



# GREENWICH COASTAL RESILIENCY ASSESSMENT

TOWN OF GREENWICH  
FAIRFIELD COUNTY, CONNECTICUT  
NOVEMBER 2022

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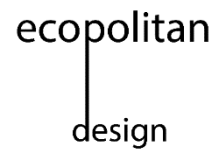
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## EXECUTIVE SUMMARY

The Greenwich Coastal Resiliency Assessment analyzed the impacts of Sea Level Rise (SLR) on the Town of Greenwich with a specific focus on municipally owned and managed facilities, and four tidally impacted ponds and their surrounding recreational facilities (Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park).

A higher sea level gives future coastal hurricanes and storm surge a higher starting point, resulting in surge that reaches further inland. It is important to note that because sea level rises gradually, it is uniquely different from other hazards, such as hurricanes and earthquakes, which cause abrupt catastrophic impacts. Impacts from SLR may take several years to be noticed as they occur gradually over time. This Assessment identifies vulnerabilities to flooding based on three types of floods – Mean Higher High Water (MHHW), 10% flood, and 1% flood – for each of the projected sea level change scenarios– 2050, 2075, 2100 (low), and 2100 (high). For each flood and SLR scenario, the flood extent, structure exposure, and road exposure were evaluated.

Land area impacted by SLR was projected to increase for all types of flood events. For instance, a 10% flood is defined as an event having a 10% chance of occurring in any given year. The 10% flood extent map displays the reaches of where water, in the absence of waves, may inundate coastal areas during a 10% flood event. Current projections, based on FEMA mapping analysis, include about 519 acres of land impacted. When adding SLR scenarios, the land impacted rises to 737 acres (2050), 836 (2075), 916 (2100 low) and 1,262 (2100 high).

Under current day conditions, a 10% flood event would impact 24 town-owned structures. The scenario for 2050 indicates that there are 32 town-owned structures at risk from a 10% flood event with an increase in sea level of 20 inches. The 2075 scenario indicates 34 impacted town-owned structures, and the 2100 low and high scenarios suggest that 39 and 43 town-owned structures, respectively, would be impacted by a 10% flood. Many of these structures are critical facilities that need to be operational during storm events.

The analysis includes a description of the land types and shoreline characteristics that will shift during increased sea levels, with urban land use the most heavily impacted land use type across nearly all scenarios. An analysis of the vulnerability of roadways was also conducted. The length of inundated roadway impacted by sea level rise ranges from 0.4 miles in 2050 to 10.8 miles in 2100 (high), rising to 26.4 miles during a 1% storm in 2100 (high). Septic system vulnerability was also assessed, and results indicate that septic systems within the study area are at low risk to SLR.

In determining a path forward, it is important to involve the community in establishing a vision and setting priorities. Many options exist that can be employed to address SLR, from planning strategies, to construction of barriers or natural systems. These all have benefits and challenges associated with them, which are presented in the final chapter of the report.

This assessment report provided an overview of the vulnerabilities faced by Greenwich under current conditions and various sea level rise and storm surge scenarios. There are two companion reports, “*Tidal Ponds Evaluation Report*,” goes into more detail on the present conditions of the four ponds included in the study. This information provides important data to help address the obvious next question, “so what should we do about it?”. The second companion report, “*Adaptation Strategies Report*” provides suggestions for projects and actions that could be taken within Greenwich to increase resiliency.

## INTRODUCTION

The Town of Greenwich, Connecticut, hereby referred to as “Greenwich,” commissioned this *Greenwich Coastal Resiliency Assessment* to evaluate Greenwich’s town-owned properties and infrastructure vulnerability from coastal flooding and sea level rise (SLR) and identify threats to coastal areas serviced by on-site sewage disposal systems. The assessment provides an understanding of the anticipated changes from a changing climate and how best to support that transition to retain the value of ecological and community assets. The assessment also focuses on the impacts to tidally influenced public recreation parks and the surrounding communities: Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park.

The assessment provided a basis for the development of Adaptation Strategies, a supplemental report which can be viewed on the township website. The Adaptation report focuses on the tidally influenced town ponds and the adjacent recreational resources and communities and provides options for further research and study.

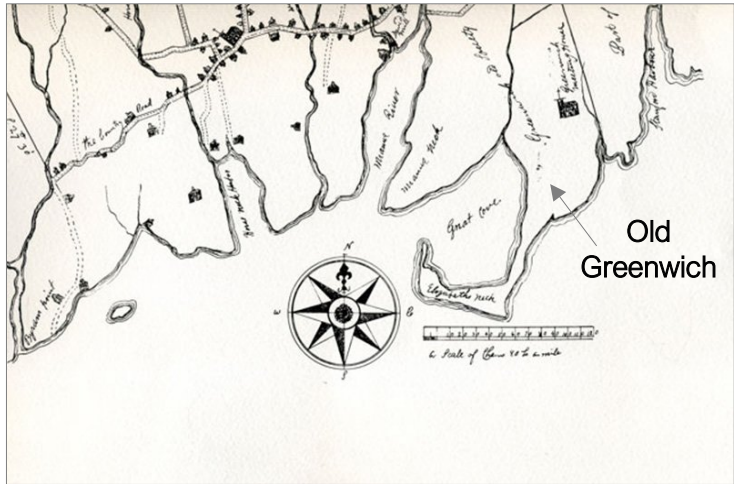


Figure 1. Map of Greenwich. Image Source: Greenwich Historical Society.



Figure 2. Aerial photo taken over Old Greenwich.

## BRIEF HISTORY

Greenwich was first settled in 1640 by English settlers who arrived in what is now Old Greenwich, Connecticut (Figure 1), named after the Borough of Greenwich in England. The early settlers farmed on large land lots, growing potatoes, grain, and fruit. By 1730, settlements along Byram River and the Long Island Sound grew from Stamford, Connecticut (east) and New York (west). In 1848, the arrival of the railroad shifted the land use and brought new settlers to the community, establishing neighborhoods and economic centers beyond farming. The railroad also brought industry and resort-seeking New Yorkers who wanted to escape city life and *vacation* along the Connecticut coast. The summer destination facilitated the building of large estates and second homes along the coast by families with substantial wealth. In the twentieth century, the development of significant roads, like the Merritt Parkway (1938) and I-95 (1957), and the growing use of automobiles further expanded the population of Greenwich with new residents seeking suburban living.

Set in the “The Gold Coast,” Greenwich is known for picturesque homes, roads, and coastal amenities (Figure 2). With 27 miles of shoreline along the Long Island Sound and 30 islands in its eight harbors, Greenwich is acutely aware of the risks posed by sea-level rise.

## DEMOGRAPHICS

Greenwich is situated less than 20 miles from New York City, NY and is considered part of the New York Metropolitan Area, a region that is home to over 23 million residents. Greenwich encompasses an area of over 48 square miles of mainland, 2 square miles of islands, and houses a population of approximately 62,000 people<sup>1</sup>.

Greenwich is an affluent community; the median income of a Greenwich household is \$142,819 and the median value of a Greenwich home is \$1,278,000 (U.S. Census, 2014-2018). Greenwich home prices are not only among the most expensive in Connecticut, but consistently rank among the most expensive in the United States. Greenwich has a lower mill rate (amount of tax payable per dollar of the assessed value of a property) than other towns in the area because of the town's strong commercial district and high property values. However, Greenwich has the sixth highest number of flood insurance policies (1,673) in the state, making such property values potentially vulnerable to SLR induced flooding.

Land in Greenwich is primarily zoned residential (95%), which encompasses housing, open space, municipal uses, places of worship, nurseries, and school uses. The remaining 5% of land area is zoned commercial, which includes multi-family development, office, retail, and service uses. Although the shoreline is primarily residential, other land uses include private and public recreation facilities, businesses, a sewage treatment plant, and infrastructure to support these uses. Additionally, the harbor areas support recreational and commercial shellfishing. The coastal area is treasured as a vital natural resource, providing a variety of environmental, economic, and community benefits.

## SEA LEVEL RISE AND COASTAL RESILIENCY

In recent years, scientific reports and expert analyses have prompted the State of Connecticut and Greenwich to make planning for SLR a priority to protect its coastal communities and prepare for potential impacts. In September 2019, the Intergovernmental Panel on Climate Change (IPCC) published a report called, Special Report on the Ocean and Cryosphere in a Changing Climate which identified that New England's geography increases its susceptibility to SLR and coastal flooding. Specifically, seas are warming along the New England shoreline at a more rapid rate than other places around the world, causing thermal expansion and accelerating SLR along New England. A rise in sea level may cause temporary and permanent inundation in low-lying coastal areas, as well as increased flooding in coastal areas and connected waterways. Moreover, on June 21, 2013, the Connecticut General Assembly passed Public Act 13-179 codified as Connecticut General Statutes (CGS) sections [8-23](#), [25-680\(b\)](#), and [28-5](#), which requires state and municipal agencies to consider SLR when making critical plans for land use, hazard mitigation, and civil preparedness.

Regionally, Greenwich is a member of the Western Connecticut Council of Governments (WestCOG), a regional planning agency composed of 18 neighboring municipalities. WestCOG authored and updates the regional [Natural Hazard Mitigation Plan](#), in which SLR vulnerability is assessed for regional transportation and emergency management.

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<sup>1</sup> U.S. Census Bureau (2019). Retrieved from <https://data.census.gov/cedsci/>

On December 26, 2019, the Connecticut Department of Energy and Environmental Protection (CT DEEP) published a [notice adopting](#) the sea level change scenario for Connecticut up to 20 inches by 2050 (Table 1). Further sea level change estimates, as shown in Table 1, were obtained from the Connecticut Institute for Resilience & Climate Adaptation’s (CIRCA) [2019 Sea Level Rise Connecticut Final Report](#) (Figure 3). It is important to note that there is uncertainty in sea level projections depending on model usage and development, changes in emissions scenarios, and shifts in dynamic processes, such as glaciers and ice sheets. The projections presented should be used as guidance for exploring coastal resilience options.

Locally, Greenwich has identified SLR as a current and upcoming challenge in its 2019 [Plan of Conservation and Development \(POCD\)](#). As part of the plan, there are 6 guiding principles, of which the plan identifies “Coastal Resiliency” as part of Guiding Principle 4 - “Sustain and improve our natural environment and landscape.” Greenwich is currently putting that plan into action by identifying climate-related vulnerabilities in Town and developing recommendations for possible mitigation measures (POCD Objective 4.3a).

The POCD identified the risk imposed by SLR’s potential to change coastal landscapes through nuisance flooding and storm surges. Additionally, it emphasized that coastal areas would become inaccessible during extreme high tides and storm events, render septic systems non-functional, creating impacts from saltwater intrusion, and diminish functionality of the stormwater management system. Additionally, historic and recent coastal storms and hurricanes have impacted Greenwich and coastal Connecticut, including the Great Hurricane of 1938, Hurricane Irene (2011), and Hurricane Sandy (2012). Recently, flooding has occurred because of heavy rainfall, causing damage to houses, and making roads impassable (Figure 4).

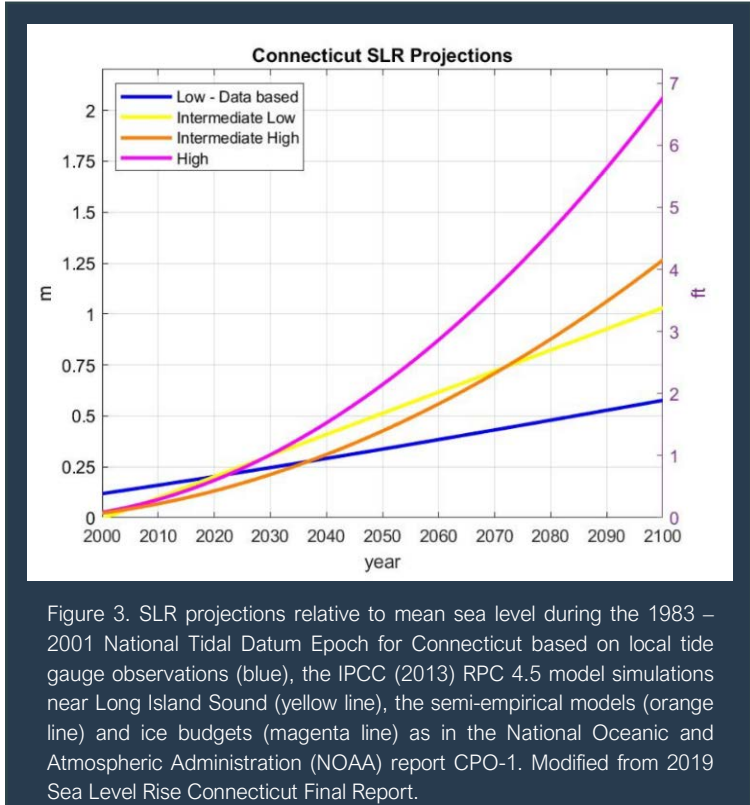


Figure 3. SLR projections relative to mean sea level during the 1983 – 2001 National Tidal Datum Epoch for Connecticut based on local tide gauge observations (blue), the IPCC (2013) RPC 4.5 model simulations near Long Island Sound (yellow line), the semi-empirical models (orange line) and ice budgets (magenta line) as in the National Oceanic and Atmospheric Administration (NOAA) report CPO-1. Modified from 2019 Sea Level Rise Connecticut Final Report.

Greenwich, Connecticut Projected Sea Level Change* CIRCA	
Year	Change (inches)
2050	20
2075	30
2100 (Low)	40
2100 (High)	80

Table 1. SLR Projections for Greenwich, CT. for 2050, 2075, and 2100 relative to mean sea level during the 1983 – 2001 National Tidal Datum Epoch.

Note: There are two numbers for 2100, the first number is the sea level change projection under a low emissions scenario and the second number is the sea level change projection under a high emissions scenario.

Building on the 2019 POCD, Greenwich sought to conduct an assessment to further understand the risks of SLR and climate change to enable the town to plan appropriately. In summer of 2019, Greenwich contracted Princeton Hydro, and their project partners BRS, Inc and Ecopolitan Design, to conduct the Greenwich Coastal Resiliency Assessment.



Figure 4. Flooding on Rocky Point Road, Greenwich Point on October 27, 2018 (Credit: Greenwich Police Department).

SLR was selected as a frame for assessing coastal vulnerabilities because rising sea levels exacerbate the impacts caused by coastal storms and accelerate shoreline erosion. A higher sea level gives future coastal hurricanes and storm surge a higher starting point, resulting in surge that reaches further inland. It is important to note that because sea level rises gradually, it is uniquely different from other hazards, such as hurricanes and earthquakes, which cause abrupt catastrophic impacts. Impacts from SLR may occur gradually over time, but result in permanent flooding and indirect hazards (i.e. damage from storm surge, shoreline erosion, road inundation, etc.).

This Greenwich Coastal Resiliency Assessment presents analyses and results related to the projected SLR at 2050, 2075, 2100 (low emissions scenario), and 2100 (high emissions scenario) including impacts from **Mean Higher High Water** (MHHW), the 10% flood (formerly referred to as the 10-year flood), the 1% flood (formerly referred to as the 100-year flood), and landscape characteristics such as shoreline characterization and migration.

## SEA LEVEL RISE RISK ASSESSMENT

Changes in sea level may affect coastal areas by disrupting economic activity, damaging utility infrastructure, flooding roads and structures, and impacting natural ecosystems. It is important to quantify and identify where these potential risks may have the greatest effects to better plan for local and regional impacts. This Greenwich Coastal Resiliency Assessment identifies vulnerabilities to flooding based on three types of floods – MHHW, 10% flood, and 1% flood – for each of the projected sea level change scenarios presented in Figure 3 – 2050, 2075, 2100 (low), and 2100 (high). For each flood and SLR scenario, the flood extent, structure exposure, and road exposure were evaluated (Table 2).

		Flood Type		
		MHHW	10% Flood	1% Flood
Analysis	Flood Extent	✓	✓	✓
	Structure Exposure	✓	✓	✓
	Road Exposure	✓	✓	✓
	Septic System Risk	✓		
	Critical Facilities Risk			✓

Table 2. Chart of analyses conducted for each flood type at projected SLR levels for 2050 (20 inches), 2075 (30 inches), 2100 (low emission – 40 inches), and 2100 (high emission – 80 inches)

Throughout this document, inset maps are provided to show community specific impacts (note: full size inset maps can be found in Appendix C in order of appearance) and coastwide impacts are provided in Appendix A. In addition, septic system vulnerability to SLR scenarios was assessed to identify potential septic system failures from inundation and a rising water table. Finally, the risk to critical facilities from a 1% flood event was assessed to identify key facilities that may be incapacitated.

This report analyzes exposure to structures, roads, and land use to aid Greenwich in planning for future impacts from SLR and coastal flooding. The analyses conducted provides the baseline information needed to explore mitigation and adaptation options in order to reduce flood impacts from a rising sea. Building, road, and land use GIS data were obtained from Greenwich. These data identify residential, commercial, town-owned structures, public roads, and land use types. Using modeled flood extents for selected scenarios, the analyses and results highlight areas where flooding impacts may be greatest. This document serves as a tool for future planning to reduce impacts to critical infrastructures that serve the community, roads that allow for town-wide evacuation, and town-owned structures that aid in day-to-day community operations.

## MEAN HIGHER HIGH WATER FLOOD EXTENT

Tide cycles along the Greenwich coastline are semidiurnal, meaning that the area experiences two high and two low tides of a different size every lunar day. The higher tide of the two high tides is known as the higher high tide. MHHW is based on the average of the higher high water height of each tidal day over a 19-year cycle, known as the National Tidal Datum Epoch. Generally, the extent of land between the Mean High Water (MHW) line and the MHHW line is accepted as the estimated area of inundation during sunny-day or lunar tidal flooding.

The extent of MHHW inundation displays the reach of water in coastal areas during a typical high tide. As sea levels rise, MHHW levels will increase and subsequently increase inundation extent. A current MHHW elevation of 3.48 feet (NAVD88) relative to mean sea level during the 1983 – 2001 National Tidal Datum Epoch was obtained from [NOAA Station 8467150](#) in Bridgeport, Connecticut (Figure 5). The NOAA station at Bridgeport was used due to its proximity and hydrologic connectivity to Greenwich. The area inundated at MHHW under each SLR scenario was calculated to provide guidance on locations that may experience flooding. Inundation extents were delineated by comparing flood elevations to 2016 LiDAR Digital Elevation Model (DEM) data obtained from the [NOAA Data Access Viewer](#).

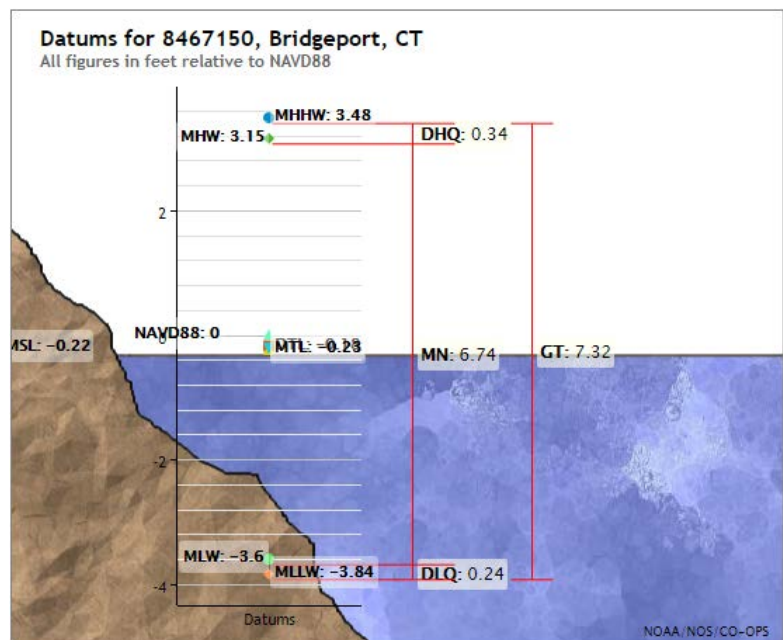


Figure 5. Tidal Datums for NOAA Station 8467150, Bridgeport, Connecticut (NOAA).

The number of acres inundated at MHHW by each SLR scenario can be found in Figure 6. This analysis provides an overview of the magnitude of area impacted by these scenarios. Flood extents only include areas of hydrologic connectivity where floodwaters can move inland, unimpeded by structures such as dams. Inundation extents include rivers and waterways located within Greenwich that are susceptible to tidal flooding. Results from the town-wide analysis can be found in Appendix A, Map 1. MHHW inundation extents for Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and Byram are presented in Inset Map 1, Inset Map 2, Inset Map 3, Inset Map 4, and Inset Map 5, respectively.

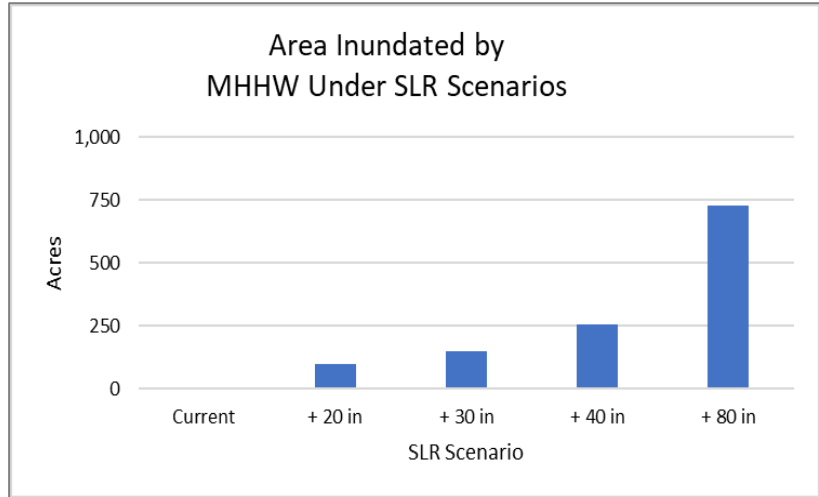


Figure 6. Acres inundated under different MHHW scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches).

### 10% FLOOD EXTENT

A 10% flood is defined as an event having a 10% chance of occurring in any given year. The 10% flood extent map displays the reaches of where water, in the absence of waves, may inundate coastal areas during a 10% flood event. Flood elevations were obtained from The FEMA National Flood Insurance Program data for Fairfield County Connecticut, effective 10/16/2013. The additional modeled scenarios show where a 10% flood event can be expected to impact given a specific SLR scenario. It was assumed there was a linear relationship between the 10% flood water surface elevation and increase in sea levels. The number of acres inundated by each 10% flood scenario can be found in Figure 7. Flood extents only include areas of hydrologic connectivity where floodwaters can move inland, unimpeded by structures such as dams. Inundation extents include rivers and waterways located within Greenwich that are susceptible to tidal flooding (Appendix A, Map 2). 10% flooding inundation extents for Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and Byram are presented in Inset Map 1, Inset Map 2, Inset Map 3, Inset Map 4, and Inset Map 5, respectively.

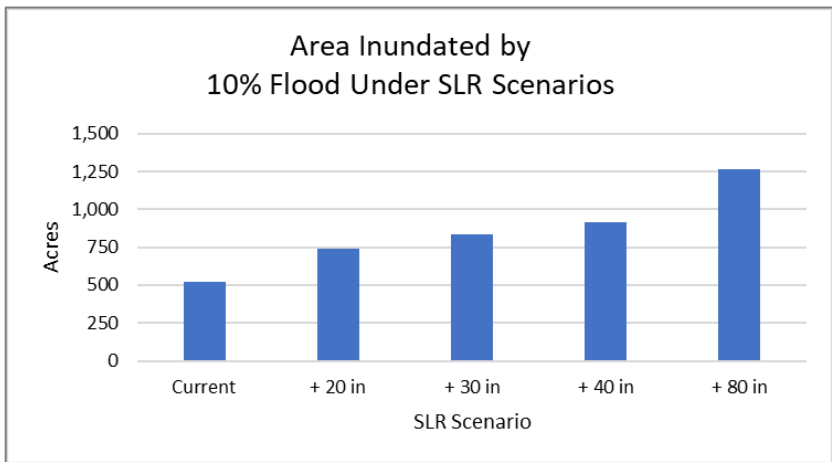


Figure 7. Acres inundated by 10% Flood scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches).

## 1% FLOOD EXTENT

A 1% flood is defined as an event having a 1% chance of occurring in any given year (in the past, this was commonly referred to as a 100-year flood). The 1% flood extent map displays the reaches of where water, including wave impacts, may inundate coastal areas during a 1% flood event. Flood elevations were obtained from the FEMA National Flood Insurance Program data for Fairfield County Connecticut, effective 10/16/2013; the area inundated during a 1% flood event is also known as the FEMA Special Flood Hazard Area (SFHA). This assessment modeled additional

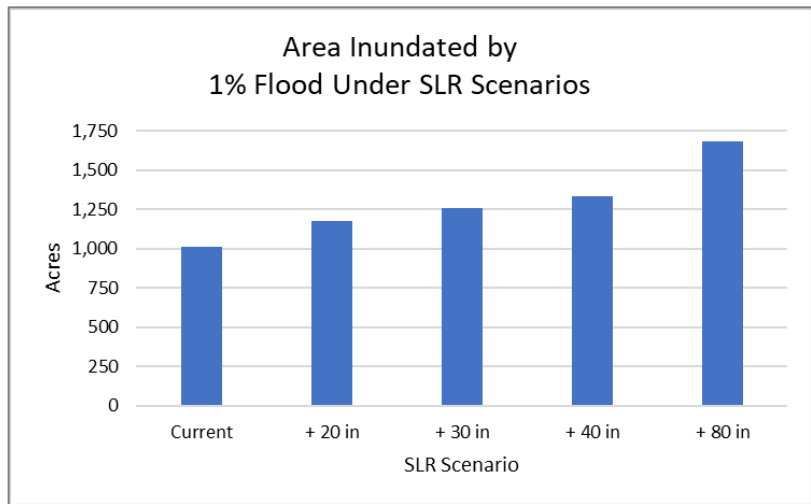
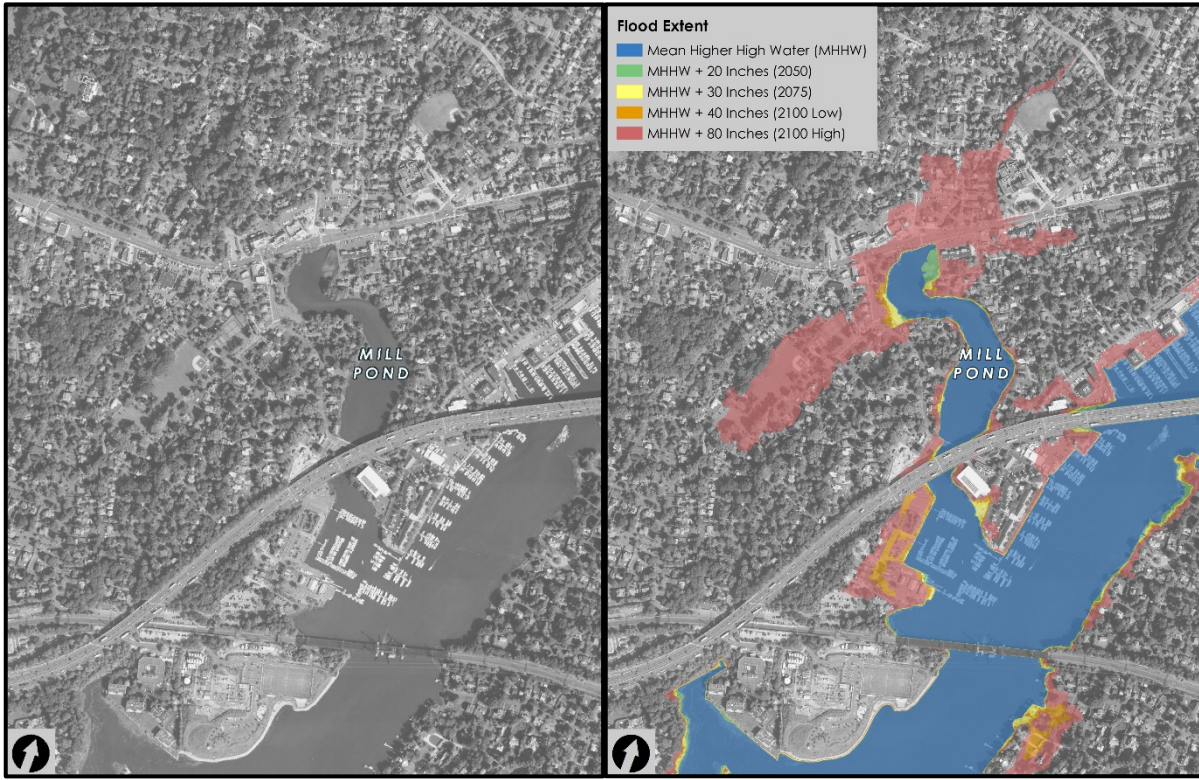


Figure 8. Acres inundated by 1% Flood scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches).

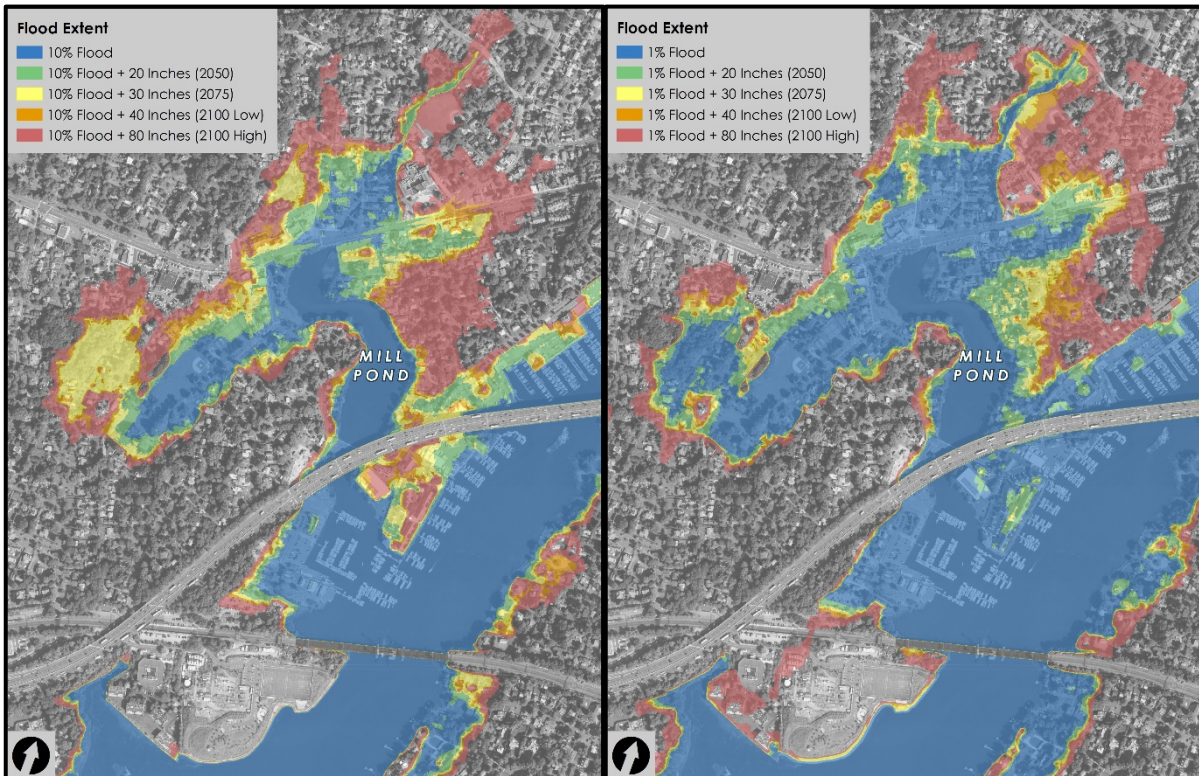
scenarios to show where a 1% flood event can be expected to impact given a specific SLR scenario and assumes a linear relationship between the 1% flood water surface elevation and increase in sea levels. The number of acres inundated for each SLR scenario are presented in Figure 8. Flood extents only include areas of hydrologic connectivity where floodwaters can move inland, unimpeded by structures such as dams. Inundation extents include rivers and waterways located within Greenwich that are susceptible to tidal flooding (Appendix A, Map 3). 1% flooding inundation extents for Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and Byram are presented in Inset Map 1, Inset Map 2, Inset Map 3, Inset Map 4, and Inset Map 5, respectively.

MILL POND PARK FLOODING EXTENTS



Existing Conditions

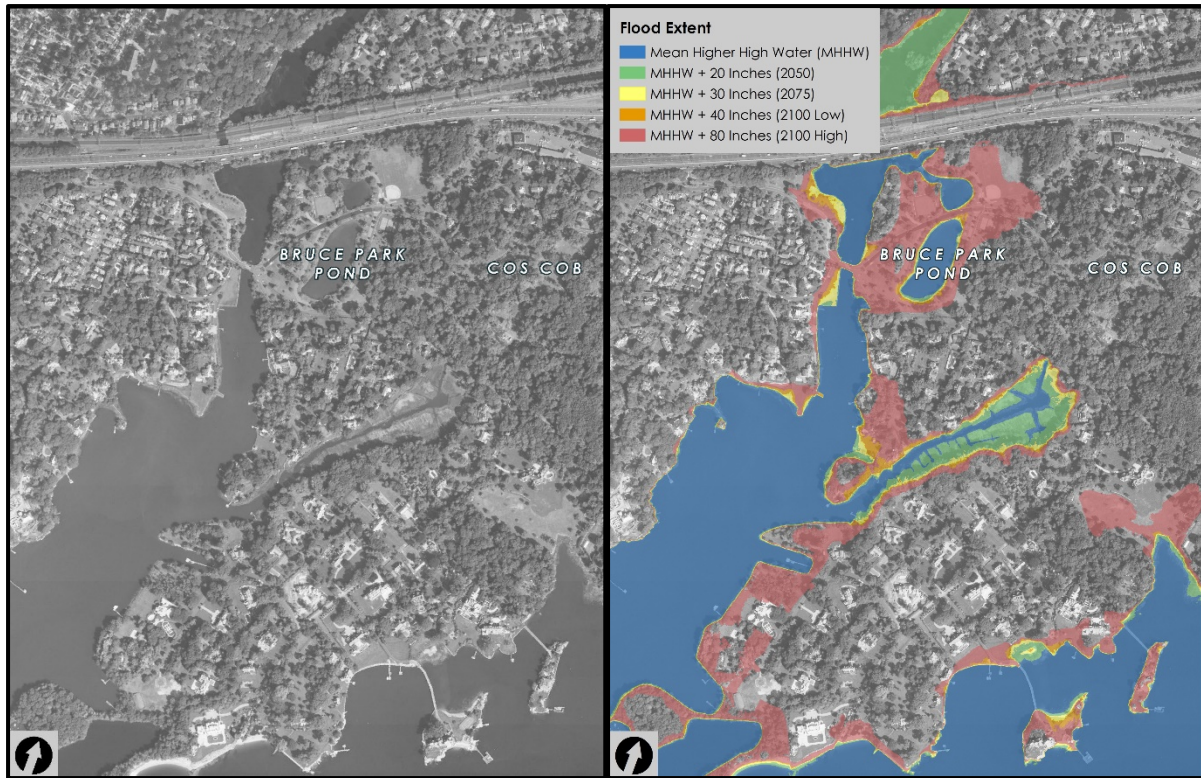
MHHW



10% Flood

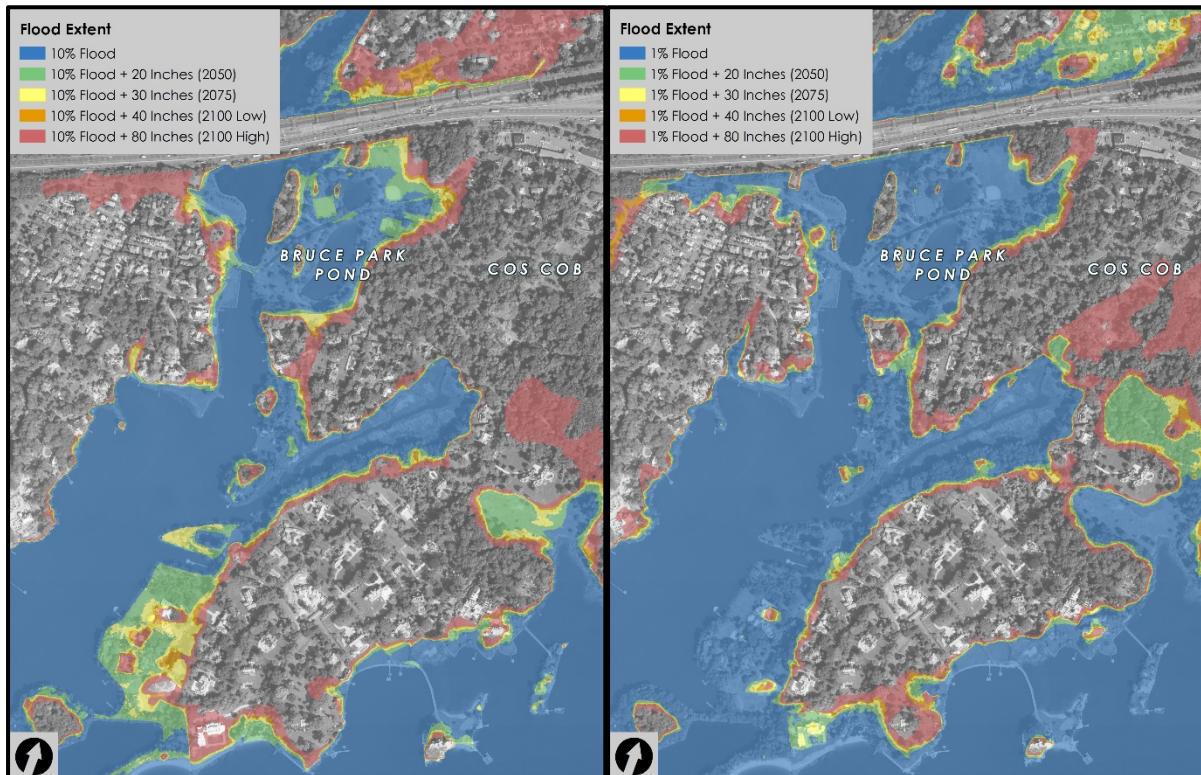
1% Flood

### BRUCE PARK FLOODING EXTENTS



Existing Conditions

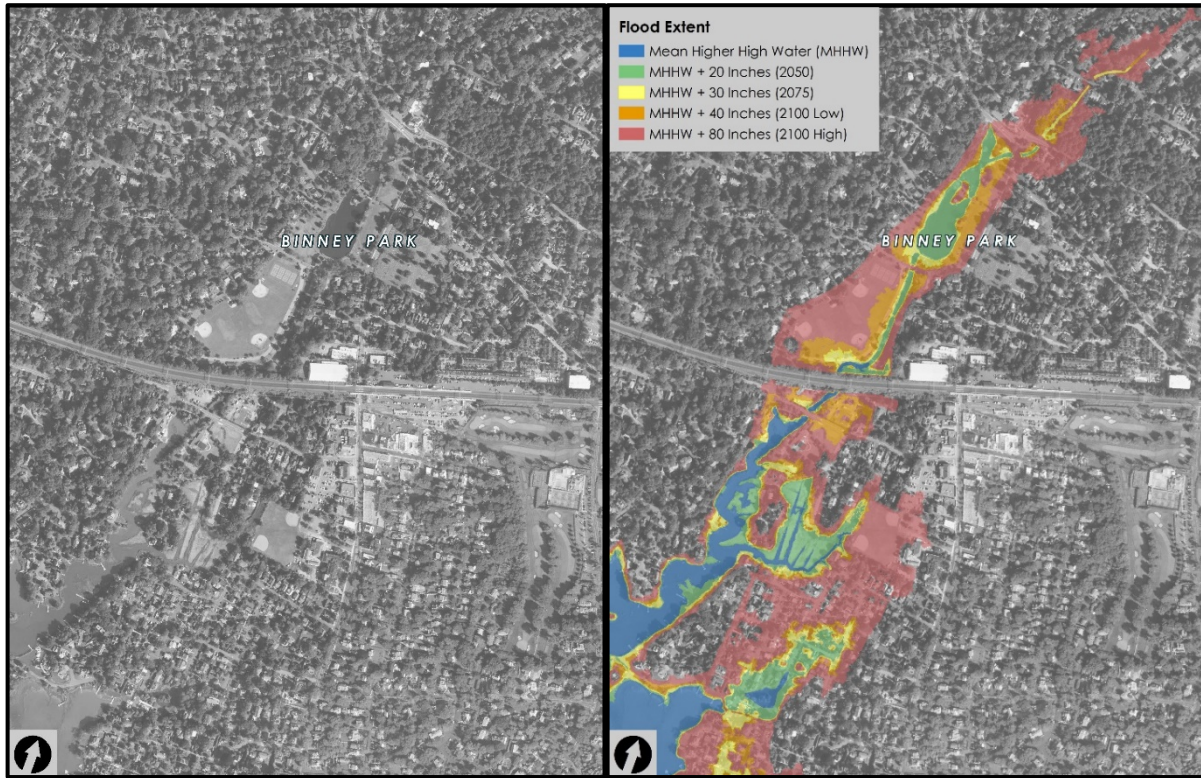
MHHW



10% Flood

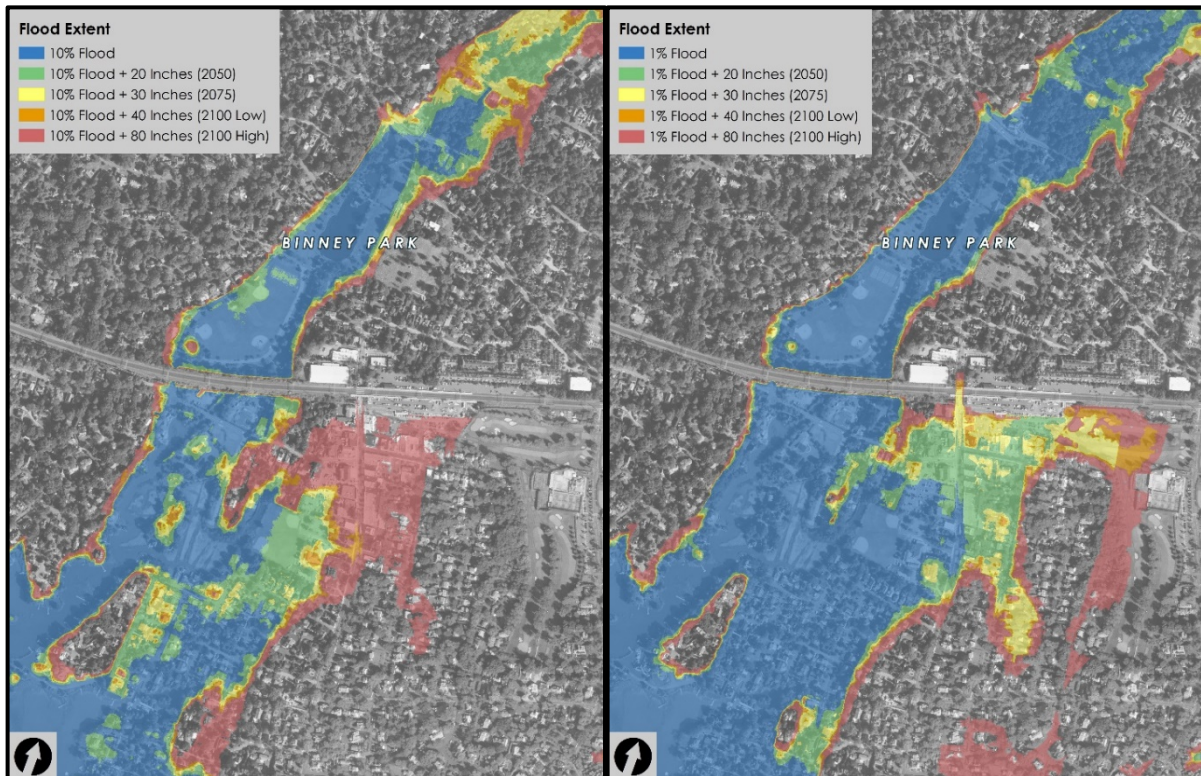
1% Flood

### BINNEY PARK FLOODING EXTENTS



Existing Conditions

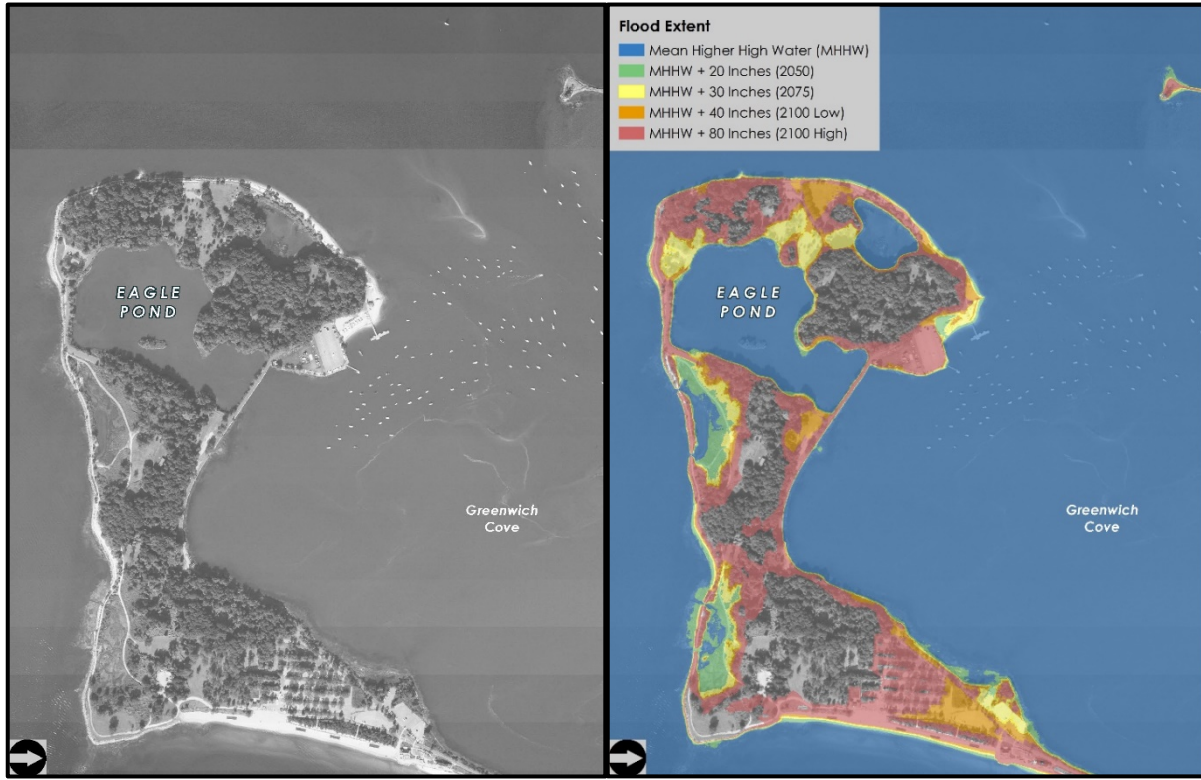
MHHW



10% Flood

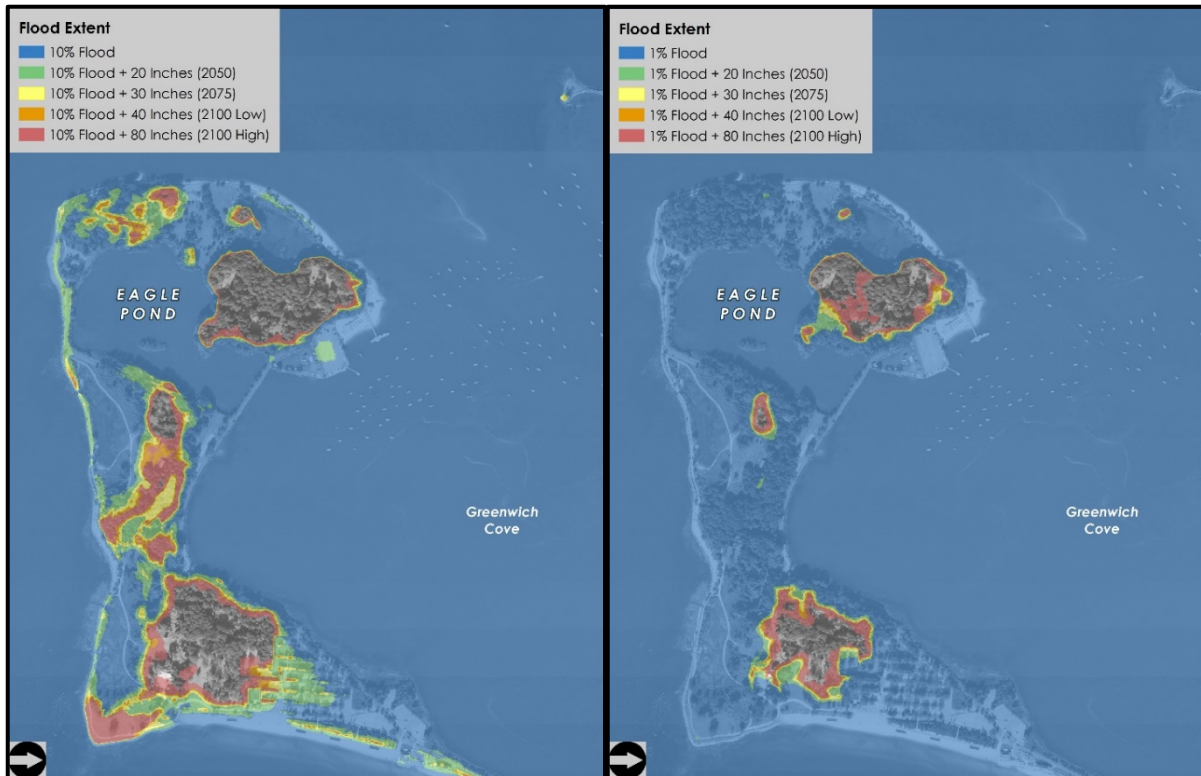
1% Flood

### GREENWICH POINT PARK FLOODING EXTENTS



Existing Conditions

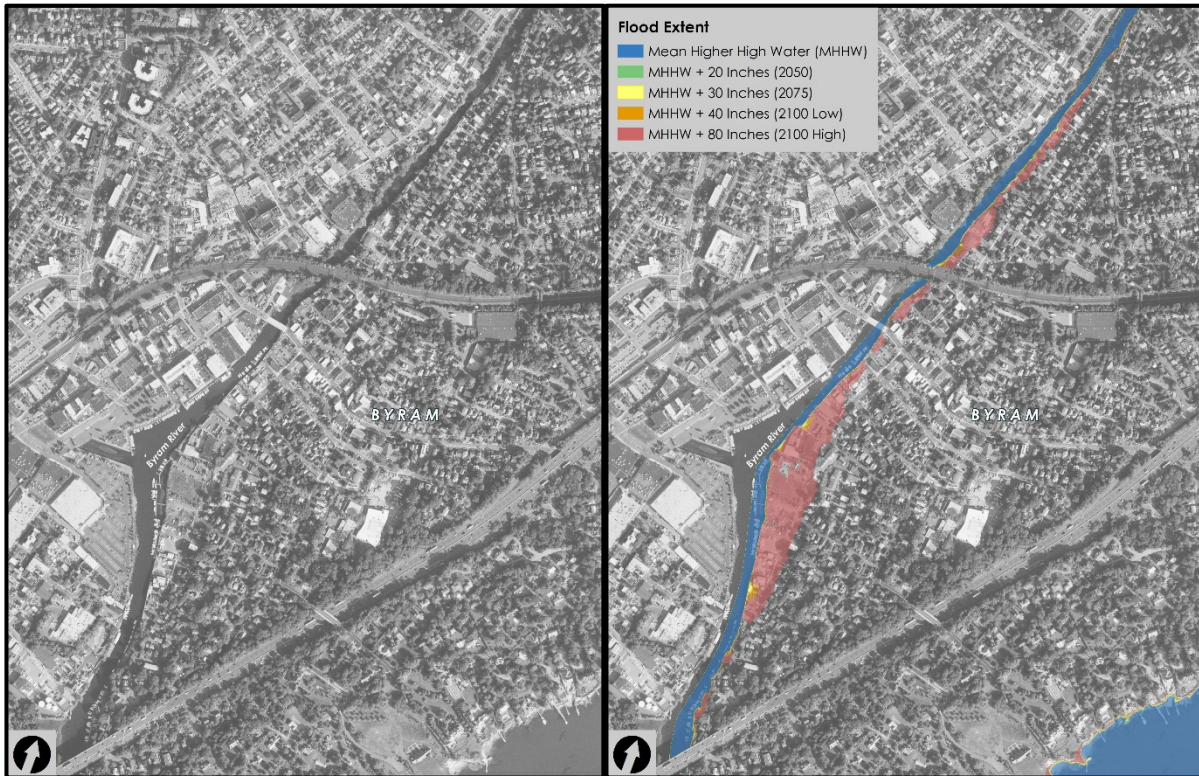
MHHW



10% Flood

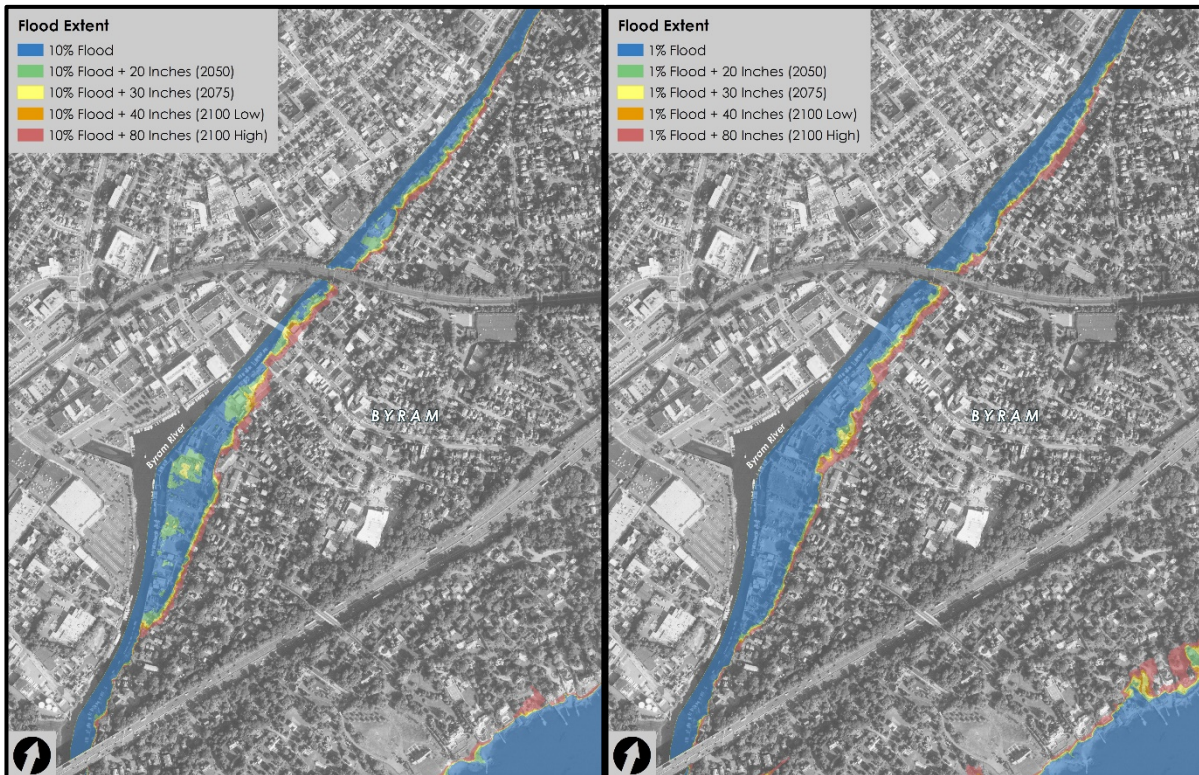
1% Flood

BYRAM FLOODING EXTENTS



Existing Conditions

MHHW



10% Flood

1% Flood

## LAND USE & LAND COVER INUNDATION

Land Use and land cover information can be used to better understand the impacts of coastal flooding on how humans use and interact with land. Land cover provides a physical description of land (wetlands, forests, agriculture, etc.) and land use shows how people use the landscape (conservation, commercial, residential, etc.). Areas of flooding were analyzed according to 2010 land use and land cover data. This analysis parses the inundated area by scenario to quantify land use types impacted by flooding. Assessing impacts from the selected scenarios provides further insight on prioritization for future mitigation and adaptation options. Scenarios under MHHW suggest chronic or permanent inundation. Results from the town-wide MHHW, 10%, and 1% flood analysis can be found in Figure 9, Figure 10, and Figure 11, respectively.

Across all events and scenarios, except for MHHW + 20 inches, urban land use is the most heavily impacted land use type. A rise of 20 inches in sea level by 2050 impacts wetland (43 acres) and urban (22 acres) areas. Given that wetlands are situated between water and land, it is no surprise that it is the most impacted land use by this initial rise in sea level. Urban inundation is visible along most of the Greenwich coastline with the highest concentration of urban land use impacted along the eastern parts of Old Greenwich and along Mill Pond Park. A rise of 30 inches in sea level by 2075 impacts urban (53 acres) and wetland (49 acres) land use types the most. Similar to the 2050 scenario, urban impacts are spread out along the coastline and concentrated near Mill Pond Park and the eastern part of Old Greenwich, along Greenwich Cove. A rise of 40 inches (2100 low) increases impacted urban land use to 121 acres, with impacts found throughout the Greenwich coastline and concentrated along the eastern part of Old Greenwich. Additional impacts are along Mill Pond Park, Binney Park, and Greenwich Point Park. Finally, a rise of 80 inches (2100 high) impacts 501 acres of urban land use. Impacts are heavily concentrated in Old Greenwich. Additional impacts are found along Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and along the easternmost portions of Byram. The commercial corridor near Mill Pond Park, along East Putnam Ave., and the marinas along Indian Harbor experience concentrated impacts. Under this scenario, the northeastern portions of Belle Haven, near the wastewater plant, are also impacted.

Under current day conditions, a 10% flood impacts 331 acres of urban land use. Land use impacts are clustered throughout Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, along the easternmost portions of Byram, and along the eastern and western portions of Old Greenwich. A rise of 20 inches increases impacted urban land use to 508 acres, a rise of 30 inches impacts 592 acres, a rise of 40 inches impacts 662 acres, and a rise of 80 inches impacts 952 acres. Land use impacts across all scenarios are clustered throughout Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, the southern portions of Riverside, the easternmost portions of Byram, and the eastern and western portions of Old Greenwich. Communities near Mill Pond Park, Binney Park, and Old Greenwich experience the highest concentration of impacts.

Under current day conditions, a 1% flood impacts 731 acres of urban land use. Land use impacts are clustered throughout Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, along the easternmost portions of Byram, and along the eastern and western portions of Old Greenwich. A rise of 20 inches increases impacted urban land use to 877 acres, a rise of 30 inches impacts 945 acres, a rise of 40 inches impacts 1,011 acres, and a rise of 80 inches impacts 1,312 acres. Land use impacts are clustered throughout Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, the southern portions of Riverside, the easternmost portions of Byram, and the eastern and western portions of Old Greenwich. Communities near Mill Pond Park, Binney Park, and Old Greenwich experience the highest concentration of impacts.

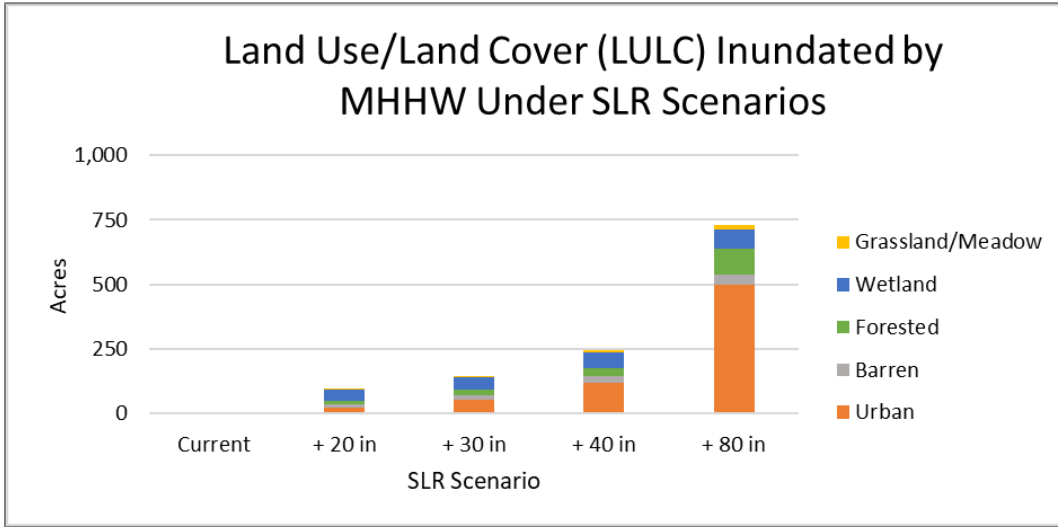


Figure 9. Land Use/ Land Cover Inundation from MHHW flooding

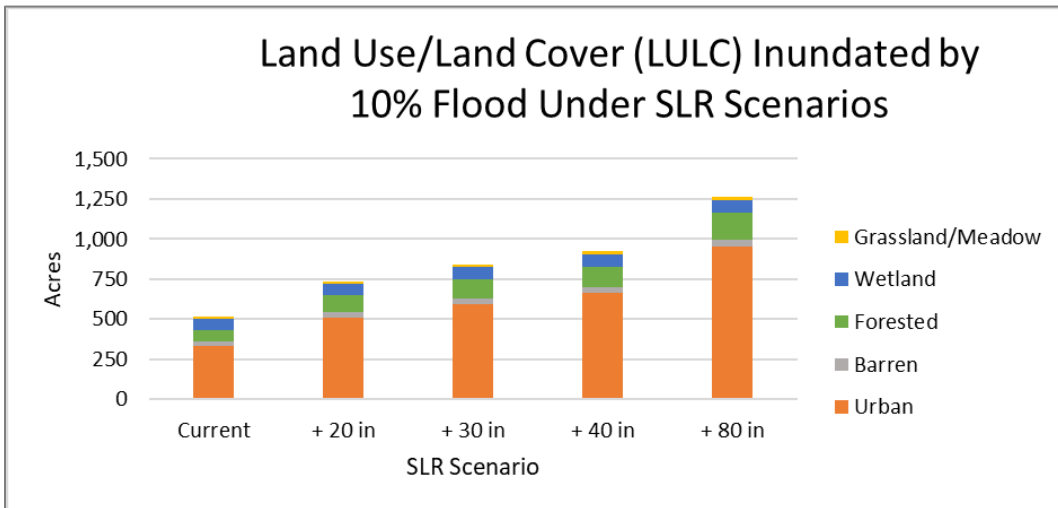


Figure 10. Land Use/ Land Cover Inundation from 10% flooding.

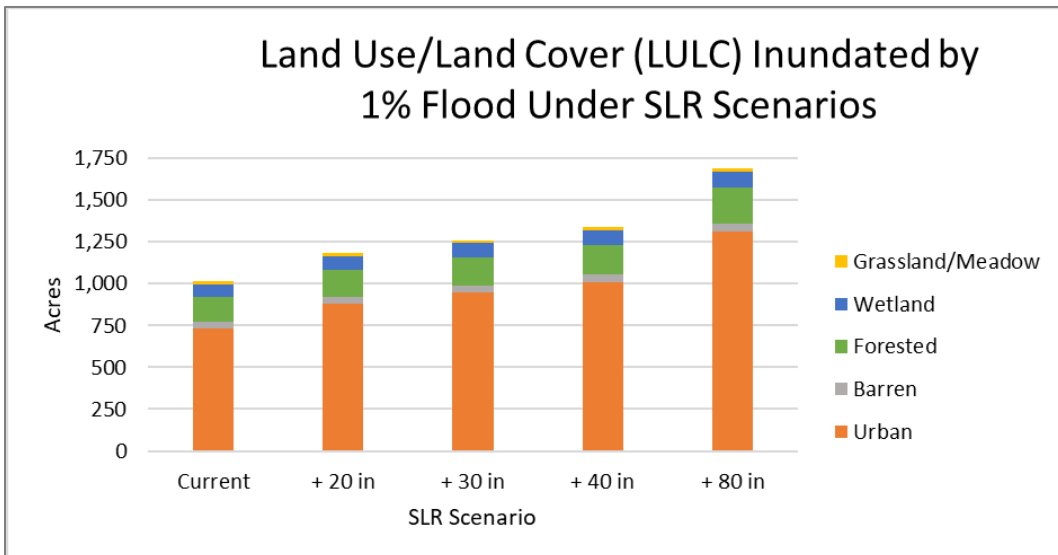


Figure 11. Land Use/ Land Cover Inundation from 1% flooding.

## STRUCTURE EXPOSURE

An analysis was performed to quantify the number of structures that would be impacted by each flood event (MHHW, 10% flood, and 1% flood) and for each SLR scenario. A structure was considered impacted if it was located within the boundary of the flood extents. Neither water depth or structure first floor elevation were considered in the analysis. Locations for town-owned, residential, and commercial structures were obtained from Greenwich.

### MHHW SCENARIOS

Under current conditions, there are no town-owned structures at risk to flooding under MHHW. The 2050 scenario identifies 1 town-owned structure impacted by an increase in sea level of 20 inches. The 2075 scenario identifies 2 town-owned structures impacted by an increase in sea level of 30 inches. The 2100 low scenario identifies 7 town-owned structures impacted by an increase in sea level of 40 inches. The 2100 high scenario identifies 32 town-

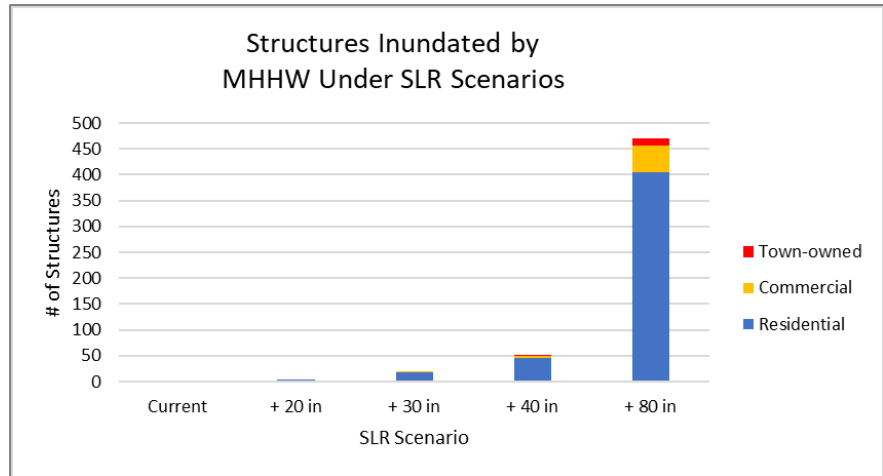


Figure 12. Number of town-owned structures impacted by MHHW scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches). Note: MHHW will serve as the baseline (zero) for all scenario impacts.

owned structures impacted by an increase in sea level of 80 inches. This analysis also identified five residential structures impacted by an increase of 20 inches in sea level. A rise of 30 inches in sea level impacts 18 residential and one commercial structure. A rise of 40 inches impacts 45 residential and four commercial structures. Lastly, a rise of 80 inches impacts 404 residential and 53 commercial structures. A list of town-owned structures impacted by MHHW flood scenarios is presented in Table 3, and results for the town-wide analysis are presented in Figure 12 and Appendix A, Map 4.

Table 3. Town-owned structures impacted by MHHW flood scenarios.

Structure Name	Town-owned Structures Impacted by Mean Higher High Water (MHHW) Scenarios				
	MHHW (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Cos Cob Library				✓	✓
Byram Shore Park - Pool House				✓	✓
Cos Cob Dockmaster				✓	✓
Grass Island - Dockmaster				✓	✓
Grass Island - Gate House				✓	✓
Grass Island - Maintenance Shed				✓	✓
Greenwich Point - Camp Kairphree				✓	✓
Greenwich Point - Dockmaster				✓	✓
Greenwich Point - Gate House				✓	✓
Greenwich Point - Life Guard Tower				✓	✓
Greenwich Point - Nurses Quarters				✓	✓
Greenwich Point - Supervisor Building				✓	✓
Cos Cob Fire House				✓	✓
Police Department, Marine Division				✓	✓
Building Construction and Maintenance Division				✓	✓
Byram Highway Shed				✓	✓
Island Beach Dock Information				✓	✓
Old Greenwich Highway Shed				✓	✓
Ballwood Road Pump Station				✓	✓
Belle Haven Pump Station				✓	✓
Bruce Park Pump Station				✓	✓
Byram Pool Pump Station				✓	✓
Club Road Pump Station				✓	✓
Cos Cob Pump Station				✓	✓
Husted Drive Pump Station			✓	✓	✓
Meadow Pump Station				✓	✓
Old Greenwich Pump Station				✓	✓
South Water Street Pump Station				✓	✓
Station A Pump Station				✓	✓
Station D Pump Station				✓	✓
Western Pump Station				✓	✓
Willowmere Pump Station		✓	✓	✓	✓

### 10% FLOOD SCENARIOS

Under current day conditions, a 10% flood event would impact 24 town-owned structures. The scenario for 2050 indicates that there are 32 town-owned structures at risk from a 10% flood event with an increase in sea level of 20 inches. The 2075 scenario indicates 34 impacted town-owned structures, and the 2100 low and high scenarios suggest that 39 and 43 town-owned structures, respectively, would be impacted by a 10% flood. This

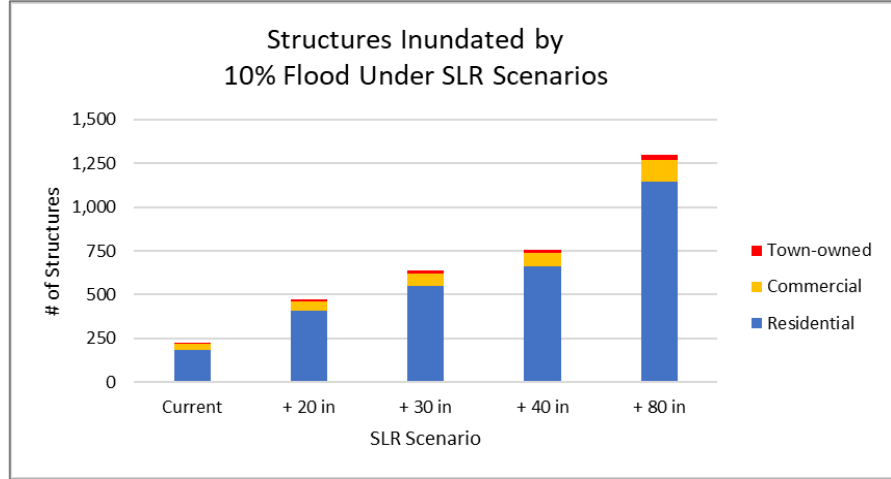


Figure 13. Number of residential, commercial, and town-owned structures impacted by 10% flood scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches).

analysis also identified 186 residential and 32 commercial structures impacted by a 10% flood. An increase of 20 inches in sea level impacts 408 residential and 53 commercial structures. A rise of 30 inches in sea level impacts 552 residential and 68 commercial structures. A rise of 40 inches impacts 662 residential and 79 commercial structures. Lastly, a rise of 80 inches impacts 1,148 residential and 121 commercial structures.

A list of town-owned impacted by 10% flood scenarios is presented in Table 4, and results from the town-wide analysis can be found in Figure 13 and Appendix A, Map 5.

Table 4. Town-owned structures impacted by 10% flood scenarios.

Structure Name	Town-Owned Structures Impacted by 10% Flood Scenarios				
	10% (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Cos Cob Library		✓	✓	✓	✓
Byram Shore Park - Pool House		✓	✓	✓	✓
Cos Cob Dockmaster	✓	✓	✓	✓	✓
Grass Island - Dockmaster	✓	✓	✓	✓	✓
Grass Island - Gate House	✓	✓	✓	✓	✓
Grass Island - Maintenance Shed	✓	✓	✓	✓	✓
Greenwich Point - Camp Kairphree	✓	✓	✓	✓	✓
Greenwich Point - Dockmaster	✓	✓	✓	✓	✓
Greenwich Point - Gate House	✓	✓	✓	✓	✓
Greenwich Point - Henry's Cottage				✓	✓
Greenwich Point - Innis Arden Cottage			✓	✓	✓
Greenwich Point - Life Guard Tower	✓	✓	✓	✓	✓
Greenwich Point - Nurses Quarters		✓	✓	✓	✓
Greenwich Point - Supervisor Building	✓	✓	✓	✓	✓

Structure Name	Town-Owned Structures Impacted by 10% Flood Scenarios				
	10% (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Parks & Tree Division - Arch St.			✓	✓	✓
Old Greenwich School				✓	✓
Cos Cob Fire House		✓	✓	✓	✓
Sound Beach (Old Greenwich) Fire house					✓
Police Department, Marine Division		✓	✓	✓	✓
Building Construction and Maintenance Division	✓	✓	✓	✓	✓
Byram Highway Shed	✓	✓	✓	✓	✓
Greenwich Waste Treatment Plant				✓	✓
Island Beach Dock Information	✓	✓	✓	✓	✓
Old Greenwich Highway Shed	✓	✓	✓	✓	✓
Ballwood Road Pump Station		✓	✓	✓	✓
Belle Haven Pump Station		✓	✓	✓	✓
Bruce Park Pump Station	✓	✓	✓	✓	✓
Byram Pool Pump Station	✓	✓	✓	✓	✓
Chapel Lane Pump Station					✓
Club Road Pump Station	✓	✓	✓	✓	✓
Cos Cob Pump Station	✓	✓	✓	✓	✓
Den Lane Pump Station				✓	✓
Eastern Pump Station				✓	✓
Husted Drive Pump Station	✓	✓	✓	✓	✓
Meadow Pump Station	✓	✓	✓	✓	✓
Old Greenwich Pump Station	✓	✓	✓	✓	✓
Oneida Drive Pump Station					✓
South Water Street Pump Station	✓	✓	✓	✓	✓
Station A Pump Station	✓	✓	✓	✓	✓
Station D Pump Station	✓	✓	✓	✓	✓
West Brother Drive Pump Station					✓
Western Pump Station		✓	✓	✓	✓
Willowmere Pump Station	✓	✓	✓	✓	✓

### 1% FLOOD SCENARIOS

Under current day conditions, a 1% flood event would impact 40 town-owned structures. The scenarios for 2050 and 2075 for a 1% flood event with an increase in sea level of 20 inches and 30 inches, respectively, indicate that there are 43 impacted town-owned structures. The 2100 low scenario identifies 44 impacted town-owned structures. The 2100 high scenario identifies 49 impacted town-owned

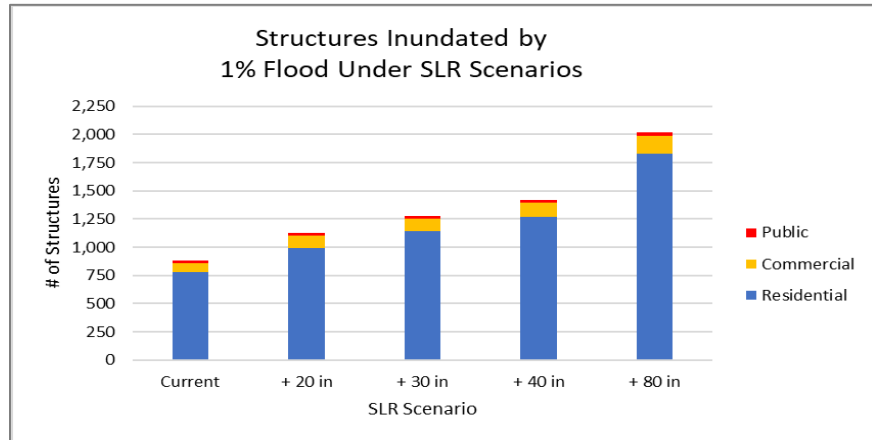


Figure 14. Number of residential, commercial, and town-owned structures impacted by 1% flood scenarios. Scenarios are based on SLR projections for 2050 (20 inches), 2075 (30 inches), 2100 low (40 inches), and 2100 high (80 inches).

structures. This analysis also identified 779 residential and 78 commercial structures impacted by a 1% flood. An increase of 20 inches in sea level impacts 996 residential and 107 commercial structures. A rise of 30 inches in sea level impacts 1,140 residential and 116 commercial structures. A rise of 40 inches impacts 1,266 residential and 126 commercial structures. Lastly, a rise of 80 inches impacts 1,826 residential and 162 commercial structures.

A list of town-owned structures impacted by 1% flood scenarios is presented in Table 5. Results from the town-wide analysis can be found in Figure 14 and Appendix A, Map 6.

A summary of impacts to structures in the communities near Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and Byram are presented in Inset Map 6, Inset Map 7, Inset Map 8, Inset Map 9, and Inset Map 10.

Table 5. Town-owned structures impacted by 1% flood scenarios.

Structure Name	Town-Owned Structures Impacted by 1% Flood Scenarios				
	1% (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Cos Cob Library	✓	✓	✓	✓	✓
Perrot Library					✓
Bruce Park Maintenance Barn					✓
Byram Shore Park - Dockmaster					✓
Byram Shore Park - Pool House	✓	✓	✓	✓	✓
Byram Shore Park - Ticket Booth				✓	✓
Cos Cob Dockmaster	✓	✓	✓	✓	✓
Grass Island - Dockmaster	✓	✓	✓	✓	✓
Grass Island - Gate House	✓	✓	✓	✓	✓
Grass Island - Maintenance Shed	✓	✓	✓	✓	✓
Greenwich Point - Camp Kairphree	✓	✓	✓	✓	✓
Greenwich Point - Dockmaster	✓	✓	✓	✓	✓

Structure Name	Town-Owned Structures Impacted by 1% Flood Scenarios				
	1% (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Greenwich Point - Gate House	✓	✓	✓	✓	✓
Greenwich Point - Henry's Cottage	✓	✓	✓	✓	✓
Greenwich Point - Innis Arden Cottage	✓	✓	✓	✓	✓
Greenwich Point - Life Guard Tower	✓	✓	✓	✓	✓
Greenwich Point - Nurses Quarters	✓	✓	✓	✓	✓
Greenwich Point - Supervisor Building	✓	✓	✓	✓	✓
Parks & Tree Division - Arch St.	✓	✓	✓	✓	✓
Cos Cob School					✓
Old Greenwich School	✓	✓	✓	✓	✓
Cos Cob Fire House	✓	✓	✓	✓	✓
Sound Beach (Old Greenwich) Fire house		✓	✓	✓	✓
Police Department, Marine Division	✓	✓	✓	✓	✓
Building Construction and Maintenance Division	✓	✓	✓	✓	✓
Byram Highway Shed	✓	✓	✓	✓	✓
Greenwich Waste Treatment Plant	✓	✓	✓	✓	✓
Island Beach Dock Information	✓	✓	✓	✓	✓
Old Greenwich Highway Shed	✓	✓	✓	✓	✓
Ballwood Road Pump Station	✓	✓	✓	✓	✓
Belle Haven Pump Station	✓	✓	✓	✓	✓
Bruce Park Pump Station	✓	✓	✓	✓	✓
Byram Pool Pump Station	✓	✓	✓	✓	✓
Chapel Lane Pump Station	✓	✓	✓	✓	✓
Club Road Pump Station	✓	✓	✓	✓	✓
Cos Cob Pump Station	✓	✓	✓	✓	✓
Den Lane Pump Station	✓	✓	✓	✓	✓
Eastern Pump Station	✓	✓	✓	✓	✓
Husted Drive Pump Station	✓	✓	✓	✓	✓
Meadow Pump Station	✓	✓	✓	✓	✓
Old Greenwich Pump Station	✓	✓	✓	✓	✓
Oneida Drive Pump Station		✓	✓	✓	✓
South Water Street Pump Station	✓	✓	✓	✓	✓
Station A Pump Station	✓	✓	✓	✓	✓
Station D Pump Station	✓	✓	✓	✓	✓
West Brother Drive Pump Station		✓	✓	✓	✓

Structure Name	Town-Owned Structures Impacted by 1% Flood Scenarios				
	1% (Current)	Plus 20 inches (2050)	Plus 30 Inches (2075)	Plus 40 Inches (2100 Low)	Plus 80 Inches (2100 High)
Western Pump Station	✓	✓	✓	✓	✓
Willowmere Pump Station	✓	✓	✓	✓	✓
River House Adult Day Center					✓

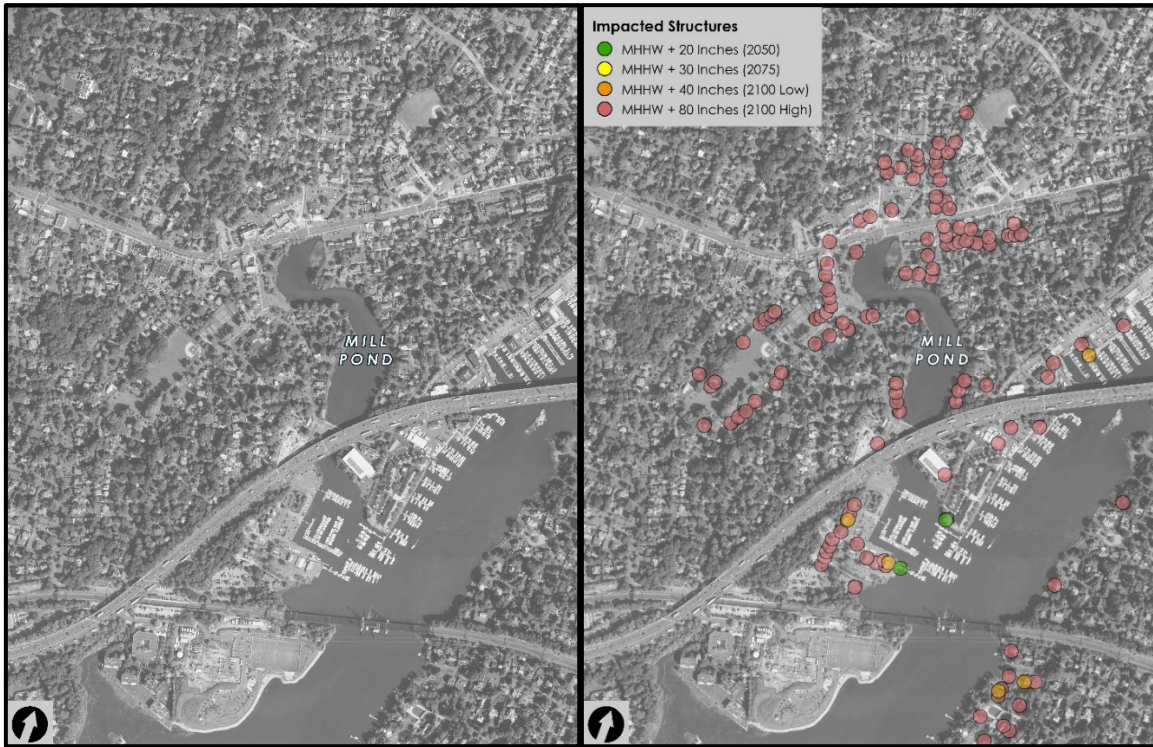
As part of this assessment, Greenwich’s critical facilities were mapped and analyzed for the current day 1% flood event and for future flood scenarios within the study area. A “critical facility” is one that provides services and functions essential to a community, such as police, fire, and emergency response installations, especially during and after a disaster. Other types of critical facilities may be those that house vulnerable populations such as schools and nursing homes. While most of Greenwich’s critical facilities are located outside of the 1% flood extent, the following facilities may be at risk during a 1% flood (Appendix A, Map 7).

#### CRITICAL FACILITIES AT RISK DURING A 1% FLOOD

- Old Greenwich Elementary School.** The rear portion of the school is located within the extent of a 1% flood and includes the athletic fields and portions of the parking lot. A small portion of the school building is also located within the flood extent. A rise of 20 inches in sea level (2050) exacerbates the extent of flooding to the school. Most of the school and the northbound sections of South Beach Ave. may cause accessibility issues. A rise of 30 inches (2075) engulfs the entirety of the school and further impacts flooding along South Beach Ave. A rise of 40 inches (2100 low) and a rise of 80 inches (2100 high) impact the entirety of Old Greenwich School and further extends the reach of flooding down South Beach Ave.
- Sound Beach (Old Greenwich) Fire House.** The Sound Beach Fire house is located directly adjacent to the 1% flood extent, and portions of the parking lot are located within the flood extent. Emergency responders may encounter access issues to nearby locations, should low-lying roadways become flooded during 1% storm events. A rise of 20 inches in sea level (2050) engulfs the fire station, its parking lot, and its main access roads, West End Ave. and Sound Beach Ave. Ingress and egress from the fire station may be difficult. A rise of 30 inches (2075), 40 inches (2100 low), and 80 inches (2100 high) all increase the flood extent and further road and building access concerns.
- Greenwich Wastewater Treatment Plant.** The wastewater treatment plant is located entirely within the 1% flood extent and is directly adjacent to a tidal waterbody. Shore Rd. and Grass Island Rd, the two main access roads are also within the 1% flood extent. A rise of 20 inches (2050), 30 inches (2075), 40 inches (2100 low) and 80 inches (2100 high) completely flood the wastewater treatment plant and further extends flooding along Shore Rd, Interval Pl., and Grass Island Rd.
- Greenwich Police Department, Marine Division.** The entire Marine Police facility is within the 1% flood extent and is directly adjacent to a tidal waterbody, by necessity. A rise of 20 inches (2050), 30 inches (2075), 40 inches (2100 low) and 80 inches (2100 high) completely flood the police facility and its sole access road, Arch St.
- Cos Cob Elementary School.** The school itself is not located within the 1% flood extent. However, East Putnam Ave., Suburban Ave., and School St., are located within the flood extent, and therefore, access to the school may be impeded. A rise in 20 inches of sea level does not impact the school, but further impacts the surrounding roads, including Orchard St. and Valley Rd. A rise in 30 inches of sea level also does not impact the school itself, but further impacts the roads around the school, significantly limiting access. A rise of 40 inches (2100 low) impacts small portions of the school along Brothers Brook. A rise of 80 inches (2100 high) engulfs the school and all surrounding roads.

- **Cos Cob Fire Department.** The Cos Cob Fire Department is located within the 1% flood extent. Flooding along Sinaway Rd. and East Putnam Ave. may pose access issues to emergency responders. A rise of 20 inches (2050), 30 inches (2075), 40 inches (2100 low) and 80 inches (2100 high) completely flood the fire department and surrounding roads.
- **Glenville Fire Department.** The property is adjacent to a tidal waterbody. However, only the rear of the property, and a small portion of the facility is located within the 1% flood extent.
- **Parkway School (public) and Whitby School (private).** Neither school is located within the 1% flood extent; however, they would be impacted by 1% flooding to the East, South, and West. The school(s) may become difficult to access should any of the nearby roads become impassible during a 1% flood.
- **Byram Highway Shed.** The entire property, and a large portion of the street that services it (South Water Street), is currently located within the 1% flood extent and is directly adjacent to a tidal waterbody. Rises in sea level would not significantly expand the extent of flooding in the area but would increase the depth of floodwaters.
- **River House Adult Day Center.** The property is located adjacent the dam which impounds Mianus Pond, separating it from the tidal waters of Cos Cob Harbor. The building and parking lot would become impacted with a rise of 80 inches (2100 high). However, the site may face additional hazards before then as increased storm intensity and frequency may impact the adjacent dam structure.
- **Pump Stations.** 17 of the Town's pump stations are currently located within the extent of a 1% flood. 2 additional pump stations will be impacted by a rise of 20 inches (2050).
  - **Pump stations currently impacted by a 1% storm event:**
    - Ballwood Road Pump Station
    - Belle Haven Pump Station
    - Bruce Park Pump Station
    - Byram Pool Pump Station
    - Chapel Lane Pump Station
    - Club Road Pump Station
    - Cos Cob Pump Station
    - Den Lane Pump Station
    - Eastern Pump Station
    - Husted Drive Pump Station
    - Meadow Pump Station
    - Old Greenwich Pump Station
    - Oneida Drive Pump Station
    - South Water Street Pump Station
    - Station A Pump Station
    - Station D Pump Station
    - Western Pump Station
    - Willowmere Pump Station
  - **Additional pump stations impacted by a 1% storm event plus a rise of 20 inches (2050):**
    - Oneida Drive Pump Station
    - West Brother Drive Pump Station

MILL POND PARK IMPACTED STRUCTURES FROM FLOODING SCENARIOS



Existing Conditions

MHHW

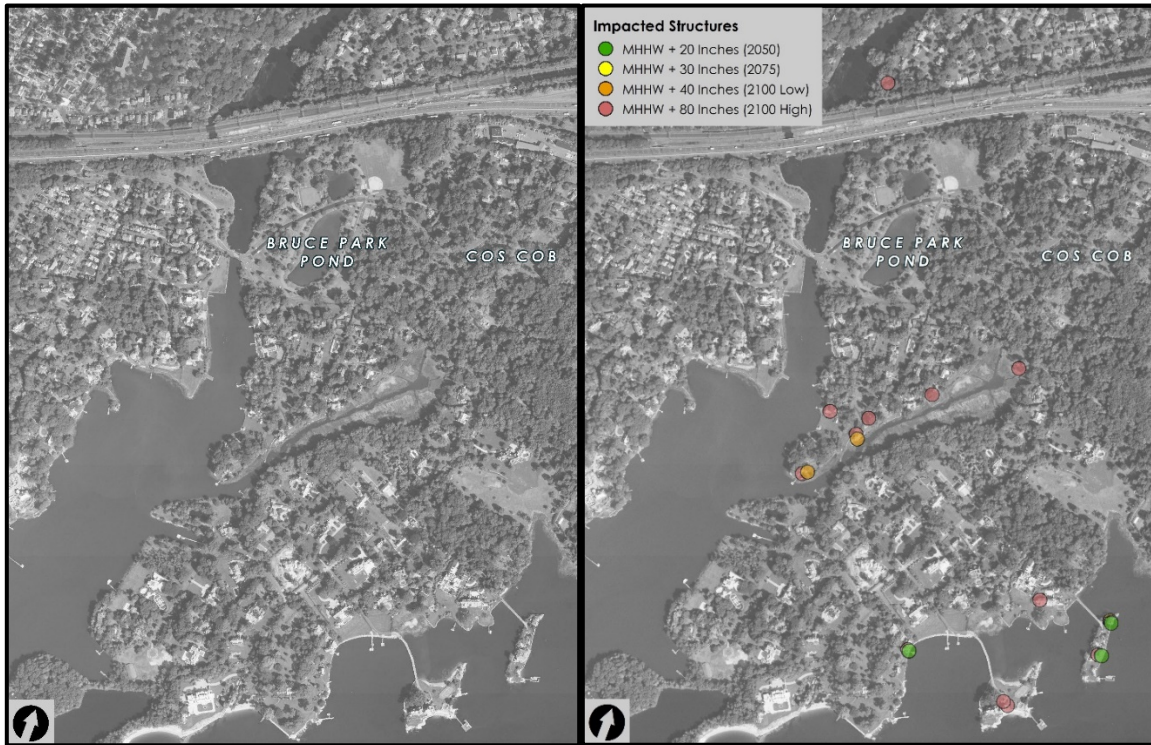


10% Flood

1% Flood

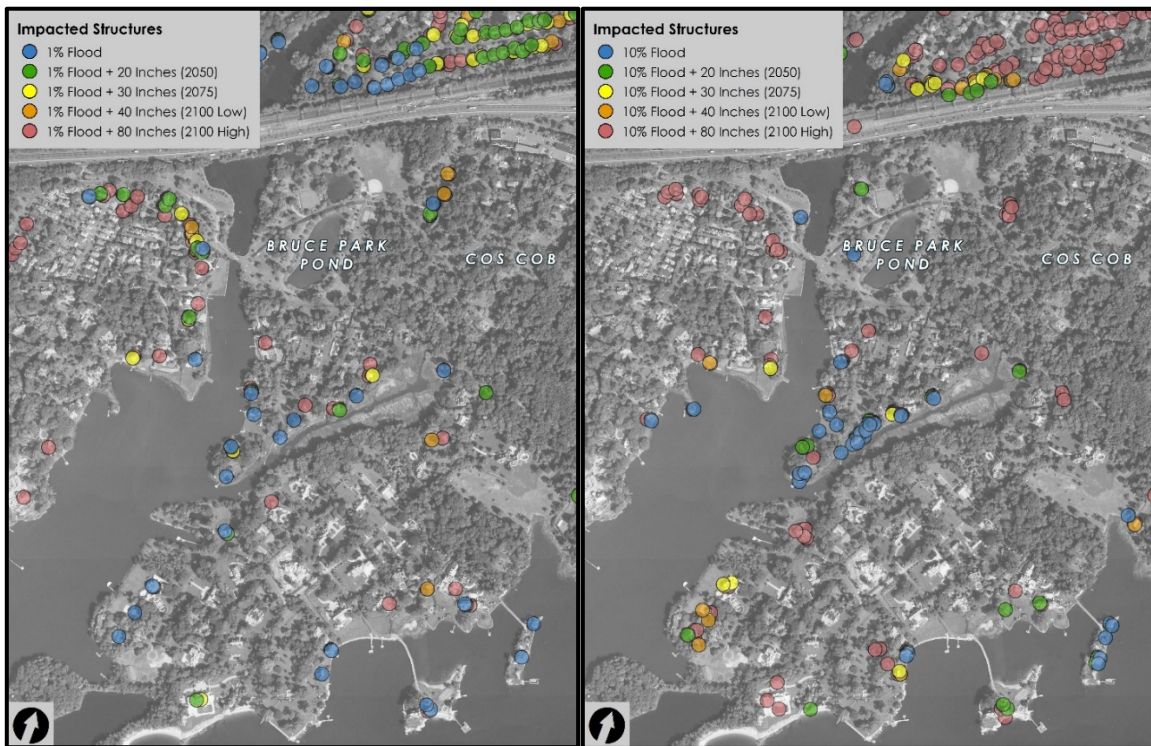
Inset Map 6. Impacted structures from MHHW, 10% flooding, and 1% flooding for Mill Pond Park and surrounding communities.

BRUCE PARK IMPACTED STRUCTURES FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

1% Flood

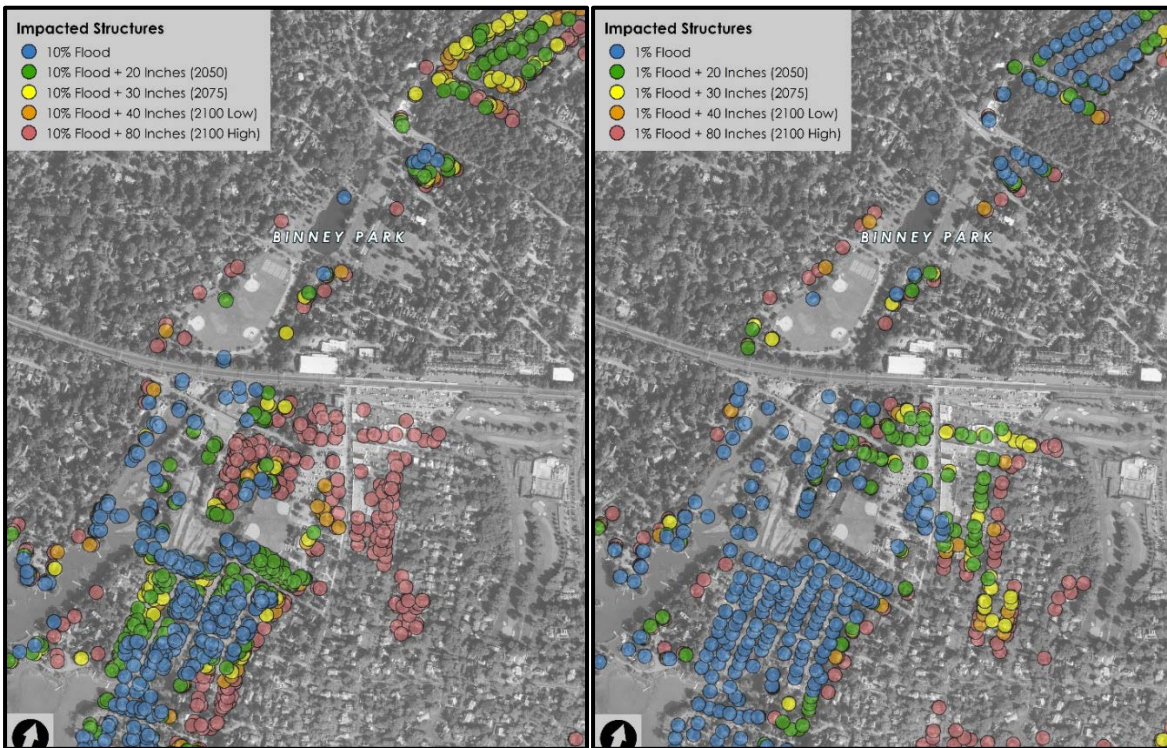
Inset Map 7. Impacted structures from MHHW, 10% flooding, and 1% flooding for Bruce Park and the surrounding communities.

### BINNEY PARK IMPACTED STRUCTURES FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

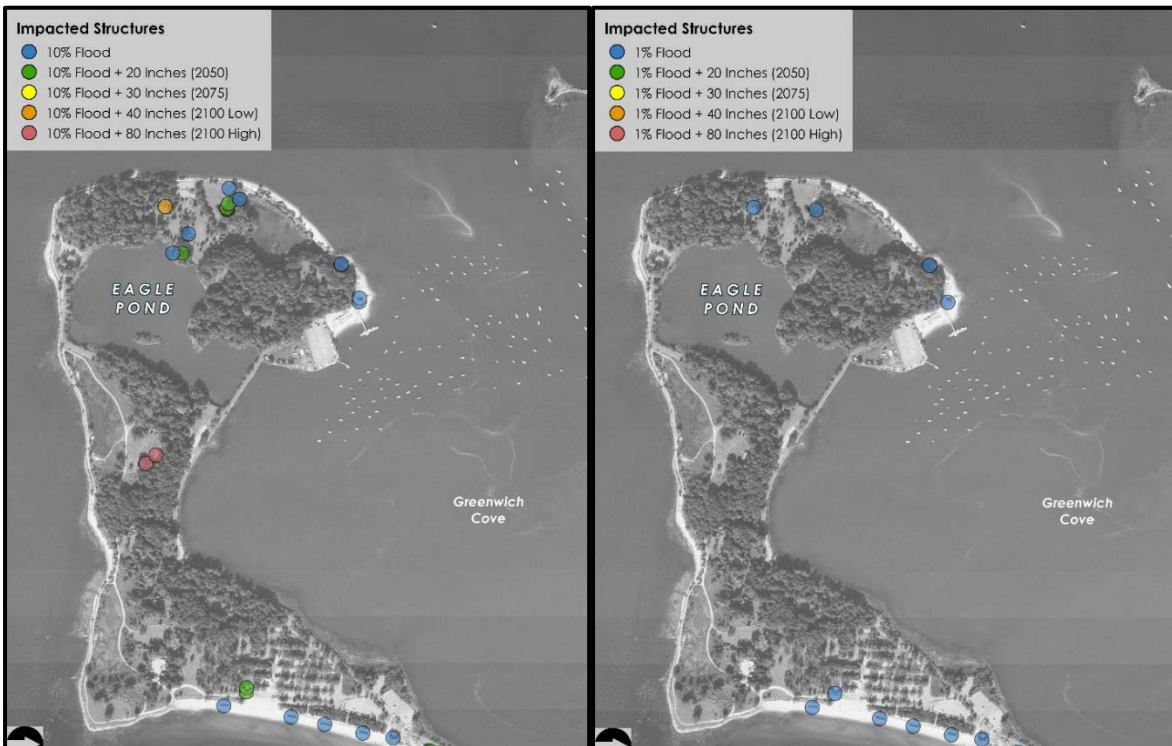
1% Flood

GREENWICH POINT PARK IMPACTED STRUCTURES FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

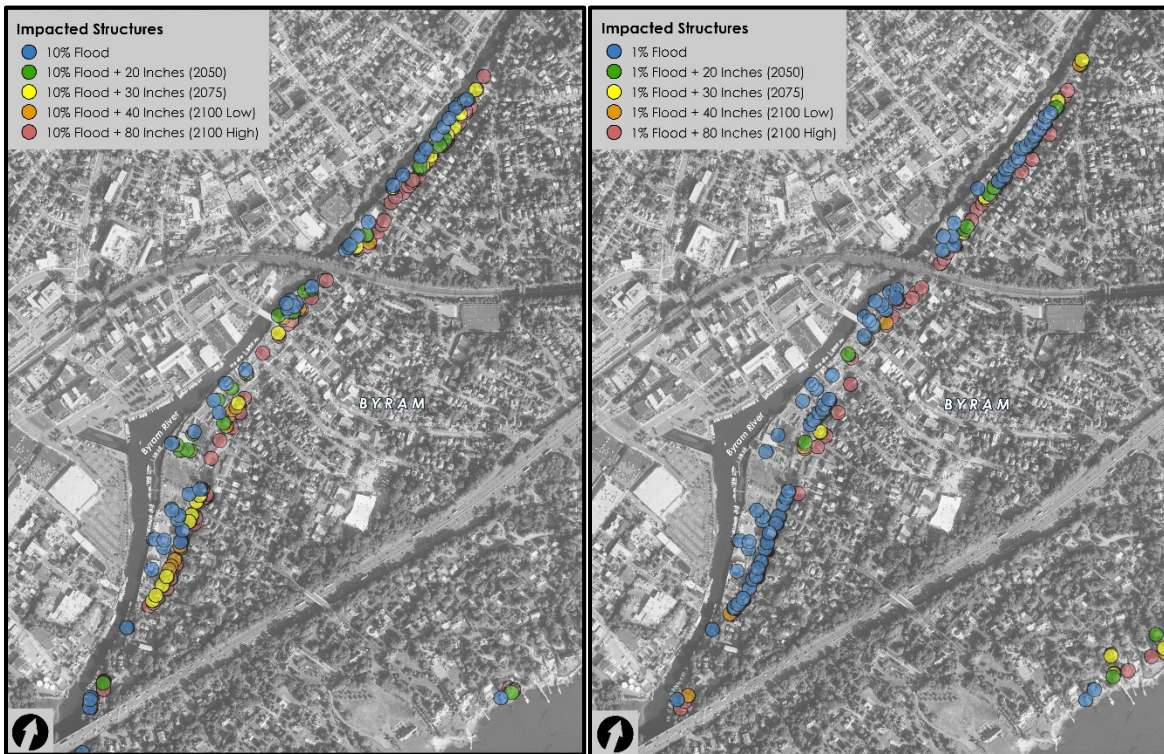
1% Flood

BYRAM IMPACTED STRUCTURES FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

1% Flood

Inset Map 10. Impacted structures from MHHW, 10% flooding, and 1% flooding for Byram and the surrounding communities.

**ROAD EXPOSURE**

Public Road Length Impacted by MHHW Scenarios	
Scenario	Road Length (Miles)
MHHW+20 inches (2050)	0.4
MHHW+30 inches (2075)	0.8
MHHW+40 inches (2100 Low)	1.7
MHHW+80 inches (2100 High)	10.8

Table 6. Mileage of Roads impacted by MHHW scenarios.

**Public roads inundated by each flood event** (MHHW, 10% flood, and 1% flood) and for each SLR scenario were mapped and quantified by the mileage of impacted roadway that overlaps with each flood extent. Road elevations were based on topographic data derived from LiDAR and are not based on site survey; discrepancies may exist for over- and under-passes due to data limitations. In the maps presented, the road colors illustrate when the structure

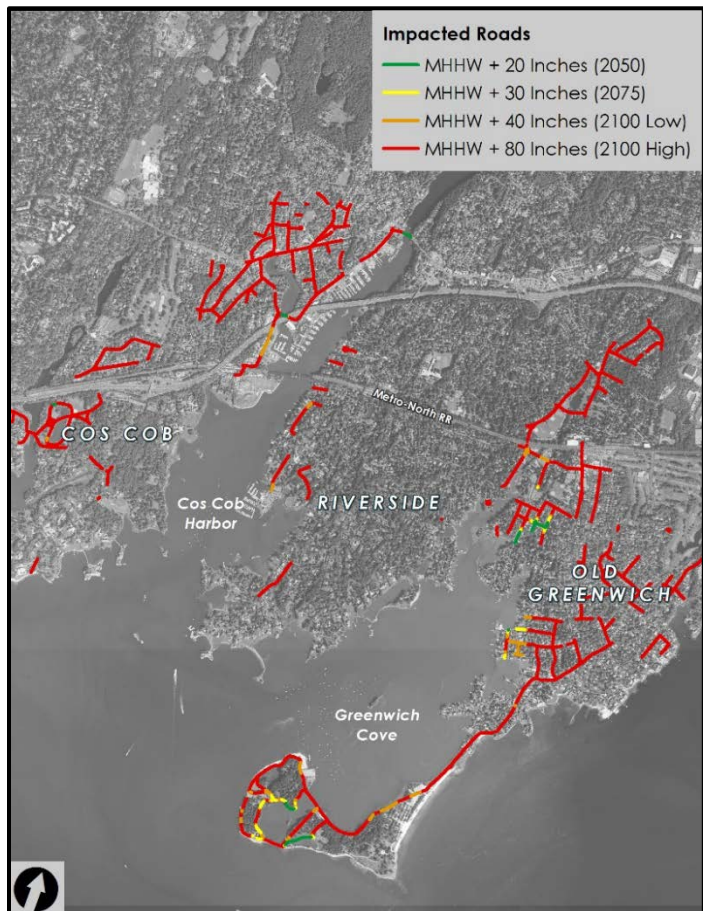
would first be impacted by the designated scenario. For example, a road impacted by MHHW+20 inches would also be impacted by MHHW+30 inches to MHHW+80 inches. Impacts to public roads in the communities near Mill Pond Park, Bruce Park, Binney Park, Greenwich Point Park, and Byram for all flood events and SLR scenarios are presented in Inset Map 14, Inset Map 15, Inset Map 16, Inset Map 17, and Inset Map 18.

**MHHW SCENARIOS**

The length of inundated roadway impacted by sea level rise ranges from 0.4 miles in 2050 to 10.8 miles in 2100 (high) (Table 6). The communities most heavily impacted by road inundation are near Mill Pond Park, Bruce Park, and Binney Park (Inset Map 11).

Modeled impacts from SLR in 2050 show that a section of River Rd., beneath I-95 and intersecting Strickland Rd., may be impacted from flooding. Portions of Tod's Driftway (0.16 miles) are also impacted under the 2050 SLR scenario; the impacted portions of Tod's Driftway will likely not affect vehicular traffic as they are segmented off for use by pedestrians. Under this same SLR scenario, the eastern portion of Old Greenwich, along Heusted Dr, (0.05 miles), Cove View Dr. (0.05 miles), Mortimer Dr. (0.05 miles), and Lockwood Dr. (0.02 miles), has the highest concentration of impacted structures (15 structures).

Modeled impacts in 2075 suggest flooding expands on already affected portions of Heusted Dr. (0.06 miles), Cove View Rd. (0.07 miles), Mortimer Dr. (0.06), and Lockwood Dr. (0.06 miles) which were flooded in the 2050 scenario. Flooding impacts to Tod's Driftway (0.34 miles) increases and begins to affect



Inset Map 11. Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park impacted roads from MHHW flood scenarios.

roads in the southwestern portion of the peninsula, which are used for vehicular traffic.

The 2100 low scenario, a rise in sea level of 40 inches, suggests flooding expands on already affected portions of Heusted Dr. (0.07 miles), Cove View Rd. (0.08 miles), Mortimer Dr. (0.07 miles), and Lockwood Dr. (0.08 miles) which were flooded in the 2050 scenario. Strickland Rd. (0.11 miles) becomes one of the more heavily impacted roads, impacting the marinas along the Cos Cob River.

In the 2100 high scenario, a rise in sea level of 80 inches, impacts the greatest number of roads, a total of 10.8 miles. Flooding on Tod’s Driftway (2.98 miles) impacts the main passage between Old Greenwich and Green Point. Flooding continues to expand throughout the eastern portion of Old Greenwich further affecting Heusted Dr. (0.18 miles), Cove View Rd. (0.15 miles), Mortimer Dr. (0.10 miles), Lockwood Dr. (0.16 miles), and Edgewater Dr. (0.23 miles). In Belle Haven, the two roads that lead to Greenwich’s water treatment plant, Shore Rd. (0.07 miles) and Grass Island Rd. (0.22 miles), are also flooded which may lead to accessibility issues. Bruce Park, Binney Park, and Mill Pond Park are areas that are also heavily impacted, resulting in the flooding of surrounding roads.

Results from the town-wide analysis can be found in Appendix A, Map 8, and a complete list of roads impacted by MHHW flood scenarios can be found in Appendix C.

**10% FLOOD SCENARIOS**

The length of inundated roadway by the 10% flood scenarios range from 7.4 miles during current day conditions to 19.5 miles in 2100 (high). The communities most heavily impacted by road inundation are near Mill Pond Park, Bruce Park, and Binney Park (Inset Map 12).

A 10% flood under current conditions impacts 7.4 miles of roadways throughout Greenwich. Tod’s Driftway (2.41 miles) is the most impacted road and impacts the main connection between Old Greenwich and Green Point Park. Along the Byram River,

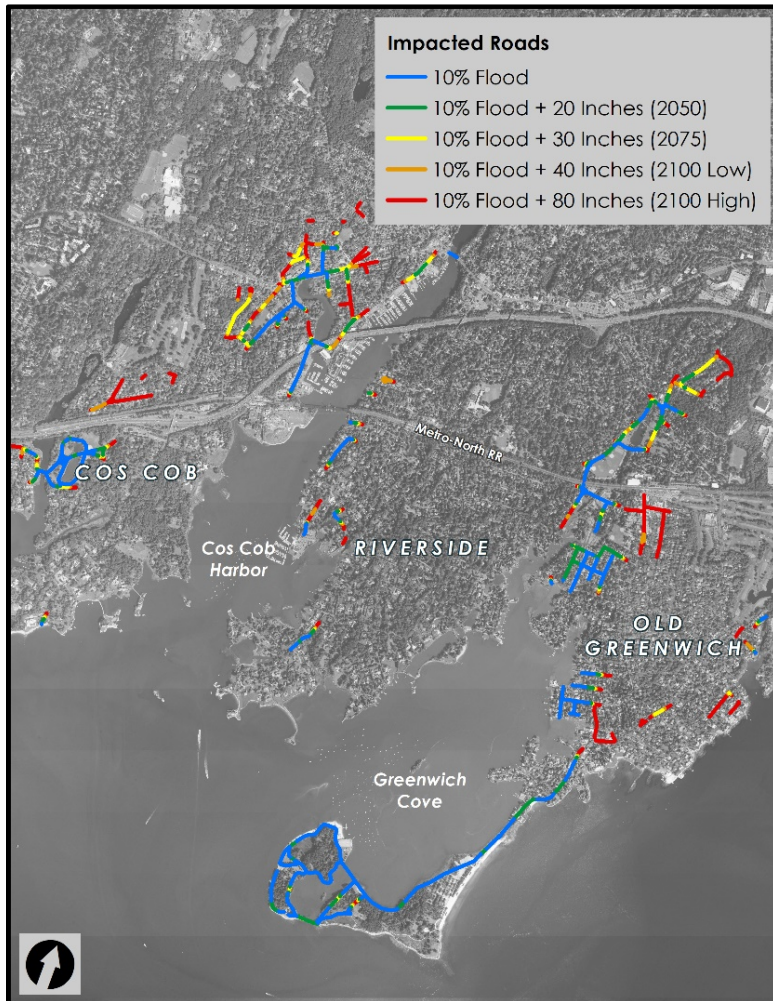
South Water St. (0.28 miles) floods, impacting a commercial and residential area. Around Mill Pond Park, the flooding of Strickland Rd. (0.33 miles) and Loughlin Ave. (0.22 miles) reduces access to East Putnam Ave. and extends south along Loughlin Avenue Playground. Strickland Rd. (0.33 miles) and sections of River Rd. (0.04 miles), beneath I-95 are impacted by flooding. Along Bruce Park, Bruce Park (0.5 miles) and Bruce Park Dr. (0.25 miles) are also impacted. The flooding of these two roads would limit access to Bruce Park and traffic that may need to access Davis Ave. (0.10 miles) to cross Indian Harbor. Flooding of roads along Binney Park, such as Arch St. (0.20 miles), South Beach Ave. (0.07 miles), and Wesskum Wood Rd. (0.10 miles) limit access to the park. Flooding of South Beach Ave. (0.07 miles) may pose traffic issues at its intersection with Laddins Rock Rd. (not impacted) and Harding Rd. (0.03 miles). The eastern portion of Old Greenwich, along Heusted Dr. (0.17 miles), Cove View Dr. (0.11 miles), Mortimer Dr. (0.09 miles), and Lockwood Dr. (0.12 miles) may also experience flooding, limiting residential access. Further south, flooding impacts Keofferam Rd. (0.11 miles), all of Meadow Pl. (0.08 miles), and all of Little Cove Pl. (0.04 miles), which may limit residential access. In Belle Haven, the two roads that lead to Greenwich’s water treatment plant, Shore Rd. (0.28 miles) and Grass Island Rd. (0.22 miles), are also flooded, which may lead to accessibility issues. A 10% flood impacts several roads

Public Road Length (miles) Impacted by 10% Flooding Scenario	
Scenario	Road Length Impacted
10% Flood	7.4
10% Flood + 20 inches (2050)	10.9
10% Flood + 30 inches (2075)	12.4
10% Flood + 40 inches (2100 Low)	13.8
10% Flood + 80 inches (2100 High)	19.5

Table 7. Mileage of Roads impacted by 10% Flood scenarios.

and communities, posing residential access issues and the flow of traffic. A rise in sea level is likely to exacerbate these impacts.

A 10% flood with a rise in 20 inches (2050) of sea level increases the mileage of impacted roads by 3.5 miles. Modeled impacts from SLR by a 10% flood further impacts Tod's Driftway (2.98 miles), flooding roads within Greenwich Point Park and with floodwaters extending towards Uncas Point Beach. Flooding impacts to Mill Pond Park, Bruce Park, and Binney Park expand. Flooding along East Putnam Ave. (0.25 miles) further extends towards Mead Ave. (0.04 miles), Suburban Ave. (0.11 miles), and Sinawoy Rd. (0.10 miles), increasing the impact to Route 1 and its commercial corridor. This flood scenario further extends flooding along the eastern portion of Old Greenwich, Heusted Dr. (0.18 miles), Cove View Dr. (0.15 miles), Mortimer Dr. (0.10 miles), Lockwood Dr. (0.16 miles), and extends into Hendrie Dr. (0.03 miles). A rise in 30 inches (2075) in sea level increases the mileage of impacted roads by 5 miles from current conditions. Many of the already impacted communities see flooding extend to neighboring roads. In Byram, flooding occurs in a previously unaffected community along Homestead Ln. (0.04 miles) and Den Ln. (0.01 miles).



Inset Map 12. Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park impacted roads from 10% flood scenarios.

A rise of 40 (2100 low) and 80 inches (2100 high) increases the mileage of impacted roads by 6.4 miles and 12.1 miles from current day conditions, respectively. The communities around Mill Pond Park, Bruce Park, and Binney Park are all further impacted by flooding, to varying degrees. The 2100 high scenario limits all access from the Bruce Park community with Arch St. (0.83 miles), Steamboat Rd. (0.42 miles), Davis Rd. (0.50 miles), and Bruce Park Dr. (0.39 miles) all being inundated by floodwaters. A new area that experiences flooding in these scenarios is Steamboat Rd. (0.08 miles-2100 low and 0.42 miles- 2100 high), which impacts access to a residential and commercial corridor and to the Indian Harbor Yacht Club.

Results from the town-wide analysis can be found in Table 7 and Appendix A, Map 9, and a complete list of roads impacted by 10% flood scenarios can be found in Appendix D.

## 1% FLOOD SCENARIOS

Public roads that would be inundated by the 1% flood scenarios were also evaluated for each SLR scenario. The length of inundated roadway ranges from 14.2 miles by a 1% flood today to 26.4 miles in 2100 (high). The communities most heavily impacted by a 1% flood are Mill Pond Park, Bruce Park, and Binney Park (Inset Map 13).

A 1% flood under current conditions impacts 14.2 miles of roadways throughout Greenwich. A 1% flood event fully inundates the entire length of Tod's Driftway (3.08 miles). In Byram, along the

Public Road Length (miles) Impacted by 1% Flooding Scenario	
Scenario	Road Length Impacted
1% Flood	14.2
1% Flood + 20 inches (2050)	17.6
1% Flood + 30 inches (2075)	19.0
1% Flood + 40 inches (2100 Low)	20.2
1% Flood + 80 inches (2100 High)	26.4

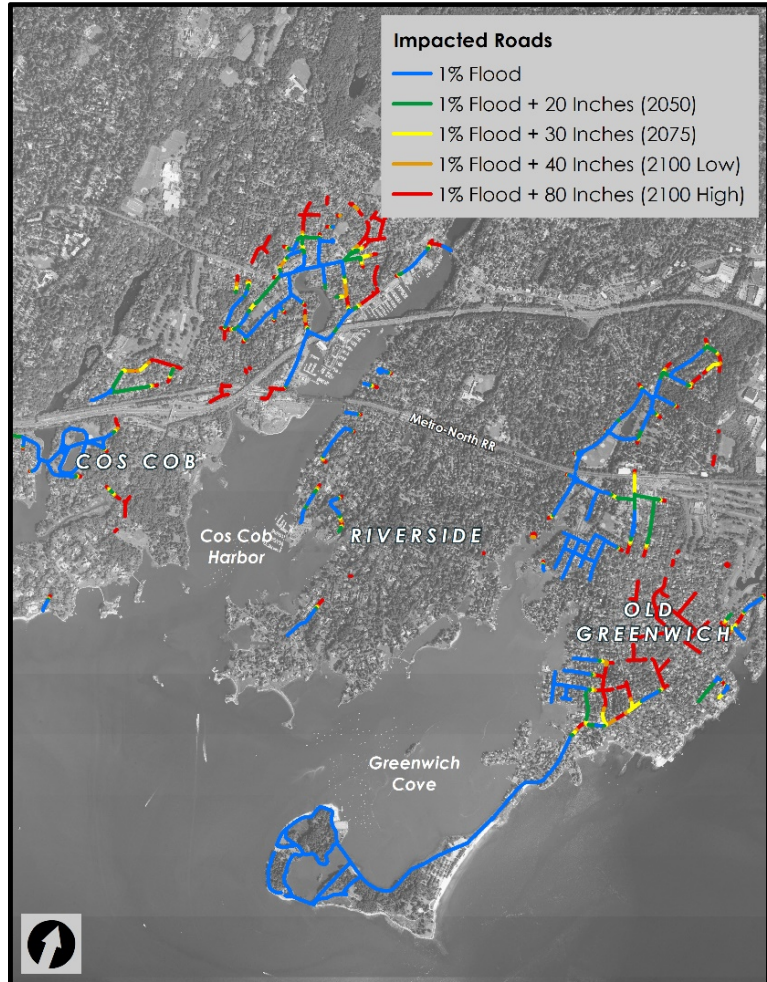
Table 8. Mileage of Roads impacted by 1% flooding scenarios.

Byram River, South Water St (0.37 miles) floods, impacting a commercial and residential area. Around Mill Pond Park, portions of Strickland Rd. (0.39 miles), River Rd. (0.35 miles) East Putman Ave. (0.29 miles), Sinoway Rd. (0.11 miles) Suburban Ave. (0.11 miles), Relay Pl. (0.07 miles), and Mead Ave. (0.06 miles) are significantly impacted. The flooding of East Putman Ave. may cause significant traffic issues as this road serves as the main thoroughfare between Riverside and Cos Cob. In Bruce Park, Bruce Park (0.55 miles) and Bruce Park Dr. (0.38 miles) are nearly completely impacted. Davis Ave. (0.42 miles) and Oneida Dr. (0.15 miles), roads that connect to Bruce Park Dr. are impacted, limiting ingress and egress from Bruce Park and the Cos Cob area. Flooding of roads along Binney Park, such as Arch St. (0.58 miles), South Beach Ave. (0.38 miles), and Wesskum Wood Rd. (0.12 miles) limits access throughout the park. Flooding of South Beach Ave. (0.38 miles) will likely pose traffic issues at its intersection with Laddins Rock Rd. (0.07 miles) and Harding Rd. (0.08 miles). The eastern portion of Old Greenwich, along Heusted Dr. (0.18 miles), Cove View Dr. (0.15 miles), Mortimer Dr. (0.10 miles), and Lockwood Dr. (0.18 miles) experiences flooding, limiting residential access. Further south, flooding impacts Keofferam Rd. (0.14 miles), all of Meadow Pl. (0.08 miles), and all of Little Cove Pl. (0.04 miles), which may limit residential access. In Belle Haven, the two roads that lead to Greenwich's water treatment plant, Shore Rd. (0.43 miles) and all of Grass Island Rd. (0.22 miles), are also flooded, which may lead to accessibility issues. A 1% flood event affects many of the same roads impacted by a 10% storm, with the possibility of higher water depth and a larger flood extent. A flood event of this scale will significantly restrict the flow of traffic throughout the several Greenwich communities. Ingress and egress from the Bruce Park community will be limited due to the main roads being impacted. Finally, Belle Haven will only have one access road into and out of the community, Field Point Rd.

A 1% flood with a rise in 20 inches (2050) of sea level increases the mileage of impacted roads by 3.4 miles. Flooding around Mill Pond Park expands to inundate portions of Cross Ln. (0.25 miles), Sachem Ln. (0.21 miles), Field Rd. (0.09 miles), Taylor Dr. (0.10 miles), Randolph Pl. (0.06), and Orchard St. (0.05 miles). Flood extents to Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park are similar to that of a current day 1% flood, with the possibility of higher water depths. Around Binney Park, flooding extends south towards Old Greenwich School, along Sound Beach Ave. (0.53 miles) and into Arcadia Rd. (0.11 miles) and Park Ave. (0.19 miles).

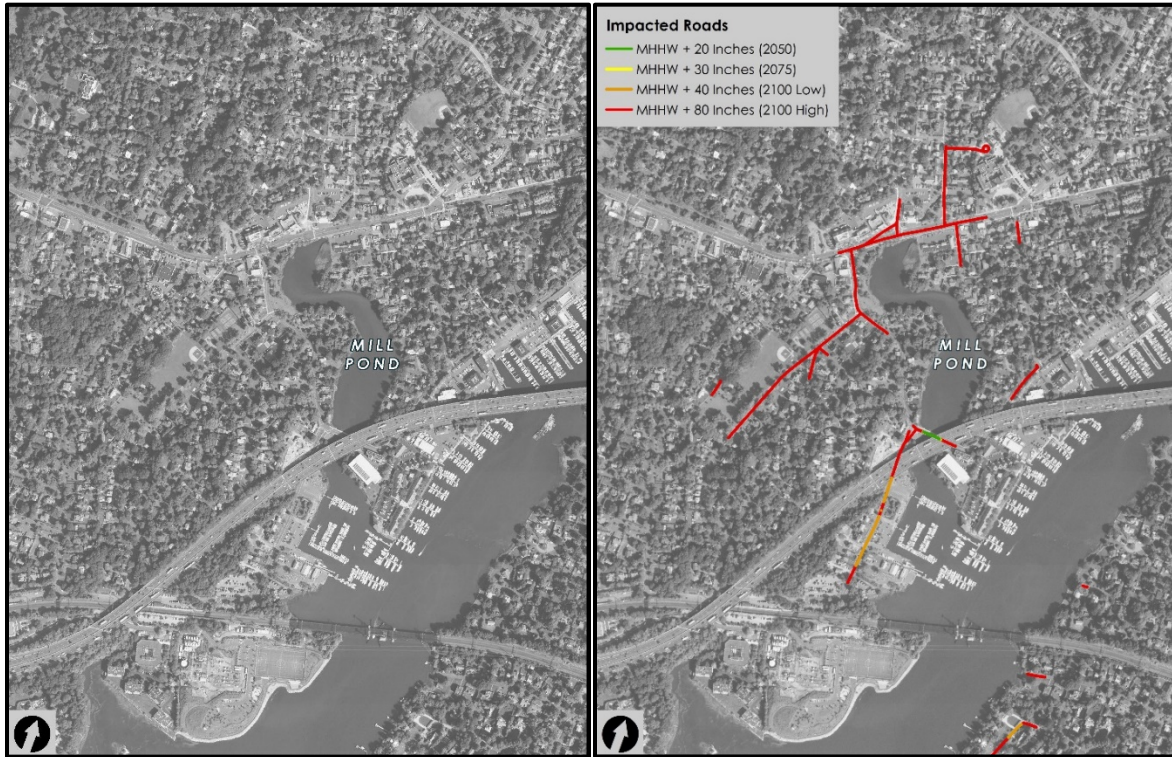
A rise of 40 (2100 low) and 80 inches (2100 high) increases the mileage of impacted roads by 6 miles and 12.2 miles from current day. Impacts to the communities around Mill Pond Park and Binney Park are all further impacted by flooding, to varying degrees. The 2100 high scenario limits all access from the Bruce Park community with Arch St. (0.84 miles), Steamboat Rd. (0.67 miles), Davis Rd. (0.61 miles), and Bruce Park Dr. (0.41 miles) being impacted by floodwaters. In the 2100 high scenario, central sections of Old Greenwich experiences inland flooding impacting residential areas.

Results from the town-wide analysis can be found in Table 8 and Appendix A, Map 10. A complete list of roads impacted by 1% flood scenarios can be found in Appendix C.



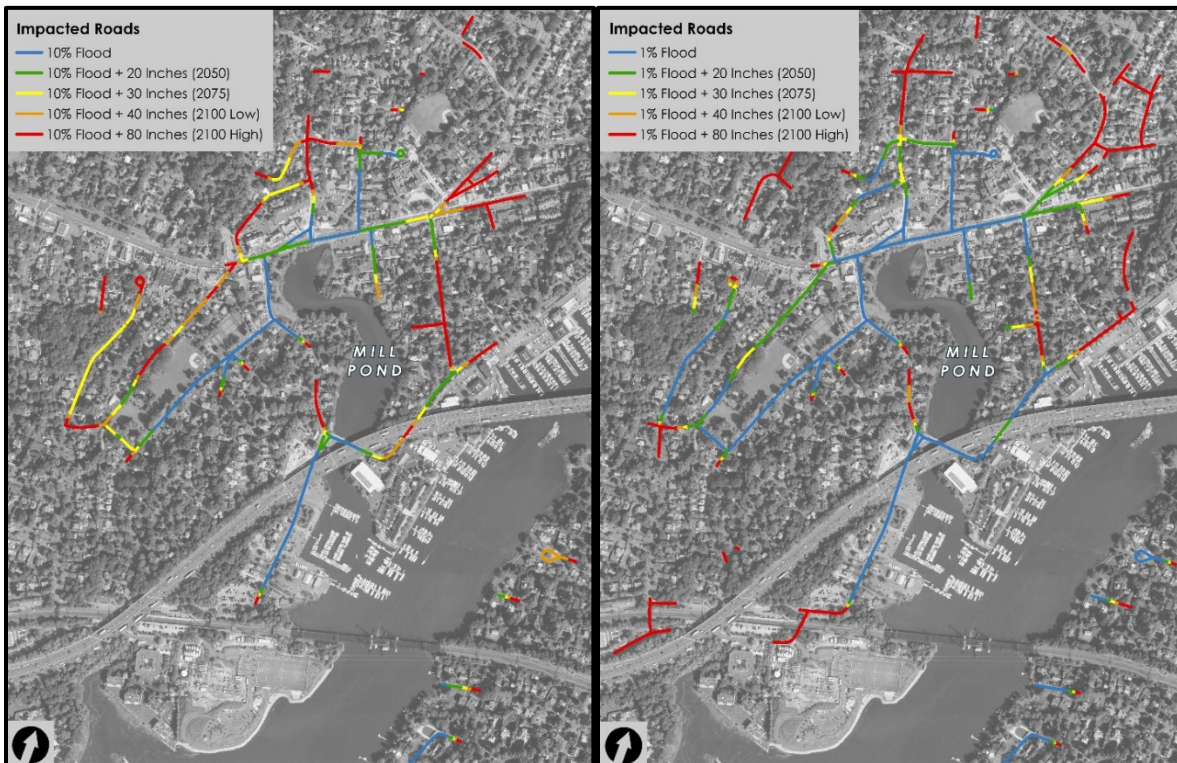
Inset Map 13. Cos Cob, Riverside, and Old Greenwich impacted roads from 1% flood scenarios.

MILL POND PARK IMPACTED ROADS FROM FLOODING SCENARIOS



Existing Conditions

MHHW

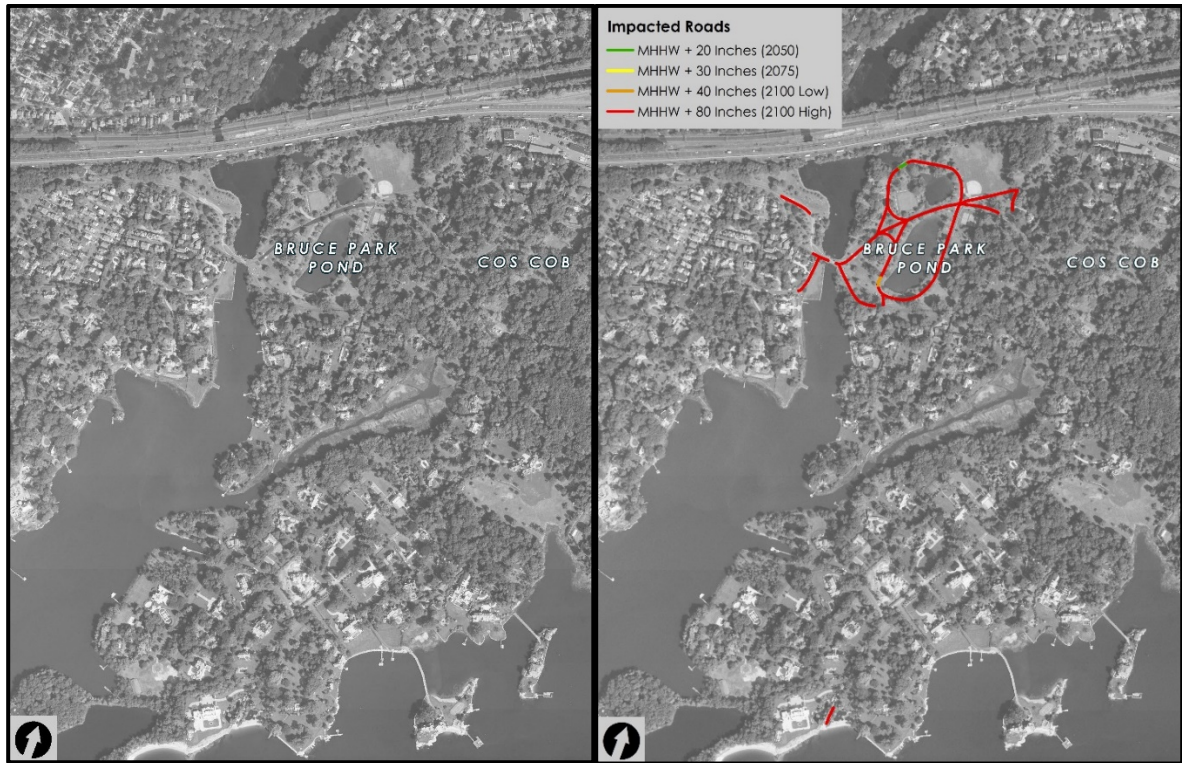


10% Flood

1% Flood

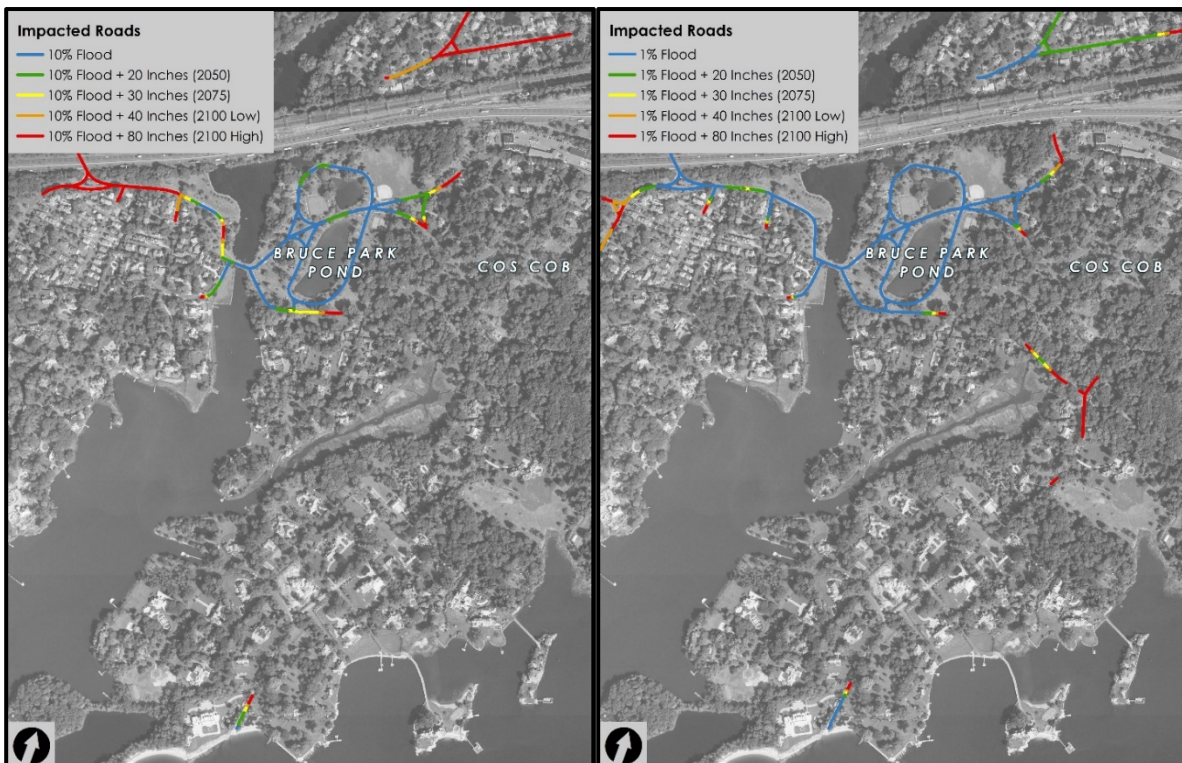
Inset Map 14. Roads impacted from MHHW, 10% flooding, and 1% flooding for Mill Pond Park and the surrounding communities.

### BRUCE PARK IMPACTED ROADS FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

1% Flood

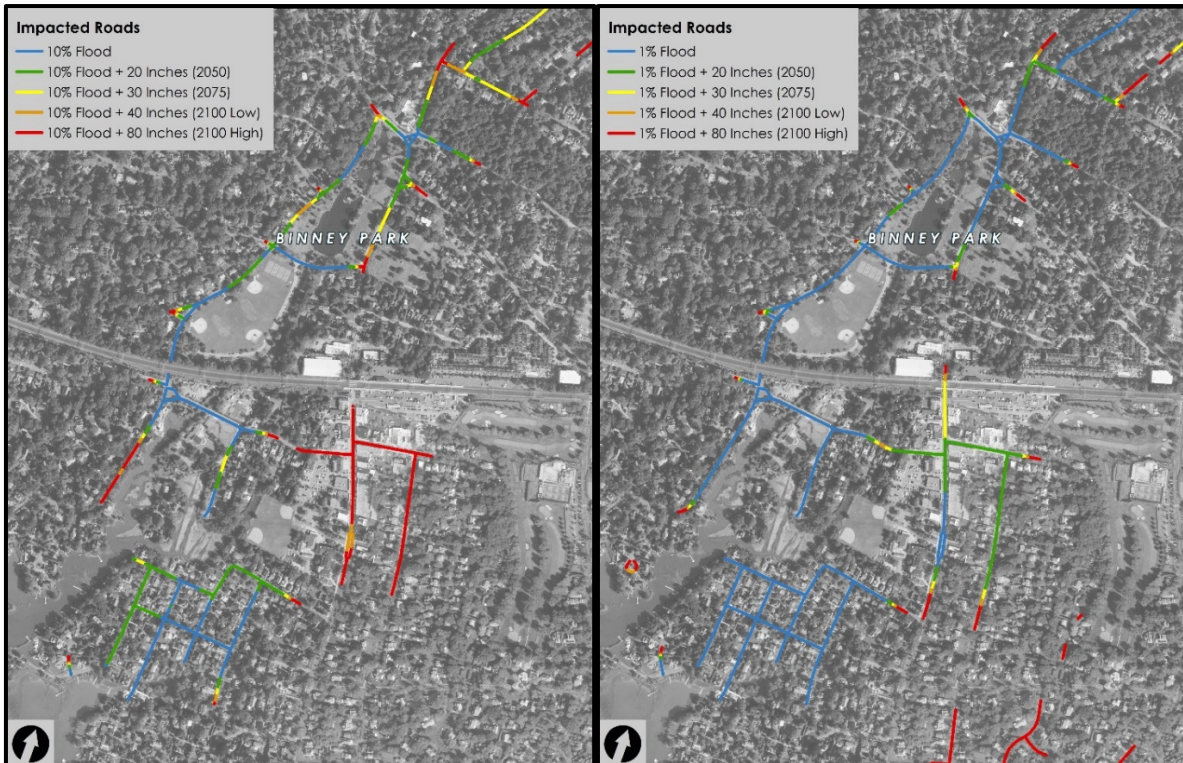
Inset Map 15. Roads impacted from MHHW, 10% flooding, and 1% flooding for Bruce Park and the surrounding communities.

### BINNEY PARK IMPACTED ROADS FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

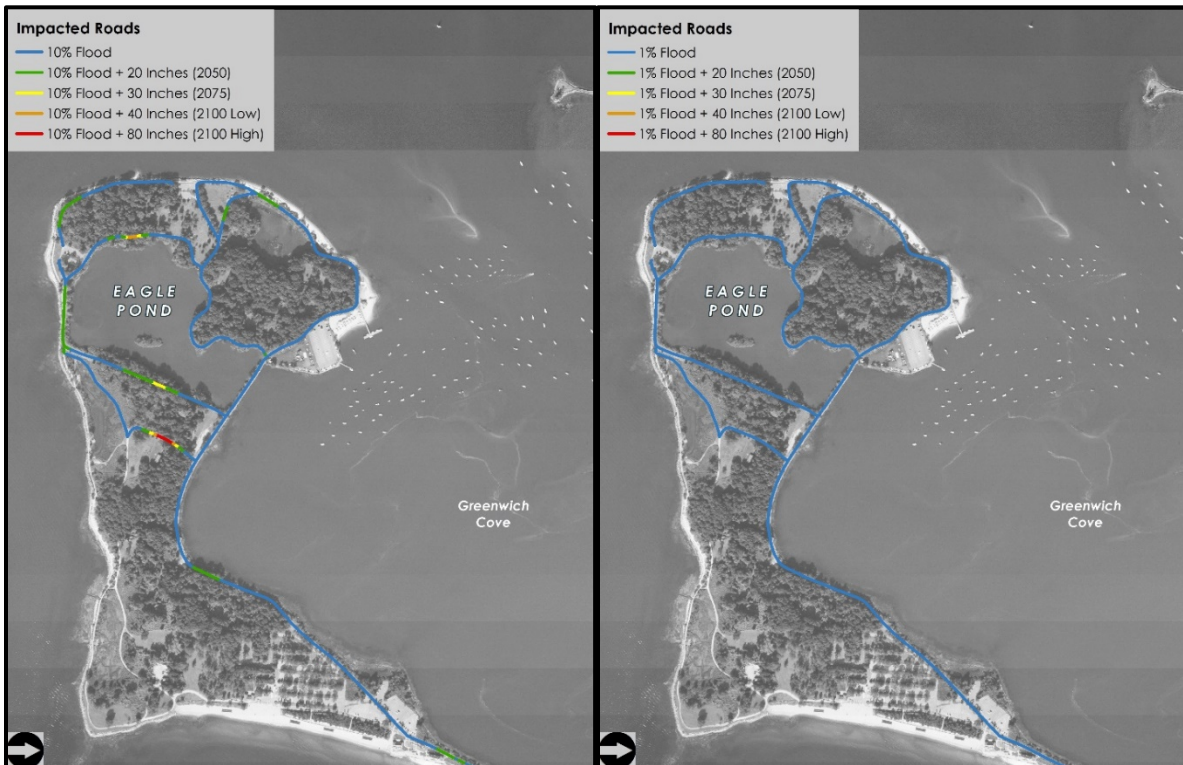
1% Flood

GREENWICH POINT PARK IMPACTED ROADS FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

1% Flood

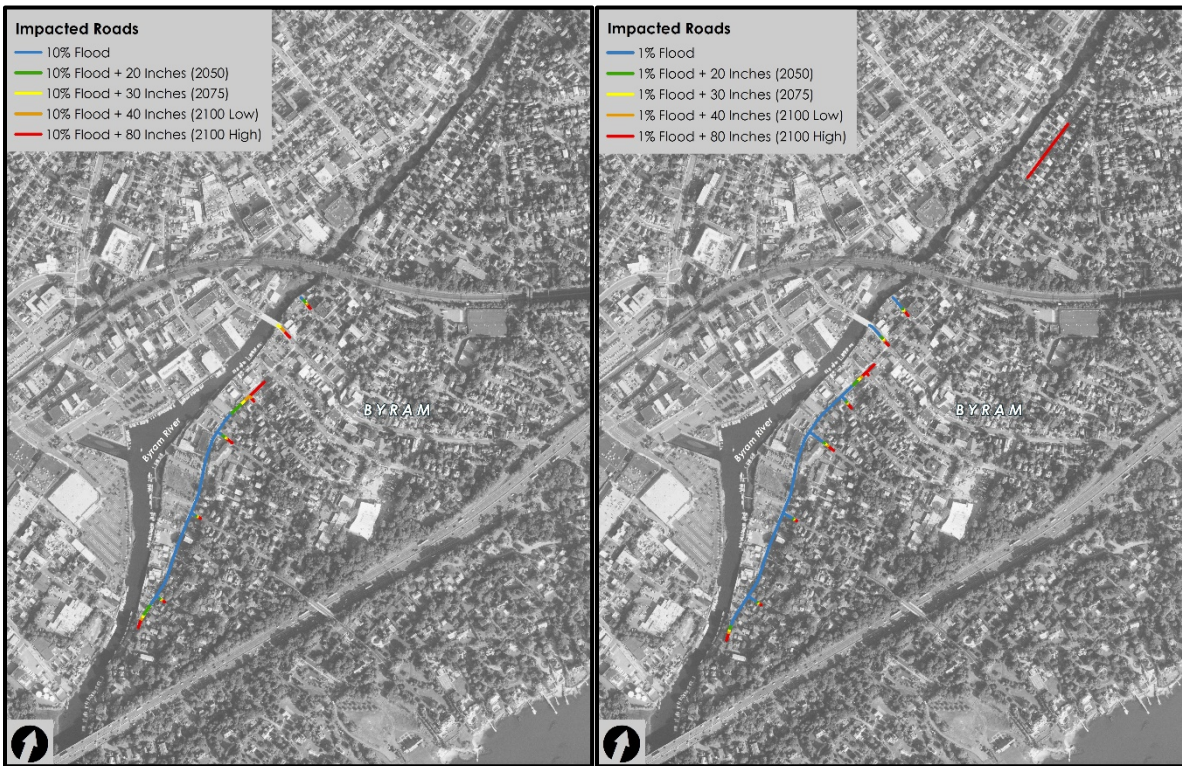
Inset Map 17. Roads impacted from MHHW, 10% flooding, and 1% flooding for Greenwich Point Park and the surrounding communities.

### BYRAM IMPACTED ROADS FROM FLOODING SCENARIOS



Existing Conditions

MHHW



10% Flood

1% Flood

## SEPTIC SYSTEM VULNERABILITY TO SEA LEVEL RISE

A rising sea may cause an increase in groundwater levels, decreasing depth to groundwater, and increasing the vulnerability of septic systems. A significant increase in groundwater may compromise the septic system's ability to treat bacteria and pathogens, rendering the system useless. Septic system failures pose public risk hazards and unsafe conditions for residents near or downstream of the failed system. These health hazards stem from bacterial and viral pathogens and nitrates<sup>2</sup>. The U.S Environmental Protection Agency has identified that contaminated residential wastewater from failed septic systems is the third-largest contributor to groundwater pollution in the country<sup>3</sup>.

Septic system vulnerability and risk were evaluated for SLR due to the chronic nature of the impacts from a rising sea; whereas a 10% or 1% storm would have acute impacts that would pose a lesser risk to septic systems. The area analyzed included those areas not currently serviced by sewers (Appendix A, Map 11). Properties within the septic analysis area were assessed according to the estimated elevation of the septic system, depth to groundwater, and distance of the septic system to the reaches of the MHHW scenario. Results indicate that septic systems within the study area are at low risk to SLR. However, vulnerability of individual septic systems should be completed on a site-by-site basis due to variable site conditions such as depth to groundwater. For the purposes of this analysis, all septic systems were compared to each other to rank relative risk from low to high. A high-risk ranking means that a given septic system is at higher risk than another septic system within the same analysis area. Results from this analysis can be found in Appendix A, Maps 12a-12e.

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<sup>2</sup> Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change Cooper JA, Loomis GW, Amador JA (2016) Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change. PLOS ONE 11(9): e0162104. <https://doi.org/10.1371/journal.pone.0162104>.

<sup>3</sup> Office of Water, United States Environmental Protection Agency, ONSITE WASTEWATER TREATMENT SYSTEMS MANUAL (2002), <https://perma.cc/NR2M-WSMR>.

## STORMWATER MANAGEMENT AND SEA LEVEL RISE

The [Fourth National Climate Assessment](#), a congressionally mandated report by the U.S. Global Change Research Program, reports that between 1958-2016 there was a 55% increase in precipitation<sup>4</sup>. Moreover, model projections suggest that there are increases in heavy precipitation events along the northeast in both low and high emissions scenarios (Figure 15). Increased precipitation intensity and depths will exacerbate stormwater runoff, acute flooding, soil erosion, and overextend stormwater management infrastructure. Stormwater management infrastructure will be further taxed by sea level rise in coastal regions.

In particular, stormwater infrastructure may include catch basins and pipes that are hydrologically connected to a tidal waterbody. As sea level increases, the outlet pipes will become submerged causing the waterbody to backflow into the stormwater system and potentially flood roads and the surrounding area (Figure 16). The flooding of stormwater infrastructure can also lead to accelerated corrosion of pipes from saltwater and reduced flow capacity.

Due to its geography, Greenwich may be presented with the following stormwater management challenges:

- Coastal high-water events such as high tides and storm surges may drive backflow into the system, causing flooding through street drains and drainage ditches. Backflow and the prolonged presence of saltwater can damage stormwater infrastructure.
- Stormwater systems that depend on gravity to convey runoff may increase localized flooding when downstream

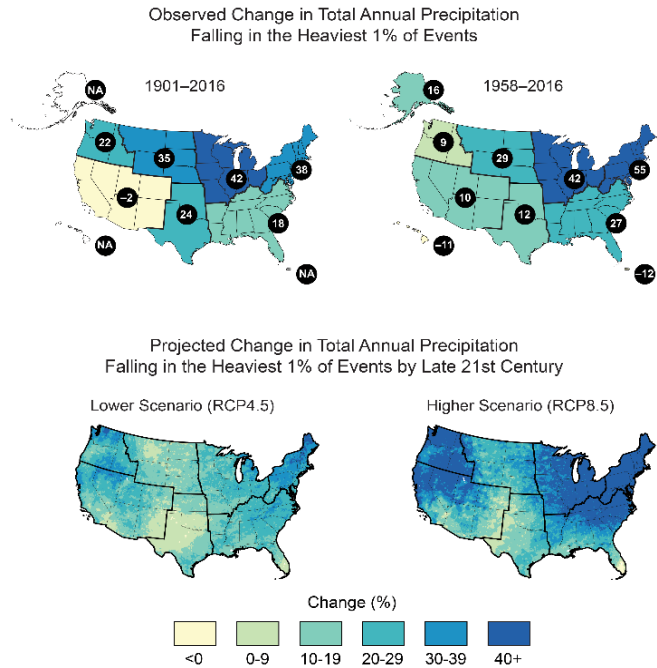


Figure 16. Observed and projected precipitation changes by region. Historically, the northeastern United States has experienced increased precipitation. Source: adapted from Easterling et al. 2017.



Figure 15. Meadow Pump Station flooded during a high tide on December 30, 2019. Photo Courtesy of Greenwich.

<sup>4</sup> Easterling, D.R., K.E. Kunkel, J.R. Arnold, T. Knutson, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner, 2017: Precipitation change in the United States. Climate Science Special Report: Fourth National Climate Assessment, Volume I. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 207-230. <http://dx.doi.org/10.7930/J0H993CC>

components of the system are partially or completely submerged by tidal flows. This combination of precipitation and coastal events can prolong a flooding event.

- More frequent, higher, and longer-lasting high-water events could also increase groundwater levels and saturate the soils, thus reducing the soil's ability to absorb precipitation and increasing stormwater runoff volume.

To understand the impact associated with increased precipitation and sea level rise to the stormwater management system, a detailed study is required and outside the scope of this Assessment. However, a rudimentary analysis was performed to identify the number of catch basins and length of stormwater pipes within the vicinity of the modeled flood extents (Table 9). **Results from this analysis can be found in Appendix A, Maps 13a-13c.**

Stormwater Infrastructure Impacted by All Flooding Scenarios		
Scenario	# of Catch Basins	Length of Stormwater Pipes (ft.)
MHHW + 20 Inches (2050)	24	2,668
MHHW + 30 inches (2075)	51	5,227
MHHW + 40 Inches (2100 Low)	147	12,512
MHHW + 80 Inches (2100 High)	593	54,723
<b>10% Flood</b>		
10% Flood	412	34,815
10% Flood + 20 Inches (2050)	600	55,599
10% Flood + 30 inches (2075)	698	65,271
10% Flood + 40 Inches (2100 Low)	755	72,265
10% Flood + 80 Inches (2100 High)	1,038	102,849
<b>1% Flood</b>		
1% Flood	788	75,070
1% Flood + 20 Inches (2050)	944	93,584
1% Flood + 30 inches (2075)	1,008	100,726
1% Flood + 40 Inches (2100 Low)	1,068	106,558
1% Flood + 80 Inches (2100 High)	1,342	137,688

Table 9. Number of catch basins and length of stormwater pipes impacted by MHHW, 10%, and 1% flood events.

## BUILDING ZONE REGULATIONS

Similar to how land use describes how humans interact with the landscape, building zones are the result of dividing land according to where certain land uses are permitted or prohibited. This Coastal Resiliency Assessment includes a review of Greenwich's current Building Zone Regulations from Chapter 6 of the Greenwich Municipal Code to identify those parts of the regulations that could be modified to be more consistent with coastal resiliency objectives. As a coastal community, Greenwich faces increased flooding from sea level rise and coastal storms that impact its land use and development patterns. Revisions to the Greenwich Municipal Code will help to protect residents, property, infrastructure, and wildlife habitats from risks associated with flooding from SLR and coastal storms. The Building Code Review Memo can be found in Appendix B.

## LANDSCAPE CHARACTERISTICS

Landscape characteristics are unique qualities that can be classified into physical and human elements. Physical landscape characteristics include, but are not limited to, topography, vegetation, and natural water features. Human landscape characteristics include land use, buildings and infrastructure, and constructed water features. Together, physical and human landscape characteristics define a region and its cultural history.



Figure 17. Aerial view of Port Chester Harbor, June 1987 (U.S. Army Corps of Engineers).

Changes in sea level may also have impacts on natural features, such as shorelines. An increase in sea level can cause permanent inundation of coastline, resulting in a loss of shoreline. These changes happen

gradually over time but can be expedited through anthropogenic impacts. Anthropogenic impacts such as development, beach replenishment, maritime activities, and changes in zoning can have lasting impacts to natural features and may increase vulnerability to coastal hazards. An increasing sea level coupled with anthropogenic impacts may result in coastal erosion, loss of tidal marshes, and increased flooding.

This section documents some of the current characteristics of the Greenwich coastline, observed changes over the years, projected marsh migration, and coastal vulnerability to erosion.



Figure 18. Island Beach, Greenwich (Greenwich.gov).

## SHORELINE CHARACTERIZATION

The Shoreline Characterization Assessment for Greenwich quantifies the types of shorelines throughout the municipality and provides an overview of possible at-risk coastal shorelines (Table 10). This analysis was performed by refining the NOAA Environmental Sensitivity Index (ESI) dataset for the entire study area. ESI data were created by NOAA to identify coastal habitats that may be vulnerable to off-shore and near-shore chemical spills. The ESI classifies features, including man-made and natural features, along the shoreline into categories based on feature/habitat type and vegetation. These data provide an initial characterization of the shoreline within the study area.



Figure 19. Aerial of Greenwich Point with Old Greenwich in the distance.

For this assessment, classifications were modified to fit the categories listed in Table 10. In addition to refining the categories, the shoreline spatial extent created by the ESI was adapted to the shoreline digitized from 2016 aerial imagery. This allows the assessment to reflect the most accurate data available throughout the town, found in Appendix A, Map 14.

As part of the analysis, shoreline types were separated into armored and unarmored. Armored shorelines can range from naturally occurring rocky coastlines to engineered bulkheads designed to reduce impacts from storm surge and flooding. These hardened shorelines may provide increased protection to coastal communities by providing a buffer between land and water and minimize damage to structures and critical infrastructure. They can also limit the naturally occurring inland movement of sandy beaches, wetlands, and other intertidal areas leading to coastal squeeze. Armored shorelines also have the potential to reduce and fragment habitat for marine organisms and reduce beach fronts by limiting the natural movement of sediments. In contrast, unarmored shorelines include beaches, wetlands, and dunes, for example. Unarmored shorelines are vulnerable to change and erosion, both from storms and daily wave action. The difference between sheltered and exposed shoreline types listed in Table 10 are determined by the modifying effect that waves have on the coastline.

Greenwich Shoreline Characterization Type		
	Shoreline Type	Miles
Unarmored	Sand and Gravel Beaches	8.6
	Exposed, Man-made	6.3
	Wetlands	15.0
Armored	Rock or Riprap	10.0
	Sheltered, Man-made	8.9
<b>Total</b>		<b>48.8</b>

Table 10. Greenwich shoreline characterization by shoreline type and mileage.

## SHORELINE MIGRATION



Figure 20. Field Point Park shoreline. Source: Greenwich Historical Society

Shorelines are susceptible to change over time from natural and anthropogenic causes. This ranges from wave and wind-induced erosion to shoreline modification for development or beach replenishment. Shoreline change can vary year-to-year depending on coastal development, marsh expansion and contraction, coastal storms, and a variety of other factors. Data from these analyses provide both insight where shoreline movement may increase the risk to coastal structures and a starting point for municipal planning and prioritization.

For this analysis, shoreline movement over time was analyzed using the United States Geological Survey's (USGS) Digital Shoreline Analysis System (DSAS), which is a computer software program that

computes rate-of-change statistics from multiple historic shoreline positions<sup>5</sup>. The analysis was supplemented with the 2014 study titled "[Analysis of Shoreline Change in Connecticut](#)" by CT DEEP, Connecticut Sea Grant, and the University of Connecticut Center for Land Use Education and Research. The 2014 study assessed short-term (1983- 2006) and long-term (1880-2006) change along the Connecticut shoreline.

The DSAS analysis, performed as part of this assessment, extended the short-term analysis from 2006 to 2012 using the best available data from NOAA's [Shoreline Data Explorer](#). At each transect, the net shoreline movement and endpoint rate were computed. Net shoreline movement addresses "How much change has occurred?" while End Point Rate addresses "How quickly has this change happened?". Positive values indicate accretion and negative values indicate erosion. Statistics are based on 495 transects along Greenwich's shoreline. Results from this analysis can be found in Table 11 and Table 12.

Results identified the following shoreline regions as areas of positive movement (accretion or gain of land) primarily due to infill of water, Byram Harbor, Greenwich Harbor, Indian Harbor, Cos Cob Harbor, and Greenwich Cove. In particular, the development of marinas and houses has added land to Byram Harbor. Additionally, the expansion of I-95, Roger Sherman Baldwin Park, and development along Steamboat Rd. and Grass Island have contributed to the gain of land in Greenwich Harbor. Likewise, the development of houses along the western shores of Cos Cob and Old Greenwich have contributed to the gain of land.

Areas of negative shoreline movement (erosion or loss of land) are along Byram Point, Field Point, and Greenwich Point. Over time the sandy shoreline of Byram Point has eroded away. This shoreline once extended further south into the Long Island Sound and is near present day Hawthorne Beach. Along Field Point, the hardening of the shoreline and the loss of sandy shores have also attributed to the loss of land. At Greenwich Point, the gradual erosion of the sandy shoreline has contributed to loss of land.

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<sup>5</sup> Thieler, E.R., and Danforth, W.W., 1994, Historical shoreline mapping (1)—Improving techniques and reducing positioning errors: *Journal of Coastal Research*, v. 10, p. 549–563.

Greenwich Short Term (1983 -2016) Shoreline Change (Feet)		
	Net Shoreline Movement (Feet)	End Point Rate (Feet/Year)
<b>Min</b>	-98.9	-3.5
<b>Max</b>	182.7	6.6
<b>Average</b>	0.4	0.2

Table 12. Descriptive statistics for short term shoreline change between 1983 to 2016.

Greenwich Long Term (1880 -2006) Shoreline Change (Feet)		
	Net Shoreline Movement (Feet)	End Point Rate (Feet/Year)
<b>Min</b>	-299.96	-4.13
<b>Max</b>	1117.73	9.25
<b>Average</b>	49.33	0.40

Table 12. Descriptive statistics for shore term shoreline change between 1880 and 2006.

## MARSH MIGRATION

According to the U.S. Fish and Wildlife’s National Wetland Inventory (NWI), Greenwich has approximately 337 acres of coastal wetlands (Appendix A, Map 15). Currently, the highest concentration of tidal marshes is located along Greenwich Point Park, Cos Cob Harbor, and Greenwich Cove. Additional tidal marshes can be found throughout Indian Harbor, Smith Cove, Inner Cove Rock, Greenwich Harbor, Byram Harbor, and along islands located in the Long Island Sound.

Tidal marshes are dynamic ecosystems that are located at the nexus of land and water, and are intrinsically dependent on sea levels. Given this dependency, they are one of the most vulnerable ecosystems to a changing climate and associated sea level rise. Marshes can adapt to a shift in sea level through a process known as marsh migration, which is the gradual inland shift of marshes into formerly dry and upland transition areas. An accelerating rise in sea level may cause marshes to migrate inland, as described, if suitable land is available, or not keep pace in gaining elevation, resulting in marsh loss, slumping, and conversion of marshland to mudflat or open water.

To identify the potential responses of coastal marshes and migration to SLR, Warren Pinnacle Consulting, Inc. (WPC), the Northeast Regional Ocean Council (NROC), and CT DEEP applied the Sea Level Affecting Marshes Model (SLAMM) Version 6 to Connecticut’s coast<sup>6</sup>. SLAMM simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term SLR. This study included probability outputs for 2025, 2040, 2055, 2070, 2085, and 2100. The results for 2055, 2070, and 2100 were selected since they most closely align to the SLR scenarios presented throughout this assessment. Outputs produced by SLAMM are reported based upon percent likelihood (1%-100%) of a predicted outcome occurring. Model results for Greenwich are presented in Appendix A, Maps 16a-16c. and acreage is summarized in Table 13.

<sup>6</sup> Clough, J., Polaczyk, A., & Propato, M. (2014). Application of SLAMM to Coastal Connecticut. *report prepared for New England Interstate Water Pollution Control Commission, Warren Pinnacle Consulting, Waitsfield, VT. Available at [http://warrenpinnacle.com/prof/SLAMM/LISS/NEIWPCCFinal\\_CT\\_Report\\_Amended.pdf](http://warrenpinnacle.com/prof/SLAMM/LISS/NEIWPCCFinal_CT_Report_Amended.pdf).*

		Acreage of Coastal Marsh Based on SLAMM Projections		
		2055	2070	2100
Likelihood of Coastal Marsh	Less Likely to be Coastal Marsh (1-33%)	161	183	193
	Likely to be Coastal Marsh (34-66%)	47	73	118
	Most likely to be Coastal Marsh (66-100%)	211	246	331

Table 13. Likelihood coastal marsh loss and gain based on SLAMM model projections for 2055, 2070, and 2100.

The 2055 model suggests that there will likely be marsh loss along Bruce Park, the eastern portions of Indian Harbor, Loughlin Avenue Playground, and Binney Park. Whereas, there is a high likelihood of marsh gain throughout Green Point Park, the eastern parts of Old Greenwich, the eastern and western portions of Cos Cob Harbor (Cos Cob and Riverside), and the eastern portion of Indian Harbor. In 2070, marshes near the water treatment plant and the southwestern parts of Cos Cob may be lost. In addition, it is likely that the southern sections of Bruce Park will be marsh. Like the 2055 model, the 2070 model indicates that there may be marsh gain along the eastern parts of Indian Harbor, Cos Cob Harbor, Greenwich Cove, and throughout Greenwich Point Park. As sea level continues to rise, upland and dry areas may be suitable for marsh establishment. Lastly, the 2100 model suggests that many of the existing coastal marshes of Greenwich have a low to medium likelihood of being marshland; this loss may be attributed to the rise in sea level which could permanently inundate many of the existing coastal marshes. In many cases, hard shorelines and roads limit the migration of wetlands, causing marsh loss. In the 2100 scenario, Bruce Park and Binney Park are more likely to gain marshes. Many portions of Old Greenwich are likely to have marshes, given its low elevation and the projected rise in sea level.



Figure 21. Marshes along the rocky Greenwich Coastline. Source: Town of Greenwich

## COASTAL EROSION

The previous three sections, Shoreline Characterization, Shoreline Migration, and Marsh Migration provide key information about the built, biological, and physical environments needed to understand the vulnerability of the coastline to erosion. Coastal regions, like Greenwich, are in a dynamic interface between land and sea, constantly exposed to waves and storms. Over time, these coastlines naturally experience erosion, changing the shoreline and posing a threat to people and built infrastructure. Rocky shorelines can provide a degree of protection against waves and storms and may reduce erodibility of coastlines. On the other hand, sandy shorelines are highly susceptible to erosion and may lead to land loss over time. The aim of this section is to identify areas of vulnerability to erosion based off the geophysical characteristics of the coastline.

This analysis utilized InVest (Integrated Valuation of Ecosystem Services and Tradeoffs), a software model that uses spatially explicit geophysical data to compare their exposure to erosion and flooding in severe weather. The model produces an exposure index along the coastline that ranges between 1 (low exposure) and 5 (high exposure). The exposure index represents relative exposure of the coastline to erosion using the following variables: 1) Wind Exposure, 2) Wave Exposure, 3) Bathymetry, 4) Surge Potential, and 5) Elevation. Results from the town-wide analysis can be found in Appendix A, Map 17.

According to the InVest model, shorelines from the easternmost part of Greenwich, along Byram to the inlet of Wilson Head, are between high and very high risk of erosion exposure. Moving inland past Byram Park, erosion exposure is between average and high, this may be due to the increased protection from wind fetch and waves offered by inlets, a pattern that is observed along portions of Greenwich Harbor, Indian Harbor, Cos Cob Harbor, and Greenwich Cove. Areas of high erosion exposure are along Belle Haven, Smith Cove, and the southern portions of Cos Cob. Erosion exposure of Greenwich Point ranges from average to high, with the areas of higher risk adjacent the Long Island Sound while areas of lower risk are adjacent to Greenwich Cove.

## LANDSCAPE CHANGE

To document alterations in the landscape specific to the tidally influenced public recreation ponds (Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park), historic aerial images from 1934 and more recent 2018 imagery were compared to highlight land modifications that have occurred over the years. Identifying these shifts in landscape patterns can help inform future land use and zoning. One of the most apparent changes in Greenwich is the urbanization and development of residences throughout the town and described in more detail in the following sections. The images from 1934 were obtained from UCONN's Map and Geographic Information Center (MAGIC) and CT DEEP's [website](#). 2018 National Agriculture Imagery Program orthoimagery was obtained from University of Connecticut, Connecticut Environmental Conditions Online (CT ECO) [website](#).



Figure 22. Aerial view of Binney Park (Town of Greenwich).

## MILL POND PARK

The starkest changes in the landscape near Mill Pond Park is the construction of the Connecticut Turnpike, which began in 1954 and opened in 1958, and the development and expansion of marinas along the Cos Cob Harbor where the Greenwich Water Club, Shell Marina, and Cos Cob Marina are today. Additional changes include an increase in urban and residential development, along with the expansion of Route 1 (Inset Map 19). This development around Mill Pond Park has resulted in an increase in impermeable surfaces, such as houses, pavements, and lawns. Furthermore, marshes along the Cos Cob Harbor have been filled and developed on, removing the natural buffer between land and water. The hardening of the shoreline along Cos Cob Harbor also limits inland marsh migration, leading to marsh loss.



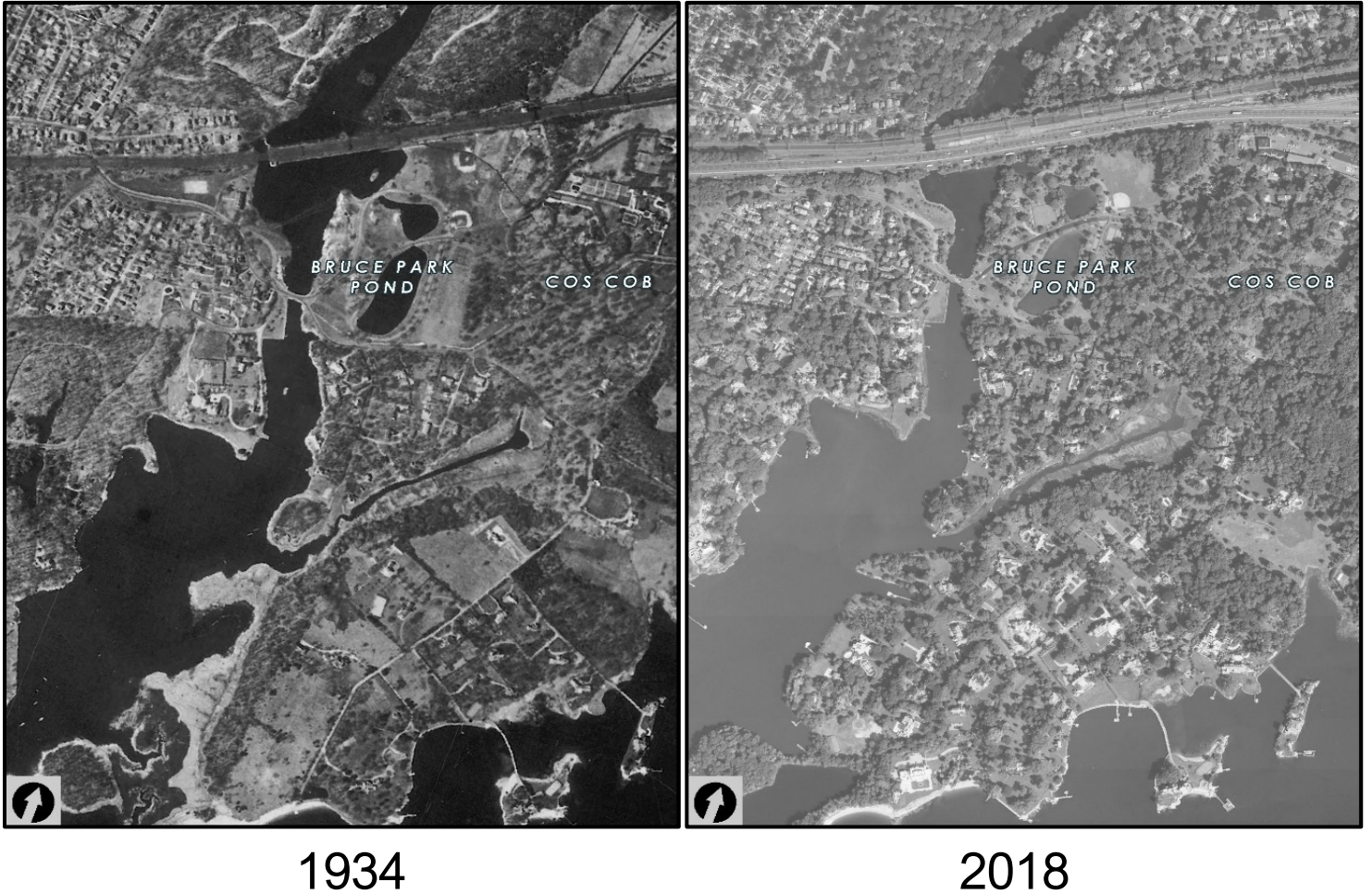
1934

2018

Inset Map 19. Aerial photography of Mill Pond and the surrounding community in 1934 and 2018.

## BRUCE PARK

Changes near Bruce Park include residential development in the southernmost portions of Cos Cob, the loss of wetlands along Indian Harbor, and the hardening of the shoreline (Inset Map 20). Across Indian Harbor, many of the shorelines have also been armored with riprap, changing the shoreline from what appears to be marshland.



Inset Map 20. Aerial photography of Bruce Park and the surrounding community in 1934 and 2018.

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## BINNEY PARK

Prior to the opening of Binney Park in 1933, the area was swampland that was filled to raise the ground elevation. Since 1934, observable landscape changes include the increase in residential developments and loss of wetlands downstream of Binney Park (Inset Map 21). The development of Cove Ridge Ln. and Hendrie Dr. can also be seen in the aerial image. Additional changes include the expansion of forested areas along Harding Rd.

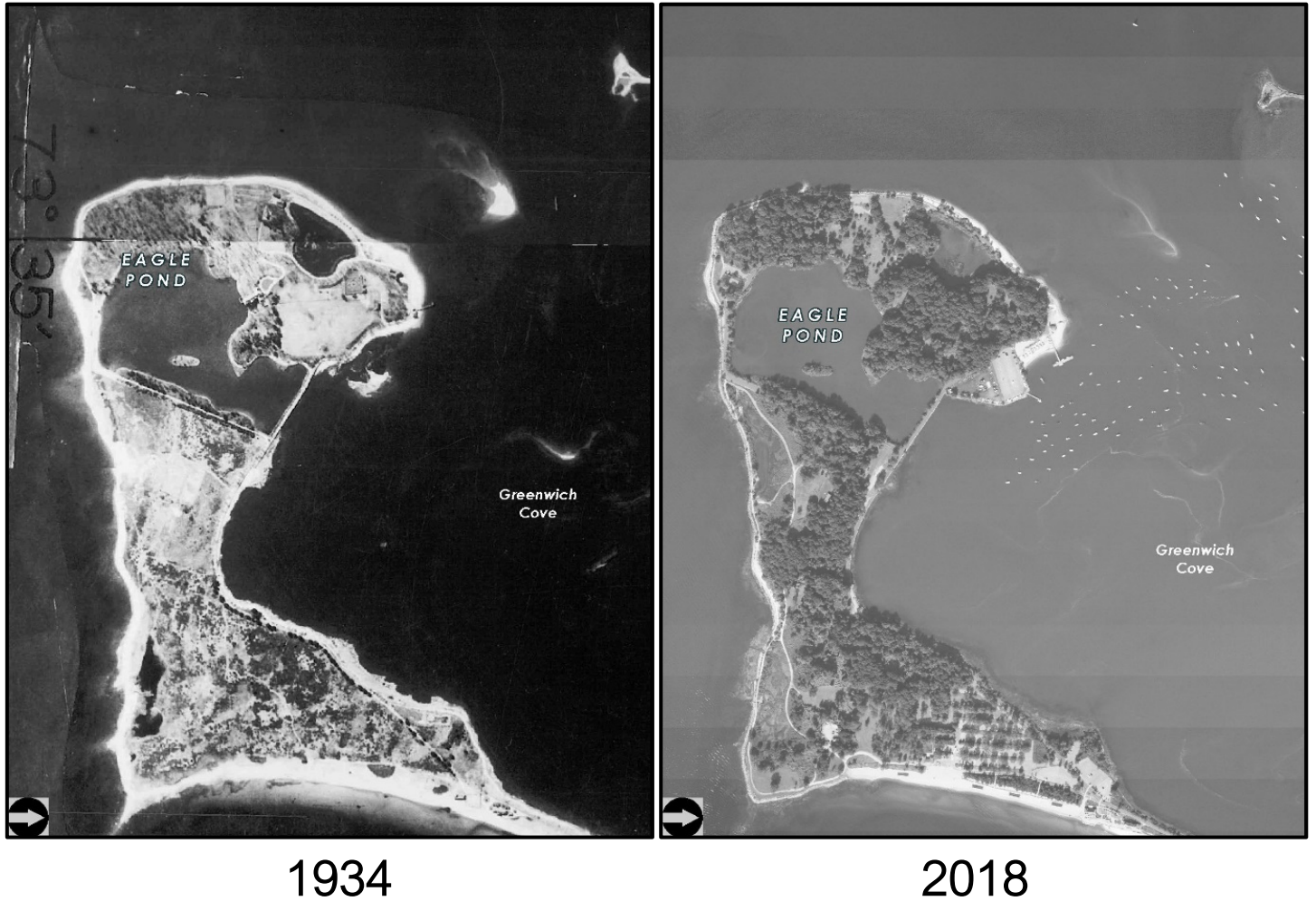


Inset Map 21. Aerial photography of Binney Park and the surrounding community in 1934 and 2018.

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## GREENWICH POINT PARK

Eagle Pond, located in Greenwich Point, was acquired by the Town in 1945 and has been dedicated open space since then. Changes in Greenwich Point include the development and hardening of many of the shorelines to facilitate access and maritime activities. This area has also become more forested since 1936 (Inset Map 22).



Inset Map 22. Aerial photography of Eagle Pond and the surrounding community in 1934 and 2018.

## COMMUNITY VULNERABILITY TO SEA LEVEL RISE

The results from the analyses described above each provide insight into how Greenwich's assets may be impacted from future floods. This section synthesizes and discusses those findings to highlight impacted areas within the public recreation parks and the surrounding communities of Mill Pond Park, Bruce Park, Binney Park, and Greenwich Point Park.

### MILL POND PARK

**Current conditions:** During typical tides, sea level does not adversely impact Mill Pond Park and the surrounding community. If a 10% flood were to occur today, the commercial corridor directly north of Mill Pond Park would see impacts from flooding. The Cos Cob Fire House, a critical facility, would experience flooding impacts given its position along East Putnam Ave. Portions of Loughlin Avenue Playground and the Strickland Rd. Historic district would also experience road flooding and impacts to houses. If a 1% flood were to occur today, flooding impacts would be concentrated in the communities north and west of Mill Pond Park, affecting houses and businesses. Erosion risk from waves and storms is low as the park is sheltered.

**Short-term (2050):** During typical tides, a rise of 20 inches poses little risk to the Mill Pond Park community. This rise in sea level may impact tidal marshes, forcing them to move inland to avoid permanent inundation. Sea level also impacts two stormwater catch basins in the southern part of the park which may exacerbate flooding impacts of a 10% or 1% storm. A 10% flood concentrates impacts adjacent to East Putnam Ave. and Loughlin Ave. A 1% flood concentrates impacts along Cos Cob Harbor, East Putnam Ave. and Loughlin Ave. By 2050, new marshes may be established along the edges of the park and along Cos Cob Harbor.

**Mid-term (2075):** During typical tides, a rise of 30 inches poses little risk to the Mill Pond Park community. A rise in sea level does not impact any new stormwater catch basins. A 10% flood concentrates flooding along Cos Cob Harbor, East Putnam Ave. and Loughlin Ave. Houses along the southern half of Mill Pond Park may see flooding impacts as well. A 1% flood significantly impacts Mill Pond Park, roads and structures surrounding the park may experience impacts from flooding. Along Cos Cob Harbor, houses and businesses will also see impacts from flooding. Marshes may continue to expand along the edges of the park and Cos Cob Harbor.

**Long-term (2100 low and high):** During typical tides, a rise of 40 inches (2100 low) does not pose significant impacts to Mill Pond Park and the surrounding community; however, a rise of 80 inches significantly impacts the park and surrounding community, permanently inundating many surrounding houses and businesses, and impacting large clusters of stormwater catch basins throughout the community. A 10% and 1% storm extend flooding on the western part of Mill Pond Park towards Indian Field Rd. and as far north as Tremont St. By 2100, marshes continue to expand along the Cos Cob Harbor and conditions may be suitable for wetland establishment in Loughlin Avenue Playground.

### BRUCE PARK

**Current Conditions:** During typical tides, sea level does not impact Mill Pond Park and the surrounding community. If a 10% flood were to occur today, Bruce Park would be inundated along with Bruce Park Dr. and Davis Ave. limiting the flow of traffic across Indian Harbor. If a 1% flood were to occur today, flood impacts would affect all of Bruce Park and further impact Bruce Park Dr. and Davis Ave. The houses and roads north of I-95 and along Indian Harbor would also experience flooding. Erosion risk from waves and storms is low as the park is sheltered and in the northern section of Indian Harbor.

**Short-term (2050):** During typical tides, a rise of 20 inches in sea level poses little risk to Bruce Park. This rise in sea level does not impact any stormwater catch basins. A 10% flood with 20 inches of sea level poses little risk to surrounding buildings but impacts Bruce Park Dr. and Davis Ave. A 1% flood significantly impacts Bruce Park, flooding many of the houses upstream and downstream of Indian Harbor. The roads and houses north of

I-95 would experience moderate flooding, extending towards Circle Dr. Although sea level is rising, suitable conditions for marsh expansion within the park do not exist yet. Marshes are projected to expand along Indian Harbor.

Mid-Term (2075): During typical tides, a rise of 30 inches in sea level poses little risk to Bruce Park and does not impact any stormwater catch basins. A 10% event floods most of the park and impacts Bruce Park Dr. and Davis Ave. A 1% flood event floods all the park and the surrounding roads. A rise in sea level presents some suitable conditions for marsh expansion within the park and along sectors of Indian Harbor.

Long-term: During typical tides, a rise of 40 inches (2100 low) poses little risk to Bruce Park. This rise in sea level impacts a stormwater catch basin in the southwestern portion of the park. However, a rise of 80 inches (2100 high) poses significant risk to Bruce Park permanently inundating most of the park. This rise in sea level impacts stormwater catch basins throughout the park as well. 10% and 1% events under both scenarios flood the park, impact access across Bruce Park Dr. and Davis Ave., and affect houses on both sides of Indian Harbor. As seas continue to rise, conditions for marsh expansion are favorable throughout the southern sections of Bruce Park and some sectors along Indian Harbor.

## BINNEY PARK

Current Conditions: During typical tides, sea level does not impact Mill Pond Park and the surrounding community. If a 10% flood were to occur today, Binney Park would be flooded. A 1% storm today would flood the whole park as well as impact houses south of the railroad tracks and the eastern parts of Old Greenwich. Erosion risk from waves and storms is low as the park is sheltered.

Short-term (2050): During typical tides, a rise in sea level of 20 inches poses little risk to Binney Park. Sea level impacts a stormwater catch basin just south of the train tracks. 10% and 1% floods impact all of Binney Park, including many of the roads and structures surrounding the park, with floodwaters extending towards I-95. The intersection of Sound Beach Ave., Laddins Rock Rd., and Harding Rd. is flooded under both flood events. Many houses and roads in the eastern parts of Old Greenwich could experience flooding. With a rising sea level, sections of Binney Park have suitable conditions for marsh gain, and marshes are projected to expand along the northernmost section of Greenwich Cove.

Mid-term (2075): During typical tides, a rise in sea level of 30 inches poses little risk to Binney Park. Sea level impacts stormwater catch basins along Binney Park Dr. which may exacerbate flooding impacts of a 10% or 1% storm. 10% and 1% floods impact all of Binney Park, including many of the roads and structures surrounding the park. Many houses and roads in the northeastern parts of Old Greenwich will experience flooding. As seas continue to rise, conditions for marsh expansion are suitable throughout the southern sections of Bruce Park and some sectors along Indian Harbor.

Long-term (2100 low and high): During typical tides, a rise of 40 inches poses high risk to Binney Park with most of the park being permanently inundated. Sea level may impact stormwater catch basins along Binney Park Dr. and Wesskum Wood Rd., which may exacerbate flooding impacts of a 10% or 1% storm. During typical tides, a rise of 80 inches fully inundates Binney Park, impacting several surrounding houses and roads north of the park. Sea level impacts stormwater catch basins throughout the park and northward towards Deepwoods Ln. 10% and 1% floods impact all of Binney Park, including many of the surrounding roads and

houses. Under both scenarios, the eastern parts of Old Greenwich experience significant flooding to roads and houses. In the 1% flood scenario, the flood extent impacts inland portions of Old Greenwich. A rising sea level creates optimal conditions for marsh gain throughout Binney Park and sections of Old Greenwich.

## GREENWICH POINT PARK

Current Conditions: During typical tides, sea level does not pose a risk to Greenwich Point Park. If a 10% flood were to occur today, flooding would limit access between Old Greenwich and the park. A 1% flood would significantly flood Greenwich Point Park and limit access to the park from Old Greenwich. Currently, marshes exist along most of the edges of Greenwich Point Park. The southern and eastern portions of Greenwich Point Park are at high risk to erosion, the eastern part of the peninsula is at average risk, and the parts along Greenwich Cove are at average to low risk of erosion. Areas at high risk of erosion may see losses in land and shifts of beachy areas throughout the park.

Short-term (2050): During typical tides, a rise in sea level of 20 inches floods many of Greenwich Point Park's beachy areas and impacts some of the walking and vehicular sections of Tod's Driftway. This rise in sea level does not impact any stormwater catch basins. 10% flood and 1% flood events significantly impact Greenwich Point Park, flooding most of the park, and restricting access to the park. A rise in sea level and the availability of open space creates suitable conditions for marsh migration.

Mid-term (2075): During typical tides, a rise in sea level of 30 inches floods many of Greenwich Point Park's beachy areas and further impacts some of the walking and vehicular sections of Tod's Driftway. This rise in sea level does not impact any stormwater catch basins. A 10% flood and 1% flood significantly impact Greenwich Point Park, flooding most of the park, and restricting access to the park. A rise in sea level allows marshes to continue to expand inland.

Long-Term (2100 low and high): During typical tides, a rise in sea level of 40 inches poses moderate risk to Greenwich Point Park, flooding many roads and inundating much of the beachy shoreline. A rise in sea level impacts stormwater catch basins in the parking lot across from Greenwich Point Beach. During typical tides, a rise in 80 inches significantly impacts Greenwich Point Park, flooding most of the park. This rise in sea level impacts a catch basin near Flat Neck Point. 10% and 1% events flood most of the park, flooding all roads and structures. By 2100, marshes will continue to expand and move inland, converting most of the park to marshland.

## GREENWICH RESILIENCY STRATEGIES

This assessment report provided an overview of the vulnerabilities faced by Greenwich under current conditions and various sea level rise and storm surge scenarios. The companion report, “Tidal Ponds Evaluation Report,” goes into more detail on the present conditions of the four ponds included in the study. This information provides important data to help address the obvious next question, “so what should we do about it?”. The second companion report, “Adaptation Strategies Report” provides suggestions for projects and actions that could be taken within Greenwich to increase resiliency. However, in order to prioritize among these actions, and to determine their appropriateness, an important interim step is required.

In order to make informed choices about what projects to devote limited resources to, it is important to have an understanding of where you are trying to go. This is a multi-step and iterative process. Just as sea level rise will produce different conditions over time, so will the responses of the town evolve and change over time. Engaging in a dialogue with the entire community to develop a shared vision must occur before the appropriate strategies for achieving that vision can be identified. Understanding the appropriate strategies should occur prior to investments in specific resiliency projects.

## OUTREACH

Numerous adaptation and management options exist, but in order to select the suite of options that is right for Greenwich, it is critical to develop a shared vision of what the community wants to accomplish with these measures. The selection of options to reduce all risk to existing structures will look different than options to allow for flooding to occur but which will enable faster recovery. Likewise, management of the ponds as open water resources will look different than if the community is willing to allow them to revert to saltwater marsh. Each of these choices involves tradeoffs, to include cost, water access, viewsheds, etc. Thus, it is important to have open conversations with residents to ensure that these tradeoffs are understood and that the resiliency goals represent a shared vision for Greenwich’s future.

Greenwich already has in place a strong leadership team who is aware of the risks associated with climate change and is taking a proactive approach toward improving the resiliency of town facilities. Regular cross-departmental discussions should occur to ensure a consistent approach to projected risks, and to allow for a consistent public message.

The leadership team would be the conduit for providing information, education, and soliciting input from the community overall. Providing a mechanism for community outreach, education, and input is critical for development of a shared vision for a Resilient Greenwich.

As part of the development of this Assessment, two public meetings were held, one on June 9, 2021 and one on June 16, 2021. Both meetings were held virtually to address concerns about COVID 19 and to maximize participation. An average of 50 people participated in each session. The goal of the engagement was to provide information about the preliminary findings of the Assessment. Presentations and recordings from both meetings may be viewed [here](#).

Part I, on June 9<sup>th</sup>, 2021, focused on providing a current conditions grounding including a presentation about what sea level rise is, how it is determined for future horizons, and a summary of the impacts of SLR scenarios. A testimonial video of town representatives was featured with their observations and experiences during their tenure as it related to the impacts of water and flooding, entitled “The Voices of Greenwich,” which may be viewed [here](#). A detailed evaluation of the four tidal ponds (Eagle Pond at Greenwich Point Park, Bruce Park Pond, Mill Pond at Mill Pond Cos Cob Park, and Binney Park Pond) was presented, providing a technical analysis of the impacts of increased tidal inundation on the natural habitat..

Part II, on June 16<sup>th</sup>, 2021 built on the first meeting and provided a deeper dive into inundation mapping that was prepared, including a deeper focus on town assets and critical facilities. Previewed at this session was the StoryMap that was developed to provide an interactive online tool for the public to engage with the data and assessment of coastal impacts. The StoryMap closely follows this report with interactive maps allowing viewers to zoom and add layers to better understand SLR projections. The meeting then hosted a panel of municipal staff about what was already being implemented at the municipal level to address changing conditions.

Both sessions included engaging question and answer sessions to provide additional context and provide answers about the materials presented. As appropriate, this feedback was incorporated into the strategies matrix found later in this chapter. Questions raised by stakeholders included the following topics:

- Clarifying questions about flooding scenarios
- How did previous storms (Sandy and Irene) rank on the inundation scale, i.e., were they 1%, 10% storm events?
- National Flood Insurance Program (NFIP) and how that reflects actual risk
- Suggestions for opportunities to mitigate flooding impacts at ponds, specifically reducing amount of paved area
- Costs associated with individual flooding mitigation interventions (i.e., elevating structures)
- Clarifying questions about the efficacy of dredging ponds to increase stormwater storage capacity
- Floodgates
- Debris management in ponds
- Upland drainage

Based on the outreach and the variety of questions that were raised, additional community engagement and educational opportunities related to Coastal Resiliency Strategies, Pond Management, Dredging, NFIP, and continued engagement about SLR impacts are warranted.

This outreach serves as an important foundation for engagement that should occur to develop the vision, goals, and strategy prioritization that is necessary to move this assessment to implementation of resiliency projects.

## RESILIENCY VISION STATEMENT

Establishing an overall vision statement for what the town will look like is a foundational tool to guide resiliency decisions. The community's vision statement defines what the community wants to become and establishes the means to get there. The vision should include the planning time horizon as well as incorporate the values of Greenwich. The resiliency vision statement should be linked to the existing conditions, and shocks and stresses particular to Greenwich. This process is illustrated in the below graphic.

### **Example Resiliency Vision Statement:**

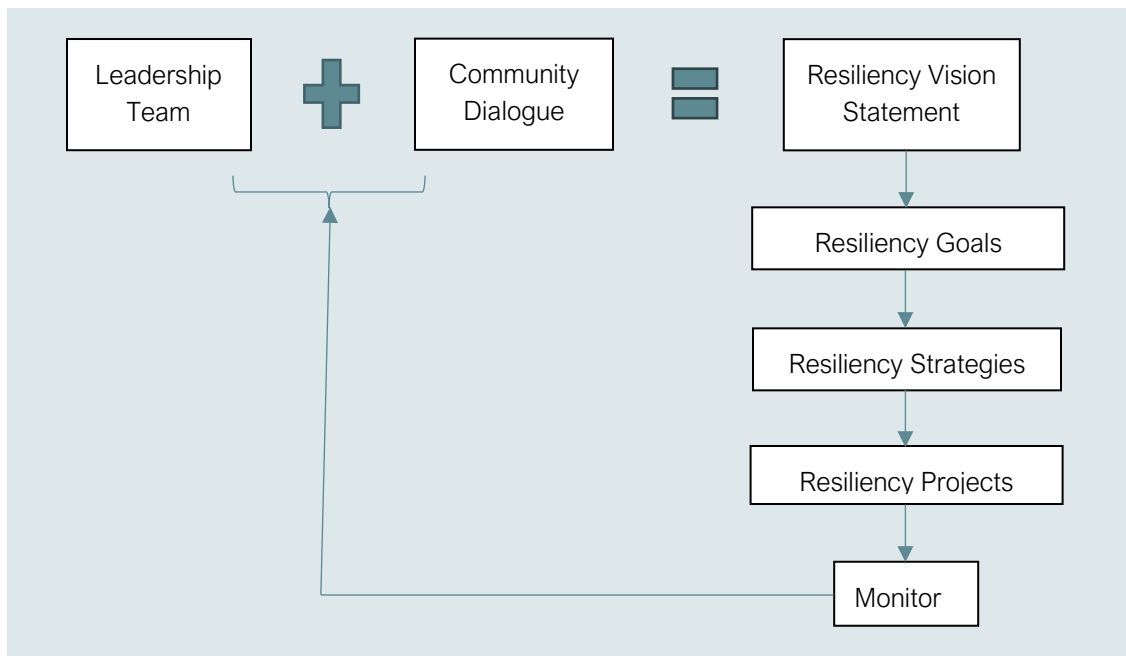
Our community will demonstrate a culture of resilience and personal responsibility, which enhances connectivity, supports the most vulnerable, and engages the whole community. We will preserve our identity as a coastal community with a vibrant downtown, safe and attractive residential areas, and welcoming public space. Our coastal areas will prioritize water dependent businesses and open spaces that allow for marsh expansion and robust ecological functions balanced with public access and enjoyment.

Questions to help residents generate a Greenwich specific resiliency vision could include:

1. What should resilient coastal communities look like 10 / 20 / 30 years from now? How will they function?
2. How does this differ from what Greenwich looks like and functions like today?
3. What vision statements has Greenwich established in other planning documents?
4. What is Greenwich known for? What are critical place-based elements that define Greenwich's culture, that should be prioritized for preservation?
5. What time period should the framework address (10, 20, 30 years)?

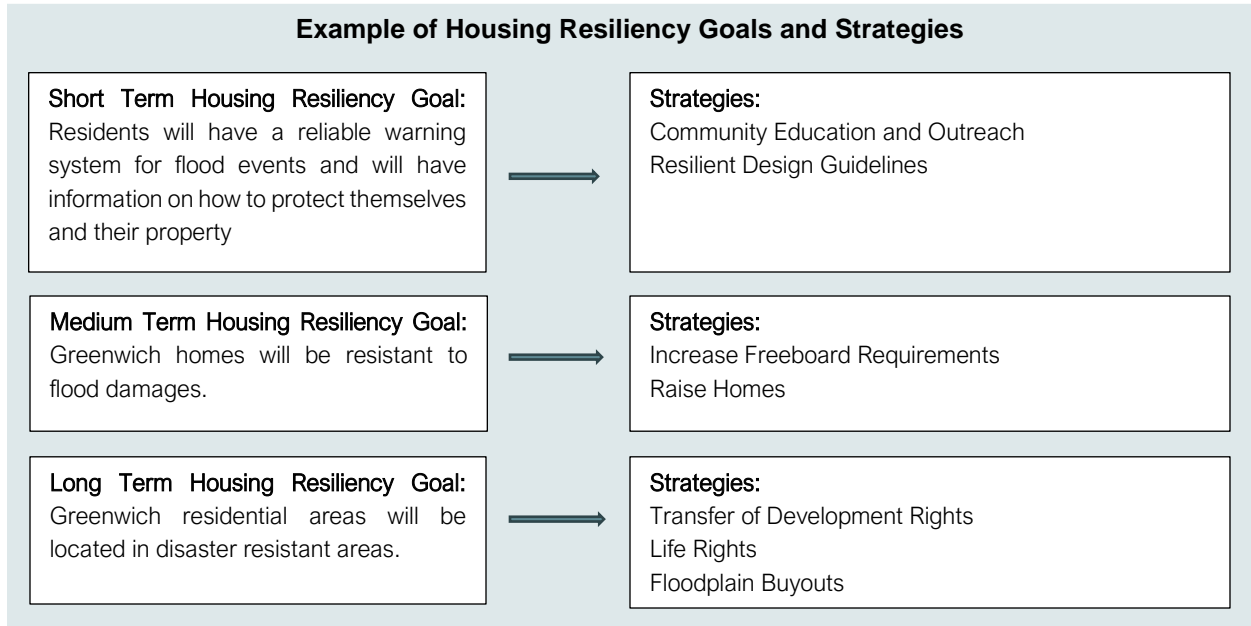
## RESILIENCY GOALS

This vision statement can then be used as a guiding principle to develop goals for specific areas, as illustrated by the graphic below. Such areas may include housing, critical facilities, energy, parks, transportation, economy, water, etc. For example, Greenwich's goals may include fewer new structures built in areas at risk for flooding, a robust warning and evacuation system for storm events, and public utilities protected from regular inundation.



Goals establish observable and measurable end results that will help shape the overall vision the community foresees. Additional public engagement can help to define these goals, which will further enable the selection of strategies to achieve the stated vision. The goals are more specific than the vision, and can be developed to fit the various categories of issues faced by Greenwich, such as housing, safety, economy, social systems, communication systems, water and wastewater, energy, transportation, critical facilities, etc. The categories should be based on the community priorities and stressors. For each of these categories, goals can be established for short term, medium term, and long term. Each goal should have defined performance metrics that can be used to measure progress for implementation.

RESILIENCY STRATEGIES



As illustrated in the above example, strategies are methods of reaching the community’s specified goals and should align with the overall vision. Creating implementable strategies may require revisions and further stakeholder engagement. The matrix that follows provides various strategies that can be employed to meet a variety of resiliency goals. They are organized by Strategy Type to assist in identifying which implementation projects would be applicable. Information on the overall benefits and challenges of each approach, the relative cost, and regulatory constraints of each strategy, as well as the typical project lead (federal, state, local, private), and type (construction, planning, outreach, etc.) are provided.

Through the Assessment process, areas requiring further study were identified, which would provide more detailed information to guide project selection. These more specific recommendation areas include but are not limited to:

- Vulnerability of individual septic systems should be completed on a site-by-site basis due to variable site conditions such as depth to groundwater.
- To understand the impact associated with increased precipitation and sea level rise to the stormwater management system, a detailed study is required.
- Many of the strategies outlined below address land use planning. As part of this assessment, a review of Greenwich’s building zone was conducted. The results are included in Appendix B to this report and are additional recommendations for resilient action.

The Adaptation Strategies Report, a companion document to this Assessment, provides additional areas of study that would be recommended in the event that Greenwich elected to examine related adaptation projects for implementation.

ADAPTATION OPTIONS CHART

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Living Shoreline</b>	Living shorelines are comprised of a system of green infrastructure and natural solutions that create a buffer along the water's edge to minimize erosion and absorb wave action. Town of Greenwich 2019 Plan of Conservation and Development, <i>Objective 4.3 #86</i> .	Provide flood protection along the shoreline and the least damaging solution to surrounding environmental resources.	Salt marshes occupy estuarine shorelines across a pretty wide range of wave energies, but there is a limit to where a salt marsh can be sustainable. Salt marshes require a gentle slope so steep sediment bluffs may not be easily adaptable to the salt marsh version of a living shoreline. Deep water offshore may impact installation.	High	\$\$\$- \$\$\$\$	Local	Construction
<b>Offshore Breakwaters</b>	Offshore breakwaters are stone or concrete structures constructed off the coast to absorb wave energy before the waves reach the shore.	Reduce the need for sea walls and other solutions along the shoreline and could protect a large area of the town.	Prevent natural rehabilitation of the beach (and the dunes) from the seaward side of the breakwaters towards the coast, but also due to the reduced wave conditions behind the breakwaters from the landward side.  Breakwaters that are continuous can pose an ecological hazard when placed in wetlands by barring organisms from entering or leaving. Fixed breakwaters are often an eyesore -- an aesthetically displeasing sight on the shoreline.	High	\$\$\$- \$\$\$\$	Federal	Construction
<b>Relocate Critical Facilities</b>	Identify and analyze critical infrastructure in relation to known hazards and develop a comprehensive strategy. The results should include a list of prioritized capital improvements and associated costs and potential funding sources. The strategy should be incorporated into the local hazard mitigation plan's list of mitigation projects, the local comprehensive plan, and the capital improvement program/plan. It is especially important to develop plans for the long-term maintenance of critical infrastructure.	Ensuring faster and less costly recovery from storm events. Ability to maintain services.	Gaining funding support to implement can be a struggle. Some critical facilities may also be classified as historic structures, which may introduce additional challenges in terms of upgrading the structures to be more resilient. Land availability constraints.	High	\$\$\$	Local	Construction

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Road Raising</b>	Raise roadways that are prone to flooding above the flood elevation.	Solves access and egress issues during flood events by protecting roadways from flooding.	Elevated roads may cause ponding of water on adjacent properties. May need to be done repeatedly, unless there are reasonable predictions of the final elevation needed and the available funds to do a large, one time project.	High	\$\$\$	Local, State, and Federal	Construction
<b>Seawall</b>	Protect exposed shorelines from erosion and coastal flooding with a stone or concrete wall to minimize sea level and storm impacts.	Can protect a large region with one solution, reducing the need for individual building adaptations.	Expensive to construct, maintain & repair, does not always prevent or mitigate erosion, waves overtopping seawalls and bulkheads during storm surge events can erode landward of the structure. In addition, armoring can shift and intensify erosion downstream to unprotected shorelines. Can create a false sense of security (failure of a seawall or levee = potentially catastrophic consequences). May encourage further development along the coast. Limits the upland migration of wetlands.	High	\$\$\$-\$\$\$\$	Local, State, and Federal	Construction
<b>Tide Gates</b>	Tide gates are deployable floodgates that can control water flow and prevent flooding. They can vary in size and are typically installed as a part of a larger flood control system.	Can protect a large area of a town without causing significant impact to environmental resources.	Limited applicability to coastal storm risk, high cost and environmental impact. Has potential upland stormwater discharge impacts. May cause water quality concerns within closed creeks.	High	\$\$\$-\$\$\$\$	Federal	Construction

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Ecosystem Restoration, Creation, and Enhancement</b>	Ecosystem restoration, creation, and enhancement focuses on activities to restore, create, or enhance coastal and marine ecosystems through manipulation of a site's physical, chemical, or biological characteristics at sites including wetlands, coral, artificial reefs. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.2 #66.	Restoration of natural functionality of coastal marshes and shorelines slows shoreline erosion. Salt marshes serve as buffers linking natural and built defense structures while removing incentives to build in high-risk areas.	Desirable locations may be privately owned or difficult to access. Limited applicability to coastal storm risks.	Low	\$ - \$\$	Local and State	Construction
<b>Floodable Parks</b>	Design recreational space and sports fields to accommodate floodwaters as a part of their function. Includes the incorporation of native and flood-tolerant plants and an interpretation of stormwater flow patterns to encourage stormwater collection at the park.	Encourages groundwater absorption and aquifer regeneration, reducing stormwater runoff while maximizing the functional value of the park space when not inundated and offering habitat value during periods of inundation.	Maintenance concerns, as floodwaters slow down, the sediment and sand slowly drop out of the water column, potentially requiring a need to clean and remove the settled sediment from the park. Similarly, even when properly designed to weather a storm event, minor damage may occur to infrastructure (play equipment, benches, etc.) within the park which will need to be repaired once floodwaters have receded.	Low	\$\$	Local	Construction
<b>Temporary FloodBarriers</b>	Temporary flood barriers are barriers that can be constructed prior to a flood event and deconstructed after the event. They can range significantly in cost and construction effort, from sandbags to deployable barriers that rise automatically as floodwaters rise.	Can provide effective flood protection, are reusable and easy to deploy, and do not require building or site modifications.	Requires human intervention and sufficient installation time for larger buildings. Without adequate warning, flooding can occur before shields can be put in place. Most temporary barriers do not protect structures from high-velocity flooding and wave action.	Low	\$ - \$\$	Local	Construction

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Beach Nourishment</b>	Beach nourishment places sand on an eroding beach, making it higher and wider while creating a buffer against wave action and flooding. Generally requires further renourishment after the initial nourishment.	May improve recreational value, adjacent beaches, and create, restore, and protect habitat.	Expensive short-term solution (nourished beaches can erode 2-3x faster than natural beaches) which has negative impact on marine life and shorebird nesting.  Encourages development in high-hazard areas.	Medium	\$\$\$\$	Local	Construction
<b>Floodproof At-Risk Community Facilities</b>	To make these facilities more resilient requires taking actions that removes risk to physical infrastructure. In terms of buildings, examples include: elevation of the building above the base flood elevation (BFE); dry proofing and wet floodproofing; fire-resistant building materials; and, in some cases, engineered solutions such as levees and floodwalls. In terms of hardening capital facilities, examples include: double sleeving water pipes, elevating roadways prone to flooding above BFE, expanding the capacity of road culverts, removing physical impediments that restrict water flow in rivers and floodplains, and elevating heating and air conditioning equipment and generators.	Ensuring faster and less costly recovery from storm events. Ability to maintain services.	Although many floodproofing strategies may be implemented they may not actually address the long-term impacts of sea level rise, For instance, if a building is protected but can't be accessed for periods of time due to surrounding flooding, then its utility is diminished.	Low- High	-\$\$\$\$\$	Local	Construction
<b>Reduce Services</b>	Gradually limit or stop public infrastructure investments in areas at risk.	Passively discourages continued businesses and residences in flood-threatened areas.	Opposition of impacted residents, infrastructure costs.	Medium	\$	Local	Construction

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Green Infrastructure</b>	Balancing traditional “hard” infrastructure with “green infrastructure” for coastal protection measures which mimic or enhance native protection systems such as vegetated dunes, salt marshes, submerged aquatic vegetation, oyster reefs, or woody debris. Some protection strategies include creating or enhancing these natural systems, while other approaches replicate the benefits these systems provide along the coast. In any shoreline protection strategy, a combination of “grey” and “green” techniques allow the most comprehensive protection of infrastructure, natural resources, and flexibility for dynamic conditions. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.3 #81 and Objective 4.4 #94.	Reducing flood impacts, reduction of wave energy, beautifying the community, improving air quality, providing more outdoor space, and reducing urban heat island impacts. Solutions can also be scaled to the site constraints and budget.	May require specialized maintenance and monitoring	Low-High	\$	Local, State, and Federal	Construction and Planning
<b>Stormwater Management</b>	Stormwater management controls the rate and volume of stormwater and the amount of pollutants, sediment, and nutrients entering water bodies through precipitation-generated runoff. Modifications including incorporating green infrastructure such as green streets, limiting impervious surfaces, installing larger pipes and culverts, and creating retention and detention basins can help mitigate stormwater impacts. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.2 #69 and Objective 4.4 #91.	Many strategies, such as detention basins and rain gardens, add recreationally and aesthetically-appealing features that can add habitat and landscape value to a site impacted by increased storm and water events	A system wide analysis and approach is needed to understand and address the impacts of coastal flooding on the storm water system. A variety of solutions would need to be deployed throughout the system primarily to manage the system functionality during storm and flooding events.	Low	\$ - \$\$	Local	Construction and Planning & Zoning

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Raising Structures</b>	Structures are raised above freeboard to minimize interior flooding. Structures can be raised in a way that is architecturally consistent with the individual building and neighborhood to accommodate aesthetics.	Provides a long-term solution to coastal dwellings faced with potential flooding from storm events and high tides, reduces the number of properties that are at risk from flooding during a storm event, provides a buffer between the expected flood elevation during a storm event and the height of the first usable floor of the structure, and reduces insurance premiums.	Challenging for multifamily dwellings, can be expensive for home owners. May provide a safety risk for residents who remain during storm events and have limited rescue access.	Medium	\$\$\$ - \$\$\$\$	Local	Construction and Planning & Zoning
<b>Community Education and Outreach</b>	Institutionalize a leadership team, consisting of the Office of Sustainability, Department of Public Works, Department of Parks, and Department of Planning, Risk Management, Tax Collector, Town Clerk, Community Development, Conservation, Harbor Management, Historic District, Housing Authority, Inland Wetlands & Watercourses Agency, including others as appropriate, as a Climate Change Leadership Team, with regular meetings to share concerns, observations, planned projects, and jointly plan for community outreach efforts. The Climate Change Leadership Team will establish goals, set timelines, and synthesize input from the public.	Goals and strategies of the team can be integrated throughout departments and programs. Provide an opportunity to understand implication of actions for various actions in a collaborative space.	Staff turnover has potential to limit action implementation.	Low	\$	Local	Outreach

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Disclosure Requirements</b>	Modify current local or state real estate disclosure requirements to include projected flood risk from sea level rise.	Educates prospective homeowners on potential risks to dwelling due to sea level rise and coastal flooding. Protects property owners, tenants, and potential buyers from the impacts of unknown risks, and empowers those who choose to occupy property in flood zones to take steps to mitigate potential damage before an event occurs. Protects seller liability.	Potential impact to property values, challenges for local government to engage in risk valuation and could have large administrative costs.  Pursuit of State legislative action is likely to be time consuming and receive industry pushback	Low	\$	Local or State	Outreach
<b>Floodplain Buyout and Acquisition Programs</b>	Floodplain buyout and acquisition programs are voluntary programs where homeowners in at-risk flood areas can sell their homes to the government. The government will either remove those properties from the floodplain and return the land to nature or redevelop those properties in a more flood resilient manner.	Provide a long-term solution to protecting private and public property by removing the structures from the floodplain or ensuring that they are better protected. This solution could remove the need for an expensive engineering solution to protect the shoreline.	High initial cost buyout cost to municipality and could disadvantage lower income residents.  Program resistance by property owners.	High	\$\$ - \$\$\$	Local	Planning
<b>Sea Level Rise Overlay Zone &amp; Relocation</b>	Extend boundaries of the regulated floodplain and relocate development and structures in highly-vulnerable areas outside of the floodplain. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.3 #77.	Provide a long-term solution to protecting private property by removing the structures from the floodplain. Could remove the need for an expensive engineering solution to protect the shoreline.	Rezoning that reduce development rights can face potential opposition from affected property owners. While zoning ordinances affect new development & redevelopment projects, areas that are already built out are less influenced by new zoning measures. Relocation is expensive and can have significant impact on property value and tax revenue.	High	\$\$ - \$\$\$	State and Local	Planning

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Cumulative Substantial Damage Accounting</b>	Establish a maximum payout based on the total of all claims filed beyond which no further assistance will be provided. Adds the cost of insured repairs or improvements over a set period of time and then evaluates that total against the 50-percent threshold in order to determine a requirement to improve the structure. The threshold could be reduced to a value lower than 50 percent (e.g., 40 percent), which would require properties to meet flood-protection criteria even sooner. Not currently a town policy.	Passively discourages continued businesses and residences in flood-threatened areas through financial constraints.	Can face local opposition and will have a disproportionate impact on low income communities.	Low	\$	Local	Planning
<b>Resilient Design Guidelines</b>	Provide simple, accessible, guidance to homeowners and businesses about flood-resilient design in advance of rebuilding. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.2 #61, Objective 4.3 #81, and #84.	Educating homeowners and businesses regarding flooding threats and resilient design strategies may reduce future risk, gradually creating a more resilient building stock, and providing guidance for rebuilding after a flood event.	Guidelines need to be clearly implementable and communicated to the stakeholders to be effective.	Low	\$	Local, State and Federal	Planning
<b>Special Flood Hazard Zone Tax District</b>	Tax residents who continue to live in areas at risk with a tax amount based upon the incremental difference in the costs to provide services (roads, stormwater, storm cleanup, sewer, water, gas, electric, bulkheads, communications, ER process).	Passively discourages continued businesses and residences in flood-threatened areas. Garners additional town funding to address town services provided to residents and businesses in at-risk areas.	Could lead to significant pushback from residents in zones and impact property values.	Medium	\$	Local	Planning

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Adjust Building Setbacks</b>	Increase the minimum distance required between a property boundary and any buildings or improvements on the property, allowing for more land available during water inundation events. Town of Greenwich 2019 Plan of Conservation and Development, Objective 4.3 #81.	Minimizes risk of new structures in areas prone to flooding and prevents damage to structures from flooding and erosion, by creating a buffer between the structure and anticipated impacts.	Inability to implement along corridors where properties are already developed unless the property is destroyed or redeveloped.	Medium	\$	Local	Planning
<b>Increase Freeboard Requirements</b>	Increase the required distance between the lowest part of a habitable structure and predicted sea level rise estimates. Increased freeboard requirements can be extended to zones and properties that are expected to be at risk from future storm events.	Minimizes structural impacts from sea level rise.	Can create inconsistency with utility heights, increasing the complexity of service and may increase construction costs.	Medium	\$ - \$\$	Local	Planning
<b>Life Rights</b>	Grant current owner the right to live in a home for the duration of the owner's life but once that current owner no longer inhabits the property it cannot be resold or reused. In exchange the owner is paid a fair market value for the property at the time the life rights agreement is executed.	Ensures a finite duration of use for a dwelling to encourage additional sustainability efforts on the property by preventing future transfer of ownership.	High initial cost.	Medium	\$\$ - \$\$\$	Local	Planning
<b>Restricting Rebuilding &amp; Limiting Building Size and Density</b>	Use the local land use ordinances to regulate how a property can be redeveloped after an existing structure has been destroyed, with an emphasis towards smaller or more mobile structures that can be easily relocated, structures that are more resilient, and/or those that have a higher freeboard.	Limiting building size and density in coastal hazard areas will minimize property damage, protect beach, dune, and other natural systems, and reduce the amount of infrastructure at risk.	Restrictions that reduce development rights can face potential opposition from affected property owners. While zoning ordinances affect new development & redevelopment projects, areas that are already built out are less influenced by new zoning measures.	Medium	\$ - \$\$	Local	Planning

Resilience Solution	Description	Benefits	Challenges	Regulatory Constraints	Cost	Project Lead	Type
<b>Rolling Easement</b>	Rolling easements are shoreline easements designed to facilitate the natural migration of shorelines. They typically prohibit shore protection structures with the understanding that structures and buildings will be removed as sea level inundates areas. The easement moves relative to sea level rise, allowing for sediment transport and marsh and wetland migration.	Reflect changing conditions and may be a more effective climate change response than traditional zoning. Allows for preservation of eco system functions.	Takings liability and potential reluctance from property owners to lose land as shoreline migrates. The most plausible approach to using a rolling easement may be through a voluntary easement agreement. The rolling easement would be considered a variation from a more traditional open space easement. Coastal property owners could agree to limit development on coastal property in exchange for tax incentives.	Medium	\$\$ - \$\$\$	Local	Planning
<b>Transfer of Development Rights</b>	Transfer the development potential of one parcel of land for use at another parcel of land in an area that is capable of absorbing and supporting additional density. Redirects development that would otherwise occur in areas of risk to areas that are designated to accommodate growth.	Reduces development in flood-prone areas to those that are less likely to have issues while protecting the economic benefit to the landowner.	Administering a successful TDR program is not as simple as protecting one area and increasing the density elsewhere by means of a transaction. TDR programs are often highly political and can be difficult to both map and maintain over time. Receiving areas can be potentially contentious. Conversely to the receiving areas, designation of sending areas can be perceived as stripping a landowner's right to develop and can result in legal challenges and lengthy negotiations. Values of a development right must be calculated and recalibrated to respond to market conditions.	Medium	\$ - \$\$\$	Local and Regional	Planning

## RESILIENCY PROJECTS / MONITORING

The above strategies comprise general types of resiliency measures. The appropriate strategy will be selected in concert with the identified problem that is to be solved. For example, if the identified problem is flooding on access roads to specific critical facilities, the strategy selected could be road raising, construction of a seawall, or relocation of critical facilities. The selected strategy will depend upon a number of factors, including what best would meet the overall Resiliency Vision of Greenwich, which would perform best over time, cost, and other factors. The Adaptation Strategies Report provides a suite of potential actions that could be taken to address problems identified by the community.

It is important as a project is being developed, that success measures are established. What would a successful project look like? Roads becoming impassable only once per month? Once per year? How will this be measured? Once a project has been implemented, it is important to monitor these success metrics to determine how well the project has met the objectives set out at the beginning.

The process of measuring resilience can provide community leaders and members information to help prioritize investments, allocate limited resources, and target the most effective programs and policies to mitigate the effects of shocks and stressors. It helps communities know how or whether their resilience has increased, whether their investments are providing adequate returns, and how their hazard mitigation, climate adaptation, and other resilience-related activities are impacting community wellbeing. If it is not performing adequately, a reassessment of the solution will have to occur. This reassessment can provide additional information that will help to improve the community decision making moving forward.

## RESOURCES

U.S. Climate Resilience Toolkit: <https://toolkit.climate.gov/topics/built-environment/community-resilience>

National Institute of Standards and Technology (NIST): [Community Resilience Planning Guide for Buildings and Infrastructure Systems](#)

U.S. Department of Health and Human Services: <https://www.phe.gov/Preparedness/planning/abc/Pages/community-resilience.aspx>

Transition US: Overview of Community Resilience Models and Toolkits:  
[https://naaee.org/sites/default/files/overview\\_of\\_community\\_resilience\\_models\\_and\\_toolkits\\_1.pdf](https://naaee.org/sites/default/files/overview_of_community_resilience_models_and_toolkits_1.pdf)

RAND Corporation Community Resilience Learn and Tell Toolkit:  
[https://www.rand.org/content/dam/rand/pubs/tools/TL100/TL163/RAND\\_TL163.pdf](https://www.rand.org/content/dam/rand/pubs/tools/TL100/TL163/RAND_TL163.pdf)