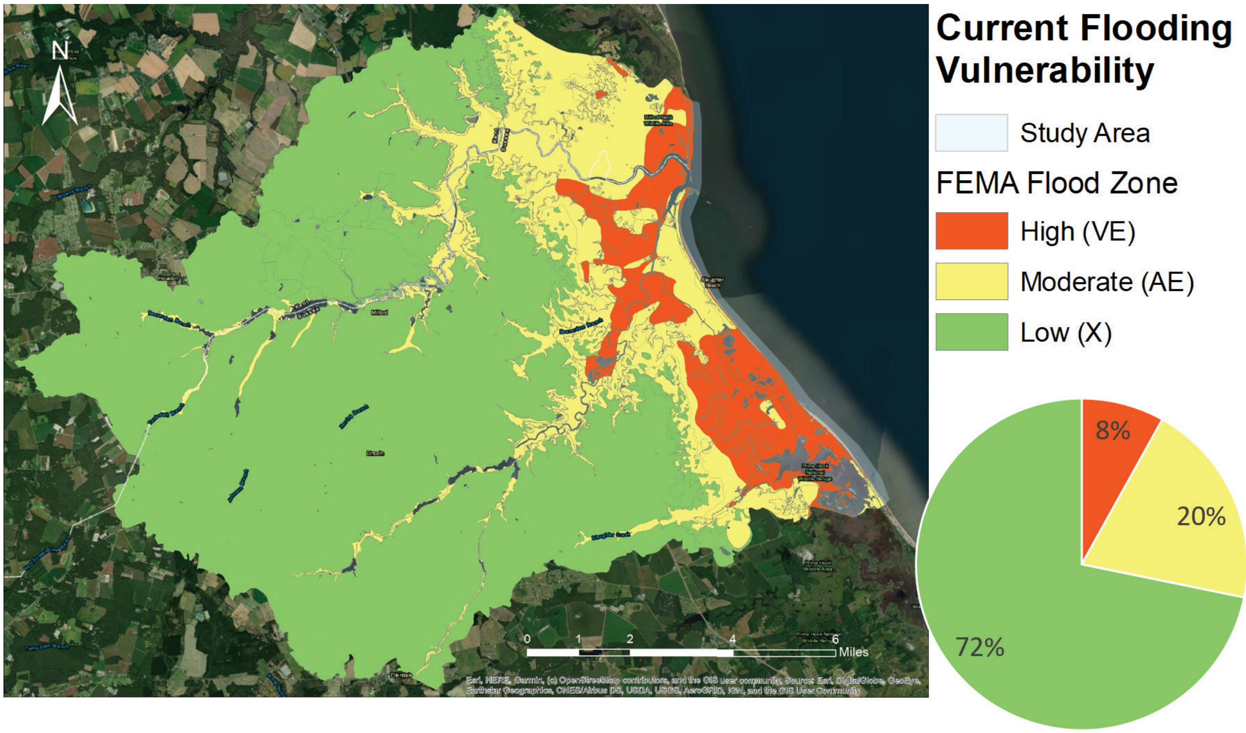

Figure 8. Current Flooding Vulnerability. Current flooding data encompasses a total of 74,385 Acres.

5. Future Flooding Risk

Future flooding scenarios in the Mispillion region are difficult to predict given the numerous complex and overlapping processes such as sea level rise, erosion, storm surge, and saltwater intrusion that will influence flooding impacts. Additionally, there is a lack of existing models that incorporate these different processes into future projections of flooding risk across a dynamic landscape. A series of coastal inundation geospatial data layers produced by the Delaware Geologic Survey in cooperation with DNREC Delaware Coastal Programs presented a region-specific and highly-detailed data source for future flooding risk. The inundation layers depict a "bathtub" model of water surfaces extending from mean higher-high water (MHHW), based in 1-foot increments. Although this model is derived from a high-quality, 1-meter Digital Elevation Model based on the 2014 state-wide LiDAR acquisition, it is a static layer based on current features that does not account for water dynamics or interacting factors that may introduce unexpected patterns to future flooding. Delaware Geologic Survey experts suggested that these datasets have a higher local accuracy than regional models, due to data smoothing at larger, regional, spatial scales. Additionally, it was suggested that inundation up to 3′ be considered due to the absence of wave-based inundation. These suggestions were presented to stakeholders from the towns of Milford and Slaughter Beach, and it was agreed to use the Delaware-specific inundation datasets, but to constrain analyses to the 1′ and 2′ contours to represent potential flooding scenarios over the coming decades. Coverage by 1′ and 2′ inundation layers was translated into vulnerability to future flooding as outlined below:

a) Features covered by 1′ of inundation
   Vulnerability: High
b) Features covered between 1′ and 2′ of inundation
   Vulnerability: Moderate
c) Features not touched by either level of inundation
   Vulnerability: Low

Similar to current flood risk, future flood risk categories were calculated using attribute table manipulations to associate each inundation layer with the determined level of vulnerability. Since inundation levels were directly correlated with vulnerability categories, only future flooding vulnerability was included in the final attribute table. Like other attributes, future flooding risk base shapefile categories can be depicted, filtered, or selected in different ways depending on user needs.

Compared with low vulnerability to current flooding, low vulnerability to future flooding makes up an even larger percentage of the study area (83%; Figure 9). Areas with high vulnerability to future flooding (areas covered by 1′ of inundation) are again located near the coast and connected waterways, placing the towns of Milford and Slaughter Beach at increased risk of inundation impacts. Moderate future flooding vulnerability locations (areas covered only at 2′ of inundation) are relatively small in area; the amount of area covered at 1′ of inundation is much greater than the extra area added by another foot of inundation (15% and 2% of total area, respectively).

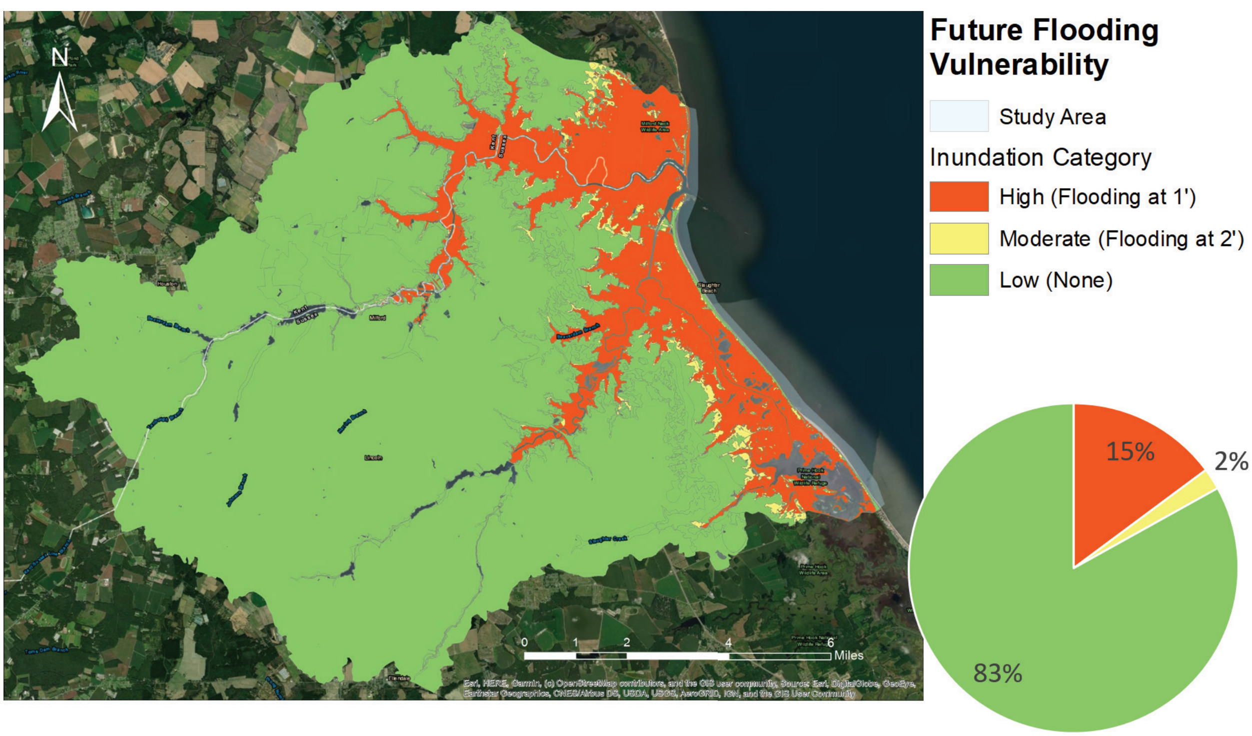

Figure 9. Future Flooding Vulnerability. Future flooding data encompasses a total of 74,385 Acres.

Vulnerability Classification and Assessment Process

Following base shapefile creation, vulnerability factors were combined to holistically identify hazards to features of interest. Both social vulnerability and flooding vulnerability were summarized by weighing factors from the base shapefiles described in the previous sections. The proceeding sections will describe how vulnerability was classified and added to current land use and areas of concern shapefiles to provide a complete assessment product.

1. Social Vulnerability Classification

Base shapefile socioeconomic, household composition, and minority status vulnerability categories were integrated to provide a snapshot view of social vulnerability. The household composition indicator looked at the percentage of the population that is over 65 because this is the fastest growing demographic in Delaware and this demographic is at a stage of life where they may be disproportionately impacted by climate change and environmental change. A composite social vulnerability status was calculated using a matrix of possible delineations between high and low vulnerability levels for each social theme. Composite vulnerability fell into only four out of eight possible attribute combinations, and no census tracts had either entirely high or low vulnerability to all social vulnerability indicators (Table 3).

Areas with low socioeconomic and minority status vulnerability, but high percentage of population aged 65+ make up the majority (58%) of the Mispillion and Cedar Creek watersheds, primarily located in the coastal region surrounding Slaughter Beach and in the tracts immediately west of the town of Milford. A population that is highly vulnerable regarding socioeconomic and minority status, but primarily younger, accounts for 23% of the total area and is located in the middle of the study region, around the town of Milford. Smaller areas are represented by highly vulnerable, but low minority and less vulnerable, but lower income census tracts and are located near the periphery of the study area (Table 3 & Figure 10).

Table 3. Deliniation of Composite Social Vulnerability

Level	Socioeconomic	Household Comp	Minority Status	Area% (acres)	
Highest	h	h	h	0	
High	l	h	h	0	
High	h	l	h	23	High, but younger
High	h	h	l	7	High, non-minority
Low	h	l	l	12	Low, less income
Low	l	h	l	58	Low, but older
Low	l	l	h	0	
Lowest	l	l	l	0	

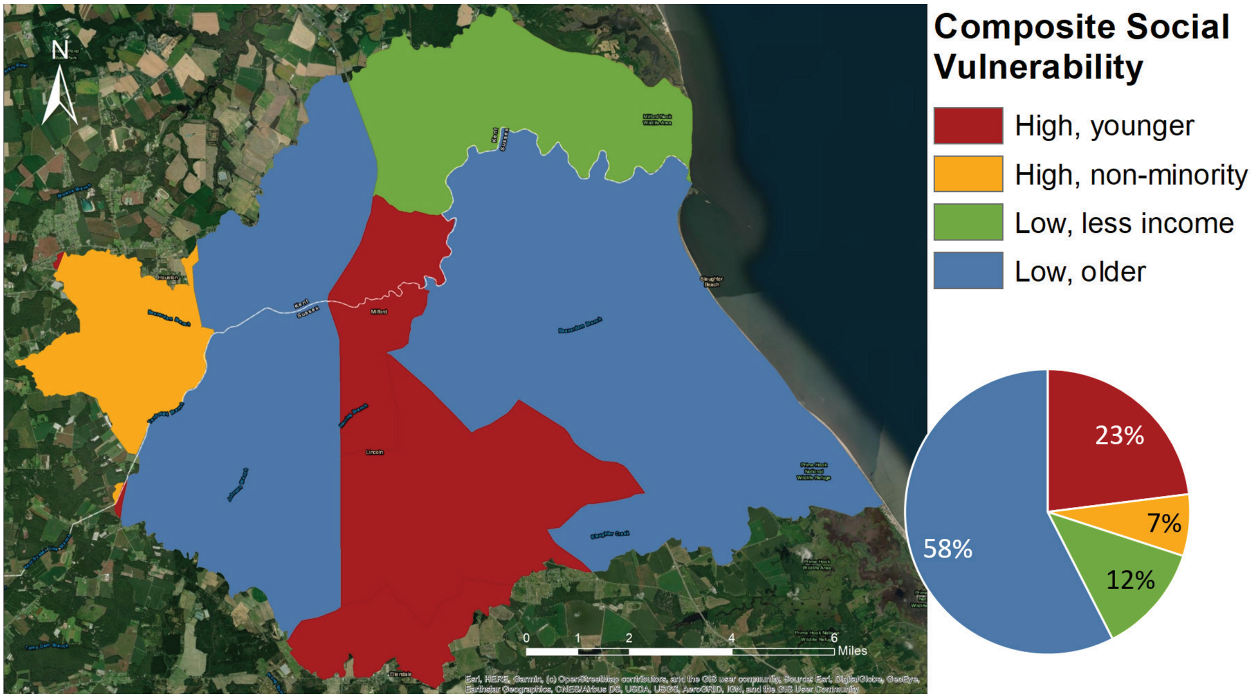

Figure 10. Composite Social Vulnerability. Total area of social vulnerability census tracts is 76,612 Acres.

The final attribute table for the social vulnerability base shapefile contains a column for each theme and a designation of "high" or "low" socioeconomic status, household composition, or minority status for each census tract polygon feature, along with composite social vulnerability (Table 4). Columns for census tract identification and total feature acreage are also included. Social vulnerability classifications can be visualized individually or used as a selection query for other features in the map package. All original CDC SVI attributes are retained in the final base shapefile attribute table, but are hidden to reduce clutter. The user can navigate to "Table Options" and select "Turn All Fields On" to view other data types or social vulnerability factors that were not considered in this assessment.

Table 4. Description of Social Vulnerability base shapefile attribute table features.

Attribute Column Header	LOCATION	SocEconom	HouseComp	Minority	SocialVuln	Acres
Description of attribute	Census tract identification number and county	Socioeconomic vulnerability class	Household composition vulnerability class	Minority status vulnerability class	Composite social vulnerability designation	Total area of the census tract, in Acres (US)

2. Categorization of Flooding Vulnerability, Today and Tomorrow

Like social vulnerability, base shapefiles for flooding risk were integrated in a vulnerability matrix to calculate a composite flooding vulnerability score (Table 5). The nine possible current and future vulnerability combinations were partitioned into six final composite flooding vulnerability categories (Table 5 & Figure 11):

1. Lowest (72% of total study area): low vulnerability to either current or future flooding. To facilitate easier comparison of holistic risk levels, areas in this lowest composite vulnerability category are excluded from data summary maps and figures.
2. Low (10% of total study area): areas that currently have moderate vulnerability to flooding but have a low likelihood of being vulnerable to future inundation. These regions mostly lie inland within the study area (Figure 11).
3. Moderate (3% of total study area): areas that could become flooded at 2′ that are currently at a low or moderate flooding risk as well as areas that are at a high risk of current flooding but have no vulnerability to future inundation.
4. High (10% of total study area): High current with moderate future flooding vulnerability, or high future with moderate or low current flooding vulnerability. In this category, future predictions were weighted higher than current categorization so that any area predicted to be inundated at 1′ is included (high future vulnerability), but areas of current high vulnerability for which there is no evidence of future inundation at 1′ are excluded. This method partitioned future vulnerability at 1′ & 2′. The high composite flooding category encompasses a large portion of the vulnerable study area and extends into the Town of Milford (Figure 11).
5. Highest (6% of total study area): High current and future vulnerability. Nearly a quarter of the region that is considered vulnerable to flooding exists in this category, which is spread across the coastal zone in a large portion of the town of Slaughter Beach (Figure 11).

Table 5. Categorization of flooding vulnerability, today and tomorrow.

Composite Vulnerability		Future Vulnerability		
		H	M	L
Current Vulnerability	H	Highest	High	Moderate
	M	High	Moderate	Low
	L	High	Moderate	Lowest

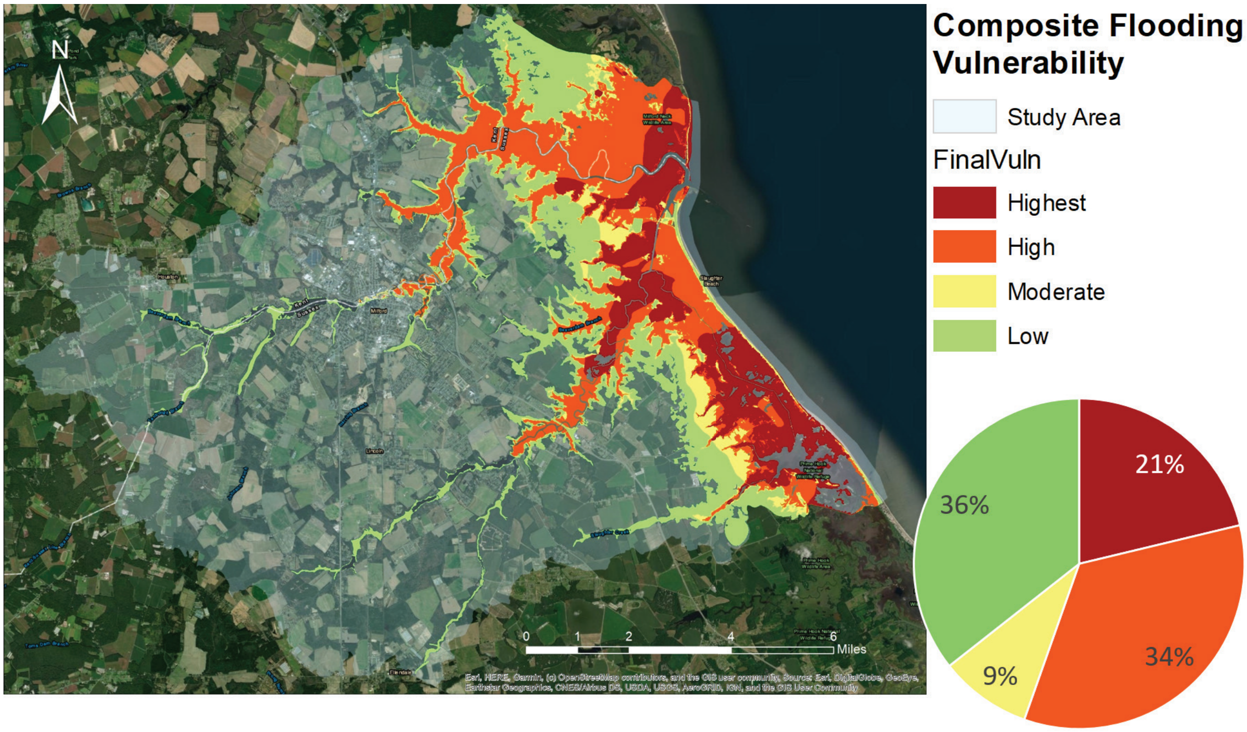

Figure 11. Composite Flooding Vulnerability of area at risk of current or future flooding. Flooding data encompasses a total of 74,385 Acres, of which 21,020 are considered vulnerable to flooding, today or tomorrow.

The attribute table for the flooding vulnerability base shapefile thus displays columns for current, future, and composite vulnerability as well as area calculations (Table 6). Some information from original FEMA layers and acreage calculations are also provided.

Table 6. Description of Flooding Vulnerability base shapefile attribute table features.

Attribute Column Header	FLD_ZONE	ZONE_SUBTY	CurrentVuln	FutureVuln	FinalVuln	Acres
Description of attribute	Original FEMA flood zone designation	Details from original FEMA dataset	Current vulnerability to flooding	Future vulnerability to flooding	Composite vulnerability to flooding	Total area of the flood risk polygon, in Acres (US)

3. Layered Steps of the Vulnerability Assessment Process: Current Land Use and Areas of Concern Analysis Shapefiles

Final vulnerability assessment products were created by combining the base and analysis shapefiles described above as presented in Figure 12. To provide both region-wide and site-specific vulnerability details, current land use and areas of concern base shapefiles underwent a process of layered data intersection. First, each of the shapefiles (both general current land use and specific areas of concern), were combined with the final social vulnerability analysis shapefile using the intersection tool in ArcGIS. This tool computes the geometric intersection of the input features such that all features or portions of features are retained in the attribute table of the output. Thus, new polygon features were created for every instance where land use and social vulnerability intersected, with every new combination of attributes being listed in the resulting attribute table. The combined land use and social vulnerability shapefiles were then intersected with the flooding vulnerability shapefile, which contained attribute columns for current, future, and composite flooding vulnerability. The final vulnerability assessment analysis shapefiles for current and future land use thus contain all original attributes of land use type or category along with columns indicating socioeconomic, household composition, minority, composite social, current flooding, future flooding, and composite flooding vulnerability for each feature (Tables 7 and 8). Final area calculations in acres are also included in the attribute table to facilitate simple summaries and comparisons of vulnerability. Areas of concern in the "Road" type are included in the map package as a unique analysis layer and contain the same attributes as the areas of concern analysis layer. Together, these intersected shapefiles represent the vulnerability assessment tool that can be used to display or query vulnerability information in complex combinations.

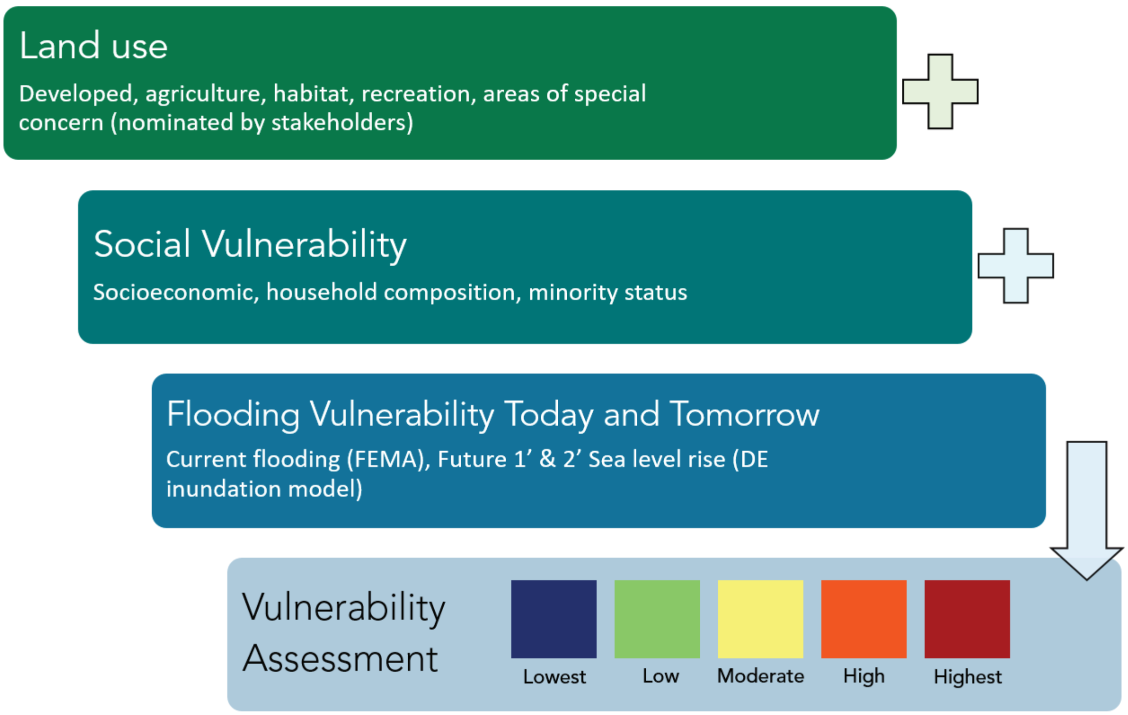

Figure 12. Flow chart of vulnerability assessment steps

Table 7. Description of Current Land Use analysis shapefile attribute table features.

Attribute Column Header	Type	Category	SocEconom	HouseComp	Minority	SocialVuln	CurrentVuln	FutureVuln	FinalVuln	Acres
Description of attribute	Current Land Use general classification	Current Land Use more-specific classification	Socioeconomic vulnerability class	Household composition vulnerability class	Minority status vulnerability class	Composite social vulnerability designation	Current vulnerability to flooding	Future vulnerability to flooding	Composite vulnerability to flooding	Total area of the flood risk polygon, in Acres (US)

Table 8. Description of Areas of Concern analysis shapefile attribute table features.

Attribute Column Header	Type	Detail	SocEconom	HouseComp	Minority	SocialVuln	CurrentVuln	FutureVuln	FinalVuln	Acres
Description of attribute	Area of Concern general classification	Area of Concern specific identifier	Socioeconomic vulnerability class	Household composition vulnerability class	Minority status vulnerability class	Composite social vulnerability designation	Current vulnerability to flooding	Future vulnerability to flooding	Composite vulnerability to flooding	Total area of the flood risk polygon, in Acres (US)

Limitations

Although formulated shapefile products use the best available data and reflect current understanding of relative risk, there are a number of limitations and assumptions surrounding their representation that need to be understood. First, the coarse scale of CDC SVI census data necessitates that large swaths of land are assumed to have a certain social risk status, even though large sums of area within these tracts may be habitat or sparsely inhabited. Despite maps not necessarily reflecting exact social conditions over all land covered by a census tract, the social vulnerability information included in the following tool allows for a general comparison of relative risk throughout the watershed. Although certain assets themselves may not be socially vulnerable, their proximity to a vulnerable population in the same census tract is a valuable piece of information when filtering or eventually prioritizing sites for enhancement or protection.

It is also important to note that current and future land use projections used here are not necessarily comprehensive and may not reflect the reality of all land use or development plans. For example, LULC data relies on classification of satellite images and certain types of development may be more likely to exhibit classification errors. Ground-truthing or community input could help increase the accuracy of current land use designations if additional detail is eventually required for precise planning purposes. Additionally, future development, which is a crucial component of impending changes in the Mispillion and Cedar Creek Watersheds, is included only as an area of interest in this analysis. The source shapefile for future developing areas may not reflect the most up-to-date plans for the watershed and more information could be gathered from stakeholders and municipalities to allow for the most accurate depiction of current and future development pressure. The current development area of concern features can still be isolated and examined to visualize where they intersect with vulnerable areas or with other key assets of interest.

Lastly, there is significant uncertainty associated with sea level rise scenarios in the Mispillion region. As mentioned previously, this vulnerability assessment relies on a bathtub model of inundation to project potential future flooding conditions. Although experts and community members felt that the choice of 1’ and 2’ inundation layers provided a reasonable approximation of future risk over the next 30 years, many factors could interact with sea level rise to influence the course of future flooding scenarios. The Delaware inundation models do not account for complexities such as water dynamics or storm surge that may increase the landward boundary of flooding. Similarly, inundation threats do not consider compounding effects such as saltwater intrusion or water table changes that could impact upland areas beyond the predicted boundaries of flooding. Bathtub modeling also relies on the current state of topography and therefore projections may become inaccurate as changing conditions such as erosion, subsidence, dune loss, or marsh decline/migration occur.

Given these known assumptions and limitations, it is important to emphasize that this vulnerability assessment is intended to act as an adaptable and living tool rather than a prescriptive decision on hazard risk. Shapefile products are meant to be queried and filtered to examine relevant questions that will be central to the process of investment prioritization. Additionally, the documented workflow presented here along with the flexible GIS-based platform of the tool will allow for easy incorporation of any future changes, updates, or new modeling insights by tool owners as they become available. The living aspect of the vulnerability tool will enable managers and stakeholders to assess the most relevant information available over time.

Vulnerability Summary

Current Land Use Vulnerability Takeaways

The following section provides bar graph summaries of composite vulnerability across different current land use types and categories. Accompanying pie charts illustrate the relative area within each of the categories that makes up the four main land use types. All regions within the "lowest" vulnerability classification have been excluded so that summaries focus on portions of the study area that are considered vulnerable to current and future flooding risks (the lowest composite vulnerability classification indicates negligible risk of current or future flooding). Summary bar graphs are intended to illustrate which current land use classifications are most and least vulnerable relative to one another.

Across the four current land use types, habitat and recreation assets had a relatively higher proportion of highest- or high-risk classification areas in comparison to developed land and agricultural land (Figure 13). Developed land had the greatest amount of area in the low composite vulnerability class (75.35%) and the smallest area in the high and highest composite vulnerability classes (7.42% and 0.54%, respectively). Meanwhile, habitat had the largest proportion of area in both the high and highest classifications for vulnerability (45.35% and 27.98%, respectively). Agricultural land vulnerability had a spread of risk classes that was similar to developed land, with more than half of agriculture land area in the low classification (63.80%) and smaller portions in the moderate, high, and highest classes. Recreational assets had a relatively even distribution of risk classifications across their total area, with a slightly higher proportion of regions in the low-risk class.

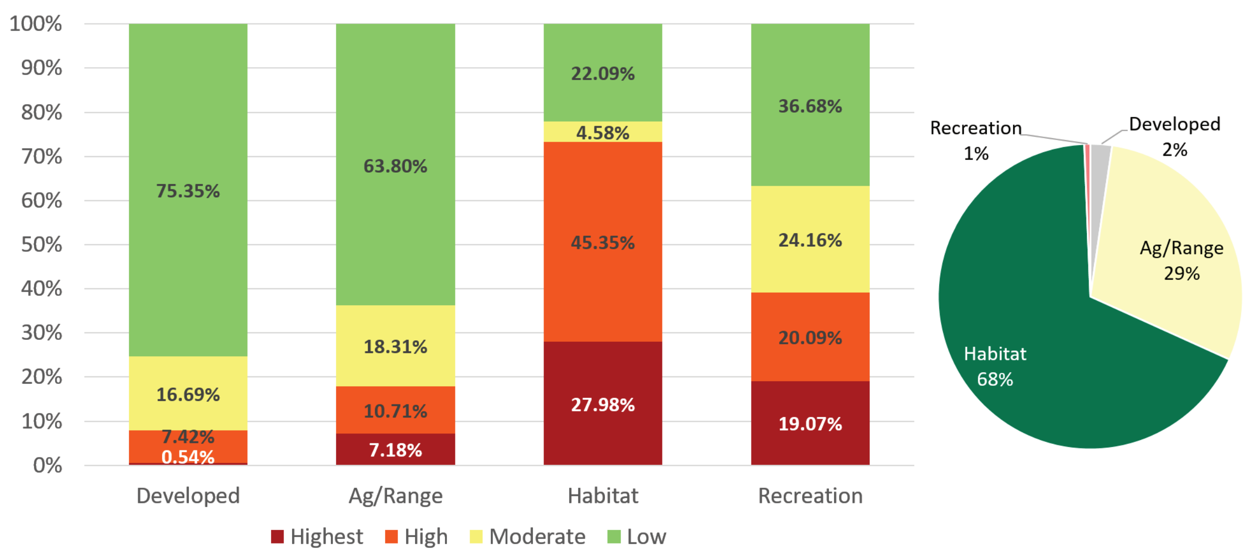

Figure 13. Composite vulnerability across all current land use types (left) and comparison of relative area in each land use type that has some level of vulnerability to flooding (right). Acreage with the lowest classification of flooding vulnerability (i.e. no vulnerability to flooding, today or tomorrow) is excluded from these visualizations. Of 74,317 Acres in the study area, 20,975 total Acres are at risk of current or future flooding.

Within the developed land type, most categories had a similar distribution of vulnerability; more than half of each category was in the lowest-risk class and less than 10% of each category was made up of highest or high vulnerability land (Figure 14). Residential land use, which made up 80% of overall developed land, had a slightly higher proportion of area at a high vulnerability to flooding. Still, nearly 75% of residential land was classified as low-risk. Although critical infrastructure made up only 7% of all threatened developed land, 92.28% of this category was in the low vulnerability class.

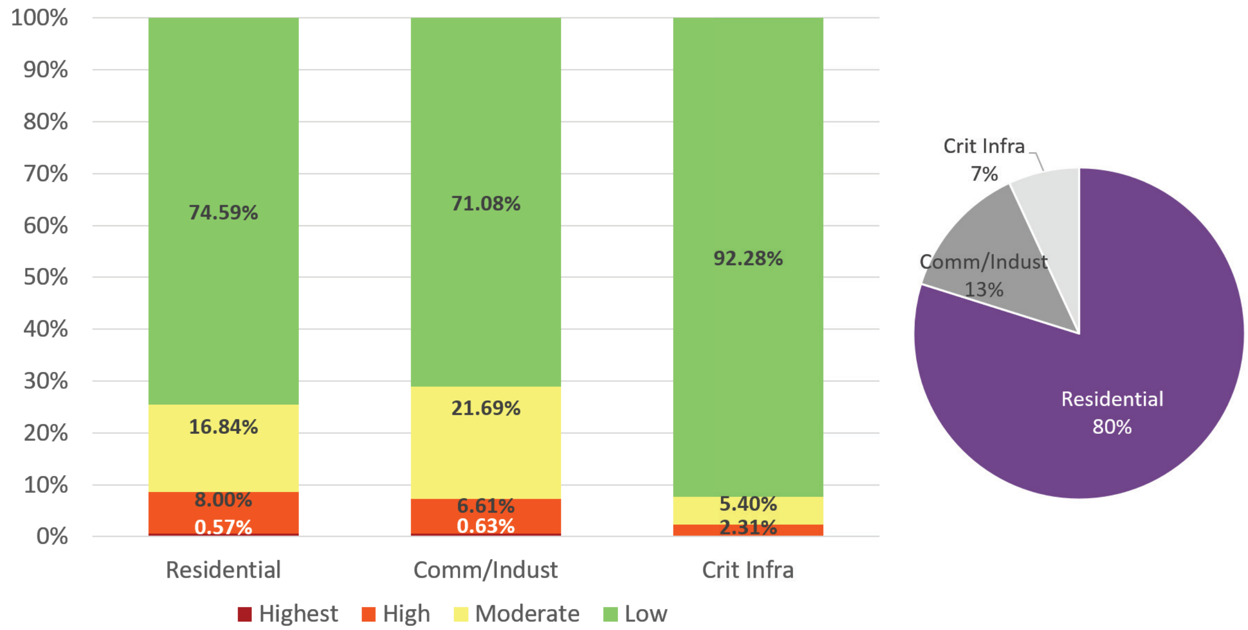

Figure 14. Composite vulnerability across current developed land use categories (left) and comparison of relative area in each developed land use category that has some level of vulnerability to flooding (right). Acreage with the lowest classification of flooding vulnerability (i.e. no vulnerability to flooding, today or tomorrow) is excluded from these visualizations. Of 11,275 Acres in the developed type, 481 total Acres are at risk of current or future flooding.

Agricultural lands had a greater amount of area in the moderate to highest vulnerability classifications compared to developed land (Figure 15). Although both rangeland and other agricultural categories were composed of more than 50% high and highest-risk regions, these categories only made up ~12% of all agricultural land. General agricultural land use, which made up 88% of the agricultural land use type mostly (68%) fell into the low vulnerability classification.

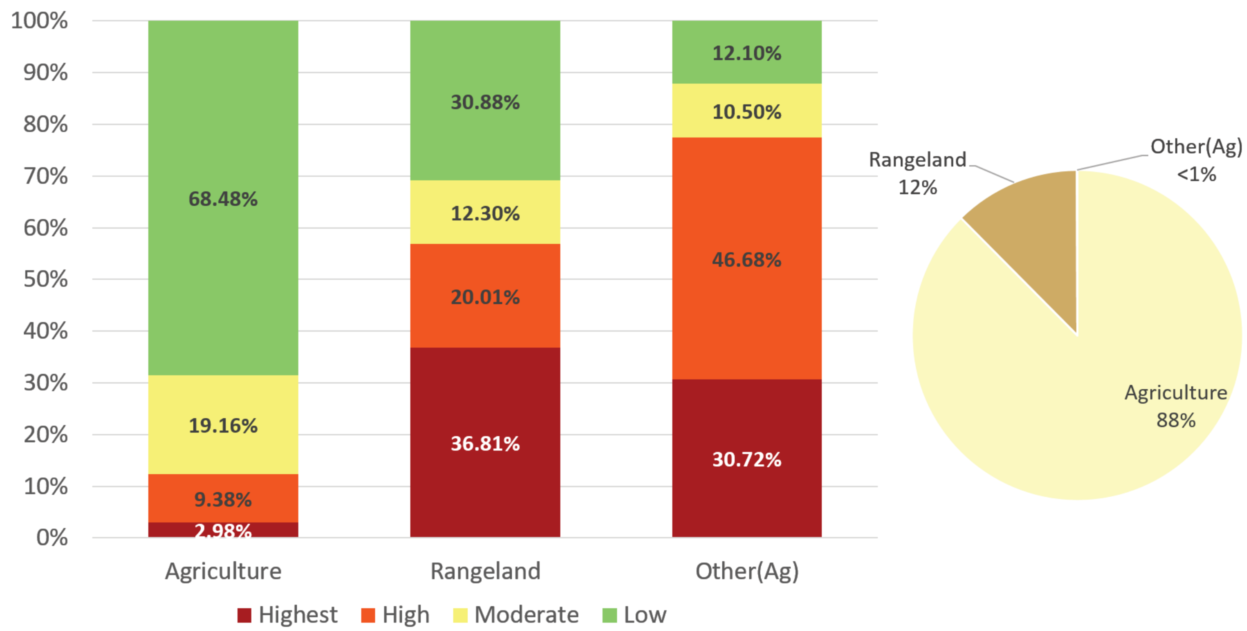

Figure 15. Composite vulnerability across current agricultural land use categories (left) and comparison of relative area in each agricultural land use category that has some level of vulnerability to flooding (right). Acreage with the lowest classification of flooding vulnerability (i.e. no vulnerability to flooding, today or tomorrow) is excluded from these visualizations. Of 36,057 Acres in the agricultural type, 6,178 total Acres are at risk of current or future flooding.

Larger proportions of habitat were composed of high and higher vulnerability designations (Figure 16). Sand/Shore was the most vulnerable habitat land use category, with 60.54% of land in the highest-risk class. Forest habitats had a lower amount of area outside of the low vulnerability classification, but more than 25% of land within this category still had at least moderate risk of current and future flooding. Welands, which made up the greatest percentage (92%) of threatened habitat land use, was comprised of a relatively large proportion of high- to highest-risk classes (>77%, combined).

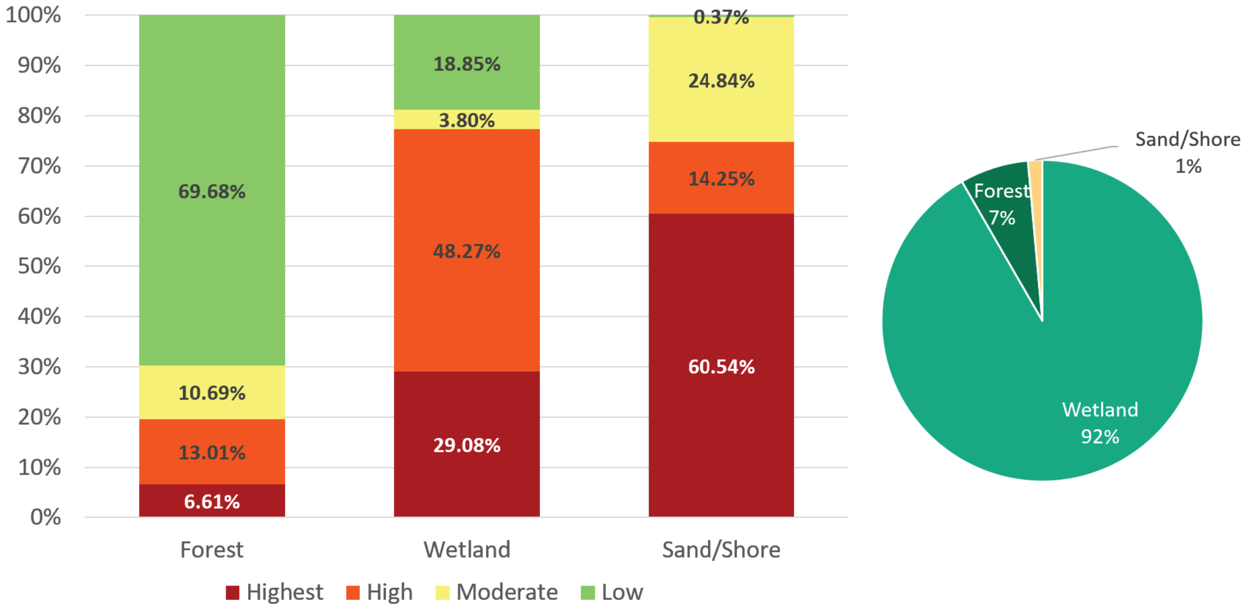

Figure 16. Composite vulnerability across current habitat land use categories (left) and comparison of relative area in each habitat land use category that has some level of vulnerability to flooding (right). Acreage with the lowest classification of flooding vulnerability (i.e. no vulnerability to flooding, today or tomorrow) is excluded from these visualizations. Of 26,500 Acres in the habitat type, 14,180 total Acres are at risk of current or future flooding.

Compared to most developed and agricultural land use categories, recreational land had relatively greater acreage in moderate, high, and highest vulnerability classes (Figure 17). The parks/recreation category, which made up 72% of all threatened recreational land, also had the largest amount of highest-risk area. Meanwhile, historic areas, which were small in total acreage compared to other recreational categories (<1%), had the least amount of area in the low-risk class (27.40%), but the highest amount of area in the high-risk class. Marinas/Boat recreational areas had a relatively higher proportion of moderate composite flooding vulnerability. Recreation categorized as "other" had the largest proportion of low vulnerability acreage (69.63%).

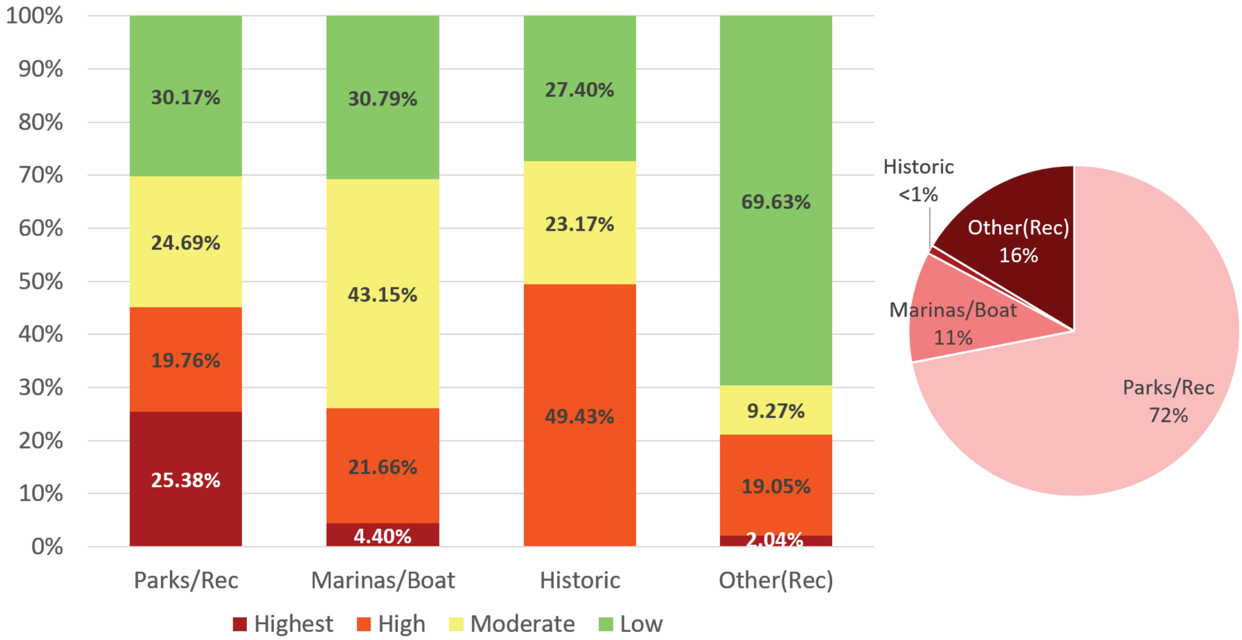

Figure 17. Composite vulnerability across current recreational land use categories (left) and comparison of relative area in each recreational land use category that has some level of vulnerability to flooding (right). Acreage with the lowest classification of flooding vulnerability (i.e. no vulnerability to flooding, today or tomorrow) is excluded from these visualizations. . Of 485 Acres in the recreational type, 135 total Acres are at risk of current or future flooding.

Areas of Concern Vulnerability Takeaways

Nominated areas of concern varied in their composite vulnerability. Combined, more than half (67%) of all areas of concern fell into the lowest category of vulnerability and had no risk of flooding today or tomorrow (Table 9). Among area of concern types, schools and hospitals were the only features with 100% of area in the lowest-risk classification. Other features such as wellhead recharge areas, historic sites, and developing areas also had >70% area at lowest risk of current or future flooding, however, these features still had low, moderate, and high vulnerabilities in select areas. Features with the most area in higher-risk (e.g. highest, high, or moderate composite vulnerability) classes included protected land, parks and recreation, water access, existing developing areas, and certain agricultural preservation areas. Many assets of these types are located near the coast or waterways, which likely accounts for their increased relative flooding vulnerability.

Table 9. Composite vulnerability summary of each area of concern by percent of type area in each classification. Area of concern types are ordered from most to least vulnerable as determined by the percent of area in the highest-risk classes moving from highest to lowest vulnerability.

Type	Highest	High	Moderate	Low	Lowest
Protected Land	58.39%	25.69%	3.72%	2.69%	9.50%
Parks/Rec	41.43%	12.53%	11.08%	9.42%	25.55%
Water Access	14.13%	4.96%	22.59%	36.68%	21.64%
Agricultural Preservation: Easement	3.72%	14.37%	4.25%	17.73%	59.92%
Existing Developing Areas	2.32%	4.80%	1.24%	3.38%	88.27%
Agricultural Preservation: District	0.46%	29.18%	5.07%	29.53%	35.76%
Recreation Facility	0.44%	49.48%	3.52%	11.00%	35.55%
Agricultural Preservation: Expansion	0.15%	5.04%	1.86%	7.85%	85.10%
Historic Site	0%	11.34%	5.33%	9.96%	73.37%
Other	0%	10.44%	14.47%	0%	75.09%
Developing Area	0%	3.65%	0.39%	4.81%	91.15%
Wellhead Recharge	0%	0%	0%	1.69%	98.31%
School	0%	0%	0%	0%	100%
Hospital	0%	0%	0%	0%	100%
Grand Total	**8.00%**	**11.46%**	**2.52%**	**10.58%**	**67.44%**

In terms of road areas of concern, Bayshore byways were more vulnerable to flooding risks than evacuation routes (40% and 4% of area vulnerable to current or future flooding, respectively; Figure 18). As mentioned in previous sections, the "Roads analysis" layer depicted in Figure 18 is a separate shapefile that can be used to locate portions of roadways that are most vulnerable to current and future flooding hazards.

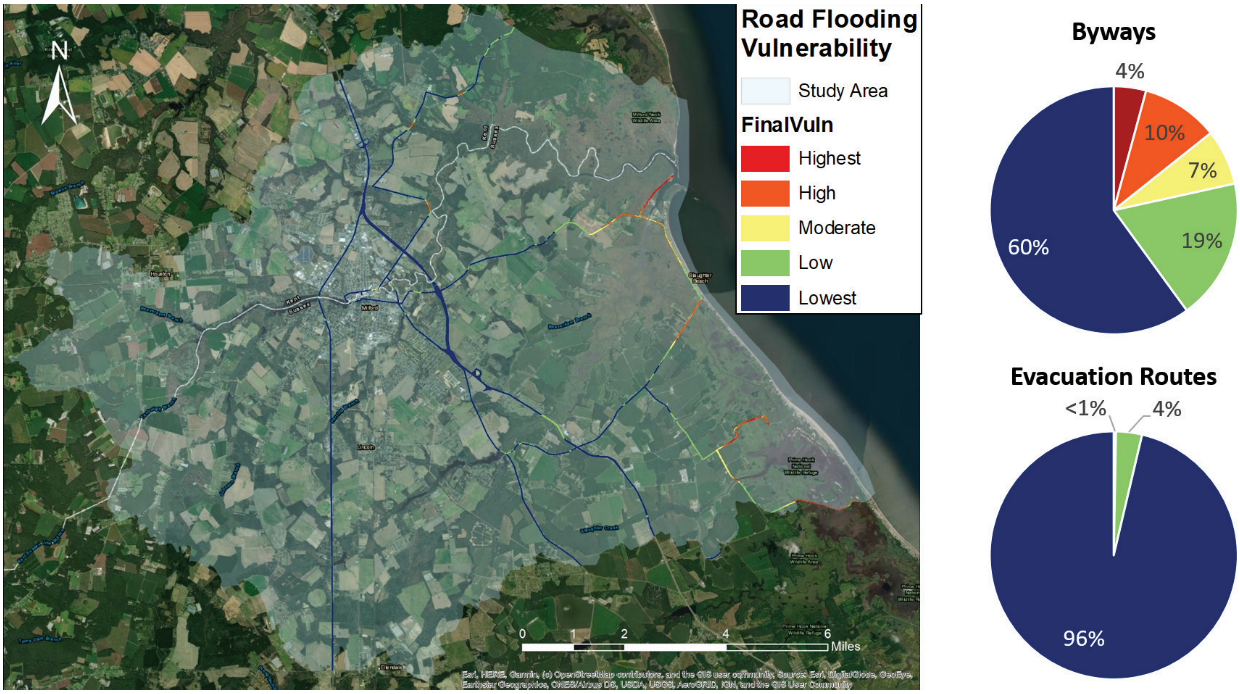

Figure 18. Composite flooding vulnerability of road areas of concern (left) and relative percent of vulnerability classes that make up each road type (979 Acres for byways and 811 Acres for evacuation routes).

Vulnerability in the Towns of Milford and Slaughter Beach

Due to its inland location, the Town of Milford does not contain any land at a high risk of current flooding (i.e. FEMA flood zone VE) and therefore no areas are at the highest level of composite flooding vulnerability. Additionally, both census tracts surrounding the town have a highly-vulnerable, but younger, social vulnerability designation. Although Milford areas of concern are mostly (53%) within the lowest composite vulnerability class, the town does contain regions at a moderate risk of current flooding (FEMA flood zone AE) that are also moderately or highly vulnerable to future flooding (both 1′ and 2′ inundation; Figure 19). Thus, some Milford areas of interest contain land with a high composite vulnerability to flooding. Among town assets, water access points, Goat Island, and different portions of the Mispillion Riverwalk have the greatest proportion of area at a high risk of current and future flooding (Table 10). Depending on future plans and stakeholder interests, these assets and other areas of concern listed in Table 10 may present viable areas for nature-based resilience enhancements. Combined with a relatively low economic status and a high minority status (e.g. highly socially vulnerable) designation, these results could also be used as evidence for future economic investment needs surrounding Milford's nature-based assets.

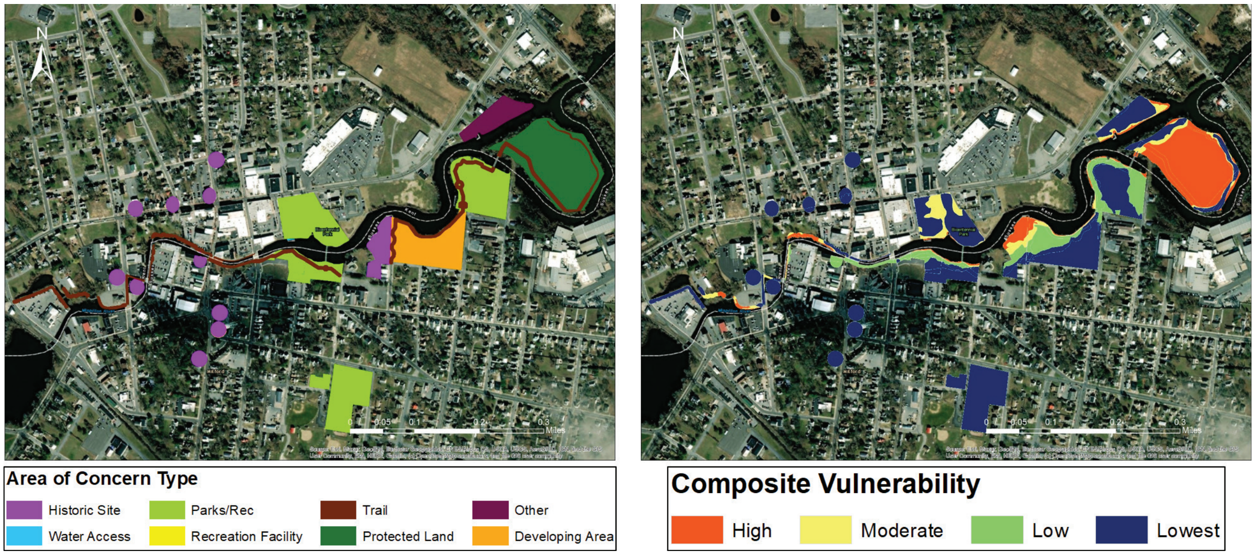

Figure 19. Map of Town of Milford areas of concern types (left) and their corresponding composite vulnerability (right).

Table 10. Composite vulnerability summary of Milford areas of concern by percent of area making up each risk class for individual town assets. Areas of concern with any high to moderate flooding vulnerability are shown and ordered from highest to lowest percentage of area in the high-risk classification. All other assets are within low or lowest vulnerability designations.

Detail	High	Moderate	Low	Lowest
Dog Park Dock	100%	0%	0%	0%
Ramp- Police Station	100%	0%	0%	0%
Arena’s Kayak Launch	99.93%	0.07%	0%	0%
Goat Island	80.24%	5.86%	0%	13.91%
Riverwalk East/Goat Island	61.63%	6.34%	0%	32.03%
Riverwalk Annex Building	40.97%	18.38%	18.87%	21.77%
Vinyard Shipyard	37.07%	17.38%	20.55%	25.00%
Riverwalk West/Church St.	25.09%	27.52%	1.90%	45.48%
Riverwalk East/Dog Park	12.99%	14.10%	53.19%	19.72%
Police Station	10.44%	14.47%	0%	75.09%
Riverwalk West Start	10.19%	17.63%	0%	72.18%
Milford Memorial Park	4.65%	2.71%	26.56%	66.09%
Mispillion St Partners	3.79%	5.41%	26.75%	64.06%
Riverwalk Memorial Park	3.05%	3.31%	58.94%	34.70%
Riverwalk Walnut to Washington	2.91%	0%	73.68%	23.41%
Milford Dog Park	2.60%	1.72%	42.31%	53.36%
W. H. Burkett General Merchandise	1.32%	0.84%	93.30%	4.53%

The Town of Slaughter Beach is located within the coastal zone in an area that has at least moderate to high risk of current flooding (FEMA flood zones X and AE). Thus, all areas of concern in the proximity of the town have, at minimum, a low vulnerability to flooding today and tomorrow (Figure 20). Assets near the town proper and the associated coastal dune features (e.g. Public Access Points and Slaughter Beach/Community Park recreation areas) are largely not considered vulnerable to future flooding at 1′ or 2′ of inundation (Figure 20, Table 11). However, protected lands and agricultural preservation areas located slightly inland have a much higher proportion of area in the highest and high vulnerability classifications. These areas of concern such as Agricultural Preservation 21 (C. Rodney Sharp Agricultural Easement) and the Milford Neck Wildlife Area that are located behind coastal dunes, sit at a relatively lower elevation than Slaughter Beach and are thus at a high risk of both current and future flooding. These and other areas inland of coastal dunes may represent favorable candidates for restoration, enhancement, or preservation. Although the census tract containing the town of Slaughter Beach is comparably less vulnerable than others in terms of economic status and minority composition, residents in the area are generally older, leading to a higher household composition vulnerability compared to the rest of the watershed. A large proportion of areas in high-risk classifications and a vulnerable older population may justify Slaughter Beach as a target for investment in natural resource assets.

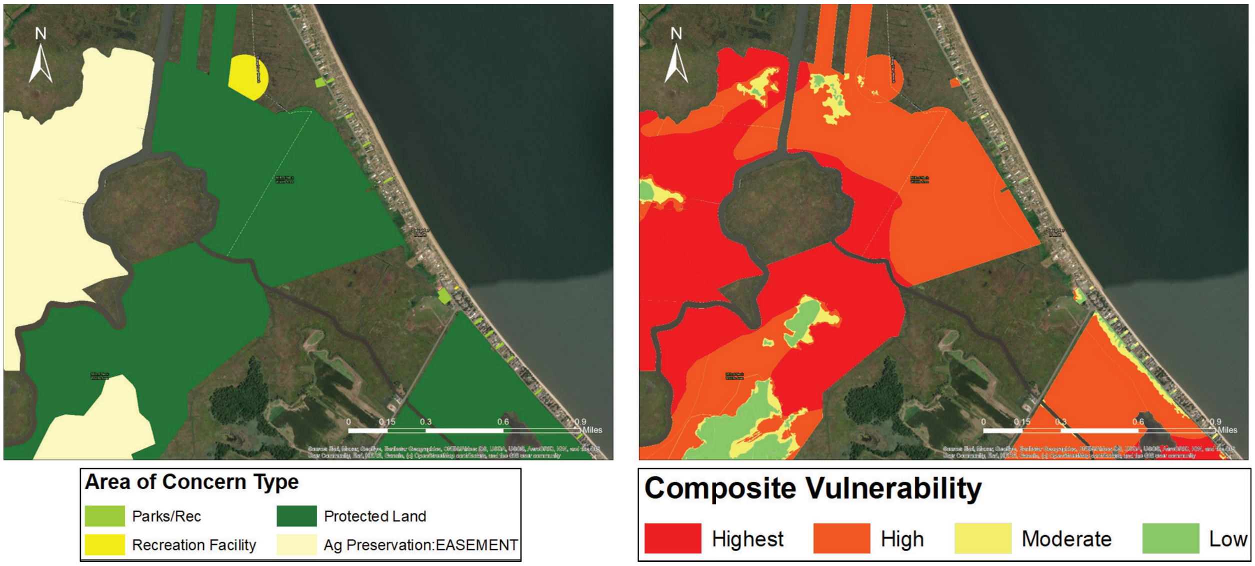

Figure 20. Map of Town of Slaughter Beach areas of concern types (left) and their corresponding composite vulnerability (right).

Table 11. Composite vulnerability summary of Slaughter Beach areas of concern by percent of area making up each risk class for individual town assets. Areas of concern with any high to moderate flooding vulnerability are shown and ordered from highest to lowest percentage of area in the highest, then high risk classification. All other assets are within moderate and/or low vulnerability designations only.

Detail	Highest	High	Moderate	Low
Agricultural Preservation 21	100%	0%	0%	0%
Agricultural Preservation 201	92.05%	7.95%	0%	0%
Agricultural Preservation 128	81.31%	18.69%	0%	0%
Wildlife Area-Prime Hook National Wildlife Refuge	81.25%	15.60%	3.03%	0.11%
Agricultural Preservation 127	77.58%	21.98%	0.44%	0%
Agricultural Preservation 209	66.02%	26.81%	4.28%	2.89%
Agricultural Preservation 113	60.49%	30.03%	8.71%	0.77%
Wildlife Area-Milford Neck Wildlife Area	37.92%	57.50%	2.64%	1.94%
Marvel Saltmarsh Preserve	0%	97.10%	2.90%	0%
Marvel Boardwalk	0%	94.29%	5.71%	0%
Agricultural Preservation 36	0%	23.08%	9.52%	67.40%
Slaughter Beach Community Park	0%	17.66%	32.78%	49.56%
Simpson Access	0%	7.56%	92.44%	0%

Vulnerability Assessment Tool and Next Steps

Use of Vulnerability Assessment as a Tool

The final vulnerability assessment tool map package "PDE_MispVulnAssessment" has been made available to project partners and can be shared with residents, stakeholders, practitioners, and managers as-is, or in an online ArcGIS-based mapping platform. The results presented previously are meant to summarize broad patterns and takeaways of this assessment. Ultimately, this map package is a tool that can be used to answer any vulnerability inquiries and is intended as a step along the larger site prioritization process. The list of attributes included in the final current land use and areas of concern analysis shapefiles provide an array of options for query and filtering by different combinations of social vulnerability, feature type, and level of flooding vulnerability. The following examples will illustrate brief walkthroughs of how the tool can be used to answer vulnerability inquiries and aid in site selection. Since there are numerous methods available in ArcGIS to perform data manipulations, the walkthroughs below illustrate only some of the standard processes that might aid in vulnerability assessment tool utilization.

1. Example: Trails in specific social vulnerability regions with risk of flooding

The "PDE_MispVulnAssessment" map package can be used to select and filter sites according to desired criteria. If, for example, a user wanted to explore the vulnerability of trail areas of concern, ArcGIS provides tools for querying. To select trails in only the less-vulnerable, but older, social vulnerability class, the user could follow the procedure below:

- Navigate to the "Selection" tab of ArcGIS and choose "Select By Attributes…" (Figure 21A)
- From the drop-down list, select the desired layer; in this instance: "Areas of Concern Analysis"
- In the code box, enter "Type = 'Trail' AND F4ClassVuln = 'Low, older' ". "F4ClassVuln" corresponds to the composite social vulnerability attribute
- Hit "Ok"

These steps highlight (in bright blue), on both the map and corresponding attribute table, all trails that exist in the Low, older composite social vulnerability class (Figure 21B; Figure 21C).

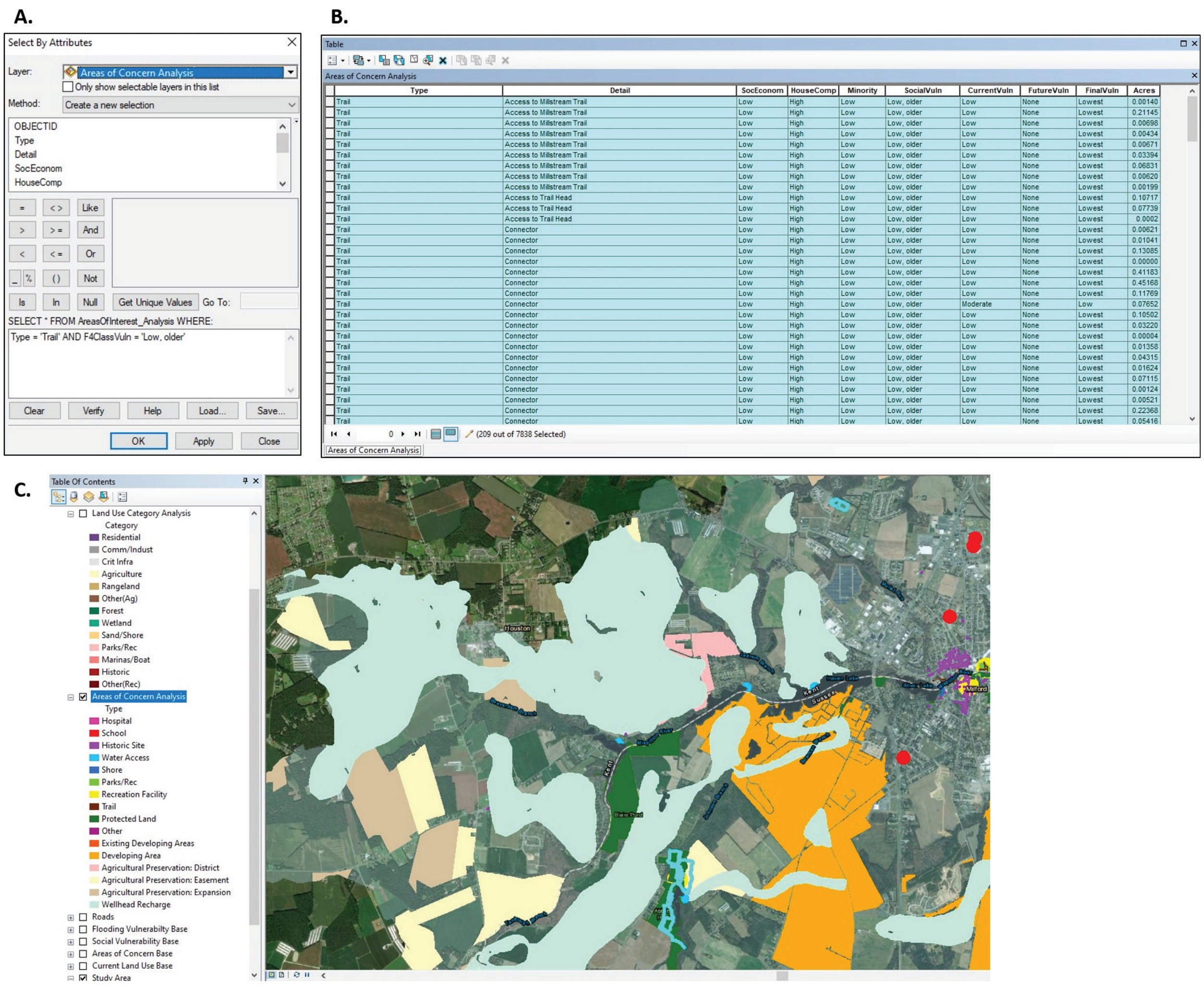

Figure 21. ArcGIS process for querying and selecting desired combinations of attributes. First, the focal attributes are highlighted using "Select By Attributes (A). The selected attributes can then be viewed as a list in the attribute table (B) or visualized on the map in a geospatial context (C).

To further examine the flooding vulnerability of the selected trails, the user can input more-specific queries. For instance, if only the trails in this category with some level of flooding risk (i.e. not in the "Lowest" risk category) are of interest, additional code can be entered into the "Select By Attributes…" box:

- Navigate to the "Selection" tab of ArcGIS and choose "Select By Attributes…" (Figure 22A)
- Be sure that the chosen layer is still "Areas of Concern Analysis"
- In the code box, add "AND NOT Final = 'Lowest'" to the existing code. The attribute "Final" corresponds to the composite flooding vulnerability
- Hit "Ok"

The process above results in a narrowed list of highlighted trails that are both located in older-population regions and vulnerable to flooding hazards (Figure 22B). Zooming in on the selected trails reveals helpful information including which portions of the trail system are vulnerable to flooding and where these features overlap with other areas of concern such as protected areas and recreation facilities (Figure 22C).

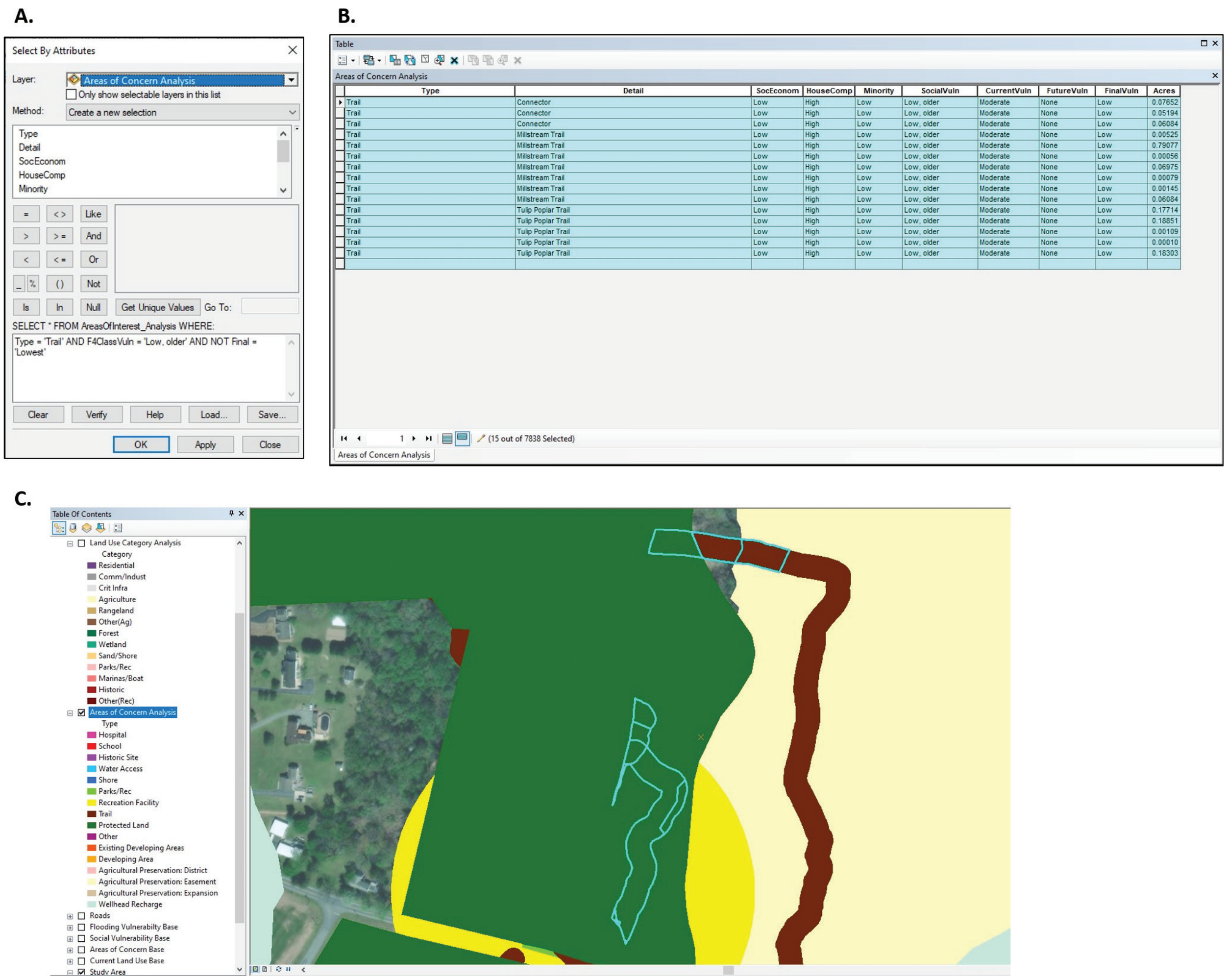

Figure 22. ArcGIS process for additional querying and selecting desired combinations of attributes. First, the focal attributes are highlighted using "Select By Attributes (A). The selected attributes can then be viewed as a list in the attribute table (B) or visualized on the map in a geospatial context (C).

2. Example: Area of habitat currently in protection

The map package can also be used to isolate and analyze key combinations of land use. In order to calculate the amount of habitat currently in protection, the user can isolate information from both the current land use and areas of concern shapefiles through the following steps:

- Navigate to the "Selection" tab of ArcGIS and choose "Select By Attributes…" (Figure 23A)
- From the drop-down list, select the desired layer; in this instance: "Land Use Type Analysis"
- In the code box, enter "Type='Habitat'"
- Hit "Ok"

This process highlights all features in the habitat current land use as shown in Figure 23B. To isolate this selection for further manipulation:

- Right click on the "Land Use Type Analysis" layer in the Table of Contents
- Choose "Selection" > "Create Layer From Selected Features" (Figure 23C)

These steps result in a new layer that consists only of current land use types classified as habitat and is automatically titled "Land Use Type Analysis Selection" (title can be changed). The previous process can be repeated using the "Areas of Concern Analysis" shapefile to select and create a new layer, "Areas of Concern Analysis Selection" representing areas of concern in the "Protected Area" type.

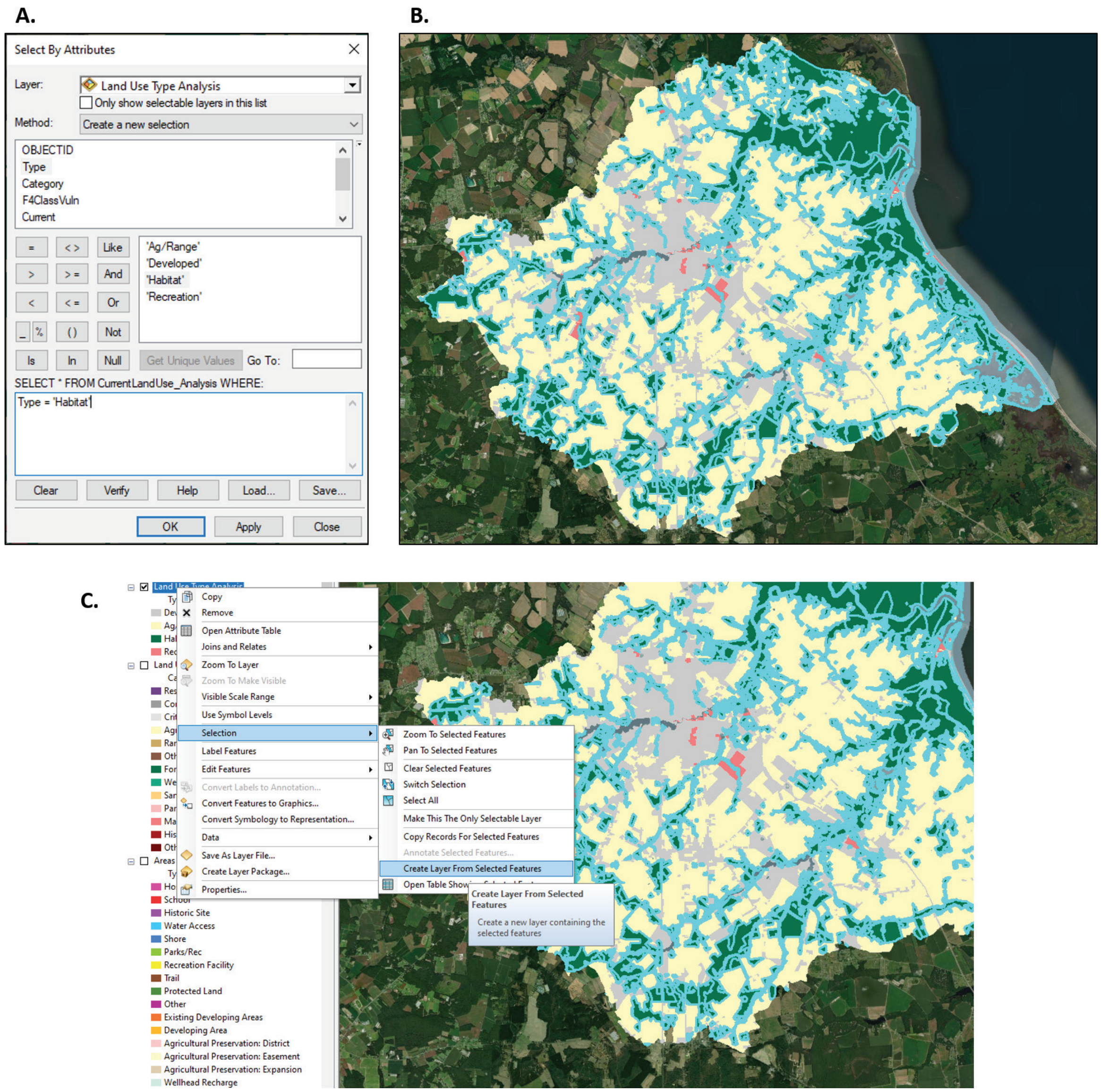

Figure 23. ArcGIS process for isolating desired attributes in a new layer. First, the focal attributes are highlighted using "Select By Attributes (A). The selected attributes (B) are then used to create a new layer that can be used independently for further manipulations or calculations.

Following the selection and isolation of habitat and protected land shapefiles, the user can undertake further manipulations to find where habitat and protected areas overlap:

- Search for the "Clip" Analysis tool in ArcToolbox
- Within the dialogue box, select "Land Use Type Analysis Selection" as the Input Features and "Areas of Concern Analysis Selection" as the Clip Features (Figure 24A)
- Select an appropriate location to save the new shapefile
- Hit "Ok"

A new shapefile (automatically titled "CurrentLandUse_Analysis_Clip") will appear in the table of contents showing all of the current habitat that is contained within protected lands (Figure 24B). From this step, further selection can be performed to search for habitat in protected areas that is vulnerable to various flooding scenarios or near certain social vulnerability classes, through steps outlined in the first example.

A.

B.

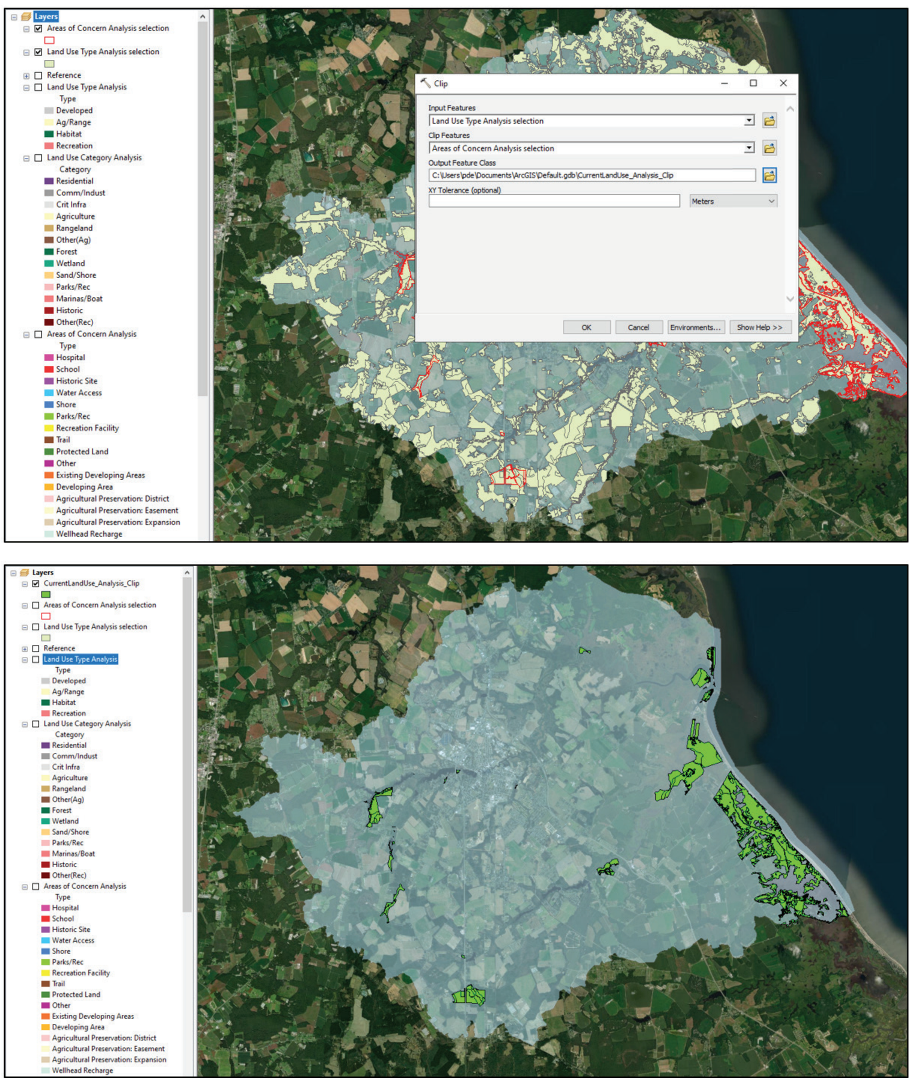

Figure 24. Steps to create a new shapefile containing habitat land use clipped by protected areas of concern. Screenshots show the clipping tool inputs (A) and the resulting shapefile (B).

In order to perform area calculations on the clipped shapefile, the "Acres" attribute must be re-calculated by following the steps below:

- Open the attribute table of the clipped habitat shapefile
- Right click on the "Acres" attribute and select "Calculate Geometry…"
- Click yes to any dialogue box that appears
- In the "Calculate Geometry" box, make sure that "Area" is the Property being calculated and select "Use coordinate system of the data frame:" (PCS: NAD 1983 StatePlane Delaware FIPS 0700; Figure 25A)
- Select "Acres US [ac] from the units dropdown box
- Hit "Ok"

After re-calculation, the user can right-click on the "Acres" attribute and select "Statistics" to see a data summary of the attribute (Figure 25B). Here, the user can see that 3,568 Acres of habitat are currently protected (Figure 25B). Similar statistics from the "Acre" attribute columns of the isolated input layers show that there are 26,500 Acres of the habitat land use type and 4,336 Acres of total protected land. Thus, 82% of protected lands are considered habitat and 13% of habitats are designated as protected. Depending on the goals of tool users, the process outlined above could be used to visualize or calculate the amount of habitat land that is overlapped by developing areas or the total area of agricultural land currently in preservation, for example.

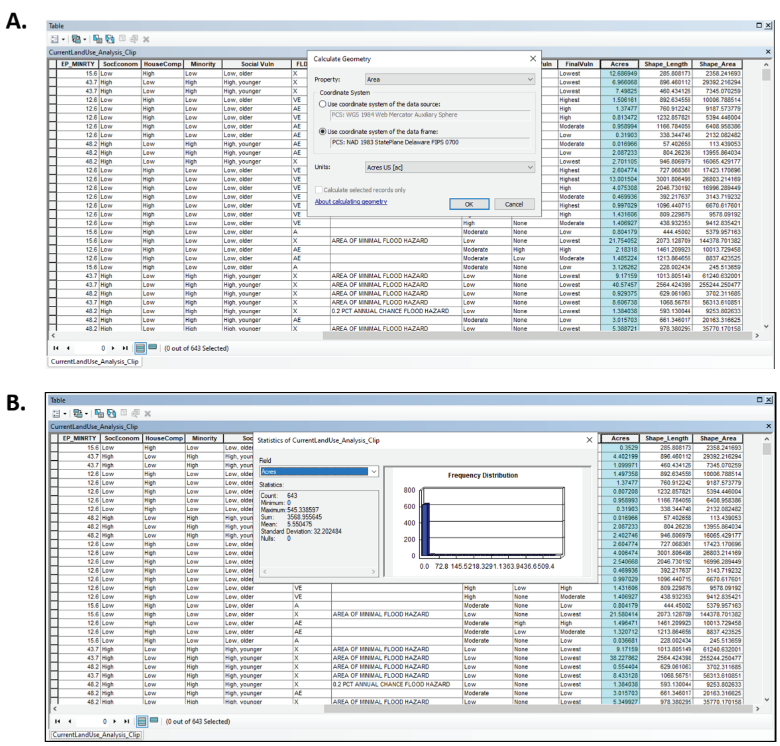

Figure 25. Attribute table manipulations showing how to calculate total area of habitat that is comprised by protected land. Acres must be re-calculated (A) and then statistics can be performed to sum total habitat in protection (B).

Recommendations for Next Steps

The vulnerability assessment tool provided with this report will allow managers and community members to generate informed strategies for increasing resilience in the Mispillion and Cedar Creek Watersheds. The data summary and guide presented in the previous sections highlights the general patterns of vulnerability across the study area, but further steps will be necessary to dive deeper into the data and achieve relevant, goal-based outcomes. Although assets identified by this assessment as highly vulnerable to current and future flooding will be the most obvious targets for investment, there are numerous other factors that may influence the feasibility of certain projects at a given location. For instance, current economic output, community support, or public accessibility could all impact the likelihood of success for nature-based investments. WIIN, in coordination with stakeholders and government leaders in Milford and Slaughter Beach, is encouraged to consult the tool and data to develop their management plan.

The methods for data gathering, manipulation, and summary used in this vulnerability assessment are outlined with maximum transparency so that community leaders and partners can continue to use the tool in a meaningful way as conditions change or new information becomes available. Base shapefiles and detailed methods for layer creation ensure that the vulnerability assessment can be adjusted by users in accordance with their needs over time. This vulnerability assessment thus provides a tool that can be used throughout nature-based resilience planning in the Mispillion region, from initial development, to future adaptation.